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PRELIMINARY REGULATORY IMPACT ANALYSIS

CORPORATE AVERAGE FUEL ECONOMY FOR MY 2011-2015 PASSENGER CARS and LIGHT TRUCKS

Office of Regulatory Analysis and Evaluation
National Center for Statistics and Analysis
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EXECUTIVE SUMMARY

This assessment examines the costs and benefits of improving the fuel economy of passenger cars and light trucks for model years (MY) 2011- 2015. It includes a discussion of the technologies that can improve fuel economy, analysis of the potential impact on retail prices, safety, lifetime fuel savings and their value to consumers, and other societal benefits such as improved energy security and reduced emissions of pollutants and greenhouse gases[1].

In the previous rulemaking, the agency reformed the corporate average fuel economy (CAFE) standards for light trucks with a size-based standard based on footprint[2]. This rulemaking continues this approach for both passenger cars and light trucks. A continuous mathematical function provides a separate fuel economy target for each footprint. Different parameters for the continuous mathematical function are derived for each model year. Individual manufacturers will be required to comply with a single fuel economy level that is based on the distribution of its production among the footprints of its vehicles in each particular model year. Although the same reformed CAFE scheme is proposed for both passenger cars and light trucks, they are established with different continuous mathematical functions specific to their design capabilities.

The agency is proposing the “Optimized (7%)” alternative. In this alternative the agency uses a 7 percent discount rate to value benefits and sets the proposed mpg levels where marginal costs equal marginal benefits. It is one of six alternatives examined in the analysis. We also examined a second optimized scenario when discounting benefits at 3 percent “Optimized (3%). In general order of increasing severity (see Table 1), the seven scenarios examined are:

1: “25% Below Optimized”: This alternative mirrors the absolute difference in mpg derived from the 25% Above Optimized scenario in going the same mpg amount below the Optimized 7% alternative
2: “Optimized (7%) An increase in the standard based upon availability of technologies and a marginal cost/benefit analysis, as was used in setting the MY 2008-2011 light truck standard. The mpg levels are set using a 7 percent discount rate for benefits.
3: “25% Above Optimized”: This alternative looks at the mpg levels of the Optimized (7%) and the Total Cost Equals Total Benefit alternative and picks mpg levels that are 25 percent of that difference.

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[1] This analysis does not contain NHTSA’s assessment of the potential environmental impacts of the proposed standards and reasonable alternatives for purposes of the National Environmental Policy Act (NEPA), 42 U.S.C. 4321-4347. On March 28, 2008, NHTSA published a notice of intent to prepare an environmental impact statement (EIS) and opened the NEPA scoping process (73 FR 16615). NHTSA will consider the potential environmental impacts of the proposed standards and reasonable alternatives through the NEPA process, and NHTSA’s NEPA analysis will inform any further action on the proposed standards, consistent with NEPA and EPCA.

[2] Vehicle Footprint is defined as the wheelbase (the distance from the center of the front axle to the center of the rear axle) times the average track width (the distance between the centerline of the tires) of the vehicle (in square feet).

4: “50% Above Optimized”: This alternative looks at the mpg levels of the Optimized (7%) and the Total Cost Equals Total Benefit alternative and picks mpg levels that are 50 percent of that difference.
5: “Optimized (3%) An increase in the standard based upon availability of technologies and a marginal cost/benefit analysis, as was used in setting the MY 2008-2011 light truck standard, except that the mpg levels are set using a 3 percent discount rate for benefits.
6: “Total Costs Equal Total Benefits”: An increase in the standard to a point where essentially total costs of the technologies added equals total benefits. In this analysis, for brevity, at times it is labeled “TC = TB”.
7: “Technology Exhaustion”: An increase in the standard based upon the maximum usage (based on NHTSA’s perspective) of available technologies, disregarding the cost impacts.

Table 1a shows the agency’s projection of the actual harmonic average that would be achieved by the manufacturers, assuming those manufacturers whose plans are above the requirements would achieve those higher levels. Table 1b shows the estimated required levels. All of the tables in this analysis compare an adjusted baseline to the achieved harmonic average in Table 1a.

Costs: Costs were estimated based on the specific technologies that were applied to improve each manufacturer’s fuel economy up to the level required under each alternative. Table 2 provides those cost estimates on an average per-vehicle basis, and Table 3 provides those estimates on a fleet-wide basis in millions of dollars. Costs are not discounted.

Benefits: Benefits are determined mainly from fuel savings over the lifetime of the vehicle, but also include externalities such as reductions in criteria pollutants. Table 4 provides those estimates on an industry-wide basis.

Net Benefits: Table 5 compares costs and benefits of each alternative. The values in Table 5 compare societal benefits to societal costs of each alternative. Thus, it does not use the values of Table 2, which include fines paid by manufacturers and transferred to consumers to pay.

Fuel Savings: Table 6 shows the lifetime fuel savings in millions of gallons.

Table 1a
Alternative CAFE Levels
Projected Harmonic Average for the Fleet[3]
(in mpg)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
25% Below Optimized	30.5	31.2	31.9	32.8	33.5
Optimized (7%)	31.0	32.3	33.1	33.9	34.7
25% Above Optimized	31.5	33.3	34.2	35.3	36.1
50% Above Optimized	31.7	34.0	35.1	36.4	37.6
Optimized (3%)	32.2	34.5	35.5	37.0	38.2
TC = TB	32.3	35.0	36.1	37.6	38.8
Technology Exhaustion	32.3	35.2	36.6	38.5	39.9
Light Trucks					
25% Below Optimized	24.3	25.5	27.3	27.3	27.4
Optimized (7%)	24.4	25.8	27.5	28.0	28.4
25% Above Optimized	24.4	26.1	27.8	28.5	29.5
50% Above Optimized	24.6	26.3	28.0	28.9	30.0
Optimized (3%)	24.4	25.8	27.7	28.2	28.8
TC = TB	24.7	26.5	28.5	29.5	30.5
Technology Exhaustion	24.7	26.6	29.4	30.3	31.3

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[3] The values represent the higher of the manufacturer's plans and the alternative level of the standard.

Table 1b
Estimated Required Average for the Fleet
(in mpg)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
25% Below Optimized	29.6	30.3	31.7	32.7	33.9
Optimized (7%)	31.2	32.8	34.0	34.8	35.7
25% Above Optimized	32.8	35.3	36.1	36.8	37.5
50% Above Optimized	34.3	37.8	38.5	38.9	39.5
Optimized (3%)	37.1	39.1	39.3	40.7	40.9
TC = TB	37.5	42.7	43.0	43.1	43.3
Technology Exhaustion	38.6	45.4	48.9	50.1	52.6
Light Trucks					
25% Below Optimized	24.9	26.0	27.5	27.5	27.5
Optimized (7%)	25.0	26.4	27.8	28.2	28.6
25% Above Optimized	25.1	26.9	28.0	28.8	29.8
50% Above Optimized	25.3	27.3	28.3	29.5	30.9
Optimized (3%)	25.0	26.4	28.0	28.5	29.0
TC = TB	25.6	28.1	28.8	30.8	33.1
Technology Exhaustion	25.9	28.6	32.2	33.1	34.7

See Appendix A for more information on the required levels.

Table 2
Average Incremental Cost
Per Vehicle – Consumer Perspective
(2006 Dollars)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
25% Below Optimized	126	126	187	294	428
Optimized (7%)	276	334	404	512	649
25% Above Optimized	494	778	871	1,078	1,185
50% Above Optimized	620	1,133	1,251	1,501	1,694
Optimized (3%)	896	1,284	1,376	1,706	1,915
TC = TB	966	1,685	1,829	2,159	2,367
Technology Exhaustion	1,038	2,032	2,406	2,889	3,264
Light Trucks					
25% Below Optimized	185	526	738	705	708
Optimized (7%)	224	617	861	924	979
25% Above Optimized	279	873	1,141	1,352	1,655
50% Above Optimized	385	1,008	1,347	1,644	2,041
Optimized (3%)	227	616	955	1,028	1,145
TC = TB	501	1,325	1,770	2,171	2,509
Technology Exhaustion	536	1,364	2,255	2,507	2,785

Table 3
Incremental Total Cost – Consumer Perspective
(Millions of 2006 Dollars)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5 year total
25% Below Optimized	835	818	1,253	2,153	3,209	8,268
Optimized (7%)	1,884	2,373	2,879	3,798	4,862	15,796
25% Above Optimized	3,387	5,653	6,445	8,240	9,084	32,808
50% Above Optimized	4,010	7,885	8,986	11,207	12,981	45,070
Optimized (3%)	5,467	8,791	9,821	12,447	14,484	51,011
TC = TB	5,913	10,796	12,303	15,403	17,398	61,812
Technology Exhaustion	6,079	12,595	14,701	18,759	21,110	73,245
Light Trucks						
25% Below Optimized	1,349	4,296	6,329	6,212	6,326	24,512
Optimized (7%)	1,649	4,986	7,394	8,160	8,761	30,949
25% Above Optimized	2,072	7,034	9,815	11,903	14,781	45,606
50% Above Optimized	2,922	8,098	11,586	14,386	17,969	54,961
Optimized (3%)	1,662	4,974	8,190	9,058	10,253	34,136
TC = TB	3,788	10,525	15,196	18,762	21,364	69,635
Technology Exhaustion	3,933	10,670	18,275	21,051	23,479	77,408
Combined PC +LT						
25% Below Optimized	2,184	5,114	7,582	8,365	9,534	32,780
Optimized (7%)	3,534	7,358	10,273	11,957	13,623	46,745
25% Above Optimized	5,459	12,687	16,261	20,143	23,865	78,414
50% Above Optimized	6,932	15,983	20,572	25,593	30,950	100,030
Optimized (3%)	7,128	13,765	18,011	21,505	24,737	85,147
TC = TB	9,702	21,321	27,499	34,164	38,761	131,447
Technology Exhaustion	10,013	23,266	32,976	39,810	44,589	150,653

Table 4a
Present Value of Lifetime Societal Benefits by Alternative
(Millions of 2006 Dollars)
(Discounted **3%**)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
25% Below Optimized	1,418	2,581	3,977	6,399	8,387	22,762
Optimized (7%)	3,181	6,054	7,561	9,716	11,616	38,128
25% Above Optimized	4,604	8,939	10,403	13,109	14,907	51,962
50% Above Optimized	5,241	10,842	12,571	15,503	17,893	62,050
Optimized (3%)	6,798	12,188	13,519	16,833	19,216	68,554
TC = TB	7,075	13,366	14,881	18,059	20,364	73,745
Technology Exhaustion	7,156	13,865	15,967	19,654	22,312	78,954
Light Trucks						
25% Below Optimized	4,414	9,959	15,910	15,715	15,745	61,743
Optimized (7%)	4,919	11,055	17,120	18,866	20,506	72,466
25% Above Optimized	5,286	12,599	17,972	20,984	24,662	81,503
50% Above Optimized	5,848	13,249	18,955	22,375	26,475	86,902
Optimized (3%)	4,939	11,075	17,976	19,902	22,246	76,138
TC = TB	6,343	14,452	20,631	24,704	28,352	94,482
Technology Exhaustion	6,420	14,528	24,517	27,951	31,387	104,803
Passenger Cars and Light Trucks Combined						
25% Below Optimized	5,832	12,540	19,887	22,114	24,132	84,505
Optimized (7%)	8,100	17,109	24,681	28,582	32,122	110,594
25% Above Optimized	9,890	21,538	28,375	34,093	39,569	133,465
50% Above Optimized	11,089	24,091	31,526	37,878	44,368	148,952
Optimized (3%)	11,737	23,263	31,495	36,735	41,462	144,692
TC = TB	13,418	27,818	35,512	42,763	48,716	168,227
Technology Exhaustion	13,576	28,393	40,484	47,605	53,699	183,757

Table 4b
Present Value of Lifetime Societal Benefits by Alternative
(Millions of 2006 Dollars)
(Discounted 7%)

Passenger Car	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
25% Below Optimized	1,156	2,104	3,235	5,197	6,799	18,491
Optimized (7%)	2,596	4,933	6,148	7,889	9,420	30,986
25% Above Optimized	3,755	7,280	8,454	10,638	12,083	42,210
50% Above Optimized	4,274	8,825	10,213	12,576	14,495	50,383
Optimized (3%)	5,543	9,922	10,983	13,654	15,569	55,671
TC = TB	5,769	10,878	12,087	14,644	16,492	59,870
Technology Exhaustion	5,834	11,282	12,968	15,930	18,061	64,075
Light Trucks						
25% Below Optimized	3,508	7,910	12,603	12,432	12,441	48,894
Optimized (7%)	3,909	8,779	13,560	14,915	16,192	57,355
25% Above Optimized	4,201	9,990	14,236	16,587	19,457	64,471
50% Above Optimized	4,642	10,507	15,011	17,687	20,892	68,739
Optimized (3%)	3,926	8,794	14,251	15,752	17,589	60,312
TC = TB	5,027	11,453	16,330	19,515	22,367	74,692
Technology Exhaustion	5,088	11,513	19,395	22,074	24,759	82,829
Passenger Cars and Light Trucks Combined						
25% Below Optimized	4,664	10,014	15,838	17,629	19,240	67,385
Optimized (7%)	6,505	13,712	19,708	22,804	25,612	88,341
25% Above Optimized	7,956	17,270	22,690	27,225	31,540	106,681
50% Above Optimized	8,916	19,332	25,224	30,263	35,387	119,122
Optimized (3%)	9,469	18,716	25,234	29,406	33,158	115,983
TC = TB	10,796	22,331	28,417	34,159	38,859	134,562
Technology Exhaustion	10,922	22,795	32,363	38,004	42,820	146,904

Table 5a

Net Total Benefits
Over the Vehicle's Lifetime – Present Value
Societal Perspective
(Millions of 2006 Dollars)
(Discounted **3%**)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
25% Below Optimized	583	1,763	2,724	4,246	5,178	14,494
Optimized (7%)	1,297	3,681	4,682	5,918	6,754	22,332
25% Above Optimized	1,217	3,286	3,958	4,869	5,823	19,154
50% Above Optimized	1,231	2,957	3,585	4,296	4,912	16,980
Optimized (3%)	1,331	3,397	3,698	4,386	4,732	17,543
TC = TB	1,162	2,570	2,578	2,656	2,966	11,933
Technology Exhaustion	1,077	1,270	1,266	895	1,202	5,709
Light Trucks						
25% Below Optimized	3,065	5,663	9,581	9,503	9,419	37,231
Optimized (7%)	3,270	6,069	9,726	10,706	11,745	41,517
25% Above Optimized	3,214	5,565	8,157	9,081	9,881	35,897
50% Above Optimized	2,926	5,151	7,369	7,989	8,506	31,941
Optimized (3%)	3,277	6,101	9,786	10,844	11,993	42,002
TC = TB	2,555	3,927	5,435	5,942	6,988	24,847
Technology Exhaustion	2,487	3,858	6,242	6,900	7,908	27,395
Passenger Cars and Light Trucks Combined						
25% Below Optimized	3,648	7,426	12,305	13,749	14,598	51,725
Optimized (7%)	4,566	9,751	14,408	16,625	18,499	63,849
25% Above Optimized	4,431	8,851	12,114	13,950	15,704	55,051
50% Above Optimized	4,157	8,108	10,954	12,285	13,418	48,922
Optimized (3%)	4,609	9,498	13,484	15,230	16,725	59,545
TC = TB	3,716	6,497	8,013	8,599	9,955	36,780
Technology Exhaustion	3,563	5,127	7,508	7,795	9,110	33,104

Table 5b
Net Total Benefits
Over the Vehicle’s Lifetime – Present Value
Societal Perspective
(Millions of 2006 Dollars)
(Discounted 7%)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
25% Below Optimized	321	1,286	1,982	3,044	3,590	10,223
Optimized (7%)	712	2,560	3,269	4,091	4,558	15,190
25% Above Optimized	368	1,627	2,009	2,398	2,999	9,402
50% Above Optimized	264	940	1,227	1,369	1,514	5,313
Optimized (3%)	76	1,131	1,162	1,207	1,085	4,660
TC = TB	-144	82	-216	-759	-906	-1,942
Technology Exhaustion	-245	-1,313	-1,733	-2,829	-3,049	-9,170
Light Trucks						
25% Below Optimized	2,159	3,614	6,274	6,220	6,115	24,382
Optimized (7%)	2,260	3,793	6,166	6,755	7,431	26,406
25% Above Optimized	2,129	2,956	4,421	4,684	4,676	18,865
50% Above Optimized	1,720	2,409	3,425	3,301	2,923	13,778
Optimized (3%)	2,264	3,820	6,061	6,694	7,336	26,176
TC = TB	1,239	928	1,134	753	1,003	5,057
Technology Exhaustion	1,155	843	1,120	1,023	1,280	5,421
Passenger Cars and Light Trucks Combined						
25% Below Optimized	2,480	4,900	8,256	9,264	9,706	34,605
Optimized (7%)	2,971	6,354	9,435	10,847	11,989	41,596
25% Above Optimized	2,497	4,583	6,429	7,082	7,675	28,267
50% Above Optimized	1,984	3,349	4,652	4,670	4,437	19,092
Optimized (3%)	2,341	4,951	7,223	7,901	8,421	30,836
TC = TB	1,094	1,010	918	-5	98	3,115
Technology Exhaustion	909	-471	-613	-1,806	-1,769	-3,749

Negative values mean that societal costs exceed societal benefits.

Table 6
Savings in Millions of Gallons of Fuel
Undiscounted Over the Lifetime of the Model Year

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
25% Below Optimized	708	1,261	1,946	3,135	4,151	11,201
Optimized (7%)	1,563	2,968	3,717	4,771	5,716	18,735
25% Above Optimized	2,313	4,480	5,221	6,601	7,476	26,091
50% Above Optimized	2,641	5,523	6,422	7,913	9,121	31,620
Optimized (3%)	3,463	6,197	6,905	8,587	9,784	34,936
TC = TB	3,599	6,860	7,676	9,320	10,461	37,916
Technology Exhaustion	3,677	7,143	8,261	10,233	11,562	40,876
Light Trucks						
25% Below Optimized	2,157	4,933	7,902	7,799	7,808	30,599
Optimized (7%)	2,404	5,478	8,509	9,392	10,195	35,978
25% Above Optimized	2,585	6,339	9,070	10,592	12,534	41,120
50% Above Optimized	2,909	6,780	9,697	11,458	13,584	44,428
Optimized (3%)	2,414	5,488	8,978	9,959	11,127	37,966
TC = TB	3,228	7,471	10,640	12,778	14,602	48,719
Technology Exhaustion	3,263	7,506	12,659	14,448	16,147	54,023
Passenger Cars and Light Trucks Combined						
25% Below Optimized	2,865	6,194	9,848	10,934	11,959	41,800
Optimized (7%)	3,967	8,446	12,226	14,163	15,911	54,713
25% Above Optimized	4,898	10,819	14,291	17,193	20,010	67,211
50% Above Optimized	5,550	12,303	16,119	19,371	22,705	76,048
Optimized (3%)	5,877	11,685	15,883	18,546	20,911	72,902
TC = TB	6,827	14,331	18,316	22,098	25,063	86,635
Technology Exhaustion	6,940	14,649	20,920	24,681	27,709	94,899

I. INTRODUCTION

The purpose of this study is to analyze the effects of changes in the fuel economy standards for passenger cars and for light trucks from MY 2011 to MY 2015. It includes a discussion of the technologies that can improve fuel economy, the potential impacts on retail prices, safety, the discounted lifetime net benefits of fuel savings, and the potential gallons of fuel saved.

The agency issued a final rule on April 7, 2003 (68 FR 16868), setting the CAFE standard applicable to light trucks for MY 2005 at 21.0 mpg, for MY 2006 at 21.6 mpg, and for MY 2007 at 22.2 mpg. On April 6, 2006 (71 FR 17566), the agency issued a final rule for MYs 2008 to 2011 under a new "CAFE Reform" structure. Similar to this report, a Final Regulatory Impact Analysis accompanied that final rule.[4] Much of the technical and cost information used in the 2006 analysis was taken from the findings in the National Academy of Sciences study[5] published in January 2002.

The new attribute-based Reformed CAFE system is based on the vehicle footprint (wheel base[6] x average wheel track width[7]). The anticipated advantages of the new reformed CAFE system are:

First, the energy-saving potential of the CAFE program was hampered by the original regulatory structure. Manufacturers who offer predominately small vehicles had little or no regulatory incentive to enhance fuel economy, because their vehicles tend to be more fuel efficient than the CAFE level. Moreover, the difference between the fuel economy standards for passenger cars and light trucks (27.5 mpg and 20.7 mpg, respectively, for MY 2004) encouraged vehicle manufacturers to offer vehicles classified as light trucks for purposes of CAFE, possibly inducing design changes that hurt overall fuel economy. A CAFE system that more closely links fuel economy standards to the various market segments and their fuel economy performance may reduce the incentive to design vehicles which are functionally similar to passenger cars but are classified as light trucks.

Second, we were concerned that the original light truck CAFE standards could create safety risks. Vehicle manufacturers are encouraged to achieve greater fuel economy by downsizing and downweighting. Alternatively, manufacturers may offer small vehicles to offset their offerings of large vehicles. The resulting increase in the disparity between the smallest and largest vehicle sizes and weights in the on-road vehicle fleet is widely believed to have increased the number of fatalities in crashes involving passenger cars and light-duty trucks. The National Academy of Sciences (NAS) report and a NHTSA study[8] have suggested that if downweighting were concentrated on the heaviest vehicles in the fleet, there could be a small fleetwide safety benefit, but downweighting of passenger cars and the lighter light trucks would increase fatalities.

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[4] "Final Regulatory Impact Analysis, Corporate Average Fuel Economy and CAFE Reform for MY 2008-2011 Light Trucks", March 2006, Docket No. 24309-5.

[5] "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards", National Research Council, 2002. The link for the NAS report is http://www.nap.edu/books/0309076013/html/

[6] "Wheel base" is essentially the distance between the centers of the axles.

[7] "Track width" is the lateral distance between the centerline of the tires.

[8] "Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks", Charles J. Kahane, Ph.D., NHTSA, October 2003, DOT HS 809-662.

A third reason for considering CAFE reform relates to the adverse economic impacts that may result from such future increases in the stringency of CAFE standards. Rapid increases in the level of the CAFE standard could have substantial economic consequences on manufacturers, especially those full-line manufacturers with product mixes dominated by large heavier vehicles. For example, full-line manufacturers – especially those with substantial sales in the heavier end of the light truck market – may generate fewer CAFE credits and incur larger compliance costs than vehicle manufacturers who focus their sales in the smaller, lighter end of the light truck market. As CAFE standards become more stringent under the original structure, the full-line manufacturers may experience adverse financial consequences, with resulting disruptions for employees in these firms and their suppliers.

EPCA also gives NHTSA authority to set passenger car CAFE standards for each model year, but sets a default standard of 27.5 mpg. NHTSA has not raised the passenger car CAFE standard from 27.5 mpg since Congress lifted the ban on CAFE rulemakings in 2002 because it did not believe that it had authority to reform passenger car CAFE as it had for light trucks. Reforming the CAFE program achieves larger fuel savings while enhancing safety and preventing adverse economic consequences—objectives which apply equally to passenger cars as to light trucks. NHTSA was unwilling to raise the passenger car CAFE standard without also reforming it, because of the same fuel savings, safety, and economic concerns that led it to reform the light truck CAFE standards.

In December 2007, Congress passed the Energy Independence and Security Act (EISA). EISA mandates the setting of separate standards for passenger cars and for light trucks at levels sufficient to ensure that the average fuel economy of the combined fleet of all passenger cars and light trucks sold by all manufacturers in the U.S. in model year 2020 equals or exceeds 35 miles per gallon. That is a 40 percent increase above the average of approximately 25 miles per gallon for the current combined fleet.

This notice proposes standards for model years (MY) 2011-2015, the maximum number of model years under EISA for which NHTSA can establish standards in a single rulemaking. However, the Act gives NHTSA authority to reform passenger car CAFE, allowing the agency to set standards for those vehicles according to an attribute-based mathematical function as it currently does for light trucks.

The dual fuel incentive program, through which manufacturers may improve their calculated fuel economies by producing vehicles capable of operating on alternative fuels, is not considered in this analysis. By law, the agency has always analyzed fuel economy without considering the dual fuel credits, since it is an incentive program designed to increase the availability of alternative fuel vehicles.

Throughout this analysis, unless otherwise noted, the agency has not considered the ability of manufacturers to use credits or credit trading in achieving the alternative fuel economy levels.

Throughout this document, confidential information is presented in brackets [ ].

II. NEED OF THE NATION TO CONSERVE ENERGY

The Energy Policy and Conservation Act (EPCA) states that:

> "When deciding maximum feasible average fuel economy … the Secretary of Transportation shall consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy."[9]

Thus, (EPCA) specifically directs the Department to balance the technological and economic challenges related to fuel economy with the nation's need to conserve energy. The concerns about energy security and the effects of energy prices and supply on national economic well-being that led to the enactment of EPCA persist today. The demand for petroleum is steadily growing in the U.S. and around the world.

Since 1970, there have been a series of events that suggest that the behavior of petroleum markets is a matter for public concern.

- Crude oil prices are currently in the neighborhood of $100 per barrel. As recently as 1998, crude prices averaged about $13 per barrel ($15.85 in 2006 dollars).[10] Gasoline prices have more than doubled during this period.[11]
- U.S. domestic oil production peaked in 1970 at 11.3 million barrels per day. Between 1970 and 2006, U.S. domestic production has declined by nearly 40 percent, while U.S. petroleum consumption has increased by 40 percent. Net petroleum imports now account for 60 percent of U.S. domestic petroleum consumption.[12]
- Worldwide oil demand is very inelastic: declining prices do not induce large increases in consumption, while higher prices do not restrain consumption. Thus, relatively minor changes in quantity demanded can induce large changes in price. Within the United States, demand for gasoline, diesel, and jet fuel within the transportation sector is particularly inelastic.
- Demand for oil may increase significantly in Asia and worldwide in the future resulting in competition for oil supplies.
- Oil production facilities, refineries, and supply chains have been disrupted from time to time, either by wars, political action by oil producers, civil unrest, or natural disasters.
- High oil prices, sometimes induced by disruptions in oil markets, have often coincided with rising inflation and subsequent economic recessions.

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[9] 49 USC 32902(f)

[10] Energy Information Administration, *Annual Energy Review 2006*, Table 5.21, p. 171. See: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec5_51.pdf

[11] Energy Information Administration, *Annual Energy Review 2006*, Table 5.24, p. 177. See: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec5_57.pdf

[12] Energy Information Administration, *Annual Energy Review 2006*, Table 5.1, p. 125. See: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec5_5.pdf

- Greenhouse gas emissions from the consumption of petroleum have become a subject of increasing public policy concern, both in the United States and internationally. Greenhouse gases in general and carbon dioxide in particular have not thus far been subject to national regulation. Studies by multiple sources suggest that rising atmospheric concentrations of greenhouse gases will damage human health and welfare.[13] There is a direct linkage between the consumption of fossil energy and emissions of the greenhouse gas carbon dioxide, as essentially all of the carbon in hydrocarbon fuels is oxidized into carbon dioxide when the fuel is combusted. Reducing U.S. fossil energy consumption will generally induce a proportional reduction in carbon dioxide emissions.

Energy is an essential input to the U.S. economy, and having a strong economy is essential to maintaining and strengthening our national security. Secure, reliable, and affordable energy sources are fundamental to economic stability and development. Rising energy demand poses a challenge to energy security, given increased reliance on global energy markets. As noted above, U.S. energy consumption has increasingly been outstripping U.S. energy production.

Table II-1 presents trend data on the production and consumption of petroleum. Domestic petroleum production has been decreasing over time, while imports of petroleum have been increasing to meet the rising U.S. demand for petroleum.

Conserving energy, especially reducing the nation’s dependence on petroleum, benefits the U.S. in several ways. Improving energy efficiency has benefits for economic growth and the environment, as well as other benefits, such as reducing pollution and improving security of energy supply. More specifically, reducing total petroleum use decreases our economy’s vulnerability to oil price shocks. Reducing dependence on oil imports from regions with uncertain conditions enhances our energy security and can reduce the flow of oil profits to certain states now hostile to the U.S.

This reformed CAFE proposal would encourage broader use of fuel saving technologies, resulting in more fuel-efficient vehicles and greater overall fuel economy.

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[13] IPCC 2007: Climate Change 2007: Synthesis Report: Contributions of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, [Core writing team, Pachauri, R.K. and Reisinger, A. 9eds.)] (Published by the Intergovernmental Panel on Climate Change, 2008). A*vailable at* *http://www.ipcc.ch/*, .

Table II-1
Petroleum Production and Supply
(millions of barrels per day)

	Domestic Petroleum Production	Net Petroleum Imports	U.S. Petroleum Supply	World Petroleum Consumption	Import Share of U.S. Supply
1975	10.01	5.85	15.86	56.20	36.9%
1985	10.58	4.29	14.87	60.09	28.9%
1995	8.32	7.89	16.21	68.91	48.7%
2005	6.89	12.55	19.44	83.00	64.6%
DOE Predictions					
2015	5.91	12.52	18.43		67.9%
2025	5.58	14.87	20.45		72.7%
2030	5.39	16.37	21.76		75.2%

“Petroleum Production and Consumption and Some Important Percent Shares, 1950-2006”, Transportation Energy Data Book: Edition 26 (2007), Table 1.12.
http://cta.ornl.gov/data/Index.shtml
“Comparison of petroleum projections, 2015, 2025, and 2030”, Department of Energy, Energy Information Administration, Annual Energy Outlook 2007, Table 23.
http://www.eia.doe.gov/emeu/aer/contents.html

Table II-2
Transportation Consumption by Mode
(millions of gallons per year)

	Passenger Cars	Light Trucks	Total Light Vehicles	Total Transportation	Light Vehicles as % of Trans.
1975	74	19	93	139	67%
1985	72	27	99	157	63%
1995	68	46	114	188	61%
2005	74	65	139	219	63%

“Automobile Fuel Use and Fuel Type Shares for Calculation of Energy Use”, Transportation Energy Data Book: Edition 26 (2007) Table A.1, (Page A-7, appendix) http://cta.ornl.gov/data/Index.shtml
“Light Truck Fuel Use and Fuel Type Shares for Calculation of Energy Use”, Transportation Energy Data Book: Edition 26 (2007) Table A.1, (Page A-7, appendix) http://cta.ornl.gov/data/Index.shtml

III. REGULATORY ALTERNATIVES

In developing the proposed standards, the agency considered the four statutory factors underlying maximum feasibility as defined in EPCA (technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the nation to conserve energy) as well as other relevant considerations such as safety. NHTSA assessed what fuel saving technologies would be available, how effective they are, and how quickly they could be introduced. This assessment considered technological feasibility, economic practicability and associated energy conservation. We also considered other standards to the extent captured by EPCA[14] and environmental and safety concerns. This information was factored into the computer model used by NHTSA for applying technologies to particular vehicle models. The agency then balanced the factors relevant to standard setting. NHTSA's NEPA analysis, discussed in the preamble of the accompanying notice, also will inform NHTSA's consideration of the proposed standards and reasonable alternatives in developing a final rule.

In balancing these factors, NHTSA generally observes that the increasing application of technologies increases fuel economy and associated benefits, but it also increases costs. Initial applications of technologies provide far more fuel savings per dollar of expenditure than applications of remaining technologies, which provide less incremental fuel savings at greater cost and, with progressive additions of technologies, eventually far greater cost. At some stage, the increasing application of technologies is not justified. A significant question is what methodology and decisionmaking criteria are used in the balancing to determine when to cease adding technologies and thus arrive at regulatory fuel economy targets.

In developing its proposed standards, the agency used a net benefit-maximizing analysis that placed monetary values on relevant externalities (both energy security and environmental externalities, including the benefits of reductions in CO_2 emissions) and produced what is called the "optimized scenario." The optimized standards reflect levels such that, considering the seven largest manufacturers, net benefits (that is, total benefits minus total costs) are higher than at every other examined level of stringency. The agency also reviewed the results of the model's estimates of stringencies maximizing net benefits to assure that the results made sense in terms of balancing EPCA's statutory factors and in meeting EISA's requirements for improved fuel economy.

In addition to the optimized scenario, NHTSA considered and analyzed five additional regulatory alternatives that do not rely upon marginal benefit-cost analysis. In ascending order of stringency, the six alternatives are:

- Standards that fall below the optimized scenario by the same absolute amount by which the +25 percent alternative exceeds the optimized scenario ("25 percent below optimized" alternative),

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[14] 71 Fed. Reg. 17566, 17669-70; April 6, 2006.

•Standards based on applying technologies until net benefits are maximized (optimized scenario), and

•Standards that exceed the optimized scenario by 25 percent of the interval between the optimized scenario and the TC=TB alternative (see below) ("25 percent above optimized" alternative),

•Standards that exceed the optimized scenario by 50 percent of the interval between the optimized scenario and the TC=TB alternative ("50 percent above optimized" alternative),

•Standards based on applying technologies until total costs equal total benefits, i.e, until there are zero net benefits (TC=TB alternative),[15] and

•Standards based on applying all feasible technologies without regard to cost (technology exhaustion alternative).[16]

NHTSA chose these alternatives in order to consider and evaluate the impacts of balancing the EPCA factors differently in determining maximum feasibility than the agency has in prior rulemakings. In *Center for Biological Diversity v. NHTSA*, the Ninth Circuit Court recognized that "EPCA gives NHTSA discretion to decide how to balance the statutory factors—as long as NHTSA's balancing does not undermine the fundamental purpose of EPCA: energy conservation." 508 F.3d 508, 527 (9th Cir. 2007). The Court also raised the possibility that NHTSA's current balancing of the statutory factors might be different from the agency's balancing in the past, given the greater importance today of the need of the nation to conserve energy and more advanced understanding of climate change. *Id.* at 530-31.

NHTSA recognizes that numerous alternative CAFE levels are theoretically conceivable and that the alternatives described above essentially represent only several on a continuum of alternatives. Along the continuum, each alternative represents a different way in which NHTSA conceivably could assign weight to each of the four EPCA factors and NEPA's policies. For the alternatives that fall above the optimized scenario (the +25, +50 and TC=TB alternatives), the agency would evaluate policies that put increasingly more emphasis on reducing energy consumption and CO_2 emissions, given their impact on global warming, and less on the other factors, including the economic impacts on the industry. Conversely, for the alternative that falls below the optimum scenario, the agency would evaluate policies that place relatively more weight on the economic health of the industry and less on reducing energy consumption and CO_2 emissions.

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[15] The agency considered the "TC=TB" alternative because one or more commenters in the rulemaking on standards for MY 2008-2011 light trucks urged NHTSA to consider setting the standards on this basis rather than on the basis of maximizing net benefits. In addition, while the Ninth Circuit Court of Appeals concluded that EPCA neither requires nor prohibits the setting of standards at the level at which net benefits are maximized, the Court raised concerns about tilting the balance more toward reducing energy consumption and CO_2.

[16] This was accomplished by determining the stringency at which a reformed standard would require every manufacturer to apply every technology estimated to be potentially available. At such stringencies, all but one manufacturer would be expected to fail to comply with the standard, and many manufacturers would owe large civil penalties as a result. The agency considered this alternative because the agency wished to explore the stringency and consequences of standards based solely on the potential availability of technologies at the individual manufacturer level.

For reasons such as those set forth in this section, NHTSA's provisional analysis of the alternatives described above suggests that some of them may not satisfy the four EPCA factors that NHTSA must apply in setting "maximum feasible" CAFE standards. NHTSA seeks comments on the proposed standards and the regulatory alternatives to aid the agency's determination of what standards to adopt in the final rule.

The graphs below show, for passenger cars, light trucks, and the combined fleet, the average annual fuel economy levels for the four alternatives as compared to the proposed standards. Subsequent graphs and tables present their estimated costs, benefits, and net benefits (in billions of dollars). In addition, tables are provided summarizing the average extent to which manufacturers' CAFE levels are projected to fall short of CAFE standards—i.e., the average shortfall—under each of these alternatives. Manufacturer-specific shortfall is shown for the proposed and TC=TB alternative.

Figure III-1. Average Required CAFE Levels (mpg) for Passenger Cars under Proposed and Alternative Standards

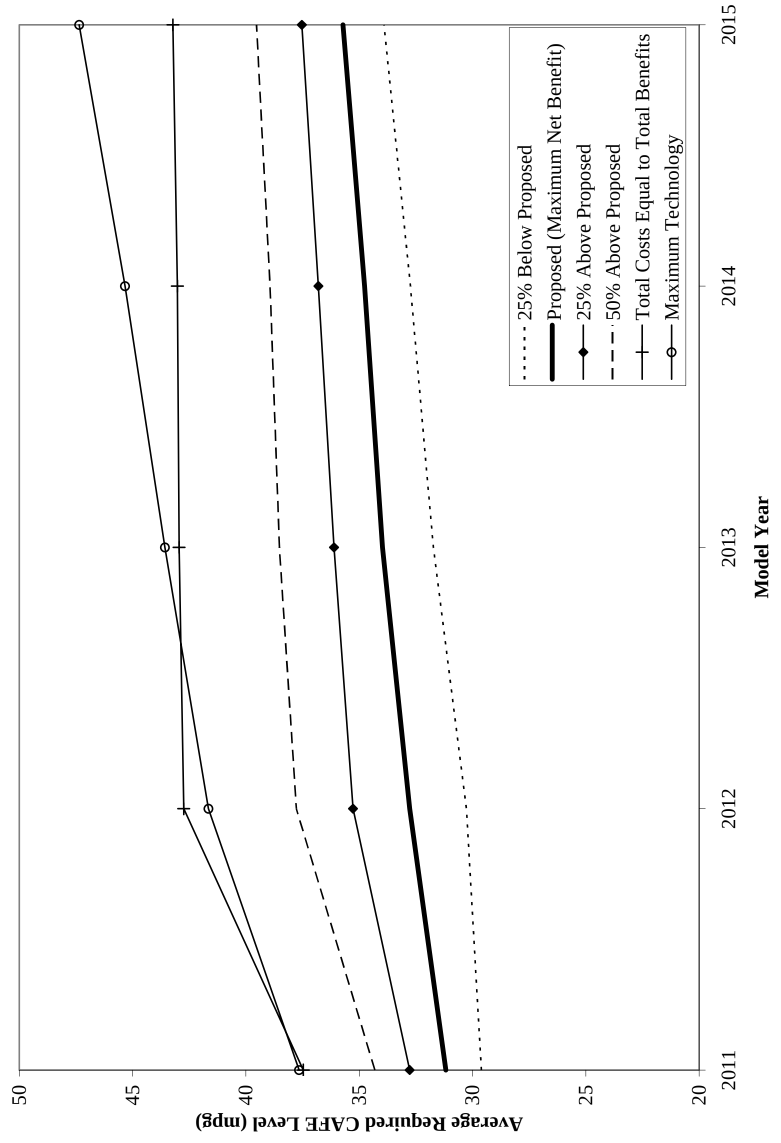


Figure III-2. Average Required CAFE Levels (mpg) for Light Trucks under Proposed and Alternative Standards

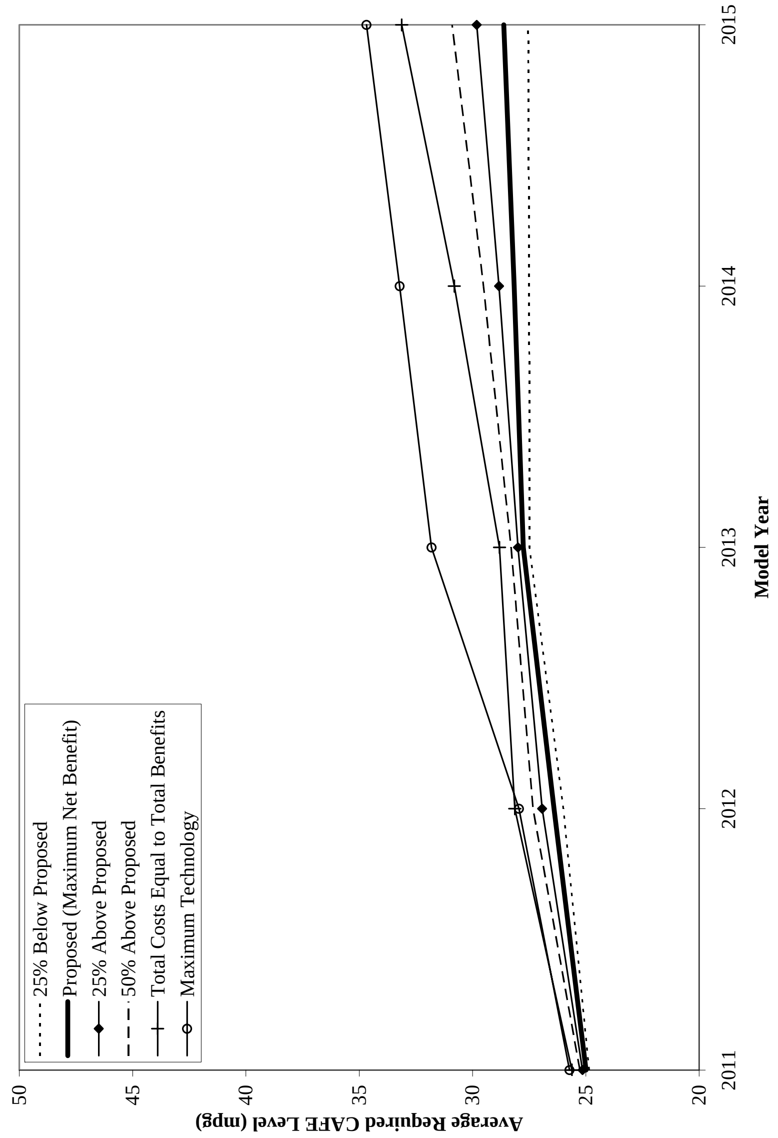


Figure III-3. Average Required CAFE Levels (mpg) for Overall Fleet under Proposed and Alternative Standards

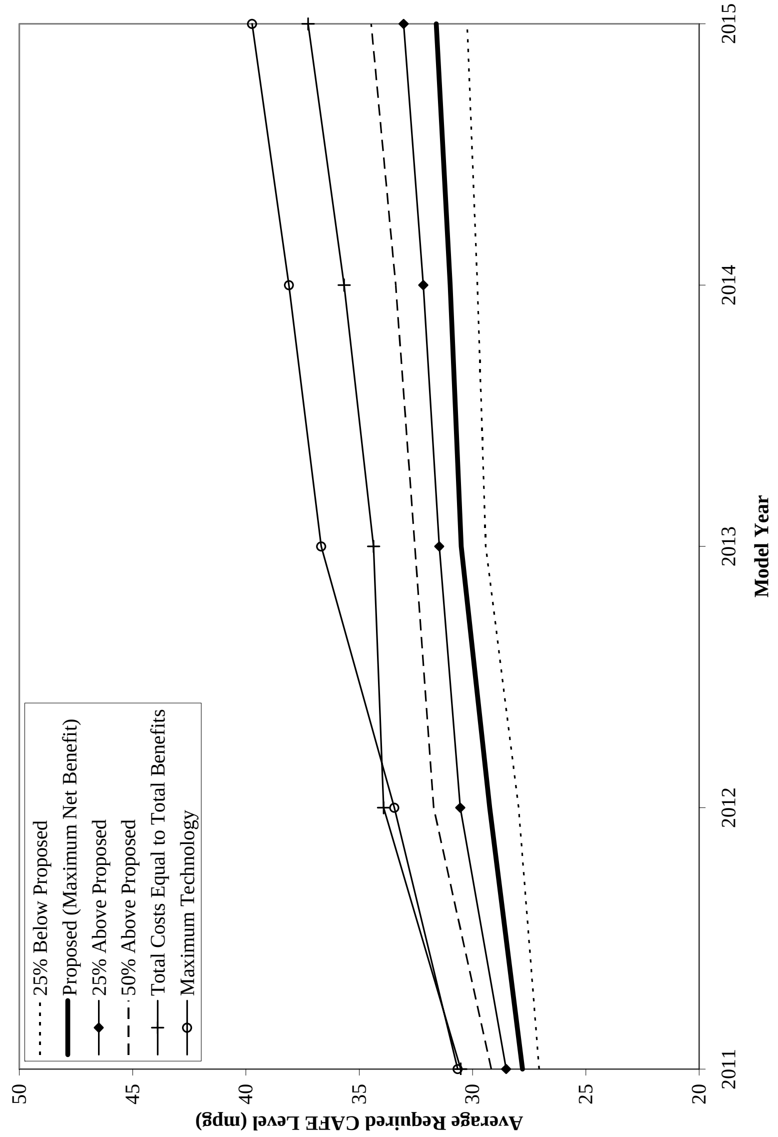


Figure III-4. Total Benefits under Proposed and Alternative Standards

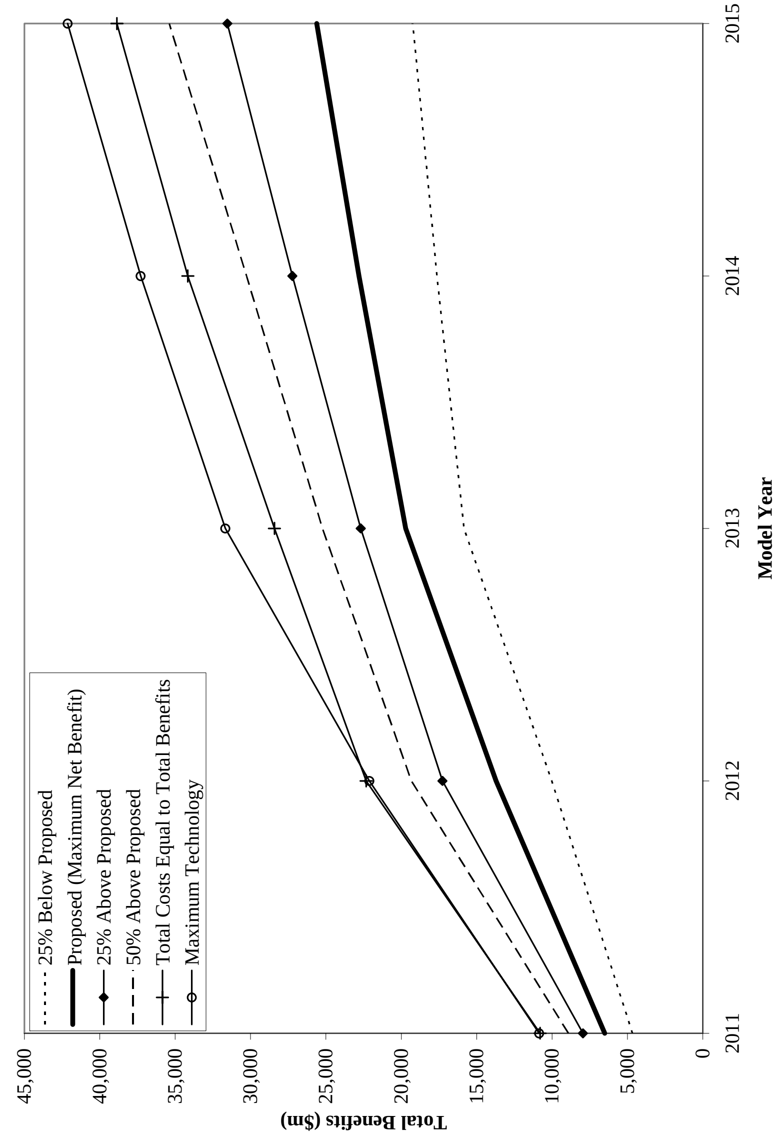


Figure III-5. Total Costs under Proposed and Alternative Standards

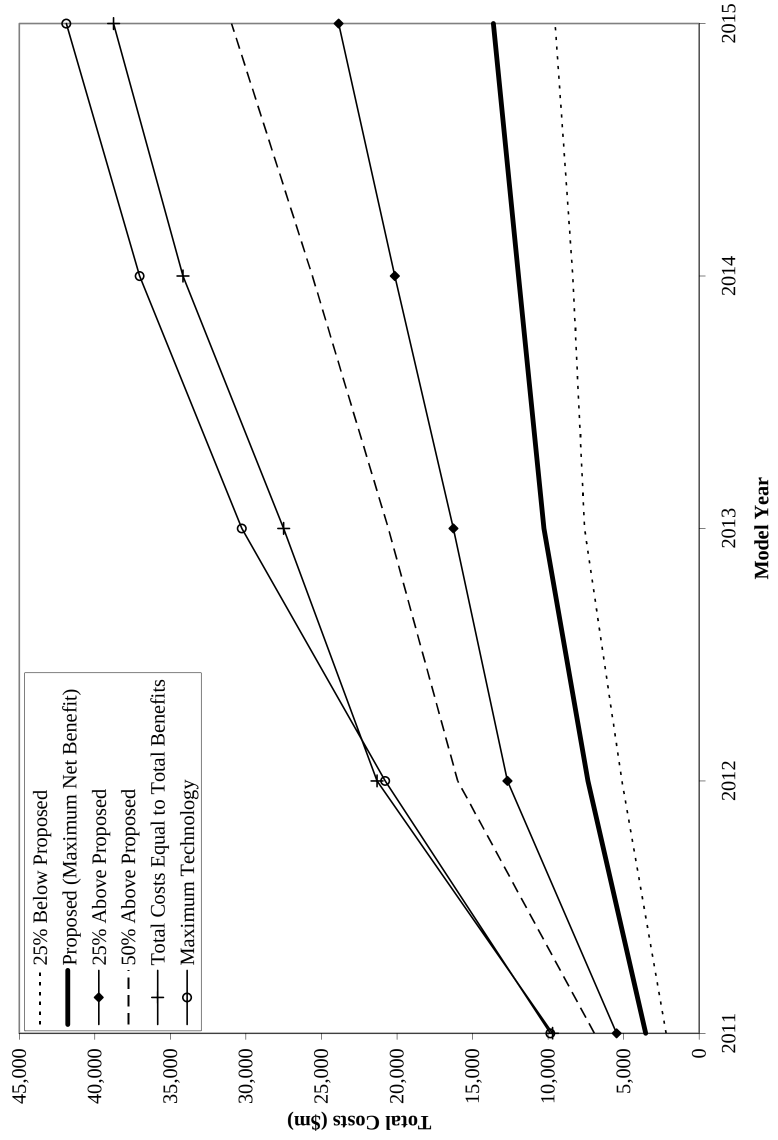
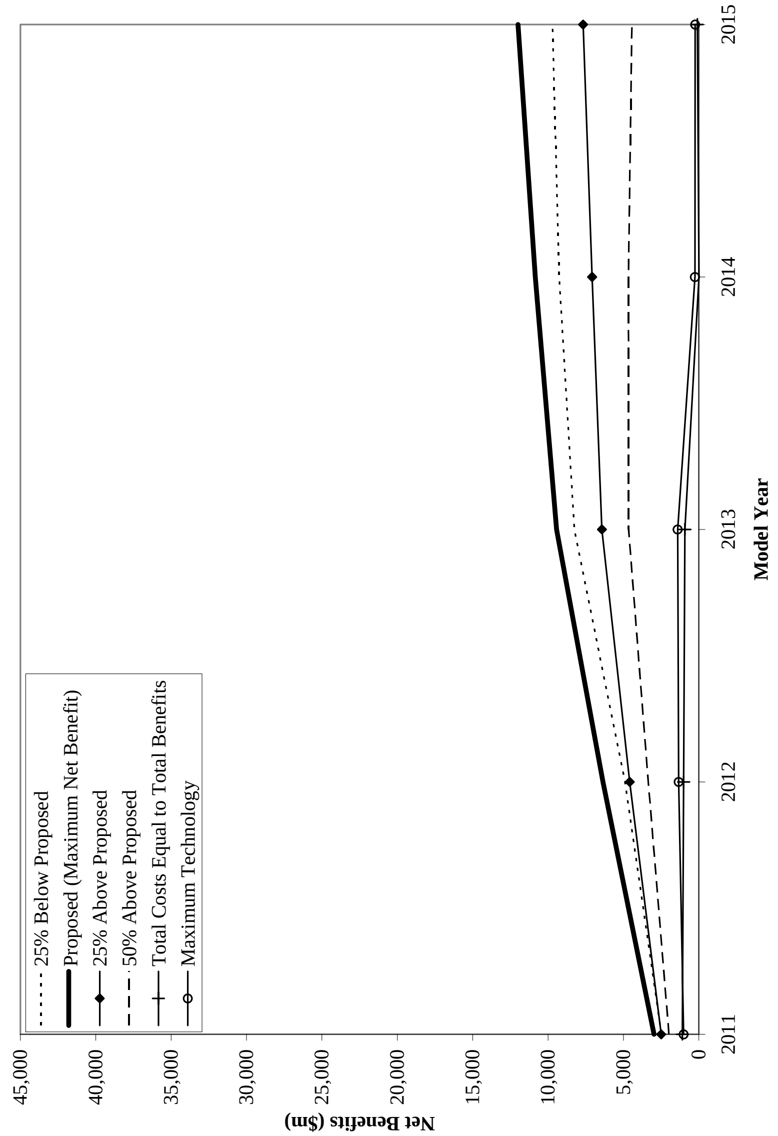


Figure III-6. Net Benefits under Proposed and Alternative Standards



For the proposal and each regulatory alternative, the Tables 22 and 23 show the total net benefits in millions of dollars at a 7 percent discount rate for the projected fleet of sales for each model year.

Table III-1
Total Benefits
Over the Vehicle's Lifetime – Present Value
(Millions of 2006 Dollars)

(Discounted 7**%**)

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below	1,156	2,104	3,235	5,197	6,799
Optimized	2,596	4,933	6,148	7,889	9,420
25% Above	3,755	7,280	8,454	10,638	12,083
50% Above	4,274	8,825	10,213	12,576	14,495
TC = TB	5,769	10,878	12,087	14,644	16,492
Technology Exhaustion	5,834	11,282	12,968	15,930	18,061
Light Trucks					
25% Below	3,508	7,910	12,603	12,433	12,441
Optimized	3,909	8,779	13,560	14,915	16,192
25% Above	4,201	9,990	14,236	16,587	19,457
50% Above	4,642	10,507	15,011	17,687	20,892
TC = TB	5,027	11,453	16,330	19,515	22,367
Technology Exhaustion	5,088	11,457	19,418	22,093	24,779
Combined PC+LT					
25% Below	4,664	10,014	15,838	17,630	19,240
Optimized	6,505	13,712	19,708	22,804	25,612
25% Above	7,956	17,270	22,690	27,225	31,540
50% Above	8,916	19,331	25,224	30,263	35,387
TC = TB	10,796	22,331	28,417	34,159	38,860
Technology Exhaustion	10,922	22,795	32,363	38,004	42,820

Table III-2
Total Costs
(Millions of 2006 Dollars)

(Discounted 7%)

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below	835	818	1,253	2,153	3,209
Optimized	1,884	2,373	2,879	3,798	4,862
25% Above	3,387	5,653	6,445	8,240	9,084
50% Above	4,010	7,885	8,986	11,207	12,981
TC = TB	5,913	10,796	12,303	15,403	17,398
Max Technology	6,079	12,595	14,701	18,759	21,110
Light Trucks					
25% Below	1,349	4,296	6,329	6,212	6,326
Optimized	1,649	4,986	7,394	8,160	8,761
25% Above	2,072	7,034	9,815	11,903	14,781
50% Above	2,922	8,098	11,586	14,386	17,969
TC = TB	3,788	10,525	15,196	18,762	21,364
Max Technology	3,933	10,670	18,275	21,051	23,479
Combined PC+LT					
25% Below	2,184	5,114	7,582	8,365	9,534
Optimized	3,534	7,358	10,273	11,957	13,623
25% Above	5,459	12,687	16,261	20,143	23,865
50% Above	6,932	15,983	20,572	25,593	30,950
TC = TB	9,702	21,321	27,499	34,164	38,761
Max Technology	10,013	23,266	32,976	39,810	44,589

Table III-3
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
(Millions of 2006 Dollars)

(Discounted 7%)

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars					
25% Below	321	1,285	1,982	3,045	3,590
Optimized	711	2,560	3,269	4,092	4,558
25% Above	368	1,627	2,009	2,398	2,999
50% Above	264	940	1,226	1,370	1,514
TC = TB	-144	82	-216	-759	-906
Max Technology	-245	-1,313	-1,733	-2,829	-3,049
Light Trucks					
25% Below	2,154	3,633	6,348	6,288	6,258
Optimized	2,260	3,793	6,167	6,755	7,432
25% Above	2,129	2,956	4,421	4,684	4,676
50% Above	1,720	2,408	3,426	3,301	2,924
TC = TB	1,239	928	1,134	753	1,004
Max Technology	1,155	843	1,120	1,023	1,280
Combined PC+LT					
25% Below	2,476	4,919	8,330	9,333	9,848
Optimized	2,971	6,353	9,435	10,847	11,989
25% Above	2,497	4,583	6,430	7,082	7,675
50% Above	1,984	3,349	4,652	4,670	4,437
TC = TB	1,094	1,010	918	-5	98
Max Technology	909	-471	-613	-1,806	-1,769

Negative values mean that costs exceed benefits.

In tentatively deciding which alternative to propose, the agency looked at a variety of factors. The agency notes that once stringency levels exceed the point at which net benefits are maximized, the societal costs of each incremental increase in stringency exceed the accompanying societal benefits. If we have valued benefits appropriately, it does not make economic sense to mandate the spending of more money than society receives in return. The resources used to meet overly stringent CAFE standards, instead of the optimized scenario standards, would better be allocated to other uses such as technology research and development, or improvements in vehicle safety.

The agency considered the burden placed on specific manufacturers, consumers and employment. As CAFE standards increase, the incremental benefits are approximately constant while the incremental costs increase rapidly. Figure III-5 above shows that as stringency is increased, costs rise out of proportion compared to the benefits or the fuel savings. Increasingly higher costs have a negative impact on sales and employment. Each of the alternatives that is more stringent than the optimized alternative negatively impact sales and employment.

The agency also considered technological feasibility. The Volpe model assumes that major manufacturers will exhaust all available technology before paying noncompliance civil penalties, even though the latter is often less costly. Historically, the large manufacturers have never paid civil penalties. NHTSA believes that there is a stigma to paying penalties that goes beyond economics. In the more stringent alternatives, the Volpe model predicts that increasing numbers of manufacturers will run out of technology to apply and, theoretically, resort to penalty payment. Setting standards this high is not technologically feasible, nor does it serve the need of the nation to conserve fuel. Paying a CAFE penalty does not result in any fuel savings.

In analyzing the "-25 percent below optimized" alternative, the agency notes that these standards are more aggressive than the standards that the agency has proposed since the first years of the program and would impose unprecedented costs on manufacturers. The agency also recognizes that even this pace of increase in the standards may burden some of the manufacturers, particularly since the agency is now increasing car and light truck standards simultaneously. However, in light of the need of the nation to conserve energy and reduce global warming, the agency does not believe that this alternative would be maximum feasible under the statute. The agency is also concerned that the combined fleet might not reach the 35 mpg requirement by 2020 under EISA.

Underlying the differences in costs, benefits, and net benefits for the other alternatives are differences in the degree to which NHTSA has estimated that technologies might be applied in response to the standards corresponding to each of these alternatives. The following tables show estimates of the average penetration rates of some selected technologies in the MY2015 passenger car and light truck fleets under each of the alternatives discussed here:

Table III-4

Estimated Average Technology Penetration (Largest Seven Manufacturers)
MY2015 Passenger Cars

Technology	Product Plan	Adjusted Baseline	25% Below Proposed	Proposed Standard	25% Above Proposed	50% Above Proposed	TC = TB	Tech. Exhaust-ion
	Average Among Seven Largest Manufacturers							
Automatically Shifted Manual Transmissions	10%	10%	23%	39%	47%	55%	63%	69%
Spark Ignited Direct Injection Engines	22%	22%	22%	30%	37%	48%	68%	63%
Turbocharging & Engine Downsizing	5%	5%	8%	17%	30%	40%	62%	57%
Diesel Engines	0%	0%	3%	2%	7%	13%	18%	21%
Hybrid Electric Vehicles	5%	5%	14%	15%	22%	28%	35%	38%

Table III-5

Estimated Average Technology Penetration (Largest Seven Manufacturers)
MY2015 Light Trucks

Technology	Product Plan	Adjusted Baseline	25% Below Proposed	Proposed Standard	25% Above Proposed	50% Above Proposed	TC = TB	Tech. Exhaust-ion
	Average Among Seven Largest Manufacturers							
Automatically Shifted Manual Transmissions	10%	14%	42%	55%	58%	60%	59%	70%
Spark Ignited Direct Injection Engines	23%	24%	31%	40%	42%	55%	60%	69%
Turbocharging & Engine Downsizing	9%	11%	21%	31%	38%	51%	54%	65%
Diesel Engines	3%	6%	8%	10%	20%	23%	26%	28%
Hybrid Electric Vehicles	2%	6%	15%	25%	29%	31%	30%	30%

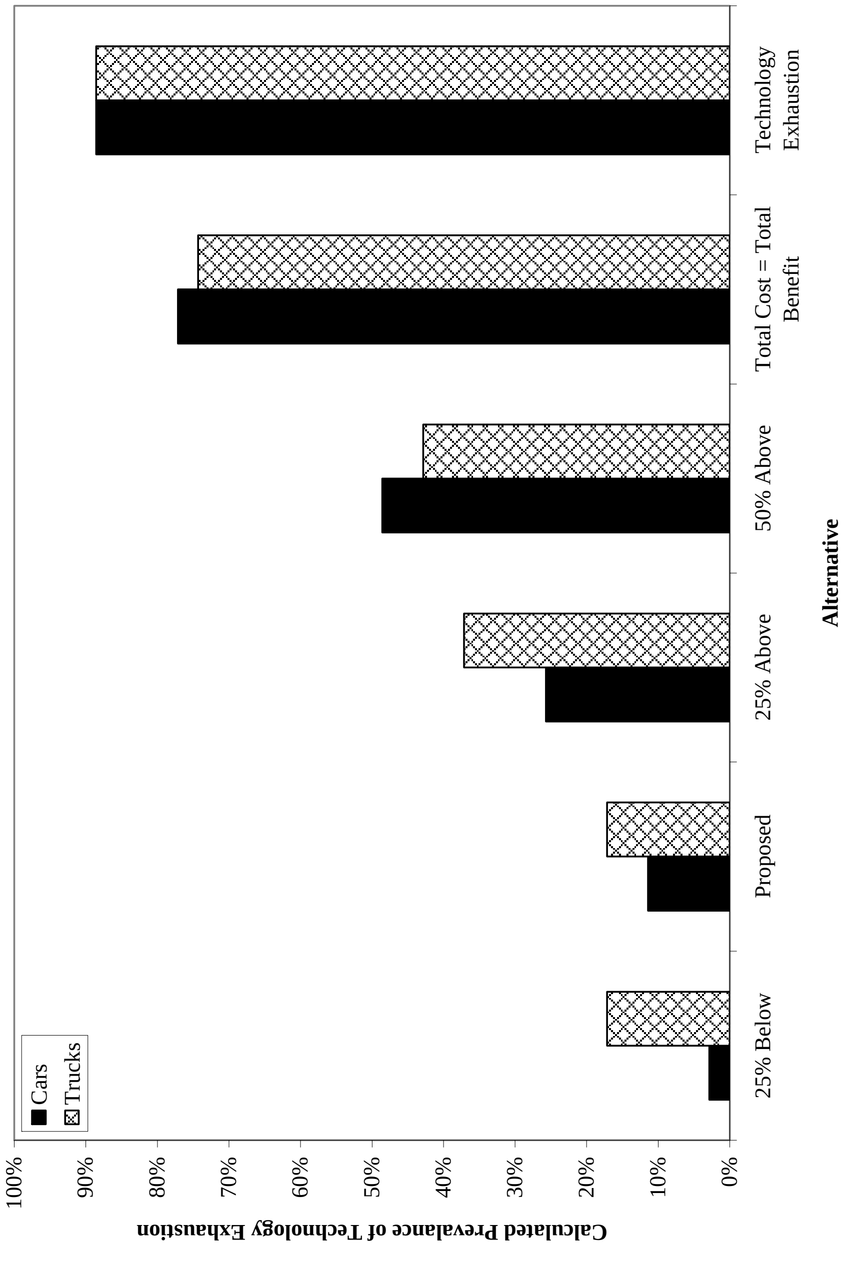
As the first of the above tables indicates, the Volpe model estimated that, under the standards proposed today, manufacturers might triple the planned utilization of turbochargers and hybrid electric powertrains in the passenger car fleet. This table also indicates that the use of turbochargers in passenger cars might increase by an additional factor of two under the “25% above proposed” alternative.

Similarly, the second table indicates that manufacturers might triple the planned utilization of diesel engines in the light truck fleet, and increase the utilization of hybrid electric powertrains by more than an order of magnitude. This table also shows a significant difference between the proposed and “25% above proposed” alternative, including an additional doubling in the utilization of diesel engines.

NHTSA has examined the extent to which each alternative would (as estimated by the Volpe model and using the input information discussed in preceding sections) cause manufacturers to exhaust technologies projected to be available during MY2011-MY2015. The following chart summarizes the frequency with which this was estimated to occur —*i.e.*, the number of instances in which an individual manufacturer exhausted technologies and thus fell below a standard in individual model years divided by 35 (seven manufacturers times five model years.

Figure III-6

Calculated Prevalence of Technology Exhaustion



As this analysis indicates, the "25% below proposed" alternative caused technologies to be exhausted 3% of the time for passenger cars, and 17% of the time for light trucks. Under the proposed standards, the rate of technology exhaustion increased to 11% for passenger cars, but did not change for light trucks. However, under the "25% above proposed" alternative, the corresponding rates increased to 26% and 37%, respectively. In other words, under this alternative, the Volpe model estimated that, more than a quarter of the time, manufacturers would be unable to comply with the passenger car standards solely using technologies expected to be available, and that they would be unable to comply with the light truck standards using available technologies more than a third of the time. These rates were estimated to be considerably higher for the remaining three alternatives.

These estimates of technology utilization and the exhaustion of available technologies indicate that all of the alternatives NHTSA has considered entail risk that one or more manufacturers would not be able comply with both the passenger car and light truck standards in every model year solely by applying technology. This risk is mitigated somewhat by the fact that our analysis may not encompass every technology that will potentially be available during MY2011-MY2015. For example, some manufacturers have made public statements regarding hopes to offer "plug-in" HEVs before MY2015, but such vehicles are not represented in our analysis.[17] Nonetheless, the agency has tentatively concluded that the scope of technologies it has included is comprehensive enough that the analysis shown above indicates that under some alternatives, there is considerable risk that some manufacturers would exhaust available technologies in some model years.

In tentatively concluding that the proposed standards are the maximum feasible standards, NHTSA has balanced this risk against the other considerations it must take into account, in particular the need of the nation to conserve energy, which encompasses concerns regarding carbon dioxide emissions. The agency's analysis includes economic measures of these needs—that is, economic measures of the externalities of petroleum consumption and the damages associated with carbon dioxide emissions. These measures are reflected in the agency's estimates of the total and net benefits of each of the alternatives.

NHTSA is proposing standards that it estimates will entail risk that some manufacturers will exhaust available technologies in some model years. However, relative to the less stringent "25% below proposed" alternative, the agency has tentatively concluded that the additional risk is outweighed by the significant increase in estimated net benefits to society, ranging from an additional \$0.5b in MY2011 to an additional \$2.1b in MY2015. Conversely, the agency has tentatively concluded that, relative to the proposed standards, the more than doubling of risk posed by the "25% above proposed" alternative is not warranted, especially considering that this alternative is estimated to significantly <u>reduce</u> net benefits, by \$0.5b in MY2011 and, eventually, \$4.3b in MY2015.

The agency invites comment regarding whether it has struck a proper balance and, if not, how it should do so. The alternatives identified by the agency are intended to aid public commenters in helping the agency to explore that issue.

Notwithstanding the tentative conclusions described above, NHTSA seeks comment on these regulatory alternatives to aid in determining what standards to adopt in the final rule. Specific sensitivity runs that vary fuel prices, the rebound effect, CO_2 and discount rate were conducted for the proposed optimized standards. These analyses have an

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[17] If included in the new product plans that the agency is requesting, these vehicles will be included in our analysis for the final rule.

impact on the standards, costs and benefits. For example, in analyzing the “optimized alternative”, we estimated that following the same methods and criteria for setting the standards, but applying a 3% discount rate rather than a 7% discount rate, would suggest standards reaching about 33.6 mpg (average required fuel economy among both passenger cars and light trucks) in MY2015, 2 mpg higher than the 31.6 mpg average resulting from the standards we are proposing based on a 7% discount rate. The more stringent standards during MY2011-MY2015 would reduce CO_2 emissions by 672 million metric tons (mmt), or 29% more than the 521 mmt achieved by the proposed standards. On the other hand, we estimate that standards increasing at this pace would require about $85b in technology outlays during MY2011-MY2015, or 89% more than the $45b in technology outlays associated with the standards proposed today. The impact of the 3% rate is shown in the body of the PRIA along with the 6 formal alternatives. All other sensitivity analyses are shown in Chapter IX.

IV. IMPACT OF OTHER FEDERAL MOTOR VEHICLE STANDARDS ON FUEL ECONOMY

Introduction

The Energy Policy and Conservation (EPCA or the Act) requires that fuel economy standards be set at the maximum feasible level after taking into account the following criteria: (1) technological feasibility, (2) economic practicability, (3) the impact of other Federal Motor Vehicle Standards on fuel economy, and (4) the need of the Nation to conserve energy. This section discusses the effects of other government regulations on model year (MY) 2011-2015 passenger car and light truck fuel economy.

The Impact of Safety Standards and Voluntary Safety Improvements

The fuel economy impact of safety improvements will typically take the form of increased vehicle weight, which reduces the fuel economy of the vehicle. The manufacturer's estimates of weight and fuel economy impact have already been included in their baseline fuel economy projections. In some instances the manufacturers' weight estimates are similar to NHTSA's, in some instances they are less than NHTSA's, but often they are more than NHTSA's. The agency's estimates are based on cost and weight tear-down studies of a few vehicles and cannot possibly cover all the variations in the manufacturers' fleets. NHTSA requested and various manufacturers provided estimates of increases in weight resulting from safety improvements, based on a MY 2007 baseline. However, for the passenger car and light truck proposal MY 2010 is the baseline. Thus, only safety equipment required to be installed or voluntarily installed after these dates are included in this analysis.

We have broken down our analysis of the impact of safety standards that might affect the MY 2011-2015 fleets into two parts, those final rules with known effective dates, and proposed rules without final effective dates or currently voluntary safety improvements.

Weight Impacts of Required Safety Standards (Final Rules)

The National Highway Traffic Safety Administration (NHTSA) has issued two final rules on safety standards that become effective for passenger cars and light trucks between MY 2011 and MY 2015. These have been analyzed for their potential impact on passenger car and light truck weights, using MY 2010 as a baseline.

1. FMVSS 126, Electronic Stability Control
2. FMVSS 214, Side Impact Oblique Pole Test

FMVSS 126, Electronic Stability Control

The phase-in schedule for vehicle manufacturers is:

Model Year	Production Beginning Date	Requirement
2009	September 1, 2008	55% with carryover credit
2010	September 1, 2009	75% with carryover credit
2011	September 1, 2010	95% with carryover credit
2012	September 1, 2011	All light vehicles

The final rule requires 75 percent of all light vehicles to meet the ESC requirement for MY 2010, 95 percent of all light vehicles to meet the ESC requirements by MY 2011, and all light vehicles must meet the requirements by MY 2012.

The agency's analysis of weight impacts found that ABS adds 10.7 lbs. and ESC adds 1.8 lbs. per vehicle for a total of 12.5 lbs. Based on manufacturers' plans for voluntary installation of ESC, 85 percent of passenger cars in MY 2010 would have ABS and 52 percent would have ESC. Thus, the total incremental added weight over manufacturers' plans in MY 2011 for passenger cars would be about 1.8 lbs. (0.10*10.7 + 0.43*1.8) and in MY 2012 an incremental 0.6 lbs. (0.05*10.7 + 0.05*1.8). Light trucks manufacturers' plans show that 99 percent of all light trucks would have ABS and that 74 percent would have ESC by MY 2010. Thus, for light trucks the incremental weight impacts of adding ESC would be 0.4 lbs. (0.21*1.8) in MY 2011 and an incremental 0.1 lbs. (0.01*10.7 + 0.05*1.8) in MY 2012.

FMVSS 214, Oblique Pole Side Impact Test

The phase-in requirements for the side impact test are as shown below in Table IV-1[18]:

Table IV-1

FMVSS 214 Final Rule Phase-In Schedule

Phase-in Date	Percent of each manufacturer's light vehicles that must comply during the production period
September 1, 2009 to August 31, 2010	20 percent (excluding vehicles GVWR > 8,500 lbs.)
September 1, 2010 to August 31, 2011	50 percent vehicles (excluding vehicles GVWR > 8,500 lbs.)
September 1, 2011 to August 31, 2012	75 percent vehicles (excluding vehicles GVWR > 8,500 lbs.)
September 1, 2012 to August 31, 2013	All vehicles including limited line vehicles, except vehicles with GVWR > 8,500 lbs., alterers, and multi-stage manufacturers
On or after September 1, 2013	All vehicles, including vehicles with GVWR > 8,500 lbs., alterers and multi-stage manufacturers

Based on manufacturers' plans to voluntarily provide window curtains and torso bags, we estimate that 90 percent of passenger cars and light trucks would have window curtains for MY 2010 and 72 percent would have torso bags. A very similar percentage is estimated for MY 2011. A teardown study of 5 thorax air bags resulted in an average weight increase per vehicle of 4.77 pounds (2.17 kg).[19] A second study[20] performed teardowns of 5 window curtain systems. One of the window curtain systems was very

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[18] The agency has received several petitions for reconsideration to extend the lead time.

[19] Khadilkar, et al. "Teardown Cost Estimates of Automotive Equipment Manufactured to Comply with Motor Vehicle Standard – FMVSS 214(D) – Side Impact Protection, Side Air Bag Features", April 2003, DOT HS 809 809.

[20] Ludtke & Associates, "Perform Cost and Weight Analysis, Head Protection Air Bag Systems, FMVSS 201", page 4-3 to 4-5, DOT HS 809 842.

heavy (23.45 pounds). The other four window curtain systems had an average weight increase per vehicle of 6.78 pounds (3.08 kg), a figure which is assumed to be average for all vehicles in the future.

Assuming in the future that the typical system used to comply with the requirements of FMVSS No. 214 will be thorax bags with a window curtain, the average weight increase would be 2 pounds (0.10*6.78 + 0.28*4.77) in MY 2013. However, there is the potential that some light trucks might need to add structure to meet the test. The agency has no estimate of this potential weight impact for structure.

Weight Impacts of Proposed/Planned Safety Standards

Proposed FMVSS 216, Roof Crush

On August 23, 2005, NHTSA proposed amending the roof crush standard to increase the roof crush standard from 1.5 times the vehicle weight to 2.5 times the vehicle weight[21]. The NPRM proposed to extend the standard to vehicles with a GVWR of 10,000 pounds or less, thus including many light trucks that had not been required to meet the standard in the past. The proposed effective date was the first September 1 occurring three years after publication of the final rule. In the PRIA, the average passenger car weight was estimated to increase by 4.0 pounds and the average light truck weight was estimated to increase by 6.1 pounds for a 2.5 strength to weight ratio. Based on comments to the NPRM, the agency believes that this weight estimate is likely to increase. However, the agency does not yet have an estimate for the final rule.

Planned NHTSA initiative on Ejection Mitigation

The agency is planning on issuing a proposal on ejection mitigation. The likely result of the planned proposal is for window curtain side air bags to be larger and for a rollover sensor to be installed. The likely result will be an increase in weight of at least one pound, however, this analysis is not completed. In addition, advanced glazing is one alternative that manufacturers might pursue for specific window applications (possibly for fixed windows for third row applications) or more broadly. Advanced glazing is likely to have weight implications. Again the agency has not made an estimate of the likelihood that advanced glazing might be used or its weight implications.

Possible NHTSA initiative on Pedestrian Protection

The agency has started to analyze the costs and benefits of a potential Global Technical Regulation on pedestrian protection. Whether the agency will propose a rulemaking and the effective dates have not been decided, however, it is possible that a rule on pedestrian protection could start to be phased in by the end of the period of this proposed rulemaking. Potential weight increases for pedestrian head and leg protection have not yet been identified.

Summary – Overview of Anticipated Weight Increases

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[21] See 70 FR 53753, the PRIA is in Docket No. 22143, entry #2 “Preliminary Regulatory Impact Analysis, FMVSS 216, Roof Crush Resistance,” August 2005.

The following table summarizes estimates made by NHTSA regarding the weight added in MY 2011 or later to institute the above discussed standards or likely rulemakings. In summary, NHTSA estimates that weight additions required by final rules and likely NHTSA regulations effective in MY 2011 and beyond, compared to the MY 2010 fleet and manufacturers' plans, will increase passenger car weight by at least 9.4 lbs. and light truck weight by at least 9.6 lbs.

Table IV-2
Weight Additions Due to Final Rules or Likely NHTSA Regulations
Compared to MY 2010 Baseline fleet

Standard No.	**Added Weight in pounds** Passenger Car	**Added Weight in kilograms** Passenger Car	**Added Weight in pounds** Light Trucks	**Added Weight in kilograms** Light trucks
126	2.4	1.1	0.5	0.2
214	2.0	0.9	2.0 - ?	0.9 - ?
216	4.0 - ?	1.8 - ?	6.1 - ?	2.8 - ?
Ejection Mitigation	1.0 - ?	0.4 - ?	1.0 - ?	0.4 - ?
Total	9.4 - ?	4.2 - ?	9.6 - ?	4.3 - ?

Based on NHTSA's weight-versus-fuel-economy algorithms, a 3-4 pound increase in weight equates to a loss of 0.01 mpg in fuel economy. Thus, the agency's estimate of the safety/weight effects are 0.024 to 0.032 mpg or more for already issued or likely future safety standards.

CONFIDENTIAL SUBMISSIONS

Weight Impacts of Potential Future Voluntary Safety Improvements

At the time the agency requested information about fuel economy plans and capabilities for the future, the agency also requested information on weight increases that could occur due to safety improvements. Several manufacturers provided confidential information about plans they had to meet final rules, proposed safety standards, or to voluntarily increase safety. The baseline for these plans was MY 2007. Several of these plans were to meet IIHS offset frontal of side impact testing. Most of these improvements will be installed on vehicles by MY 2011. [
.] Thus, many of them will have occurred by the time this rulemaking is effective. The areas covered above and the remaining areas described as voluntary safety initiatives that have weight implications and the confidential weight estimates are shown in Table IV-3 after MY 2007 and on Table IV-3a for those initiatives taking affect after MY 2011.

[Table IV-3
Confidential Submissions on Safety Standards and Voluntary Safety Improvements
Any model year after MY 2007

	DCX		**Ford**		**GM**	
	Pounds	Kg.	Pounds	Kg.	Pounds	Kg.
ESC						
Side Impact						
Roof Crush						
Vehicle Compatibility						
Ejection Mitigation						
Pedestrian Protection						
IIHS frontal pole test						
Lane Departure Warning						
Total all actions after MY 2007						

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[Table IV-3a
Confidential Submissions of Weight Impacts After MY 2011

	DCX		**Ford**		**GM**	
	Pounds	Kg.	Pounds	Kg.	Pounds	Kg.
ESC						
Side Impact						
Roof Crush						
Vehicle Compatibility						
Ejection Mitigation						
Pedestrian Protection						
Misc. structure for ratings						
IIHS frontal pole test						
Lane Departure Warning						
Total all actions after MY 2011						

Vehicle Size and Safety

NHTSA believes that an attribute based Reformed CAFE system removes the incentive to downsize that is inherent in the traditional fleet-wide CAFE flat standard requirement. The agency believes that the attribute based standard is likely to have beneficial impacts on safety compared to the flat standard. Other things being equal, smaller vehicles provide less protection to their occupants in the event of a crash because there is less vehicle mass to absorb the crash energy and less interior space to buffer occupants from sheet metal intrusion. In addition, smaller vehicles are generally more likely to roll over. In single vehicle crashes, smaller vehicles are less safe than larger vehicles. In multi-vehicle crashes, both individual vehicle size and the relative size of the involved vehicles play a role in determining the injury outcome of occupants. Generally, larger vehicles will provide better protection, but often at the expense of occupants of smaller vehicles. If larger vehicles were to be reduced in size, it would likely decrease the chance of injury in crashes with smaller vehicles, but it would also likely increase the chance of injury for the occupants of the larger vehicles. The makeup of any future mix-shifts in vehicle sales is purely speculative and the overall impact on injuries in multi-vehicle crashes of any future mix-shifts in vehicle size is unknown. However, downsizing is likely to increase the crash risk for vehicle occupants in single vehicle crashes, which make up 30% of all crashes and 57% of all fatalities. An attribute based system will require improvements in fuel economy for all vehicle sizes, and will thus minimize incentives to downsize vehicles.

The NAS study

The 2002 National Academy of Sciences (NAS)[22] report made explicit links between weight and vehicle safety. The NAS study conclusions were divided, with 11 of 13 committee members representing the majority view and 2 of 13 the minority view. The findings of the majority presented on page 77 were:

"In summary, the majority of the committee finds that the downsizing and weight reduction that occurred in the late 1970s and early 1980s most likely produced between 1,300 and 2,600 crash fatalities and between 13,000 and 26,000 serious injuries in 1993. The proportion of these casualties attributable to CAFE standards is uncertain. It is not clear that significant weight reduction can be achieved in the future without some downsizing, and similar downsizing would be expected to produce similar results. Even if weight reduction occurred without any downsizing, casualties would be expected to increase. Thus, any increase in CAFE as currently structured could produce additional road casualties, unless it is specifically targeted at the largest, heaviest light trucks." …

"Some might argue that this improving safety picture means that there is room to improve fuel economy without adverse safety consequences. However, such a measure would not achieve the goal of avoiding the adverse safety consequences of fuel economy increases. Rather, the safety penalty imposed by increased fuel economy (if weight reduction is one of the measures) will be more difficult to identify in the light of the continuing improvement in traffic safety. Just because these anticipated safety innovations will

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[22] "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards", National Research Council, 2002. The link for the NAS report is http://www.nap.edu/books/0309076013/html/

improve the safety of vehicles of all sizes does not mean that downsizing to achieve fuel economy improvements will have no safety costs.

If an increase in fuel economy is effected by a system that encourages either downweighting or the production and sale of more small cars, some additional traffic fatalities would be expected. Without a thoughtful restructuring of the program, that would be the trade-off that must be made if CAFE standards are increased by any significant amount."

The minority view summarized on page 123 was:

"The relationship between vehicle weight and safety are complex and not measurable with any reasonable degree of certainty at present. The relationship of fuel economy to safety is even more tenuous. But this does not mean that there is no reason for concern. Significant fuel economy improvements will require major changes in vehicle design. Safety is always an issue whenever vehicles must be redesigned.

In addition, the distribution of vehicle weights is an important safety issue. Safety benefits should be possible if the weight distribution of light-duty vehicles could be made more uniform, and economic gains might result from even partly correcting the negative externality that encourages individuals to transfer safety risks to others by buying ever larger and heavier vehicles.

Finally, it appears that in certain kinds of accidents, reducing weight will increase safety risk, while in others it may reduce it. Reducing the weights of light-duty vehicles will neither benefit nor harm all highway users, there will be winners and losers…."

The Kahane Study

The Kahane study[23] estimates the effect of 100-pound reductions in heavy light trucks and vans (LTVs), light LTVs, heavy passenger cars, and light passenger cars. It compares the fatality rates of LTVs and cars to quantify differences between vehicle types, given drivers of the same age/gender, etc. Some of its findings are:

"Heavy vehicles had lower fatality rates per billion miles of travel than lighter vehicles of the same general type. When two vehicles collide, the laws of physics favor the occupants on the heavier vehicle (momentum conservation). Furthermore, heavy vehicles were in most cases, longer, wider and less fragile than light vehicles. In part because of this, they usually had greater crashworthiness, structural integrity and directional stability. They were less rollover-prone and easier for the average driver to control in a panic situation. In other words, heavier vehicles tended to be more crashworthy and less crash-prone. Some of the advantages for heavier vehicles are not preordained by the laws of physics, but were nevertheless characteristic of the MY 9991-99 fleet. Offsetting those advantages, heavier vehicles tended to be more aggressive in crashes, increasing risk to occupants of the vehicles they collide with."

Six different crash modes were analyzed (principal rollover, fixed object, pedestrian/bicycle/motorcyclist, and multi-vehicle crashes with heavy truck, light trucks,

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[23] "Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks", Charles J. Kahane, Ph. D., NHTSA, October 2003, DOT HS 809-662.

and passenger cars). Summing all these crash modes together, the net annual effects per 100-pound weight reduction were:
For passenger cars weighing less than 2,950 pounds – fatalities increased by 597
For passenger cars weighing 2,950 pounds or more – fatalities increased by 216
For light trucks weighing less than 3,870 pounds – fatalities increased by 234
For light trucks weighing 3,870 pounds or more – fatalities increased by 71

In all cases, annual fatalities increased with a reduction in weight. However, further analysis of the Kahane study found that the net safety effect of removing 100 pounds from a light truck is zero for the <u>group</u> of all light trucks with a curb weight greater than 3,900 lbs.[24] Given the significant statistical uncertainty around that figure, we assumed a confidence bound of approximately 1,000 lbs. and used 5,000 lbs. as the threshold for considering weight reduction of <u>specific models</u>. In the MY 2008-2011 light truck final rule, NHTSA included weight reduction as a fuel improving technology for light trucks over 5,000 lbs. curb weight where we determined that weight reduction would not reduce overall safety and would be a cost-effective choice. We are applying the same methodology in this proposal, weight reduction is considered a technology that can be applied to light trucks over 5,000 lbs. curb weight.

The agency believes a number of conclusions can be drawn from these studies:

- Heavier vehicles are more crashworthy and less crash prone.[25]
- The net impacts on safety, considering the six different crash modes, of reducing weight are negative for all but the larger light trucks. However, this type of analysis can not examine extreme cases. For example, if there were a large mix shift from 50 percent passenger car and 50 percent light truck sales, to 80 percent compact or smaller passenger cars and 20 percent pickup truck sales, this analysis cannot determine the net impacts on safety. Nothing in the manufacturer's plans suggests a drastic change in the mix of vehicles, nor is there any incentive, in our opinion, for such a change based on NHTSA's attribute based proposal on fuel economy.
- Lighter vehicles fare worse in single vehicle collisions. In 2006, 57 percent of all passenger car and light truck fatalities were in single vehicle crashes and 43 percent were in multi-vehicle crashes. Fatalities are almost split between rollovers (29 percent) and fixed or non-fixed objects (28 percent).
- Reducing weight increases the likelihood of rolling over. When you are sliding sideways and digging into mud or grass or hit a curb, all things being equal, the lighter vehicle is more prone to rolling over. Increasing track width (part of the footprint calculation) reduces the likelihood of rolling over. Track width is more important than weight for rollovers. Rollover is the only area in which track

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[24] Kahane, Charles J., PhD, Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks, October 2003. DOT HS 809 662. Page 161. Docket No. NHTSA-2003-16318 (http://www.nhtsa.dot.gov/cars/rules/regrev/evaluate/pdf/809662.pdf)

[25] See Kahane study, page xiv Table 3 for prorated fatal crash involvements per billion miles.

width is the most important factor. Weight is more important than track width or wheelbase in the other five crash modes investigated.[26]

- Reducing weight increases the likelihood of being killed in a fixed or non-fixed object crash. If you run into a tree, you are safer if you knock that tree down than if the tree stops your vehicle. A heavier vehicle has a better chance of knocking the tree down.

The Kahane report also examined the total fatality crash rates in all crash modes; including fatalities to occupants of the case vehicle (i.e. in rollovers, single vehicle and multi-vehicle crashes), occupants of the other vehicle it collided with (to account for aggressive vehicles) and pedestrians. Kahane used VMT data based on CDS odometer readings and controlled for age and gender based on State data on nonculpable crash involvements (induced exposure). With these controls, the societal fatality rates per billion miles were:

TABLE IV-4

ADJUSTED FATAL-CRASH INVOLVEMENT RATES PER BILLION CASE VEHICLE MILES, BY VEHICLE TYPE

(Case vehicles are MY 1996-99 light trucks and 4-door cars with air bags in CY 1996-2000, adjusted for age/gender, rural/urban, day/night, speed limit, and other factors)

Vehicle Type and Size	Average Curb Weight	Fatal Crash Involvements Per Billion Miles
Very small 4-door cars	2,105	15.73
Small 4-door cars	2,469	11.37
Mid-size 4-door cars	3,061	9.46
Large 4-door cars	3,596	7.12
Compact pickup trucks	3,339	11.74
Large (100-series) pickup trucks	4,458	9.56
Small 4-door SUVs	3,147	10.47
Mid-size 4-door SUVs	4,022	13.68
Large 4-door SUVs	5,141	10.03
Minivans	3,942	7.97

In other words, mid-size cars had somewhat lower societal fatal crash rates than SUVs that weighed considerably more. Large cars and minivans had the lowest rates.

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[26] See Kahane (Docket No. 2003-16318-16)

Advocates for Highway and Auto Safety commented that Kahane's (NHTSA's) 2003 analysis may not apply if the effects of size and weight reductions are disaggregated, "weight reductions without corresponding reductions in vehicle wheelbase length and track width could be expected to produce net benefits in reducing occupant crash risks."

NHTSA's response is that Footprint (especially track width) is an important variable in terms of a vehicle's propensity for rollovers, a type of crash that accounts for 29 percent of all light vehicle occupant traffic fatalities. Track width is one of the two vehicle properties that define Static Stability Factor (SSF). SSF was used as a single predominant factor to predict rollover rate in the agency's original rollover NCAP, and it is still the most powerful element in the agency's current rollover NCAP risk model that also factors in a road maneuver test. Wheelbase does not have a direct effect on rollover resistance. However, there are hypotheses that an increase in wheelbase could reduce loss-of-control crashes by making the vehicle react slower in yaw and thereby reduce the number of single-vehicle pavement departure crashes that produce most rollovers. Currently, the agency does not have any data to substantiate this theory.[27]

We would like to clarify that our analysis does not mandate weight reduction, or any specific technology application for that matter. Our analysis relied exclusively on other fuel-saving technologies for passenger cars and only applied weight reduction to light trucks that have a curb weight greater than 5,000 lbs. to demonstrate that manufacturers can comply with the proposed fuel economy levels without the need for potentially unsafe compliance measures.

Honda cited several reports, which it asserted demonstrated that limited weight reductions would not reduce safety and could possibly decrease overall fatalities. Honda stated that the 2003 study by DRI found that reducing weight without reducing size slightly decreased fatalities, and that this was confirmed in a 2004 study by DRI[28] that assessed new data and methodology changes in the 2003 Kahane Study. Honda asserted that the DRI results tend to confirm "that curb weight reduction would be expected to decrease the overall number of fatalities."

DRI submitted an additional study, Supplemental Results on the Independent Effects of Curb Weight, Wheelbase, and Track Width on Fatality Risk in 1985-1998 Model Year Passenger Cars and 1985-1997 Model Year LTVs, Van Auken, R.M. and J. W. Zellner, May 20, 2005 (Docket No. 2003-16128-1456). This DRI study concluded that reductions in footprint are harmful to safety, whereas reductions in mass while holding footprint constant would benefit safety. The DRI study disagreed with NHTSA's finding that mass had greater influence than track width or wheelbase on the fatality risk of passenger cars in non-rollover crashes.

While NHTSA agrees that limited weight reduction to heavier vehicles will not reduce safety, we disagree with DRI's overall conclusion, cited by Honda, that weight reductions

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[27] See Kahane (Docket No. 2003-16318-16)

[28] See Docket Nos. 2003-16318-2, 2003-16318-3, and 2003-16318-7.

while holding footprint constant would significantly benefit safety in lighter vehicles. NHTSA's analyses of the relationships between fatality risk, mass, track width and wheelbase in 4-door 1991-1999 passenger cars (Docket No. 2003-16318-16) found a strong relationship between track width and the rollover fatality rate, but only a modest (although significant) relationship between track width and fatality rate in non-rollover crashes. Even controlling for track width and wheelbase – e.g., by holding footprint constant – weight reduction in the lighter cars is strongly, significantly associated with higher non-rollover fatality rates in the NHTSA analysis. By contrast, the DRI study of May 20, 2005 analyzed 4-door cars and found a strong relationship between track width and fatality risk, and non-significant associations of mass and wheelbase with fatality risk (Docket No. 2005-22223-78, p. 31). In other words, when DRI analyzed the same group of vehicles as NHTSA, they did not get the same results. This difference indicates that DRI's analytical method and/or database are not the same as NHTSA's.

The agency continues to believe that weight reduction in lighter vehicles would reduce safety. However, we also believe that weight reductions in the heavier light trucks, while holding footprint constant, will not likely result in a net reduction in safety. In our opinion, it is impossible to reduce weight and maintain footprint unless you (a) substitute light for heavy materials in a big way or (b) remove features that customers want and are willing to pay for. In that sense, DRI's contention that weight is unimportant could only be true for material substitution, because under present circumstance weight reduction usually also means size reduction, and DRI agrees with NHTSA that a reduction in footprint is harmful to safety.

General Motors (Docket No. 2005-22223-1493) and the Alliance (Docket No. 2005-22223-1642) were more explicit in their concerns over the safety impact associated with weight reduction. The Alliance stated that the fundamental laws of physics dictate that smaller and/or lighter vehicles are less safe than larger/heavier counterparts with equivalent safety designs and equipment. General Motors agreed that improvements in material strength, flexibility, and vehicle design have helped improve overall vehicle and highway safety. But, General Motors added, for a given vehicle, reducing mass generally reduces net safety. Further, General Motors stated that it does not intentionally reduce mass by replacing it with advanced materials, presuming that such action alone will result in improved protection for the occupants in a lighter vehicle; instead GM continues to believe that vehicles with larger mass will provide better protection to occupants involved in a crash than a vehicle of the same design with less mass, given equivalent crashes.

General Motors also questioned the agency's reliance on a 5,000 lbs. minimum vehicle weight for considering weight reduction, which was based on the finding of the 2003 Kahane report. General Motors stated that the agency's conclusion is inconsistent with the sensitivity analysis performed by William E. Wecker Associates, Inc.[29] and submitted to the ANPRM docket. General Motors stated that the inflection point on the Wecker report's graph for General Motors light trucks in both the periods of MYs 1991-1995 and MYs 1996-1999 is higher than 5,000 pounds.

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[29] Docket No. 2003-16128-1112

Additionally, General Motors stated that the NPRM did not acknowledge or respond to the main point of the Wecker report, which was that Dr. Kahane's "analysis alone does not support the proposition that a crossover weight at or near 5,085 pounds is a robust, accurate description of the field performance of the fleet."

We believe that General Motors was confusing the 5,085 lbs. crossover weight (where the safety effect of mass reduction in a vehicle weighing exactly 5,085 lbs., is zero) with the breakeven point described in the NPRM, which is the point where the total effect of reducing all vehicles heavier than the breakeven weight by an equal amount is zero. NHTSA estimated that the breakeven point as described in the NPRM is 3,900 lbs., if footprint is held constant.

If the 3,900 lbs. estimate were perfectly accurate, we would be confident that weight reductions in vehicles down to 3,900 pounds would not result in net harm to safety. However, we agree with commenters that there is considerable uncertainty about the crossover weight and also the breakeven point. Therefore, in our analysis, we limited weight reduction to vehicles with a curb weight greater than 5,000 pounds. We believe that the 5,000 lbs. limit is sufficient so that we can be confident that such weight reductions will not have net harm on safety.

SUVOA encouraged NHTSA to emphasize the importance of making sure that CAFE requirements do not encourage vehicle downsizing "or any other action that might have an adverse effect on safety." SUVOA cited several reports in support of its assertion that downsizing harms safety[30]. As explained above, the agency has applied weight reduction only to those vehicles for which we are confident that such reduction will not negatively impact safety, however, our analysis does not mandate the use of specific technologies or weight reductions.

Environmental Defense (Docket No. 2005-22223-1805) commented that by limiting the use of weight reduction to heavier vehicles, the agency disregarded the likelihood that manufacturers would rely on weight reduction in smaller, lighter vehicles. Environmental Defense suggested that the improved baselines should reflect this weight reduction strategy.

Environmental Defense asserted that weight reduction is among the most common and cost-effective options available to manufacturers for improving vehicle fuel economy

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[30] SUVOA (see Docket No. 2003-16128-1067) provided the following cites in support of its assertion:

- 2001, the National Academy of Sciences affirmed that earlier downsizing of vehicles following the imposition of CAFE regulations resulted in an additional 1,300 to 2,600 deaths and an additional 20,000 serious injuries per year.
- A Harvard School of Public Health-Brookings Institution study in the 1990s found that vehicle downsizing due to federal fuel economy mandates increased occupant deaths by 14 to 27 percent.
- An in-depth analysis by *USA Today* in 1999, using NHTSA and auto insurance industry data, found that since 1975, 7,700 additional deaths occurred for every mile per gallon gained. By 1999, vehicle downsizing had killed more than 46,000 Americans. Factoring in the ensuing six years through 2005, the total conservatively eclipses 55,000 deaths.

across the light truck fleet. Environmental Defense referenced estimates presented in DeCicco (2005) that suggest that the cost per pound of weight reduced through use of high-strength steel and advanced engineering techniques has been as low as, or lower than, 31 cents per pound reduced.

Moreover, Environmental Defense stated, the exclusion of mass reduction in NHTSA's analysis bears no relation to what will actually happen in the marketplace when standards are implemented. Environmental Defense argued that absent safety regulations prohibiting the use of mass reductions, manufacturers are likely to choose this compliance alternative in vehicles of all weights as a cost-effective way to comply with CAFE. Environmental Defense stated that NHTSA should consider the potential for mass reduction among its compliance alternatives for *all* light trucks.

As stated above, the agency does not dictate which fuel-savings technologies must be applied to vehicles. Mass reduction is a compliance alternative for all light vehicles. However, one of the considerations in setting fuel economy standards is to set standards that will not lead to a reduction in safety. The standards proposed by the agency are those capable of being achieved by the manufacturers without the need to reduce safety. If the agency were to consider weight reduction as a compliance option, we are concerned that the resulting increased stringency would force unsafe downweighting.

A group of experts at a workshop sponsored by the International Council on Clean Transportation (ICCT) examined many of the size/safety reports and wrote a June 2007 report "Sipping Fuel and Saving Lives: Increasing Fuel Economy Without Sacrificing Safety."[31] NHTSA agrees with two of the three ICCT report findings. We agree that fuel economy technologies exist that don't affect safety. We agree that reducing weight (on vehicles over 5, 000 lbs) can make certain vehicles less aggressive and reduce their weight and probably improve safety. Many, but not all of the experts at the workshop, agreed with the last conclusion: "Advanced technologies can decouple size from mass, creating important new possibilities for increasing fuel economy and safety without compromising functionality". We continue to believe, until someone demonstrates to the contrary with some kind of rigorous, scientific analysis, that reducing weight on smaller lighter vehicles will only make them more dangerous in single-vehicle crashes, because of fundamental physics.

A study examined similar safety issues - "The "Arms Race" on American Roads: The Effect of Sport Utility Vehicles and Pickup Trucks of Traffic Safety", Michelle J. White, University of California San Diego, Journal of Law and Economics, Volume XLVII, October 2004. The White paper finds that "When drivers shift from cars to light trucks or SUVS, each crash that involves fatalities from light truck or SUV occupants that is prevented comes at a cost of at least 4.3 additional crashes that involve deaths of car occupants, pedestrians, bicyclists, or motorcyclists."

The White study is an analysis of NHTSA's National Automotive Sampling System, General Estimates System and, as such, looks at the fatality risk given that a crash

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[31] See www.theicct.org/documents/ICCT_SippingFuelFull_2007.pdf

occurred. However, it does not control for VMT (likelihood of a crash given a mile of driving). Furthermore, the study does not address the safety of big cars vs. small cars or big LTVs versus small LTVs. Whether overall safety would be improved by shifting sales from SUV and pickups to passenger cars depends on what size of passenger cars you shifted to (see the table above), if you shifted to small or very small passenger cars, overall safety would decrease.

Another study examined the size/safety issues – "The Fatality Risks of Sports Utility Vehicles, Vans, and Pickups Relative to Cars", Ted Gayer, Georgetown University, The Journal of Risk and Uncertainty, 28-2, 103-133, 2004. This study finds that "Using a cross-sectional variation in snow depth as an instrument to determine VMT, the results suggest that light trucks are 2.63 to 4.00 times more likely to crash than cars." "…once one adjusts for the greater frequency of crashes by light trucks, the aggregate risk they pose substantially dominates the risk from cars. Indeed a world of light trucks would lead to three to ten times more fatalities than a world of cars."

This study does not address the safety of big cars vs. small cars or big LTVs versus small LTVs. This analysis using snow depth exaggerates the difference in crash frequency and fatality rates between passenger cars and light trucks. Kahane's study also adjusted the raw data for VMT, but we have used odometer readings by age of vehicle to control for VMT and found no such discrepancy in crash rates. The table above from the Kahane study does not show light trucks having substantially higher fatality rates than passenger cars.

A 2001 study by Dr. Leonard Evans,[32] modeled the risk of driver fatality in car 1 in a head-on collision with car 2. The equations in the report indicate that reducing the curb weight of car 1 would increase the risk to the driver of car 1, while reducing the curb weight of car 2 would decrease the risk to the driver of car 1. However, the equations also indicate that reducing the wheelbase of either car increases the total risk to both drivers.

In a 2004 SAE paper, Dr. Evans claimed that increasing the amount of lightweight materials in vehicle design can provide reduced occupant risk both in two-vehicle and single-vehicle crashes, and also reduce risk for occupants in other vehicles[33]. However, he produced no analysis using real world data of vehicles with lightweight material to substantiate that claim[34].

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[32] Evans, L., "Causal Influence of Car Mass and Size on Driver Fatality Risk", American Journal of Public Health, Vol. 91, No. 7, July 2001, pp 1076-1081.

[33] Evans, L., "How to make a car lighter and safer," SAE 2004-01-1 172, Society of Automotive Engineers, 11 March 2004.

[34] In NHTSA's opinion, there are not enough vehicles made from lightweight material on the road to support an analysis using real world crash data.

In an amicus brief, the Insurance Institute for Highway Safety[35]stated "Crash safety should be a consideration in how the balance is struck between programs to improve air quality and our efforts to protect people in crashes. Physics dictates that vehicle weight and size will always matter in a crash. Research in the private, public, and nonprofit sectors have demonstrated the relationship between vehicle size and weight and crash injuries. Simply put, Vermont's regulation encourages production of smaller, lighter vehicles which will lead to increased traffic fatalities." IIHS discusses research by NHTSA and IIHS that have led to the conclusion that "Vehicle downsizing has compromised safety because in most cases, smaller and lighter vehicles are less protective of their occupants than larger, heavier vehicles." IIHS calculated the vehicle death rates by make model using driver deaths per million registered vehicle years, presented this data, and ranked them. "None of the 15 vehicles with the lowest driver death rates were mini or small models. … Eleven of the 16 vehicles with the highest driver death rates were small cars and none were large or very large. … The pattern is unmistakable. There is an inverse relationship between driver death rates and vehicle size…"

Footprint and safety

The impact of CAFE standards on motor vehicle and passenger safety has long been recognized as an integral part of the agency's process of determining maximum feasible average fuel economy. The agency notes that there are no compelling studies that quantify the precise and separate effects of vehicle size and weight on safety, in part because there is a high degree of correlation between size and weight among vehicles now in widespread use. The agency has determined that an attribute system based on footprint with the continuous function would minimize incentives for design changes that would reduce motor vehicle safety. In a weight-based system, a manufacturer can add weight to a vehicle in order to take advantage of a category with a lower fuel economy target. As discussed above, this up-weighting can have positive and negative safety implications, with possibly negative impacts for the fleet as a whole if weight is added to heavier light trucks. A manufacturer could not as readily increase footprint as it could vehicle weight.

In order to increase footprint, a manufacturer would have to either extend a vehicle's track width, wheelbase, or both. Maintaining and increasing track width should play a positive role in limiting rollover vulnerability, whereas maintaining and increasing wheelbase should play a positive role in improving handling – especially directional stability, which is crucial in preventing unintended off-road excursions that often lead to rollovers – and maximizing crush space (though total length is probably more closely correlated with crush space than is wheelbase).

This is mentioned in Dr. Kahane's response to safety studies submitted by Dynamic Research, Inc., by Marc Ross (University of Michigan) and Tom Wenzel (Lawrence Berkeley National Laboratory), and submitted by William E. Wecker Associates.

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[35] Filed in the United States Court of Appeals for the Second Circuit, March 21, 2008, No. 07-4342-cv(L), March 21, 2008, Green Mountain Chrysler Plymouth Jeep…, by Michele Fields and Stephen L. Oesch of IIHS.

Dr. Kahane wrote:

> ”The objective of the NHTSA study was to calibrate the historical (MY 1991-99) relationships of vehicle mass and fatality risk, after controlling for driver age/gender, geographical location, and vehicle equipment. In this type of analysis, “vehicle mass” incorporates not only the effects of mass per se but also the effects of many other size attributes that are historically and/or causally related to mass, such as wheelbase, track width and structural integrity. (As vehicles get longer and wider, they almost always get heavier.)
>
> The study does not claim that mass per se is the specific factor that increases or decreases fatality risk (except in its role in determining the relative Delta V of two vehicles that collide). On the contrary, Chapter 5 of the NHTSA report shows that certain 4,000-pound SUVs have significantly higher fatal-crash rates than 3,500-pound cars. The study only shows the historical relationship between mass – taking into account all the other size attributes that have typically varied with mass – and fatality risk, for vehicles of the same type. If historical relationships between mass and other size attributes continue, in the absence of compelling reasons that would change those relationships, future changes in mass are likely to be associated with similar changes in fatality risk. (However, the increased use of advanced restraint systems and sophisticated crash avoidance safety devices in recent and future production vehicles could have a noticeable impact on the historical relationship between vehicle mass and fatality risk in future vehicle fleets.)
>
> In that sense, it is irrelevant whether mass, wheelbase, track width or some other attribute is the principal causal factor on fatality risk. If you decrease mass, you will also tend to reduce wheelbase, track width and other dimensions of size. If manufacturers respond to this proposal by building lighter vehicles of constant size, the historical relationship between mass and safety would gradually weaken.”

Changes in technology could influence the relationship between weight and size. There is emerging evidence that vehicle weight can be reduced without reductions in size or safety through the use of high strength, lightweight materials. Currently, we do not observe many vehicles built with lightweight materials in the historical data and therefore cannot separate the impact of size versus weight when lightweight materials are utilized. However, the impact of weight, whether it comes from reducing size or material substitution, will be the same for single vehicle impacts (rollovers and fixed and non-fixed object impacts).

Attribute-based standards eliminate the incentive for manufacturers to respond to CAFE standards in ways harmful to safety.[36] Because each vehicle model has its own target

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[36] The 2002 NAS Report, on which NHTSA relied in reforming the CAFE program for light trucks, described at length and quantified the potential safety problem with average fuel economy standards that specify a single numerical requirement for the entire industry. *See* National Academy of Sciences, “Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards,” (“NAS Report”)

(based on the attribute chosen), attribute-based standards provide no incentive to build smaller vehicles simply to meet a fleet-wide average, because the smaller vehicles will be subject to more stringent fuel economy and emissions targets.

The Impact of Emission Standards

EPA Labeling Rule: Fuel Economy Labeling of Motor Vehicles: Revisions to Improve Calculation of Fuel Economy Estimates

The EPA Fuel Economy Labeling Rule[37] employs a new vehicle-specific, 5-cycle approach to calculating fuel economy labels which incorporates estimates of the fuel efficiency of each vehicle during high speed, aggressive driving, air conditioning operation and cold temperatures into each vehicle's fuel economy label. The rule became effective January 26, 2007, and will take effect starting with MY 2008.

The new testing procedures will combine measured fuel economy over the two current fuel economy tests, the FTP and HFET, as well as that over the US06, SC03 and cold FTP tests into estimates of city and highway fuel economy for labeling purposes. The test results from each cycle will be weighted to represent the contribution of each cycle's attributes to on-road driving and fuel consumption. The labeling rule does not alter the FTP and HFET driving cycles, the measurement techniques, or the calculation methods used to determine CAFE.

The EPA Labeling Rule will not impact CAFE standards or test procedures or other U.S. Government regulations.[38] Rather, the changes to existing test procedures will allow for the collection of appropriate fuel economy data to ensure that existing test procedures better represent real-world conditions.[39] Further, the labeling rule does not have a direct effect upon a vehicle's weight, nor on the fuel economy level that a vehicle can achieve. Instead, the labeling law serves to provide consumers with a more accurate estimate of fuel economy based on more comprehensive factors reflecting real-world driving use. For this PRIA, the agency assumes that on-road mileage will be 80 percent of the measured CAFE, based on the FTP and HFET driving cycles, the measurement techniques, and the calculation methods used to determine CAFE.

National Academy Press, Washington, DC (2002), 5, finding 12. *Available at* http://www.nap.edu/openbook.php?record_id=10172&page=R1 (last accessed Dec. 2, 2007).

[37] See 71 FR 77872.

[38] See 71 FR 77872, section I.F.

[39] See 71 FR 77872, section II., IV.

V. FUEL ECONOMY ENHANCING TECHNOLOGIES AND THE VOLPE MODEL

A. Comparison of current with past approaches to analysis of technologies, their cost and effectiveness

In the Agency's last two rulemakings covering light truck CAFE standards for MYs 2005 – 2007 and MYs 2008 – 2011, the agency relied on the 2002 National Academy of Sciences' report, *Effectiveness and Impact of Corporate Average Fuel Economy Standards* ("the 2002 NAS Report")[40] for estimating potential fuel economy benefits and associated retail costs of applying combinations of technologies in 10 classes of production vehicles. The NAS cost and effectiveness numbers were the best available estimates at this time, determined by a panel of experts formed by the National Academy of Sciences, and the report had been peer reviewed by individuals chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the Report Review Committee of the National Research Council. However, since the publication of the 2002 NAS Report, there has been substantial advancement in fuel-saving technologies, including technologies not discussed in the NAS Report that are expected to appear on vehicles in the MY 2011-2015 timeframe. There also have been reports issued and studies conducted by several other organizations and companies that discuss fuel economy technologies and their benefits and costs. NHTSA has contracted with the NAS to update the fuel economy section, Chapter 3, of the 2002 NAS Report. However, this update will not be available in time for this rulemaking. Due to the expedited nature of this rulemaking, NHTSA, in consultation with the Environmental Protection Agency (EPA), developed an updated technology cost and effectiveness list to be used in this notice.

This list presents NHTSA and EPA technical staff's current assessment of the costs and effectiveness from a broad range of technologies which can be applied to cars and light-duty trucks. EPA published the results of this collaboration in a report and submitted it to the NAS committee[41]. A copy of the report and other studies used in the technology update will be placed in NHTSA's docket.

NHTSA believes that the estimates used for this notice, which rely on the best available public and confidential information, are defensible and reasonable predictions for the next five years. Nevertheless, NHTSA still believes that the ideal source for this information comes from a peer reviewed process such as the NAS. NHTSA will continue to work with NAS to update this list on a five year interval as required by the Energy Independence and Security Act of 2007.

The majority of the technologies discussed in this section are in production and available on vehicles today, either in the United States, Japan, or Europe. A number of the

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[40] National Research Council, "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards," National Academy Press, Washington, DC (2002). *Available at* http://www.nap.edu/openbook.php?isbn=0309076013 (last accessed Feb. 5, 2008).

[41] EPA Staff Technical Report: Cost and Effectiveness Estimates of Technologies Used to Reduce Light-duty Vehicle Carbon Dioxide Emissions. EPA420-R-08-008, March, 2008

technologies are commonly available, while others have only recently been introduced into the market. In a few cases, we provide estimates on technologies which are not currently in production, but are expected to be so in the next few years. These technologies which can be applied to cars and trucks that are capable of achieving significant improvements in fuel economy and reductions in carbon dioxide emissions, and improve vehicle fuel economy, at reasonable costs.

NHTSA and EPA conducted the technology examination using concepts from the 2002 NAS report which constituted a starting point for the analysis. In the NAS Report, there were three exemplary technology paths or scenarios identified for each class of production vehicles, which lead to successively greater improvements in fuel consumption and greater costs. Path I included production-intent technologies that will be available within 10 years and could be implemented under current economic and regulatory conditions. Path II included more costly production-intent technologies that are technically feasible for introduction within 10 years if economic and regulatory conditions justify their use. Path III included emerging technologies that will be available within 10 to 15 years but that may require further development prior to commercial introduction. These three paths represented vehicle development steps that would offer increasing levels of fuel economy gains (as incremental gains) at incrementally increasing cost. As stated earlier, since the publication of the 2002 NAS Report, automotive technology has continued to advance and many of the technologies that were identified in the report as emerging have already entered the marketplace.

In this rulemaking, NHTSA working with EPA have examined a variety of technologies and looked beyond path I and path II to path III and to emerging technologies beyond path III. These technologies were in their infancy when the 2002 NAS Report was being formulated. In addition, unlike for past rulemakings where NHTSA projected the use of different variants of a technology as a combined technology, in this rulemaking, NHTSA working with EPA examined advanced forms and subcategories of existing technologies and reflected the effectiveness and cost for each of the variants separately for all ten vehicle classes. The specific technologies affected are variable valve timing (VVT), variable valve lift and timing (VVLT) and cylinder deactivation. Manufacturers are currently using many different types of VVTs and VVLTs, which have a variety of different names and methods. This rulemaking employs specific cost and effectiveness estimates for variants of VVT, including Intake Camshaft Phasing (ICP), Coupled Camshaft Phasing (CCP), and Dual (Independent) Camshaft Phasing (DCP). It also employs specific cost and effectiveness estimates for variants of VVLT, including Discrete Variable Valve Lift (DVVL) and Continuous Variable Valve Lift (CVVL). We also now include the effectiveness and cost estimates for each of the variants of cylinder deactivation. The most common type of cylinder deactivation is one in which an eight-cylinder overhead valve engine disables four of its cylinders under light loads. Cylinder deactivation could be incorporated on overhead cam engines, and can be applied to four and six cylinder engines as well (we have restricted application to 6 and 8 cylinder engines). Thus, the variants of cylinder deactivation that now have specific cost and effectiveness estimates include both overhead valve engine cylinder deactivation and overhead cam engine cylinder deactivation.

The update also revisited technology lead time issues and took a fresh look at technology application rates, how to link certain technologies to certain redesign and refresh patterns, synergistic impacts resulting from adding technology packaging, and learning costs.

1. Data sources for technology assumptions

A large number of technical reports and papers are available which contain data and estimates of the fuel economy improvements of various vehicle technologies. In addition to specific peer-reviewed papers respecting individual technologies, we also utilized a number of recent reports which had been utilized by various State and Federal Agencies and which were specifically undertaken for the purpose of estimating future vehicle fuel economy reduction effectiveness or improvements in fuel economy. The reports we utilized most frequently were:

- 2002 National Academy of Science (NAS) report titled "Effectiveness and Impact of Corporate Average Fuel Economy Standards”. At the time it was published, the NAS report was considered by many to be the most comprehensive summary of current and future fuel efficiencies improvements which could be obtained by the application of individual technologies. The focus of this report was fuel economy, which can be directly correlated with CO2 emissions. The 2002 NAS report contains effectiveness estimates for ten different vehicle classifications (small car, mid-SUV, large truck, etc), but did not differentiate these effectiveness values across the classes. Where other sources or engineering principles indicated that a differentiation was warranted, we utilized the 2002 NAS effectiveness estimates as a starting point and further refined the estimate to one of the vehicle classes using engineering judgment or by consulting additional reliable sources.

- 2004 Northeast States Center for a Clean Air Future (NESCCAF) report "Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles". This report, which was utilized by the California Air Resources Board for their 2004 regulatory action on vehicle CO2 emissions, includes a comprehensive vehicle simulation study undertaken by AVL, a world-recognized leader in automotive technology and engineering. In addition, the report included cost estimates developed by the Martec Group, a market-based research and consulting firm which provides services to the automotive industry. The NESCCAF report considered a number of technologies not examined in the 2002 NAS report. In addition, through the use of vehicle simulation modeling, the 2004 NESCCAF report provides a scientifically rigorous estimation of the synergistic impacts of applying multiple fuel economy technologies to a given vehicle.

- 2006 Energy and Environmental Analysis Inc (EEA) report “Technology to Improve the Fuel Economy of Light Duty Trucks to 2015” Prepared for The U.S. Department of Energy and The U.S. Department of Transportation. This update of technology characteristics is based on new data obtained by EEA from technology suppliers and auto-manufacturers, and these data are compared to data from studies conducted earlier by EEA, the National Academy of Sciences (NAS), the Northeast States Center for a Clean Air future (NESCCAF) and California Air Resources Board (CARB).

- Data from Vehicle Manufacturers, Component Suppliers, and other reports. We also evaluated confidential data from a number of vehicle manufacturers as well as a number of technology component suppliers. In February of 2007, the NHTSA published a detailed Request for Comment (RFC) in the Federal Register. This RFC included, among other items, a request for information from automotive manufacturers and the public on the fuel economy improvement potential of a large number of vehicle technologies. The manufacturer's submissions to this RFC were supplemented by confidential briefing and data provided by vehicle component suppliers, who for many of the technologies considered are the actual manufacturers of the specific technology and often undertake their own development and testing efforts to investigate the fuel economy improvement potential of their products. Manufacturers that provided NHTSA and EPA with fuel economy cost and effectiveness estimates include BMW, Chrysler, Ford, General Motors, Honda, Nissan, Toyota and Volkswagen. The major suppliers that provided NHTSA with fuel economy cost and effectiveness estimates include Borg-Warner, Bosch, Corning, Delphi, and Siemens.

- Finally, to verify that the fuel economy cost and effectiveness estimates for each of the technologies was reasonable and within currently available estimates for these technologies, NHTSA examined those estimates provided by other reports or sources, such as the Martec (contained in the 2004 NESCAFF report) and Sierra Research reports[42].

2. Technologies and estimates of costs and effectiveness

This section describes each technology and associated cost and effectiveness numbers. The technologies can be classified into five main groups similar to how they were classified in the NAS Report: engine technologies; transmission technologies; accessory technologies; vehicle technologies; and hybrid technologies.

While NHTSA and EPA followed the general approach taken by the NAS in estimating the cost and effectiveness numbers, we decided to update some of these estimates to reflect better the changed marketplace and regulatory environment, as well as the advancement in and greater penetration of some production-intent and emerging technologies, which have led to lower costs. The values contained in the 2002 NAS report were used to establish a baseline for the fuel economy cost and effectiveness estimates for each of the technologies. We then examined all other estimates provided by manufacturers and major suppliers or other sources. In examining these values, we gave

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[42] "Alternative and Future Technologies for Reducing Greenhouse Gas Emissions from Road Vehicles" Sierra Research Report for Environment Canada, 1999 (SR99-07-01). http://www.sierraresearch.com/ReportListing.htm

more weight to values or estimates provided by manufacturers that have already implemented these technologies in their fleet, especially those that have introduced them in the largest quantities. Likewise, for technologies that have not penetrated the fleet to date, but will by early in the next decade (according to confidential manufacturer plans), we gave more weight to values or estimates provided by manufacturers that have stated that they will be introducing these technologies in their fleet, especially those that plan to introduce them in the largest quantities. In addition, for the technologies that will appear on vehicles by early in the next decade, we carefully examined the values provided by those suppliers who have developed these technologies and may have contracts in place to provide them to manufacturers.

Because not all technologies can be applied on all types of vehicles, engines or transmissions, we separately evaluated 10 classes of vehicles to estimate fuel economy cost and effectiveness for each of the technologies. As discussed above, these ten classes, also used in NHTSA's 2006 light truck CAFE rule, were derived from the 2002 NAS Report, which estimated the feasibility, potential incremental fuel consumption benefit and the incremental cost of three product development paths for the following ten vehicle classes: subcompact passenger cars, compact passenger cars, midsize passenger cars, large passenger cars, small sport utility vehicles, midsize sport utility vehicles, large sport utility vehicles, small pickups, large pickups, and minivans.

The application of technologies to a vehicle class is limited not only by whether the manufacturer is capable of applying it within a particular development cycle, but also by whether the technology may physically be applied to the vehicle. For example, continuously variable transmissions (CVTs) were only allowed to be projected on vehicles with unibody construction, which includes all passenger cars and minivans and some small and midsize SUVs. CVTs could not be projected for use on vehicles with ladder-frame construction, which includes all pickups and large SUVs and some small and midsize SUVs. Another example is cylinder deactivation being limited to vehicles with 6- or 8-cylinder engines. To simplify the analysis, NHTSA assumed that each class of vehicles would typically have vehicle construction and engines with a specific number of cylinders that is most representative of that vehicle class.

Although we looked at ten vehicle classes separately, for some technologies the estimated incremental fuel consumption benefit and incremental cost were the same across all vehicle classes (as for engine accessory improvement), while for other technologies the estimated incremental fuel consumption benefit and incremental cost differed across classes (as for hybrid drivetrains). The main difference was with which path(s) each technology was expected to be associated. .

The exact cost and benefit of a given technology depends on specific vehicle characteristics (size, weight, base engine, etc.) and the existence of additional technologies that were already applied to the vehicle. In the section below, ranges of incremental cost and fuel consumption reduction values are listed where the values depend on vehicle characteristics and are independent of the order in which they are applied to a vehicle. All costs, which are reflective of estimated retail price equivalents

(RPEs) were inflated by the producer price index (if needed) and are presented in year 2006 dollars, because this is the last year for which final economic indexing is available. Some cost estimates are based on supplier costs. In those instances, multipliers were included in those costs so that they would be treated in the same manner as cost estimates that are based on manufacturer costs. These incremental values were calculated by subtracting out all same-path synergies associated with a given technology and any preceding items on the same path. Essentially, the incremental percent reduction in fuel consumption and cost impacts represent improvements beyond the ones realized due to technologies already applied to the vehicle. As an example, a 5-speed automatic transmission could incrementally reduce fuel consumption by 2 to 3 percent at an incremental cost of $75 to $165 per vehicle, *relative to* a 4-speed automatic transmission. In turn, a 6-speed automatic transmission could incrementally reduce fuel consumption by 4.5 to 6.5 percent at an incremental cost of $10 to $20 per vehicle, *relative to* a 5-speed transmission.

NHTSA acknowledges that this approach is different from the one it followed in establishing the reformed light truck standards for MYs 2008-2011, where we relied nearly exclusively on the 2002 NAS report's estimates. Our preference remains to rely upon peer-review and credible studies, such as the 2002 NAS report; however we believe that the estimates made by the joint EPA/NHTSA team are accurate and defensible. The agency seeks comments on our assumptions and the cost, effectiveness and availability estimates provided. NHTSA also seeks comments on whether the order in which these technologies was applied by the Volpe model is proper and whether we have accurately accounted for technologies already included on vehicles and whether we have accurately accounted for technologies that are projected to be applied to vehicles. The agency also seeks comments on the "synergy" factors (discussed below) it has applied in order to adjust the estimated incremental effectiveness of some pairs of technology and on whether similar adjustments to the estimated incremental cost of some technologies should be made. In preparation for a final rule, NHTSA intends to update its technology-related methodologies and estimates, and expects that these anticipated updates will affect the form and stringency of the final standards.

a. Engine technologies

Low-Friction Lubricants

The use of lower viscosity engine and transmission lubricants can reduce fuel consumption. More advanced multi-viscosity engine and transmission oils are now available with improved performance in a wider temperature band, with better lubricating properties. However, even without any changes to fuel economy standards, most MY 2011-2015 vehicles are likely to use 5W-30 motor oil, and some will use even less viscous oils, such as 5W-20 or possibly even 0W-20 to reduce cold start friction. This may directionally benefit the fuel economy improvements of valvetrain technologies such as cylinder deactivation, which rely on a minimum oil temperature (viscosity) for operation. Most manufacturers therefore attributed smaller potential fuel economy reductions and cost increases to lubricant improvements.

The NAS Report projected that low-friction lubricants could incrementally reduce fuel consumption by 1 percent at an incremental cost of $8 to $11.[43] The NESCCAF study projected that low-friction lubricants could incrementally reduce fuel consumption by 1 percent at an incremental cost of $5 to $15; while the EEA report projected that low-friction lubricants could incrementally reduce fuel consumption by 1 percent at an incremental cost of $10 to $20. In contrast, manufacturer data projected an estimated fuel consumption potential of 0% to 1% at an incremental cost that ranged from $1 to $11, with many of them stating the costs as ranging from $1 to $5. NHTSA believes that these manufacturer estimates are more accurate and estimates that low-friction lubricants could reduce fuel consumption by 0.5 percent for all vehicle types at an incremental cost of $3, which represents the mid-point of $2.50, rounded up to the next dollar.

Reduction of Engine Friction Losses

All reciprocating and rotating components in the engine are candidates for friction reduction, and minute improvements in several components can add to a measurable fuel economy improvement. The amount of energy an engine loses to friction can be reduced in a variety of ways. Improvements in the design of engine components and subsystems will result in friction reduction, improved engine operation, greater fuel economy and reduced emissions. Examples include low-tension piston rings, roller cam followers, crankshaft design, improved material coatings, material substitution, more optimal thermal management, piston surface treatments, and as lubricant friction reduction. Additionally, as computer-aided modeling software continues to improve, more opportunities for incremental friction reduction might become apparent. Even without any changes to fuel economy standards, most MY 2010-2015 vehicles are likely to employ one or more such techniques to reduce engine friction and other mechanical and hydrodynamic losses.

The NAS Report predicted that such technologies could incrementally reduce fuel consumption by 1 to 5 percent at an incremental cost of $36 to $146. NESCCAF predicted that such technologies could incrementally reduce fuel consumption by 0.5 percent at an incremental cost of $5 to $15; while the EEA report predicted that such technologies could reduce fuel consumption at an incremental cost of $10 to $55. Confidential manufacturer data indicates that engine friction reduction could incrementally reduce fuel consumption by 1 to 3 percent at an incremental cost of $0 to $168. Based on available information from these reports and confidential manufacturer data, NHTSA estimates that friction reduction could reduce fuel consumption for all vehicles by 1 to 3 percent at a cost of $21 per cylinder. Thus, the incremental cost of engine friction reduction for a 4-cylinder engine is $0 to $84 (applicable to subcompact and compact cars); for a 6-cylinder engine is $0 to $126 (applicable to midsize cars, large cars, small pickups, small SUVs, minivans and midsize SUVs); and for an 8-cylinder engine is $0 to $168 (applicable to large pickups and SUVs).

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[43] The price increases noted in this chapter are slightly higher than shown in the NAS study, since they have been converted into calendar year 2006 prices.

Multi-Valve Overhead Camshaft Engine

It appears likely that many vehicles would still use overhead valve (OHV) engines with pushrods and one intake and one exhaust valve per cylinder during the early part of the next decade. Engines with overhead cams (OHC) and more than two valves per cylinder achieve increased airflow at high engine speeds and reductions of the valve train's moving mass and enable central positioning of spark plugs. Such engines, which are already used in some light trucks, typically develop higher power at high engine speeds. The NAS Report projected that multi-valve OHC engines could incrementally reduce fuel consumption by 2 percent to 5 percent at an incremental cost of $109 to $146, and NHTSA found no sources to update these projections.

For purposes of this rule, OHV engines and OHC engines were considered separately, and the model was generally not allowed to apply multivalve OHC technology to OHV engines, except where continuous variable valve timing and lift (CVVL) is applied to OHV engines. In that case, the model assumes conversion to DOHC valvetrain, because DOHC valvetrains are prerequisites for the application of any advanced engine technology over and above CVVL. Since applying CVVL to an OHV is the last improvement that could be made to such an engine, it's logical to assume that manufacturers would redesign that engine as a DOHC and include CVVL as part of that redesign.

For 4-cylinder engines we estimated that the cost to redesign an OHV engine as a DOHC that includes CVVL would be $599 ($169 for conversion to DVVL, $254 for conversion to CVVL, and $176 for conversion to DOHC, which comprises an additional camshaft and valves), with estimated fuel consumption reduction of 2 to 3 percent. For 6-cylinder engines we estimated that the cost to redesign an OHV engine as a DOHC that includes CVVL would be $1262 ($246 for conversion to DVVL, $488 for conversion to CVVL, and $550 for conversion to DOHC, which comprises an additional camshaft and valves), with estimated fuel consumption reduction of 1 to 4 percent. For 8-cylinder engines we estimated that the cost to redesign an OHV engine as a DOHC that includes CVVL would be $1380 ($322 for conversion to DVVL, $508 for conversion to CVVL, and $550 for conversion to DOHC, which comprises an additional camshaft and valves), with estimated fuel consumption reduction of 2 to 3 percent. Incremental cost estimates for DVVL and CVVL are discussed below.

NHTSA believes that the NESCCAF report and confidential manufacturer data are more accurate, and thereby estimates that a conversion of an OHV engine to a DOHC engine with CVVL could incrementally reduce fuel consumption by 1 to 4 percent at an incremental cost of $599 to $1,380 compared to an OHV with VVT.

Cylinder Deactivation

For the vast majority of vehicles, each cylinder is always active while the engine is running. Under partial load conditions, the engine's specific fuel consumption could be reduced if some cylinders could be disabled, such that the active cylinders operate at higher load. In cylinder deactivation, some (usually half) of the cylinders are "shut down" during light load operation – the valves are kept closed, and no fuel is injected – as a result, the trapped air within the deactivated cylinders is simply compressed and expanded as an air spring, with minimal friction and heat losses. The active cylinders combust at almost double the load required if all of the cylinders were operating. Pumping losses are significantly reduced as long as the engine is operated in this "part-cylinder" mode.

The theoretical engine operating region for cylinder deactivation is limited to no more than roughly 50% of peak power at any given engine speed. In practice, however, cylinder deactivation is employed primarily at lower engine cruising loads and speeds, where the transitions in and out of deactivation mode are less apparent to the operator and where the noise and vibration (NVH) associated with fewer firing cylinders may be less of an issue. Manufacturers are exploring the possibilities of increasing the amount of time that part-cylinder mode might be suitable to a vehicle with more refined powertrain and NVH treatment strategies.

General Motors and Chrysler Group have incorporated cylinder deactivation across a substantial portion of their V8-powered lineups. Honda (Odyssey, Pilot) and General Motors (Impala, Monte Carlo) offer V6 models with cylinder deactivation.

There are two variants of cylinder deactivation. The most common type of cylinder deactivation is one in which an eight-cylinder overhead valve engine disables four cylinders under light loads. Thus an eight-cylinder engine could disable four cylinders under light loads, such as when the vehicle is cruising at highway speed. This technology could be applied to four and six cylinder engines as well. General Motors and Chrysler Group have incorporated cylinder deactivation across a substantial portion of their V8-powered overhead valve lineups.

Cylinder deactivation could be incorporated on overhead cam engines and can be applied to four and six cylinder engines as well. Honda has already begun offering three V6 models with cylinder deactivation (Accord, Odyssey, and Pilot) and GM will soon release cylinder deactivation on its 3.9L 6-cylinder engine. Fuel economy improvement potential scales roughly with engine displacement-to-vehicle weight ratio: the higher displacement-to-weight vehicles, operating at lower relative loads for normal driving, have the potential to operate in part-cylinder mode more frequently.

Honda's technology includes the use of active engine mounts and noise damping amongst other items added to its V6 engines with cylinder deactivation. This, of course increases the cost relative to a four or eight cylinder OHC engine.

Some manufacturers are getting results in excess of 6 percent and most are at the high end of the range. This higher number is supported by official fuel economy test data on a V6 Honda Odyssey with cylinder deactivation compared to the same vehicle (and engine displacement) without cylinder deactivation and by confidential manufacturer information.

The NAS Report projected that cylinder deactivation could incrementally reduce fuel consumption by 3 percent to 6 percent at an incremental cost of $112 to $252. The NESCCAF study projected that cylinder deactivation could incrementally reduce fuel consumption by 1.7 percent to 4.2 percent at an incremental cost of $161 to $210; while the EEA report projected that cylinder deactivation could incrementally reduce fuel consumption by 5.2 percent to 7.2 percent at an incremental cost of $105 to $135. Confidential manufacturer data and official fuel economy test data indicates that cylinder deactivation could incrementally reduce fuel consumption by at least 6 percent at an incremental cost of $203 to $229. NHTSA believes that these manufacturer estimates are more accurate and thus estimates that cylinder deactivation could reduce fuel consumption by 4.5 percent to 6 percent at an incremental cost of $203 to $229.

Variable Valve Timing

Variable valve timing is a classification of valvetrain designs that alter the timing of the intake valve, exhaust valve, or both, primarily to reduce pumping losses, increase specific power, and control residual gases. VVT reduces pumping losses when the engine is lightly loaded by positioning the valve at the optimum position needed to sustain horsepower and torque. VVT can also improve thermal efficiency at higher engine speeds and loads. Additionally, VVT can be used to alter (and optimize) the effective compression ratio where it is advantageous for certain engine operating modes.

Variable valve timing has been available in the market for quite a while. By the early 1990s, VVT had made a significant market penetration with the arrival of Honda’s “VTEC” line of engines. VVT has now become a widely adopted technology: for the 2007 model year, over half of all new cars and light trucks have engines with some method of variable valve timing. Therefore, the degree of further improvement across the fleet is limited to vehicles that have not already implemented this technology.

Manufacturers are currently using many different types of variable valve timing, which have a variety of different names and methods. The major types of VVT are listed below:

Intake Camshaft Phasing (ICP)

Valvetrains with ICP – the simplest type of cam phasing - can modify the timing of the intake valve while the exhaust valve timing remains fixed. This requires the addition of a cam phaser for each bank of intake valves on the engine. An in-line 4-cylinder engine has one bank of intake valves, while V-configured engines would have two banks of intake valves. The NAS Report projected that ICP could incrementally reduce fuel consumption by 3 percent to 6 percent at an incremental cost of $35; while the EEA report projected that ICP could reduce fuel consumption at an incremental cost of $35. The NESCCAF study projected that ICP could incrementally reduce fuel consumption by 1 percent to 2 percent at an incremental cost of $49. Consistent with the EEA report and NESCCAF study, we have used this $35 manufacturer cost to arrive at incremental cost of $59 per cam phaser or $59 for an in-line 4 cylinder and $119 for a V-type, thus NHTSA estimates that ICP could incrementally reduce fuel consumption by 1 to 2 percent at an incremental cost of $59 to $119 above fixed-cam valvetrains.

Coupled Camshaft Phasing (CCP)

Coupled (or coordinated) cam phasing is a design in which both the intake and exhaust valve timing are varied with the same cam phaser. For an overhead cam engine, the same phaser added for ICP would be used for CCP control. As a result, its costs should be identical to those for ICP. For an overhead valve engine, only one phaser would be required for both inline and V-configured engines since only one camshaft exists. Therefore, for overhead valve engines, the cost is estimated at $59 regardless of engine configuration, using the logic provided for ICP.

The NESCCAF study projected that CCP could incrementally reduce fuel consumption by 1 percent to 3 percent above that obtained by ICP. Confidential manufacturer data also projects that that CCP could incrementally reduce fuel consumption by 1 percent to 3 percent above that obtained by ICP. According to the NESCCAF report and confidential manufacturer data, NHTSA estimates that CCP could incrementally reduce fuel consumption by 1 to 3 percent at an incremental cost of $59 to $119.

Dual (Independent) Camshaft Phasing (DCP)

The most flexible VVT design is dual cam phasing, where the intake and exhaust valve opening and closing events are controlled independently. This design allows the option of controlling valve overlap, which can be used as an internal EGR strategy. Our estimated incremental compliance cost for this technology is built upon that for VVT-ICP where an additional cam phaser is added to control each bank of exhaust valves less the cost to the manufacturer of the removed EGR valve. The incremental compliance cost for a 4-cylinder engine is estimated to be $59 for each bank of valves, plus an estimated piece cost of $30 for the valves, for a total incremental compliance cost of $89. The incremental compliance cost for a V6 or a V8 engine is estimated to be $59 for each bank of intake valves (i.e., two banks times $59/bank = $119), $59 for each bank of exhaust valves (i.e., another $119) minus an estimated $29 incremental compliance cost for the removed EGR valve; the total incremental compliance cost being $209.

According to the NESCCAF report and confidential manufacturer data, it is estimated that DCP could incrementally reduce fuel consumption by 1 to 3 percent at an incremental cost of $89 to $209 compared to engines with ICP or CCP.

Because ICP and CCP have the same cost and similar effectiveness, it is assumed that manufacturers will choose the technology that best fits the specific engine architecture and application.

Variable Valve Lift and Timing

Some vehicles have engines for which both valve timing and lift can be at least partially optimized based on engine operating conditions. Engines with variable valve timing and lift (VVLT) can achieve further reductions in pumping losses and further increases in thermal efficiency. Controlling the lift height of the valves provides additional flexibility and potential for further fuel consumption reduction. By reducing the valve lift, engines can decrease the volumetric flow at lower operating loads, improving fuel-air mixing and in-cylinder mixture motion which results in improved thermodynamic efficiency and also potentially reduced overall valvetrain friction. Also, by moving the throttling losses further downstream of the throttle valve, the heat transfer losses that occur from the throttling process are directed into the fresh charge-air mixture just prior to compression, delaying the onset of knock-limited combustion processes. At the same time, such systems may also incur increased parasitic losses associated with their actuation mechanisms.

The NAS report projected that VVLT could incrementally reduce fuel consumption by 1 to 2 percent over VVT alone at an incremental cost of $73 to 218.

Manufacturers are currently using many different types of variable valve lift and timing, which have a variety of different names and methods. The major types of VVLT are listed below:

Discrete Variable Valve Lift

Discrete variable valve lift (DVVL) is a method in which the valvetrain switches between multiple cam profiles, usually 2 or 3, for each valve. These cam profiles consist of a low and a high-lift lobe, and may include an inert or blank lobe to incorporate cylinder deactivation (in the case of a 3-step DVVL system). According to the NESCCAF report and confidential manufacturer data, it is estimated that DVVL could incrementally reduce fuel consumption by 0.5 to 3 percent at an incremental cost of $169 to $322 compared to an engine with VVT and cylinder deactivation depending on engine size and overhead cam versus overhead valve engines. Included in this cost estimate is $25 for controls and associated oil supply needs (these costs not reflected in the NESCCAF study). We also project that a single valve lifter could control valve pairs, thus engines with dual intake and/or dual exhaust valves would require only one lifter per pair of valves. Due to this, the estimated costs for applying DVVL to overhead cam and overhead valve engines are the same.

Continuous Variable Valve Lift

Continuous variable valve lift (CVVL) employs a mechanism that varies the pivot point in the rocker arm. This design is realistically limited to overhead cam engines. Currently, BMW has implemented this type of system in its Valvetronic engines, which employs fully flexible valve timing to allow an extra set of rocker arms to vary the valve lift height. CVVL enables intake valve throttling in engines, which allows for the use of more complex systems of sensors and electronic controls to enable further optimization of valve lift.

The NESCCAF study projected incremental costs from $210 to $420, depending on vehicle class, while the EEA report projected incremental costs of $180 to $350, depending on vehicle class. Confidential manufacturer data projects that CVVL could incrementally reduce fuel consumption by 1.5 by 4 percent at an incremental cost of $200 to $515. NHTSA believes that these manufacturer estimates are more accurate than NESCCAF estimates, thus it gives more weight to them. According to the NESCCAF report and confidential manufacturer data, NHTSA estimates that CVVL could incrementally reduce fuel consumption by 1.5 by 4 percent at an incremental cost of $254 to $508 compared to an engine with VVT and cylinder deactivation with cost estimates varying from $254, $466, and $508 for a 4-, 6-, and 8-cylinder engine, respectively.

Camless Valve Actuation

Camless valve actuation relies on electromechanical actuators instead of camshafts to open and close the cylinder valves. When electromechanical actuators are used to replace cams and coupled with sensors and microprocessor controls, valve timing and lift can be optimized over all conditions. An engine valvetrain that operates independently of any mechanical means provides the ultimate in flexibility for intake and exhaust timing and lift optimization. With it comes infinite valve overlap variability, the rapid response required to change between operating modes (such as HCCI and GDI), intake valve throttling, cylinder deactivation, and elimination of the camshafts (reduced friction). This level of control can enable even further incremental reductions in fuel consumption.

Camless valvetrains have been under research for many decades due to the design flexibility and the attractive fuel economy improvement potential they might provide. Despite the promising features of camless valvetrains, significant challenges remain. High costs and design complexity have reduced manufacturers' enthusiasm for camless engines in light of other competing valvetrain technologies. The advances in VVT, VVLT, and cylinder deactivation systems demonstrated in recent years have reduced the potential efficiency advantage of camless valvetrains.

The NAS Report projected that camless valve actuation could incrementally reduce fuel consumption by 5 to 10 percent over VVLT at an incremental cost of $336 to $673. Confidential manufacturer information provides incremental fuel consumption losses that range from 2 to 10 percent at costs that range from $300 to $1,100. The NESCCAF study projected that camless valve actuation could incrementally reduce fuel consumption by 11 to 13 percent at an incremental cost of $805 to $1,820; while the EEA report projected that camless valve actuation could incrementally reduce fuel consumption by 10 to 14 percent at an incremental cost of $210 to $600. These benefits and costs are believed to be incremental to engines with VVT.

In reviewing our sources for costs, we have determined that the adjusted costs presented in the 2002 NAS study, which ranged from $336 to $673 - depending on vehicle class – represent the best available estimates. Subtracting out the improvements associated with the application of VVLT provides an estimated fuel consumption reduction of 2.5 percent.

Stoichiometric Gasoline Direct Injection Technology

Gasoline direct injection (GDI, or SIDI) engines inject fuel at high pressure directly into the combustion chamber (rather than the intake port in port fuel injection). Direct injection improves cooling of the air/fuel charge within the cylinder, which allows for higher compression ratios and increased thermodynamic efficiency. Injector design advances and increases in fuel pressure have promoted better mixing of the air and fuel, enhancing combustion rates, increasing exhaust gas tolerance and improving cold start emissions. GDI engines achieve higher power density and match well with other technologies, such as boosting and variable valvetrain designs.

Several manufacturers (Audi, BMW, and Volkswagen) have recently released GDI engines while General Motors and Toyota will be introducing GDI engines. In addition, BMW and GM have announced their plans to dramatically increase the number of GDI engines in their portfolios.

The NESCCAF report projected that the incremental cost for GDI of $189 to $294; while the EEA report projected an incremental cost of $77 to $135. Confidential manufacturer data provides data with higher upper end costs than these estimates, with incremental fuel consumption estimates ranging from 1 to 2 percent. For our analysis, we have estimated the costs of individual components of a GDI system and used a “bottom up” approach looking at incremental costs for injectors, fuel pumps, etc., to arrive at system incremental compliance costs ranging from $122 to $420 for small cars and up to $228 to $525 for large trucks. The lower end of the ranges represent our best estimate using a bottom up approach while the upper end of the ranges represent levels more consistent with the manufacturer CBI submittals. As a result, we estimate that stoichiometric GDI could incrementally reduce fuel consumption by 1 to 2 percent at an incremental cost of $122 to $525 compared to engines of similar power output.

Gasoline Engine Turbocharging and Engine Downsizing

The specific power of a naturally aspirated engine is limited, in part, by the rate at which the engine is able to draw air into the combustion chambers. Turbocharging and supercharging are two methods to increase the intake manifold pressure and cylinder charge-air mass above naturally aspirated levels. By increasing the pressure differential between the atmosphere and the charging cylinders, superchargers and turbochargers increase this available airflow, and thus increase the specific power level, and with it the ability to reduce engine size while maintaining performance. This effectively reduces the pumping losses at lighter loads in comparison to a larger, naturally aspirated engine, while at the same time reducing net friction losses.

Almost every major manufacturer currently markets a vehicle with some form of boosting. While boosting has been a common practice for increasing performance for several decades, it has considerable fuel economy potential when the engine displacement is reduced. Specific power levels for a boosted engine often exceed 100 hp/L - compared to average naturally aspirated engine power densities of roughly 70 hp/L. As a result, engines can conservatively be downsized roughly 30 percent to achieve similar peak output levels.

In the last decade, improvements to turbine design have improved their reliability and performance across the entire engine operating range. New variable geometry turbines spool up to speed faster (eliminating the once-common “turbo lag”) while maintaining high flow rates for increased boost at high speeds.

Turbocharging and downsizing involves the addition of a boost system, removal of two cylinders in most cases (from an 8-cylinder to a 6, or a 6 to a 4) and associated valves, and the addition of some form of cold start control system (e.g., air injection) to address possible cold start emission control. The NAS Report projected that turbocharging and downsizing could incrementally reduce fuel consumption by 5 to 7 percent at an incremental cost of $364 to $582. The EEA report projected turbocharging and downsizing could incrementally reduce fuel consumption by 5.2 to 7.8 percent.

In developing estimated costs for turbocharging and downsizing an engine, NHTSA, in conjunction with EPA, relied upon piece cost estimates contained in the NESCCAF report. The cost estimates provided by the NESCCAF report are as follows: $600 for the turbocharger and associated parts; $90 for an air injection pump and associated parts (each turbocharger requires an air injection pump); $75 per cylinder and associated components: $15 per each valve and associated components; and $150 per camshaft.

In developing the cost estimates for each of the ten classes of vehicles, we determined the most logical type of downsizing that would occur for each class and starting with the turbocharger and air injector cost, either added or deleted cost, depending on the situation. These cost estimates are incremental to an engine with GDI. For subcompact and compact cars, we determined that the downsizing wouldn’t involve the removal of any cylinders, valves and camshafts, but instead would result in a manufacturer using a smaller displacement 4-cylinder engine and adding the turbocharger and the air injector to the smaller engine. Thus, for subcompact and compact cars, we estimated the cost of turbocharging and downsizing to be $690 ($600 for the turbocharger plus $90 for the air injector).

For large trucks and large SUVs we determined that the most logical engine downsizing would involve replacing an 8-cylinder overhead valve engine with a turbocharged 6-cylinder dual overhead cam engine. This change would result in the removal of 2 cylinders, and the addition of a turbocharger, an air injector, 8 valves and 2 camshafts. Thus, for, we have estimated the cost of turbocharging and downsizing to be $810 ($600 for the turbocharger plus $90 for the air injector, plus $120 for eight valves plus $150 for a camshaft and minus $150 for the removal of two cylinders).

For midsize cars, large cars, small trucks, small SUVs, midsize SUVs and minivans, we determined that the most logical engine downsizing would involve replacing a 6-cylinder dual overhead cam engine with a turbocharged 4-cylinder dual overhead cam engine. This change would result in the removal of 2 cylinders, 8 valves and 2 camshafts and the addition of a turbocharger and air injector. Thus, for, we have estimated the cost of turbocharging and downsizing to be $120 ($600 for the turbocharger plus $90 for the air injector, minus $150 for the removal of two cylinders, minus $120 for the removal of eight valves and minus $300 for the removal of two camshafts).

Thus, we have estimated the cost for a boosted/downsized engine system at $690 for small cars, $810 for large trucks, and $120 for other vehicle classes. Projections of the fuel consumption reduction potential of a turbocharged and downsized engine from the NAS Report are backed by EEA estimates and confidential manufacturer data. . According to the NAS Report, the EEA report, cost estimates developed in conjunction with EPA and confidential manufacturer data, NHTSA estimates that downsized turbocharged engines could incrementally reduce fuel consumption from 5 to 7.5 percent at an incremental cost of $120 to $810.

Diesel Engine

Diesel engines have several characteristics that give them superior fuel efficiency to conventional gasoline, spark-ignited engines. Pumping losses are greatly reduced due to lack of (or greatly reduced) throttling. The diesel combustion cycle operates at a higher compression ratio, with a very lean air/fuel mixture, and typically at much higher torque levels than an equivalent-displacement gasoline engine. Turbocharged light-duty diesels typically achieve much higher torque levels at lower engine speeds than equivalent-displacement naturally-aspirated gasoline engines. Additionally, diesel fuel has higher energy content per gallon. However, diesel engines have emissions characteristics that present challenges to meeting Tier 2 emissions standards.

Compliance strategies are expected to include a combination of combustion improvements and after-treatment. Several key advances in diesel technology have made it possible to reduce emissions coming from the engine (prior to after-treatment). These technologies include improved fuel systems (higher pressures and more responsive injectors), advanced controls and sensors to optimize combustion and emissions performance, higher EGR levels to reduce NO_x, lower compression ratios and advanced turbocharging systems.

For after-treatment, the traditional 3-way catalyst found on gasoline-powered vehicles is ineffective due to the lean-burn combustion of a diesel. All diesels will require a particulate filter, an oxidation catalyst, and a NO_x reduction strategy to comply with Tier 2 emissions standards.

The NO_x reduction strategies most common are outlined below:

Lean NO_x Trap Catalyst After-Treatment

A lean NO_x trap (LNT) operates, in principle, by storing NO_x (NO and NO_2) when the engine is running in its normal (lean) state. When the control system determines (via mathematical model or a NO_x sensor) that the trap is saturated with NO_x, it switches to a rich operating mode. This rich mode produces excess hydrocarbons that act as a reducing agent to convert the stored NO_x to N_2 and water, thereby “regenerating” the LNT and opening up more locations for NO_x to be stored. LNTs are sensitive to sulfur deposits which can reduce catalytic performance, but periodically undergo a desulfation engine operating mode to clean it of sulfur buildup.

According to confidential manufacturer data, NHTSA estimates that LNT-based diesels can incrementally reduce fuel consumption by 8 to 15 percent at an incremental cost of $1,500 to $1,600 compared to a direct injected turbocharged and downsized internal combustion engine. These costs are based on a “bottom up” cost analysis that was performed with EPA which then subtracted the costs of all previous steps on the decision tree prior to diesel engines.

Selective Catalytic Reduction NO_x After-Treatment

SCR uses a reductant (typically, ammonia derived from urea) continuously injected into the exhaust stream ahead of the SCR catalyst. Ammonia combines with NO_x in the SCR catalyst to form N_2 and water. The hardware configuration for an SCR system is more complicated that that of an LNT, due to the onboard urea storage and delivery system (which requires a urea pump and injector into the exhaust stream). While there is no required rich engine operating mode prescribed for NO_x reduction, the urea is typically injected at a rate of 3 to 4 percent of that of fuel consumed. Manufacturers designing SCR systems are intending to align urea tank refills with standard maintenance practices such as oil changes. Incremental fuel consumption reduction estimates for diesel engines with an SCR system range from 11 to 20 percent at an incremental cost of $2,051 to $2,411 compared to a direct injected turbocharged and downsized internal combustion engine. These costs are based on a “bottom up” cost analysis that was performed with EPA, which then subtracted the costs of all previous steps on the decision tree prior to diesel engines.

Based on public information and on recent discussions that NHTSA and EPA have had with auto manufacturers and aftertreatment device manufacturers, NHTSA has received strong indications that LNT systems would probably be used on smaller vehicles while the SCR systems would be used on larger vehicles and trucks. The primary reason given for this choice is the trade off between the rhodium needed for the LNT and the urea injection system needed for SCR. The breakeven point between these two cost factors appears to occur around 3.0 liters. Thus, it is believed that it is cheaper to manufacturer diesel engines smaller than 3.0 liters with an LNT system, and that conversely, it is cheaper to manufacturer diesel engines larger than 3.0 liters with a SCR system. Of course, there are other factors that influence a manufacturer’s decision on which system to use, but we have used this rule-of thumb for our analysis.

b. Transmission technologies

Five-, Six-, Seven- and Eight-Speed Automatic Transmissions

The number of available transmission speeds influences the width of gear ratio spacing and overall coverage and, therefore, the degree of transmission ratio optimization available under different operating conditions. In general, transmissions can offer a greater available degree of engine optimization and can therefore achieve higher fuel economy when the number of gears is increased. However, potential gains may be reduced by increases in transmission weight and rotating mass. Regardless of possible changes to fuel economy standards, manufacturers are increasingly introducing 5- and 6-speed automatic transmissions on their vehicles. Additionally, some manufacturers are introducing 7- and 8-speed automatic transmissions, with 7-speed automatic transmissions appearing with increasing frequency.

Automatic 5-speed Transmissions

As automatic transmissions have been developed over the years, more forward speeds have been added to improve fuel efficiency and performance. Increasing the number of available ratios provides the opportunity to optimize engine operation under a wider variety of vehicle speeds and load conditions. Also, additional gears allow for overdrive ratios (where the output shaft of the transmission is turning at a higher speed than the input shaft) which can lower the engine speed at a given road speed (provided the engine has sufficient power at the lower rpm point) to reduce pumping losses. However, additional gears can add weight, rotating mass, and friction. Nevertheless, manufacturers are increasingly adding 5-speed automatic transmissions to replace 3- and 4-speed automatic transmissions.

The 2002 NAS study projected that 5-speed automatic transmissions could incrementally reduce fuel consumption by 2 to 3 percent at an incremental cost of $76 to $167. The NESCCAF study projected that 5-speed automatic transmissions could incrementally reduce fuel consumption by 1 percent at an incremental cost of $140; while the EEA report projected that 5-speed automatic transmissions could incrementally reduce fuel consumption by 2 to 3 percent at an incremental cost of $130. Confidential manufacturer data projected that 5-speed automatic transmissions could incrementally reduce fuel consumption by 1 to 6 percent at an incremental cost of from $60 to $281. NHTSA believes that the NAS study’s estimates are still valid and estimates that 5-speed automatic transmissions could incrementally reduce fuel consumption by 2.5 percent at an incremental cost of $76 to $167 (relative to a 4-speed automatic transmission).

Automatic 6-, 7- and 8-speed Transmissions

In addition to 5-speed automatic transmissions, manufacturers can also choose to utilize 6-, 7-, or 8-speed automatic transmissions. Additional ratios allow for further optimization of engine operation over a wider range of conditions, but this is subject to diminishing returns as the number of speeds increases. As additional planetary gearsets are added (which may be necessary in some cases to achieve the higher number of ratios), additional weight and friction are introduced. Also, the additional shifting of such a transmission can be perceived as bothersome to some consumers, so manufacturers need to develop strategies for smooth shifts. Some manufacturers are replacing 4-speed automatics with 6-speed automatics (there are also increasing numbers of 5-speed automatic transmissions that are being replaced by 6-speed automatic transmissions), and 7-, and 8-speed automatics have entered production, albeit in lower-volume applications.

The NAS study projected that 6-, 7- or 8-speed transmissions could incrementally reduce fuel consumption by 1 to 2 percent at an incremental cost of $70 to $126. Confidential manufacturer data projected that 6-, 7- or 8-speed transmissions could incrementally reduce fuel consumption by 1 to 3 percent at an incremental cost of $20 to $120. However, according to the EEA report, a Lepelletier gear set design provides for 6-speeds at the same cost as a 5-speed automatic. Based on that analysis, we have estimated the cost of a 6-speed automatic to be equivalent to that for a 5-speed automatic. We have not developed any estimate costs for 7- or 8-speed transmissions because of the diminishing returns in efficiency versus the costs for transmissions beyond 6-speeds. NHTSA estimates that 6-, 7-, or 8-speed automatic transmissions could incrementally reduce fuel consumption by 0.5 to 2.5 percent at an incremental cost of $0 to $20 (relative to a 5-speed automatic transmission). We are estimating up to an additional $20 in costs because we have tried to account for the engineering effort in addition to the hardware which we believe the EEA did not and we wanted to capture some of the higher costs reported by manufacturers.

Aggressive Shift Logic

In operation, an automatic transmission's controller decides when to upshift or downshift based on a variety of inputs such as vehicle speed and throttle position according to programmed logic. Aggressive shift logic (ASL) can be employed so that a transmission is engineered in such a way as to maximize fuel efficiency by upshifting earlier and inhibiting downshifts under some conditions. Through partial lock-up under some operating conditions and early lock-up under others, automatic transmissions can achieve some reduction in overall fuel consumption. Aggressive shift logic is applicable to all vehicle types with automatic transmissions, and since in most cases it would require no significant hardware modifications, it can be adopted during vehicle redesign or refresh or even in the middle of a vehicle's product cycle. The application of this technology does, however, require a manufacturer to confirm that driveability, durability, and noise, vibration, and harshness (NVH) are not significantly degraded.

The NAS study projected that aggressive shift logic could incrementally reduce fuel consumption by 1 to 2 percent at an incremental cost of $0 to $70. Confidential manufacturer data projected that aggressive shift logic could incrementally reduce fuel consumption by 0.5 to 3 percent at an incremental cost of $18 to $70. The NAS study estimates and confidential manufacturer data are within the same ranges, thus NHTSA believes that the NAS estimates are still accurate. Thus, NHTSA estimates aggressive shift logic could incrementally reduce fuel consumption by 1 to 2 percent at an incremental cost of $38, which is approximately the average of the midpoint of the NAS cost range and the manufacturer cost range.

Early Torque Converter Lockup

A torque converter is a fluid coupling located between the engine and transmission in vehicles with automatic transmissions and continuously-variable transmissions (CVTs). This fluid coupling allows for slip so the engine can run while the vehicle is idling in gear, provides for smoothness of the powertrain, and also provides for torque multiplication during acceleration. During light acceleration and cruising, this slip causes increased fuel consumption, so modern automatic transmissions utilize a clutch in the torque converter to lock it and prevent this slippage. Fuel consumption can be further reduced by locking up the torque converter early, and/or by using partial-lockup strategies to reduce slippage.

Some torque converters will require upgraded clutch materials to withstand additional loading and the slipping conditions during partial lock-up. As with aggressive shift logic, confirmation of acceptable driveability, performance, durability and NVH characteristics is required to successfully implement this technology.

The 2002 NAS study did not include any estimates for this technology. The NESCCAF study projected that early torque converter lockup could incrementally reduce fuel consumption by 0.5 percent at an incremental cost of $0 to $10; while the EEA report projected that low-friction lubricants could incrementally reduce fuel consumption by 0.5 percent at an incremental cost of $5. NHTSA estimates the cost of this technology (i.e., the calibration effort) at $30 based in part on NESCCAF and the CBI submissions which provided costs with a midpoint of $30. We have used a higher value here than NESCCAF and EEA because we have tried to account for the engineering effort in addition to the hardware which we believe NESCCAF and EEA did not do and which were captured in the manufacturers' higher costs.

NHTSA estimates that early torque converter lockup could incrementally reduce fuel consumption by approximately 0.5 percent at an incremental cost of approximately $30.

Automated Shift Manual Transmissions

An automated manual transmission (AMT) is mechanically similar to a conventional transmission, but shifting and launch functions are controlled by the vehicle. There are two basic types of AMTs, single-clutch and dual-clutch. A single-clutch AMT is essentially a manual transmission with automated clutch and shifting. Because there are some shift quality issues with single-clutch designs, dual-clutch AMTs are more common. A dual-clutch AMT uses separate clutches for the even-numbered gears and odd-numbered gears. In this way, the next expected gear is pre-selected, which allows for faster and smoother shifting.

Overall, AMTs likely offer the greatest potential for fuel consumption reduction among the various transmission options presented in this report because they offer the inherently lower losses of a manual transmission with the efficiency and shift quality advantages of computer control. AMTs offer the lower losses of a manual transmission with the efficiency advantages of computer control. The lower losses stem from the elimination of the conventional lock-up torque converter and a greatly reduced need for high pressure hydraulic circuits to hold clutches to maintain gear ratios (in automatic transmissions) or hold pulleys in position to maintain gear ratio (in continuously variable transmissions, discussed below). However, the lack of a torque converter will affect how the vehicle launches from rest, so an AMT will most likely be paired with an engine that offers enough torque in the low-RPM range to allow for adequate launch performance.

An AMT is mechanically similar to a conventional manual transmission, but shifting and launch functions are controlled by the vehicle rather than the driver. A switch from a conventional automatic transmission with torque converter to an AMT incurs some costs but also allows for some cost savings. Savings can be realized through elimination of the torque converter which is a very costly part of a traditional automatic transmission, and through reduced need for high pressure hydraulic circuits to hold clutches (to maintain gear ratios in automatic transmissions) or hold pulleys (to maintain gear ratios in Continuously Variable Transmissions). Cost increases would be incurred in the form of calibration efforts since transmission calibrations would have to be redone, and the addition of a clutch assembly for launce and gear changes.

The NESCCAF study projected that AMTs could incrementally reduce fuel consumption by 5 to 8 percent at an incremental cost of $0 to $280; while the EEA report projected that low-friction lubricants could incrementally reduce fuel consumption by 6 to 7 percent at an incremental cost of $195 to $225. Confidential manufacturer data projected that AMTs could incrementally reduce fuel consumption by 2 to 5 percent at an incremental cost of $70 to $400.

Taking all these estimates into consideration, NHTSA estimates that AMTs could incrementally reduce fuel consumption by 4.5 to 7.5 percent at an incremental cost of approximately $141. We believe that, overall, the hardware associated with an AMT, whether single clutch or dual clutch, is no more costly than that for a traditional automatic transmission given the savings associated with removal of the torque converter and high pressure hydraulic circuits, which is estimated to amount to at least $30. Nonetheless, given the need for engineering effort (e.g., calibration and vehicle integration work) when transitioning from a traditional automatic to an AMT, we have estimated the incremental compliance cost at $141, independent of vehicle class, which is the midpoint of the NESCCAF estimates and within the range provided confidential manufacturer data.

Continuously Variable Transmission

A Continuously Variable Transmission (CVT) is unique in that it does not use gears to provide ratios for operation. Unlike manual and automatic transmissions with fixed transmission ratios, CVTs provide, within their operating ranges, fully variable transmission ratios with an infinite number of gears. This enables even finer optimization of the transmission ratio under different operating conditions and, therefore, some reduction of pumping and engine friction losses. CVTs use either a belt or chain on a system of two pulleys.

The main advantage of a CVT is that the engine can operate at its most efficient point more often, since there are no fixed ratios. Also, CVTs often have a wider range of ratios than conventional automatic transmissions.

The most common CVT design uses two V-shaped pulleys connected by a metal belt. Each pulley is split in half and a hydraulic actuator moves the pulley halves together or apart. This causes the belt to ride on either a larger or smaller diameter section of the pulley which changes the effective ratio of the input to the output shafts.
It is assumed that CVTs will only be used on cars, small SUVs, midsize crossover vehicles and minivans because they are currently used mainly in lower-torque applications. While a high-torque CVT could be developed for small pickup trucks and large pickup trucks and large SUVs, it would likely have to be treated separately in terms of effectiveness. We do not see development in the area of high-torque CVTs and therefore did not include this type in our analysis.

The 2002 NAS study projected that CVTs could incrementally reduce fuel consumption by 4 to 8 percent at an incremental cost of $140 to $350. The NESCCAF study projected that CVTs could incrementally reduce fuel consumption by 4 percent at an incremental cost of $210 to $245. Confidential manufacturer data projected that CVTs could incrementally reduce fuel consumption by 3 to 9 percent at an incremental cost of $140 to $800. These values are incremental to a 4-speed transmission.

Based on an aggregation of manufacturers' information, we
estimate a CVT benefit of about 6% over a 4-speed automatic. This is above the NESCCAF value, but in the range of NAS. In reviewing our sources for costs, we have determined that the adjusted costs presented in the 2002 NESCCAF study represent the best available estimates. Subtracting the estimated fuel consumption reduction and costs of replacing a 4-speed automatic transmission with a 5-speed automatic transmission results in NHTSA projecting that CVTs could incrementally reduce fuel consumption by 3.5 percent when compared to a conventional 5-speed automatic transmission at an incremental cost of $100 to $139.

Manual 6-, 7-, and 8-speed Transmissions

As with automatic transmissions, increasing the number of available ratios in a manual transmission can improve fuel economy by allowing the driver to select a ratio that optimizes engine operation at a given speed. Typically, this is achieved through adding additional overdrive ratios to reduce engine speed (which saves fuel through reduced pumping losses). Six-speed manual transmissions have already achieved significant market penetration, so manufacturers have considerable experience with them and the associated costs. For those vehicles with five-speed manual transmissions, an upgrade to a six-speed could incrementally reduce fuel consumption by 0.5 percent. Based on CBI submissions, which provided costs with a midpoint of $107, NHTSA estimates that 6-

speed manual transmissions could incrementally reduce fuel consumption by 0.5 percent when compared to 5-speed automatic transmission at an incremental cost of $107.

c. Vehicle technologies

Rolling Resistance Reduction

Tire characteristics (e.g., materials, construction, and tread design) influence durability, traction control, vehicle handling, and comfort. They also influence rolling resistance – the 30 frictional losses associated mainly with the energy dissipated in the deformation of the tires under load – and therefore, CO2 emissions. This technology is applicable to all vehicles, except for body-on-frame light trucks and performance vehicles (described in the next section). Based on a 2006 NAS/NRC report, a 10% rolling resistance reduction would provide an increase in fuel economy of 1 to 2 percent. The same report estimates a $1 per tire cost for low rolling resistance tires. For four tires, our incremental compliance cost estimate is $6 per vehicle, independent of vehicle class, although not applicable to large trucks.

Low Drag Brakes

Low drag brakes reduce the sliding friction of disc brake pads on rotors when the brakes are not engaged because the brake shoes are pulled away from the rotating drum. While most passenger cars have already adopted this technology, there are indications that this technology is still available for body-on-frame trucks. According to confidential manufacturer data, low drag brakes could incrementally reduce fuel consumption by 1 percent at an incremental cost of $85 to $90. NHTSA has adopted these values for its analysis.

Front or Secondary Axle Disconnect for Four-Wheel Drive Systems

To provide shift-on-the-fly capabilities, many part-time four-wheel drive systems use some type of axle disconnect: front axle disconnect in ladder-frame vehicles, and secondary (*i.e.*, either front or rear) axle disconnect in unibody vehicles. Front and secondary axle disconnect serve two basic purposes. Using front axle disconnect as an example, in two-wheel drive mode, the technology disengages the front axle from the front driveline so the front wheels do not turn the front driveline at road speed, saving wear and tear. Then, when shifting from two- to four-wheel drive “on the fly” (while moving), the front axle disconnect couples the front axle to the front differential side gear only when the transfer case's synchronizing mechanism has spun the front driveshaft up to the same speed as the rear driveshaft.

Four-wheel drive systems that have axle disconnect typically do not have either manual- or automatic-locking hubs. To isolate (for example) the front wheels from the rest of the front driveline, front axle disconnects use a sliding sleeve to connect or disconnect an axle shaft from the front differential side gear.

This technology has been used by ladder-frame vehicles for some time, but has only started to appear on unibody vehicles recently. The incremental costs and benefits of applying front axle disconnect differ, depending on the vehicle's type of construction. According to confidential manufacturer data, front axle disconnects for ladder frame vehicles could achieve incremental fuel consumption reductions of 1.5 percent at an incremental cost of $114, while secondary axle disconnects for unibody vehicles could achieve incremental fuel consumption reductions of 1 percent at an incremental cost of $676. NHTSA has adopted these estimates for its analysis.

Aerodynamic Drag Reduction

A vehicle's size and shape determine the amount of power needed to push the vehicle through the air at different speeds. Changes in vehicle shape or frontal area can therefore reduce CO2 emissions. Areas for potential aerodynamic drag improvements include skirts, air dams, underbody covers, and more aerodynamic side view mirrors. NHTSA and EPA estimate a fleet average of 20% total aerodynamic drag reduction is attainable for passenger cars, whereas a fleet average of 10% reduction is more realistic for trucks (with a caveat for "high-performance" vehicles, described below). These drag reductions equate to increases in fuel economy of 2% and 3% for trucks and cars, respectively. These numbers are in agreement with the technical literature and supported by confidential manufacturer information. The CBI submittals generally showed the RPE associated with these changes at less than $100. NHTSA and EPA estimate that the incremental compliance cost to range from $0 to $75, independent of vehicle class. Aerodynamic drag reduction technologies are readily available today, although the phase-in time required to distribute over a manufacturer's fleet is relatively long (6 years or so).

Weight Reduction

The term weight reduction encompasses a variety of techniques with a variety of costs and lead times. These include lighter-weight materials, higher strength materials, component redesign, and size matching of components. Lighter-weight materials involve using lower density materials in vehicle components, such as replacing steel parts with aluminum or plastic. The use of higher strength materials involves the substitution of one material for another that possesses higher strength and less weight. An example would be using high strength alloy steel versus cold rolled steel. Component redesign is an on-going process to reduce costs and/or weight of components, while improving performance and reliability. An example would be a subsystem replacing multiple components and mounting hardware.

The cost of reducing weight is difficult to determine and is dependent upon the methods used. For example, a change in design that reduces weight on a new model may or may not save money. On the other hand, material substitution can result in an increase in price per application of the technology if more expensive materials are used.

For purposes of this proposed rule, NHTSA has considered only vehicles weighing greater than 5,000 pounds for weight reduction through materials substitution. Provided that those vehicles remain above 5,000 lbs weight, vehicles may realize up to roughly 2 percent incremental fuel consumption through materials substitution (corresponding to a 3 percent reduction in vehicle weight) at incremental costs of $0.75 to $1.25 per pound reduced.

d. Accessory technologies

Electric Power Steering

Electric power steering (EPS) is advantageous over hydraulic steering in that it only draws power when the wheels are being turned, which is only a small percentage of a vehicle's operating time. EPS may be implemented on many vehicles with a standard 12V system; however, for heavier vehicles, a 42V system may be required, which adds cost and complexity.

The NAS study projected that a 12V EPS system could incrementally reduce fuel consumption by 1.5 to 2.5 percent at an incremental cost of $105 to $150. The NESCCAF study projected that a 12V EPS could incrementally reduce fuel consumption by 1 percent at an incremental cost of $28 to $56; while the EEA report projected that a 12V EPS could incrementally reduce fuel consumption by 1.5 to 1.9 percent at an incremental cost of $70 to $90. According to confidential manufacturer data, electric power steering could achieve incremental fuel consumption reductions of 1.5 to 2.0 percent at an incremental cost of $118 to $197.

NHTSA believes that these manufacturer estimates are more accurate and thus estimates that a 12V EPS system could incrementally reduce fuel consumption by 1.5 to 2 percent at an incremental cost of $118 to $197, independent of vehicle class.

Engine Accessory Improvement

The accessories on an engine, like the alternator, coolant, and oil pumps, are traditionally driven by the accessory belt. Improving the efficiency or outright electrification (12V) of these accessories (in the case of the mechanically driven pumps) would provide an opportunity to reduce the accessory loads on the engine. However, the potential for such replacement will be greater for vehicles with 42V electrical systems. Some large trucks also employ mechanical fans, some of which could also be improved or electrified. Additionally, there are now higher efficiency alternators which require less of an accessory load to achieve the same power flow to the battery.

According to the NAS Report engine accessory improvement could achieve incremental fuel consumption reductions of 1 to 2 percent at an incremental cost of $124 to $166. Confidential manufacturer information is also within these ranges. The NESCCAF study estimated a cost of $56, but that estimate included only a high efficiency generator and did not include electrification of other accessories. In reviewing our sources for costs, we have determined that the adjusted costs presented in the 2002 NAS study, which ranged from $124 to $166 - depending on vehicle class – represent the best available estimates.

Based on the NAS study and confidential manufacturer information, NHTSA estimates that accessory improvement could incrementally reduce fuel consumption by 1 to 2 percent at an incremental cost of $124 to $166.

Forty-Two Volt (42V) Electrical System

Most vehicles today (aside from hybrids) operate on 12V electrical systems. At higher voltages, which appear to be under consideration to meet expected increases in on-board electrical demands, the power density of motors, solenoids, and other electrical components may increase to the point that new and more efficient systems, such as electric power steering, may be feasible. A 42V system can also accommodate an integrated starter generator. According to the NAS Report, 42V engine accessory improvement could achieve incremental fuel consumption reductions of 1 to 2 percent at an incremental cost of $194 to $259. According to confidential manufacturer data, a 42V system could achieve incremental fuel consumption reductions of 0 to 4 percent at an incremental cost of $62 to $280.

We believe that the state of 42V technology has evolved to where it is on par with the incremental costs and benefits of 12V engine accessory improvement. In reviewing our sources, we have determined that the numbers provided in the 2002 NAS study, which estimated that engine accessory improvement could achieve incremental fuel consumption reductions of 1 to 2 percent at an incremental cost of $124 to $166 - depending on vehicle class – represent the best available estimates for both 12V and 42V systems. Thus, we are estimating that a 42V electrical system could achieve incremental fuel consumption reductions of 1 to 2 percent at an incremental cost of $124 to $166. These estimates are independent of vehicle class and exclusive of improvements to the efficiencies or electrification of 12V accessories. These estimates are incremental to a 12V system, regardless of whether the 12V system has improved efficiency or not.

e. Hybrid technologies

A hybrid describes a vehicle that combines two or more sources of propulsion energy, where one uses a consumable fuel (like gasoline) and one is rechargeable (during operation, or by another energy source). Hybrids reduce fuel consumption through three major mechanisms: by optimizing the operation of the internal combustion engine (through downsizing, or other control techniques) to operate at or near its most efficient point more of the time; by recapturing lost braking energy and storing it for later use; and by turning off the engine when it is not needed, such as when the vehicle is coasting or when stopped.

Hybrid vehicles utilize some combination of the above three mechanisms to reduce fuel consumption. The effectiveness of a hybrid depends on the utilization of the above mechanisms and how aggressively they are pursued. Different hybrid concepts utilize these mechanisms differently, so they are treated separately in this analysis. Below is a discussion of the major hybrid concepts judged to be available for use within the timeframe of this rulemaking.

Integrated Starter-Generator with Idle-Off

Integrated Starter-Generator (ISG) systems are the most basic of hybrid systems and offer mainly idle-stop capability. They offer the least power assist and regeneration capability of the hybrid approaches, but their low cost and easy adaptability to existing powertrains and platforms can make them attractive for some applications. ISG systems operate at around 42V and so have smaller electric motors and less battery capacity than other HEV designs because of their lower power demand.

ISG systems replace the conventional belt-driven alternator with a belt-driven, higher power starter-alternator. The starter-alternator starts the engine during idle-stop operation, but often a conventional 12V gear-reduction starter is retained to ensure cold-weather startability. Also, during idle-stop, some functions such as power steering and automatic transmission hydraulic pressure are lost with conventional arrangements, so electric power steering and an auxiliary transmission pump are added. These components are similar to those that would be used in other hybrid designs. An ISG system could be capable of providing some launch assist, but it would be limited in comparison to other hybrid concepts. According to the NAS Report, an EEA report and confidential manufacturer data, ISG systems could achieve incremental fuel consumption reductions that range from 5 to 10 percent.

In addition, when idle-off is used (i.e., the petroleum fuelled engine is shut off during idle operation), an electric power steering and auxiliary transmission pump are added to provide for functioning of these systems which, in a traditional vehicle, were powered by the petroleum engine. The 2002 NAS study estimated the cost of these systems at $210 to $350 with a 12 volt electrical system and independent of vehicle class, while the NESCCAF study estimated the cost for these systems at $280 with a 12 volt electrical system for a small car. The 2002 NAS study estimated the cost of these systems to be $210 to $350 with a 12 volt electrical system and independent of vehicle class, while the NESCCAF study estimated the cost for these systems of $280 with a 12 volt electrical system for a small car. Confidential manufacturer information provides cost estimates for ISGs that range from $418 to $800. We believe that the NAS and the NESCCAF estimates are still accurate for ISGs with a 12V system. Thus, if you add these cost estimates to those we estimated for 42V systems plus associated equipment, which results an estimated incremental compliance cost of these systems, including the costs associated with upgrading to a 42 volt electrical system of $563 to $600, depending on vehicle class.

Therefore, NHTSA estimates that ISG systems could achieve incremental fuel consumption reductions of 5 to 10 percent at incremental costs of $563 to $600, depending on vehicle class (this includes the costs associated with upgrading to a 42 volt electrical system). If a 42V system was already applied to a vehicle, the fuel consumption reductions and incremental cost for that technology would be subtracted in our analysis.

Integrated Motor Assist (IMA)/Integrated Starter-Alternator-Dampener (ISAD) Hybrid

Honda is the only manufacturer that uses Integrated Motor Assist (IMA), which utilizes a thin axial electric motor bolted to the engine's crankshaft and connected to the transmission through a torque converter or clutch. This electric motor acts as both a motor for helping to launch the vehicle and a generator for recovering energy while slowing down. It also acts as the starter for the engine and the electrical system's main generator. Since it is rigidly fixed to the engine, if the motor turns, the engine must turn also, but combustion does not necessarily need to occur. The Civic Hybrid uses cylinder deactivation on all four cylinders for decelerations and some cruise conditions.

The main advantage of the IMA system is it's relatively low cost and ease of adaptability to conventional vehicles and powertrains while providing excellent efficiency gains. Packaging space is a concern for the physically longer engine-motor-transmission assembly as well as the necessary battery pack, cabling and power electronics. According to EPA test data and confidential manufacturer product information, the IMA system could achieve incremental fuel consumption reductions of 3.5 to 8.5 percent.[44] NHTSA has adopted these estimates for its analysis.

The 2002 NAS study did not consider this technology while the NESCCAF study estimated the cost for these systems at $2310 to $2940 for a small car and large car, respectively. We have used these estimates combined with confidential manufacturer data as the basis for our incremental compliance costs of $1636 for the small car and $2274 for the large car, expressed in 2006 dollars. We have not estimated incremental compliance costs for the other vehicle classes because we do not believe those classes would use this technology and would, instead, use the hybrid technologies discussed below.

2-Mode Hybrids

GM, DaimlerChrysler, and BMW have formed a joint venture to develop a new HEV system based on HEV transmission technology originally developed by GM's Allison Transmission Division for heavy-duty vehicles like city buses. This technology uses an adaptation of a conventional stepped-ratio automatic transmission by replacing some of the transmission clutches with two electric motors, which makes the transmission act like a CVT. Like Toyota's Power Split design, these motors control the ratio of engine speed to vehicle speed. But unlike the Power Split system, clutches allow the motors to be bypassed, which improves both the transmission's torque capacity for heavy-duty applications and fuel economy at highway speeds. According to confidential manufacturer data, 2-mode hybrids could achieve incremental fuel consumption reductions of 25 to 40 percent. NHTSA estimates that 2-mode hybrids could achieve fuel reductions of 3.5 percent to 7 percent incremental to an Integrated Motor Assist (IMA)/Integrated Starter-Alternator-Dampener (ISAD) Hybrid.

The 2002 NAS study did not consider this technology, while the NESCCAF study estimated the costs to range from $4340 to $5600, depending on vehicle class. These

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[44] Honda's cost estimates are protected per Honda's confidentiality agreement with NHTSA.

estimates are not incremental to an Integrated Motor Assist (IMA)/Integrated Starter-Alternator-Dampener (ISAD) Hybrid. To accurately project the cost of 2-mode hybrids when they were applied to midsize and large cars we subtracted the estimated costs of an Integrated Motor Assist (IMA)/Integrated Starter-Alternator-Dampener (ISAD) Hybrid We have used the NESCCAF estimates as the basis for our incremental compliance costs of $1,501 to $5,127 in 2006 dollars, incremental to an Integrated Motor Assist (IMA)/Integrated Starter-Alternator-Dampener (ISAD) Hybrid or an ISG system depending on vehicle class.[45] We have not estimated incremental compliance costs for small cars because we believe that this ISG or IMA/ISAD technology is a better fit for small cars.

Power Split Hybrid

Toyota's Hybrid Synergy Drive system as used in the Prius is a completely different approach than Honda's IMA system and uses a "Power Split" device in place of a conventional transmission. The Power Split system replaces the vehicle's transmission with a single planetary gear and a motor/generator. A second, more powerful motor/generator is permanently connected to the vehicle's final drive and always turns with the wheels. The planetary gear splits the engine's torque between the first motor/generator and the drive motor. The first motor/generator uses its engine torque to either charge the battery or supply additional power to the drive motor. The speed of the first motor/generator determines the relative speed of the engine to the wheels. In this way, the planetary gear allows the engine to operate completely independently of vehicle speed, much like a CVT.

The Power Split system allows for outstanding fuel economy in city driving. The vehicle also avoids the cost of a conventional transmission, replacing it with a much simpler single planetary and motor/generator. However, it is less efficient at highway speeds due to the requirement that the first motor/generator must be constantly spinning at a relatively high speed to maintain the correct ratio. Also, load capacity is limited to the first motor/generator's capacity to resist the reaction torque of the drive train.

A version of Toyota's Power Split system is also used in the Lexus RX400h and Toyota Highlander sport utility vehicles. This version has more powerful motor/generators to handle higher loads and also adds a third motor/generator on the rear axle of four-wheel-drive models. This provides the vehicle with four wheel drive capability and four wheel regenerative braking capability. Ford's CVT system used in the hybrid Escape is another version of the Power Split system, but four-wheel-drive models use a conventional transfer case and drive shaft to power the rear wheels.

Other versions of this system are used in the Lexus GS450h and Lexus LS600h luxury sedans. These systems have modifications and additional hardware for sustained high-speed operation and/or all-wheel-drive capability. However, the Power Split system isn't planned for usage on full-size trucks and SUVs due to its limited ability to provide the

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[45] GM's cost estimates are protected per GM's confidentiality agreement with NHTSA.

torque needed by these vehicles. It's anticipated that full-size trucks and SUVs would use the 2-mode hybrid system. The 2002 NAS study didn't consider this technology, while the NESCCAF study estimated the incremental costs at to be $3500 prior to any cost adjustment. Based on the NESCCAF study and fuel economy test data from EPA's certification database which shows these systems being capable of reducing fuel consumption by 25 to 35 percent, NHTSA estimates that Power Split hybrids can achieve incremental fuel consumption reductions of 25 to 35 percent over conventionally powered vehicles at an incremental cost of $3,700 to $3,850. Because NHTSA applies technologies incrementally to the technologies preceding them on our decision trees, the incremental fuel consumption reductions for Power Split hybrids are estimated to be 5 to 6.5 percent incremental to 2-Mode Hybrids (the technology that precedes Power Split hybrids on the decision tree), because the technologies applied prior to and including 2-Mode hybrids are estimated to have incremental fuel consumption reductions of 20 to 28.5 percent over conventionally powered vehicles. The technologies discussed below were not projected for use during the MY 2011 to 2015 timeframes because NHTSA isn't aware that any manufacturer is including these technologies in any vehicle for which we have production plans for nor has any manufacturer publicly stated that any of these technologies will definitively be included on future products. If NHTSA receives such information regarding any technology(ies), it will revisit this decision for the final rule. NHTSA is including its discussion of these technologies and their estimated costs and fuel consumption reductions as a reference for commenters and in anticipation of their possible inclusion in the final rule.

Variable Compression Ratio

A spark-ignited engine's specific power is limited by the engine's compression ratio, which is, in turn, currently limited by the engine's susceptibility to knock, particularly under high load conditions. Engines with variable compression ratio (VCR) improve fuel economy by the use of higher compression ratios at lower loads and lower compression ratios under higher loads. The NAS Report projected that VCR could incrementally reduce fuel consumption by 2 to 6 percent over 4-valve VVT at an incremental cost of $218 to $510. NHTSA has no information which suggests that VCR will be included on any vehicles during the MY 2011-2015 timeframe, thus NHTSA does not use this technology in its analysis. Additionally, no updates to these estimates were sought.

Lean-Burn Gasoline Direct Injection Technology

One way to improve dramatically an engine's thermodynamic efficiency is by operating at a lean air-fuel mixture (excess air). Fuel system improvements, changes in combustion chamber design and repositioning of the injectors have allowed for better air/fuel mixing and combustion efficiency. There is currently a shift from wall-guided injection to spray guided injection, which improves injection precision and targeting towards the spark plug, increasing lean combustion stability. Combined with advances in NO_x after-treatment, lean-burn GDI engines may be a possibility in North America.

However, a key technical requirement for lean-burn GDI engines to meet EPA's Tier 2 NO_x emissions levels is the availability of low-sulfur gasoline, which is projected to be unavailable during MY 2011 – 2015.

According to the NESCCAF report and confidential manufacturer data NHTSA estimates that lean-burn GDI engines could incrementally reduce fuel consumption from 9 to 16 percent at an incremental cost of $500 to $750 compared to a port-fueled (stoichiometric) engine. NHTSA did not project the use of this technology during the time frame covered by this proposal, due to large uncertainties surrounding the availability of low-sulfur gasoline. Nonetheless, we have estimated the incremental compliance cost for these systems at $750, independent of vehicle class, and incremental to a stoichiometric GDI engine.

Homogeneous Charge Compression Ignition

Homogeneous charge compression ignition (HCCI), also referred to as controlled auto ignition (CAI), is an alternate engine operating mode that does not rely on a spark event to initiate combustion. The principles are more closely aligned with a diesel combustion cycle, in which the compressed charge exceeds a temperature and pressure necessary for spontaneous ignition. The resulting burn is much shorter in duration with higher thermal efficiency.

An HCCI engine has inherent advantages in its overall efficiency for several reasons. An extremely lean fuel/air charge increases thermodynamic efficiency. Shorter combustion times and higher EGR tolerance permit very high compression ratios (which also increase thermodynamic efficiency). Additionally, pumping losses are reduced because the engine can run unthrottled.

However, due to the nature of its combustion process, HCCI is difficult to control, requiring in-cylinder pressure sensors and very fast engine control logic to optimize combustion timing, especially considering the variable nature of operating conditions seen in a vehicle. To be used in a commercially acceptable vehicle application, an HCCI-equipped engine would most likely be "dual-mode," in which HCCI operation is complemented with a traditional SI combustion process at idle and at higher loads and speeds.

Until recently, HCCI technology was considered to still be in the research phase. However, several manufacturers have made public statements about the viability of incorporating HCCI into production vehicles over the next 10 years. The NESCCAF study estimated the cost to range from $560 to $840, depending on vehicle class, including the costs for a stoichiometric GDI system with DVVL. We have based our estimated incremental compliance cost on the NESCCAF estimates and, after subtracting out the estimated incremental cost for a stoichiometric GDI system with DVVL, we estimate the incremental cost for HCCI to be from $263 to $685, depending on vehicle class. This estimated incremental compliance cost is incremental to a stoichiometric GDI engine.

Advanced CVT

Advanced CVTs have the ability to deliver higher torques than existing CVTs and have the potential for broader market penetration. These new designs incorporate toroidal friction elements or cone-and-ring assemblies with varying diameters. According to the NAS Report, advanced CVT could incrementally reduce fuel consumption by up to 2 percent at an incremental cost of $364 to $874. NHTSA has no information which suggests that VCR will be included on any vehicles during the MY 2011-2015 timeframe, thus NHTSA does not use this technology in its analysis. Additionally, no updates to these estimates were sought.

Plug-in Hybrids

Plug-In Hybrid Electric Vehicles (PHEVs) are very similar to hybrid electric vehicles, but with three significant functional differences. The first is the addition of a means to charge the battery pack from an outside source of electricity (usually the electric grid). Second, a PHEV would have a larger battery pack with more energy storage, and a greater capability to be discharged. Finally, a PHEV would have a control system that allows the battery pack to be significantly depleted during normal operation.

Deriving some of their propulsion energy from the electric grid provides several advantages for PHEVs. PHEVs offer a significant opportunity to replace petroleum used for transportation energy with domestically-produced electricity. The reduction in petroleum usage does, of course, depend on the amount of electric drive the vehicle is capable of under its duty cycle.

The fuel consumption reduction potential of PHEVs depends on many factors, the most important being the electrical capacity designed into the battery pack. To estimate the fuel consumption reduction potential of PHEVs, EPA has developed an in-house vehicle energy model (PEREGRIN) which is based on the PERE (Physical Emission Rate Estimator) physics-based model used as a fuel consumption input for EPA's MOVES mobile source emissions modelB.

EPA modeled the PHEV small car, large car, minivan and small trucks using parameters from a midsize car similar to today's hybrids and scaled to each vehicle's weight. The large truck PHEV was modeled separately assuming very little engine downsizing. Each PHEV was assumed to have enough battery capacity for a 20-mile-equivalent all-electric range and a power requirement to provide similar performance to a hybrid vehicle. A twenty mile range was selected because it offers a good compromise for vehicle performance, weight, battery packaging and cost.

To calculate the total energy use of a PHEV, a vehicle can be thought of as operating in two distinct modes, electric (EV) mode, and hybrid (HEV) mode. The energy consumed during EV operation can be accounted for and calculated in terms of gasoline-equivalent MPG by using 10CFR474, *Electric and Hybrid Vehicle Research, Development, and Demonstration Program; Petroleum-Equivalent Fuel Economy*

Calculation. The EV mode fuel economy can then be combined with the HEV mode fuel economy using the Utility Factor calculation in SAE J1711 to determine a total MPG value for the vehicle. Calculating a total fuel consumption reduction based on model outputs, gasoline-equivalent calculations, and the Utility Factor calculations, results in a 28% fuel consumption reduction for small cars, large cars, minivans, and small trucks and a 31% fuel consumption reduction for large trucks.

The fuel consumption reduction potential of PHEVs will vary based on the electrical capacity designed into the battery pack. Assuming a 20-mile "all-electric range" design, a PHEV might incrementally reduce fuel consumption by 28 to 31 percent.[46] Based on discussions with EPA, we have estimated the incremental cost of PHEVs to be from $4500 to $10200, depending on vehicle class.

NHTSA is aware that manufacturers have made public statements about their intent to produce PHEVs during the MY 2011 – 2015 timeframe. However, NHTSA has received no information from these manufacturers that provides all the specifications and production data that is necessary for NHTSA to include these vehicles in this analysis. NHTSA hopes to receive complete product plan information from these manufacturers concerning any PHEVs that they plan on producing during the MY 2011- 2015 timeframe.

NHTSA would like to note that if it receives new and/or updated information from manufacturers regarding the likelihood of PHEV production during the MY 2011 to 2015 timeframe, it will make every effort to include PHEVs as a technology in its final rule. To enable the possible inclusion of PHEVs as a technology, NHTSA would also have to configure the Volpe model to account for the estimated source(s) that would supply the electricity for electrical grid charging of the battery. Work has started on this effort, but has not yet been completed.

Additionally, NHTSA is unaware of the existence of any batteries that are deemed acceptable for the performance characteristics necessary for a plug-in hybrid. Therefore, although we discuss them here, the model does not currently apply them.

The tables below summarize for each of the 10 classes of vehicles the cost and effectiveness assumptions used in this rulemaking as well as the year of availability of each technology. The agency seeks comments on our assumptions and the cost and effectiveness estimates provided.

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[46] This estimate is based on the EPA test cycle. We are unable to provide cost estimates for PHEV technology due to the great amount of uncertainty surrounding the chemistry, safety and performance requirements of the appropriate battery technology that would be used.

Table V-1 Technology Cost Estimates

Technologies	**Vehicle Technology Incremental Retail Price Equivalent per Vehicle ($) by Vehicle Class**									
	Subcompact Car	**Compact Car**	**Midsize Car**	**Large Car**	**Small Pickup**	**Small SUV**	**Minivan**	**Midsize SUV**	**Large Pickup**	**Large SUV**
Low friction lubricants – incremental to base engine	3	3	3	3	3	3	3	3	3	3
Engine friction reduction – incremental to base engine	0-84	0-84	0-126	0-126	0-126	0-126	0-126	0-126	0-168	0-168
Overhead Cam Branch										
VVT – intake cam phasing	59	59	119	119	119	119	119	119	119	119
VVT – coupled cam phasing	59	59	119	119	119	119	119	119	119	119
VVT – dual cam phasing	89	89	209	209	209	209	209	209	209	209
Cylinder deactivation	n.a.	n.a.	203	203	203	203	203	203	229	229
Discrete VVLT	169	169	246	246	246	246	246	246	322	322
Continuous VVLT	254	254	466	466	466	466	466	466	508	508
Overhead Valve Branch										
Cylinder deactivation	n.a.	n.a.	203	203	203	203	203	203	229	229
VVT – coupled cam phasing	59	59	59	59	59	59	59	59	59	59
Discrete VVLT	169	169	246	246	246	246	246	246	322	322
Continuous VVLT (includes conversion to Overhead Cam)	599	599	1262	1262	1262	1262	1262	1262	1380	1380
Camless valvetrain (electromagnetic)	336-673	336-673	336-673	336-673	336-673	336-673	336-673	336-673	336-673	336-673
GDI – stoichiometric	122-420	122-420	204-525	204-525	204-525	204-525	204-525	204-525	228-525	228-525
GDI – lean burn	750	750	750	750	750	750	750	750	750	750
Gasoline HCCI dual-mode	263	263	390	390	390	390	390	390	685	685
Turbocharge & downsize	690	690	120	120	120	120	120	120	810	810
Diesel – Lean NOx trap	1586	1586								
Diesel – urea SCR			2051	2051	2411	2411	2126	2411	2261	2261
Aggressive shift logic	38	38	38	38	38	38	38	38	38	38
Early torque converter lockup	30	30	30	30	30	30	30	30	30	30
5-speed automatic	76-167	76-167	76-167	76-167	76-167	76-167	76-167	76-167	76-167	76-167
6-speed automatic	76-187	76-187	76-187	76-187	76-187	76-187	76-187	76-187	76-187	76-187
6-speed AMT	141	141	141	141	141	141	141	141	141	141

6-speed manual	107	107	107	107	107	107	107	107	107	107
CVT	100	100	139	139	n.a.	139	139	139	n.a.	n.a.

Stop-Start with 42 volt system	563	563	600	600	600	600	600	600	600	600
IMA/ISA/BSG (includes engine downsize)	1636	1636	2274	2274	n.a	n.a	n.a	n.a	n.a	n.a
2-Mode hybrid electric vehicle	n.a	n.a	4655	4655	4655	4655	4655	4655	6006	6006
Power-split hybrid electric vehicle (P-S HEV)	3700-3850	3700-3850	3700-3850	3700-3850	3700-3850	3700-3850	3700-3850	3700-3850		
Plug-in hybrid electric vehicle (PHEV)	4500	4500	6750	6750	6750	6750	6750	6750	10200	10200
Improved high efficiency alternator & electrification of accessories (12 volt)	124-166	124-166	124-166	124-166	124-166	124-166	124-166	124-166	124-166	124-166
Electric power steering (12 or 42 volt)	118-197	118-197	118-197	118-197	118-197	118-197	118-197	118-197	118-197	118-197
Improved high efficiency alternator & electrification of accessories (42 volt)	124-166	124-166	124-166	124-166	124-166	124-166	124-166	124-166	124-166	124-166
Aero drag reduction (20% on cars, 10% on trucks)	0-75	0-75	0-75	0-75	0-75	0-75	0-75	0-75	0-75	0-75
Low rolling resistance tires (10%)	6	6	6	6	6	6	6	6		
Low drag brakes (ladder frame only)					87	87		87	87	87
Secondary axle disconnect (unibody only)	676	676	676	676	676	676	676	676		
Front axle disconnect (ladder frame only)					114	114		114	114	114
Weight reduction (1%) – above 5,000 lbs only									2/pound	2/pound
Weight reduction (2%) – incremental to 1%									2/pound	2/pound
Weight reduction (3%) – incremental to 2%									3/pound	3/pound
	Subcompact Car	**Compact Car**	**Midsize Car**	**Large Car**	**Small Pickup**	**Small SUV**	**Minivan**	**Midsize SUV**	**Large Pickup**	**Large SUV**

Table V-2: Technology Percent Effectiveness Estimates

Technologies	**Vehicle Technology Incremental Fuel Consumption Reduction (%) by Vehicle Class**									
	Subcompact Car	**Compact Car**	**Midsize Car**	**Large Car**	**Small Pickup**	**Small SUV**	**Minivan**	**Midsize SUV**	**Large Pickup**	**Large SUV**
Low friction lubricants – incremental to base engine	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Engine friction reduction – incremental to base engine	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3
Overhead Cam Branch										
VVT – intake cam phasing	2	2	1	1	1	1	1	1	2	2
VVT – coupled cam phasing	1	1	3	3	2	2	1	1	2	2
VVT – dual cam phasing	1	1	3	3	1	1	1	1	2	2
Cylinder deactivation	n/a	n/a	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Discrete VVLT	3	3	1.5	1.5	1.5	1.5	0.5	0.5	1.5	1.5
Continuous VVLT	4	4	3.5	3.5	2.5	2.5	1.5	1.5	2.5	2.5
Overhead Valve Branch										
Cylinder deactivation	n/a	n/a	6	6	6	6	6	6	6	6
VVT – coupled cam phasing	3	3	2.5	2.5	1.5	1.5	0.5	0.5	2.5	2.5
Discrete VVLT	1.5	1.5	1.5	1.5	1.5	1.5	0.5	0.5	1.5	1.5
Continuous VVLT (includes conversion to Overhead Cam)	2.5	2.5	3.5	3.5	2.5	2.5	1.5	1.5	2.5	2.5
Camless valvetrain (electromagnetic)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
GDI – stoichiometric	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2
GDI – lean burn	-	-	-	-	-	-	-	-	-	-
Gasoline HCCI dual-mode	10-12	10-12	10-12	10-12	10-12	10-12	10-12	10-12	10-12	10-12
Turbocharge & Downsize	5.0 – 7.5	5.0 – 7.5	5.0 – 7.5	5.0 – 7.5	5.0 – 7.5	5.0 – 7.5	5.0 – 7.5	5.0 – 7.5	5.0 – 7.5	5.0 – 7.5
Diesel – Lean NOx trap	11.5	11.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Diesel – urea SCR	n/a	n/a	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
Aggressive shift logic	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2
Early torque converter lockup	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
5-speed automatic	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
6-speed automatic	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5	0.5-2.5
6-speed AMT	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5	4.5-7.5
6-speed manual	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
CVT	3.5	3.5	3.5	3.5	n/a	3.5	3.5	3.5	n/a	n/a

Stop-Start with 42 volt system	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
IMA/ISA/BSG (includes engine downsize)	8.5	8.5	3.5	3.5	n/a	n/a	n/a	n/a	n/a	n/a
2-Mode hybrid electric vehicle	n/a	n/a	3.5	3.5	7	7	7	7	3.5	3.5
Power-split hybrid electric vehicle (P-S HEV)	5	5	6.5	6.5	6.5	6.5	6.5	6.5	n/a	n/a
Plug-in hybrid electric vehicle (PHEV)	28	28	28	28	28	28	28	28	31	31
Improved high efficiency alternator & electrification of accessories (12 volt)	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2
Electric power steering (12 or 42 volt)	1.5	1.5	1.5-2	1.5-2	2	2	2	2	2	2
Improved high efficiency alternator & electrification of accessories (42 volt)	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2
Aero drag reduction (20% on cars, 10% on trucks)	3	3	3	3	2	2	3	3	2	2
Low rolling resistance tires (10%)	1-2	1-2	1-2	1-2	1-2	1-2	1-2	1-2	n/a	n/a
Low drag brakes (ladder frame only)	n/a	n/a	n/a	n/a	1	1	n/a	n/a	1	1
Secondary axle disconnect (unibody only)	1	1	1	1	1	1	1	1	n/a	n/a
Front axle disconnect (ladder frame only)	n/a	n/a	n/a	n/a	1.5	1.5	n/a	n/a	1.5	1.5
Weight reduction (1%) – above 5,000 lbs only	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.7	0.7
Weight reduction (2%) – incremental to 1%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.7	0.7
Weight reduction (3%) – incremental to 2%	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0.7	0.7
	Sub compact Car	**Compact Car**	**Midsize Car**	**Large Car**	**Small Pickup**	**Small SUV**	**Minivan**	**Midsize SUV**	**Large Pickup**	**Large SUV**

Table V-3: Year of Availability

Technologies	Year of Availability
Low friction lubricants – incremental to base engine	Present
Engine friction reduction – incremental to base engine	Present
Overhead Cam Branch	
VVT – intake cam phasing	Present
VVT – coupled cam phasing	Present
VVT – dual cam phasing	Present
Cylinder deactivation	Present
Discrete VVLT	Present
Continuous VVLT	Present
Overhead Valve Branch	
Cylinder deactivation	Present
VVT – coupled cam phasing	Present
Discrete VVLT	Present
Continuous VVLT (includes conversion to Overhead Cam)	Present
Camless valvetrain (electromagnetic)	2020
GDI – stoichiometric	Present
GDI – lean burn	2020
Gasoline HCCI dual-mode	2016
Turbocharging & Downsizing	2010
Diesel – Lean NOx trap	2010
Diesel – urea SCR	2010
Aggressive shift logic	Present
Early torque converter lockup	Present
5-speed automatic	Present
6-speed automatic	Present
6-speed AMT	2010
6-speed manual	Present
CVT	Present
Stop-Start with 42 volt system	2014
IMA/ISA/BSG (includes engine downsize)	2014
2-Mode hybrid electric vehicle	2014
Power-split hybrid electric vehicle (P-S HEV)	2014
Full-Series hydraulic hybrid	NA
Plug-in hybrid electric vehicle (PHEV)	NA
Full electric vehicle (EV)	NA
Improved high efficiency alternator & electrification of accessories (12 volt)	Present
Electric power steering (12 or 42 volt)	Present
Improved high efficiency alternator & electrification of accessories (42 volt)	Present
Aero drag reduction (20% on cars, 10% on trucks)	Present
Low rolling resistance tires (10%)	Present
Low drag brakes (ladder frame only)	Present
Secondary axle disconnect (unibody only)	2012
Front axle disconnect (ladder frame only)	Present
Weight reduction (1%) – above 6000 lbs only	Present
Weight reduction (2%) – incremental to 1%	Present
Weight reduction (3%) – incremental to 2%	Present

C. Technology synergies

When two or more technologies are added to a particular vehicle model to improve its fuel efficiency, the resultant fuel consumption reduction may sometimes be higher or lower than the product of the individual effectiveness values for those items. This may occur because one or more technologies applied to the same vehicle partially address the same source or sources of engine or vehicle losses. Alternately, this effect may be seen when one technology shifts the engine operating points, and therefore increases or reduces the fuel consumption reduction achieved by another technology or set of technologies. The difference between the observed fuel consumption reduction associated with a set of technologies and the product of the individual effectiveness values in that set is sometimes referred to as a "synergy." Synergies may be positive (increased fuel consumption reduction compared to the product of the individual effects) or negative (decreased fuel consumption reduction).

The NAS committee which authored the 2002 Report was aware of technology synergies and considered criticisms as part of the peer-review process that its analysis was "judgment-simplified," but concluded overall that its approach was "sufficiently rigorous" for purposes of the report.[47] After examining its analysis again, the committee stated that "…the path 1 and path 2 estimate average fuel consumption improvements … appear quite reasonable, although the uncertainty in the analysis grows as more technology features are considered."[48] In essence, as more technology features are considered, the features are more likely to overlap and result in synergies. Because NAS did not expect vehicle manufacturers to reach "path 3" in the timeframe considered, it did not concern itself deeply with the effect of technology synergies in its analysis.

NHTSA's rulemaking regarding CAFE standards for MY 2008-MY 2011 light trucks made significant use of NAS' "path 2" estimates of the effectiveness and cost of available technologies. In part because its analysis did not extend to the more aggressive "path 3," the agency concluded that the NAS-based multiplicative approach it followed when aggregating these technologies was reasonable. In contrast, the agency's current proposal is based on an analysis that includes a broader range of technologies than was considered by NAS in 2001 and 2002. Also, the extent to which technologies are included in the current analysis is more consistent with NAS' prior "path 3" approach. Therefore, the agency's current analysis uses estimated "synergies" to address the uncertainties mentioned in the 2002 NAS report.

The Volpe model has been modified to estimate the interactions of technologies using estimates of incremental synergies associated with a number of technology pairs identified by NHTSA, Volpe Center, and EPA staff. The use of discrete technology pair incremental synergies is similar to that in DOE's National Energy Modeling System (NEMS).[49] Inputs to the Volpe model incorporate NEMS-identified pairs, as well as additional pairs from the set of technologies considered in the Volpe model. However, to maintain an approach that was consistent with the

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[47] NAS Report, p. 151.

[48] *Id.*

[49] U.S. Department of Energy, Energy Information Administration, *Transportation Sector Module of the National Energy Modeling System: Model Documentation 2007*, May 2007, Washington, DC, DOE/EIA-M070(2007), pp. 29-30.

technology sequencing developed by NHTSA, Volpe Center, and EPA staff, new incremental synergy estimates for all pairs were obtained from a first-order “lumped parameter” analysis tool created by EPA.[50] Results of this analysis were generally consistent with those of full-scale vehicle simulation modeling performed by Ricardo, Inc.[51] NHTSA’s analysis applies these incremental synergy values, obtained from the tool using baseline passenger car engine and vehicle inputs, to all vehicle classes.

Incremental synergy values are specified in Volpe model input files in two ways: as part of the incremental effectiveness values table (same path technologies) and in a separate incremental synergies table (separate path technologies). In the case of same path technologies, each technology's incremental effectiveness value was obtained from the technical literature and manufacturers’ submitted information, and then the sum of all incremental synergies associated with that technology and each technology located higher on the same path was subtracted to determine the incremental effectiveness. For example, all engine technologies take into account incremental synergy factors of preceding engine technologies; all transmission technologies take into account incremental synergy factors of preceding transmission technologies. These factors are expressed in the fuel consumption improvement factors in the input files used by the Volpe model.

For applying incremental synergy factors in separate path technologies, the Volpe model uses an input table which lists technology pairings and incremental synergy factors associated with those pairings, most of which are between engine technologies and transmission technologies. When a technology is applied to a vehicle by the Volpe model, all instances of that technology in the incremental synergy table which match technologies already applied to the vehicle (either pre-existing or previously applied by the Volpe model) are summed and applied to the fuel consumption improvement factor of the technology being applied. When the Volpe model applies incremental synergies, the fuel consumption improvement factors cannot be reduced below zero.

Incremental synergy values were calculated assuming the prior application (implying succession in some cases) of all technologies located higher along both paths than the pair considered. This is usually a true reflection of a given vehicle's equipment at any point in the model run and thus the method is expected to produce reasonable results in most cases.

NHTSA considered other methods for estimating interactions between technologies. For example, the agency has considered integrating detailed simulation of individual vehicles’ performance into the Volpe model.[52] However, while application of such simulation techniques could provide a useful source of information when developing <u>inputs</u> to the Volpe model, the

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[50] This tool is a simple spreadsheet model that represents energy consumption in terns of average performance over the fuel economy test procedure, rather than explicitly analyzing specific drive cycles. The tool begins with an apportionment of fuel consumption across several loss mechanisms, and accounts for the average extent to which different technologies affect these loss mechanisms

[51] EPA contracted with Ricardo, Inc. (an independent consulting firm) to study the potential effectiveness of carbon dioxide-reducing (and thus, fuel economy-improving) vehicle technologies. The Ricardo study is available in the docket for this NPRM.

[52] In other words, having the Volpe model run a full vehicle simulation every time the Volpe model is evaluating the potential effect of applying a specific technology to a specific vehicle model.

agency believes that applying detailed simulation when analyzing the entire fleet of future vehicles is neither necessary nor feasible. NHTSA is charged with setting standards at the maximum feasible level. To understand the potential impacts of its standards, the agency analyzes entire fleets of vehicles expected to be produced in the future. Although some expected engineering characteristics of these vehicles are available, the level of detail needed for full vehicle simulation—a level of detail that would be important if NHTSA were actually designing vehicles—is not available.

As another possible alternative to using "synergy" factors, NHTSA has also considered modifying the Volpe model to accept as inputs different measures of efficiency for each engine, transmission, and vehicle model in the product plans. For instance, manufacturers could provide estimates of mechanical and drivetrain efficiencies. Mechanical efficiency (usually between 70 and 90 percent) gives an estimate of the amount of fuel consumed by engine friction and pumping losses. Drivetrain efficiency (usually between 80 and 90 percent) gives an estimate of the amount of fuel consumed by parasitic loads and gearbox friction. From these efficiencies along with other inputs such as compression ratio, aerodynamic drag, rolling resistance, and vehicle mass, the model could estimate the fuel consumption associated with each loss mechanism and enforce a maximum fuel consumption reduction for each vehicle model based on those estimates and the technologies applied. Like the use of incremental synergies, this method could help the model avoid double counting fuel consumption benefits when applying multiple technologies to the same vehicle model.[53] The agency believes that this approach, like the use of "synergy" factors currently used by the Volpe model, could conceivably provide a means of addressing uncertainty in fuel consumption estimation within the context of CAFE analysis. However, the agency is not confident that model-by-model estimates of baseline fuel consumption partitioning would be available. Also, partitioned estimates of the effects of all the technologies considered in the analysis of this proposal were not available. If both of these concerns could be addressed, NHTSA believes it would be possible to implement partitioned accounting of fuel consumption. However, the agency is unsure whether and, if so, to what extent doing so would represent an improvement over our current approach of using incremental synergy factors.

The agency solicits comments on its use of incremental synergy factors to address uncertainty in the estimation of the extent to which fuel consumption is reduced by applying technologies. In particular, the agency solicits comment on (a) the values of the factors the agency has applied, (b) possible variations across the ten categories of vehicles the agency has considered, and (c) additional technology pairs that may involve such interactions. The proposal of any additional methodologies, such as prototyping and testing, full vehicle simulation, or partitioned accounting, should address information and resource requirements, particularly as related to the analysis of entire fleets of future vehicles expected to be produced through MY 2015.

4. Technology cost learning curve

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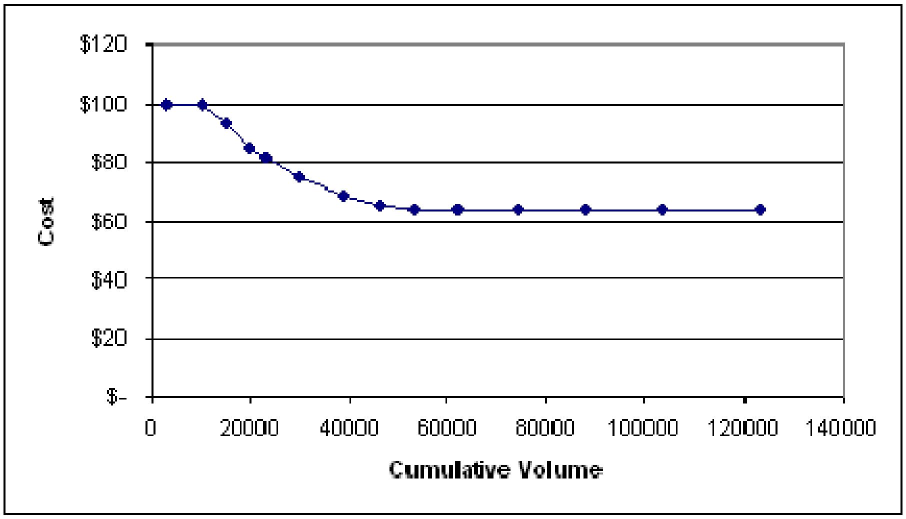
[53] This approach was proposed in a paper criticizing NAS' approach to synergies in the 2001-02 peer-review process for the NAS Report. *See* Patton, et al., "Aggregating Technologies for Reduced Fuel Consumption: A Review of the Technical Content in the 2002 National Research Council Report on CAFE", SAE 2002-01-0628, March 2002.

In past rulemaking analyses, NHTSA did not explicitly account for the cost reductions a manufacturer may realize through learning achieved from experience in actually applying a given technology. NHTSA understood technology cost-estimates to reflect already the full learning costs of technology. EPA felt that for some of the newer, emerging technologies, cost estimates did not reflect the full impact of learning. NHTSA tentatively agreed, but is seeking comment on the impact of learning on cost and the production volumes where it occurs. NHTSA has modified its previous approach in this rulemaking for that reason. In this rulemaking we have included a learning factor for some of the technologies. The "learning curve" describes the reduction in unit incremental production costs as a function of accumulated production volume and small redesigns that reduce costs.

NHTSA implemented technology learning curves by using three parameters: (1) the initial production volume that must be reached before cost reductions begin to be realized (referred to as "threshold volume"); (2) the percent reduction in average unit cost that results from each successive doubling of cumulative production volume (usually referred to as the "learning rate"); and (3) the initial cost of the technology. Section V below describing the Volpe model contains additional information on learning curve functions.

Figure 2 illustrates a learning curve for a vehicle technology with an initial average unit cost of $100 and a learning rate of approximately 20 percent. In this hypothetical example, the initial production volume before cost reductions begin to be realized is set at 12,000 units and the production volume at the cost floor is set at roughly 50,000 units with a cost of $64.

Figure 2. Typical Experience Curve



Most studies of the effect of the learning curve on production costs appear to assume that cost reductions begin only after some initial volume threshold has been reached, but not all of these studies specify what this threshold volume is. The rate at which costs decline beyond the initial threshold is usually expressed as the percent reduction in average unit cost that results from each successive doubling of cumulative production volume, sometimes referred to as the learning rate. Many estimates of learning experience curves do not specify a cumulative production volume beyond which cost reductions no longer occur, instead depending on the asymptotic behavior of the above expression of (CQ) for learning rates below 100 percent to establish a floor on costs.

For this analysis, NHTSA has applied learning curve cost reductions on a manufacturer-specific basis, and has assumed that learning-based reductions in technology costs occur at the point that a manufacturer applies the given technology to 25,000 cars or trucks, and are repeated a second time as it produces another 25,000 cars or trucks for the second learning step (car and truck volumes are treated separately for determining these sales volumes). The volumes chosen represent our best estimate for where learning would occur. As such, we believe that these estimates are better suited to this analysis than a more general approach of a single number for the learning curve factor, because each manufacturer would be implementing technologies at its own pace in this rule, rather than assuming that all manufacturers implement identical technology at the same time. NHTSA is aware that some of the cost estimates that is has relied upon were derived from suppliers and has added multipliers so that these costs are reflective of what manufacturers would pay for this technology. NHTSA seeks comments on the estimated level of price markups that manufacturers pay for technologies purchased from suppliers and whether different learning curves should be applied to those types of technologies.

Ideally, we would know the development production cycle and maturity level for each technology so that we could calculate learning curves precisely. Without that knowledge, we have to use engineering judgment. After having produced 25,000 cars or trucks with a specific part or system, we believe that sufficient learning will have taken place such that costs will be lower by 20 percent for some technologies and 10 percent for others. After another 25,000 units, its expected that, for some technologies, such as 6-speed AMTs, that another cost reduction will have been realized.

For each of the technologies, we have considered whether we could project future cost reductions due to manufacturer learning. In making this determination, we considered whether or not the technology was in wide-spread use today or expected to be by the model year 2011-2012 time frame, in which case no future learning curve would apply because the technology would already be in wide-spread production by the automotive industry by that timeframe, e.g., on the order of multi-millions of units per year. (Examples of these include 5-speed automatic transmissions and intake-cam phasing variable valve timing. These technologies have been in production for light-duty vehicles for more than 10 years.) In addition, we carefully considered the underlying source data for our cost estimates. If the source data specifically stated that manufacturer cost reduction from future learning would occur, we took that information into account in determining whether we would apply manufacturer learning in our cost projections. Thus, for many of the technologies, we have not applied any future cost reduction learning curve.

However, there are a number of technologies which are not yet in mass production for which we have applied a learning curve. As indicated in Table 7 below, we have applied the learning curve beginning in MY 2011 to one set of technologies, and for a number of additional technologies we did not apply manufacturer learning until MY 2014. The distinction between MYs 2011 and 2014 is due to our source data for our cost estimates. For those technologies where we have applied manufacturer learning in MY 2011, the source of our cost estimate did not rely on manufacturer learning to develop the initial cost estimate we have used – therefore we apply the manufacturer learning methodology beginning in MY 2011.

Table 7. Learning Curve Application to Technologies

Technology	First Year of Application	Learning Factor
Overhead Cam Branch		
Cylinder deactivation	2014	20%
Continuous VVLT	2014	20%
Camless valvetrain (electromagnetic)	2011	20%
GDI – lean burn	2011	20%
Gasoline HCCI dual-mode	2011	20%
Turbocharging & downsizing	2014	20%
Diesel – Lean NOx trap*	2011	10%
Diesel – urea SCR*	2011	10%
6-speed AMT	2011	20%
Stop-Start with 42 volt system	2014	20%
IMA/ISA/BSG (includes engine downsize)	2014	20%
2-Mode hybrid electric vehicle	2014	20%
Power-split hybrid electric vehicle (P-S HEV)	2014	20%
Plug-in hybrid electric vehicle (PHEV)	2011	20%
Improved high efficiency alternator & electrification of accessories (42 volt)	2011	20%
Secondary axle disconnect (unibody only)	2011	20%
Weight reduction (1%) – above 6000 lbs only	2011	20%
Weight reduction (2%) – incremental to 1%	2011	20%
Weight reduction (3%) – incremental to 2%	2011	20%

* For diesel technologies, learning is only applied to the cost of the emission control equipment, not the cost for the entire diesel system.

The technologies for which we do not begin applying learning until 2014 all have the same reference source, the 2004 NESCCAF study, for which the sub-contractor was The Martec Group. In the work done for the 2004 NESCCAF report, Martec relied upon actual price quotes from Tier 1 automotive suppliers to develop automotive manufacturer cost estimates. Based on information presented by Martec to the National Academy of Sciences (NAS) Committee during their January 24, 2008, public meeting in Dearborn, Michigan,[54] we understand that the Martec cost estimates incorporated some element of manufacturer learning. Martec stated that the Tier 1 suppliers were specifically requested to provide price quotes which would be valid for three years (2009-2011), and that for some components the Tier 1 supplier included cost reductions in years two and three which the supplier anticipated could occur, and which they anticipated would be necessary in order for their quote to be competitive with other suppliers. Therefore, for this analysis, we did not apply any learning curve to any of the Martec-sourced costs for the first three years of this proposal (2011-2013). However, the theory of manufacturer learning is that it is a continuous process, though the rate of improvement decreases as the number of units

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[54] "Variable Costs of Fuel Economy Technologies" Martec Group, Inc Report Presented to: Committee to Assess Technologies for Improving Light-Duty Vehicle Fuel Economy. Division on Engineering and Physical Systems, Board on Energy and Environmental Systems, the National Academy of Sciences, January 24, 2008.

produced increases. While we were not able to gain access to the detailed submissions from Tier 1 suppliers which Martec relied upon for their estimates, we do believe that additional cost reductions will occur in the future for a number of the technologies for which we relied upon the Martec cost estimates for the reasons stated above in reference to the general learning curve effect. For those technologies we applied a learning curve beginning in 2014. Martec has recently submitted a study to the NAS Committee comparing the 2004 NESCCAF study with new updated cost information. Given that this study had just been completed, the agency could not take it into consideration for the NPRM. However, the agency will review the new study and consider its findings in time for the final rule.

Manufacturers' actual costs for applying these technologies to specific vehicle models are likely to include significant additional outlays for accompanying design or engineering changes to each model, development and testing of prototype versions, recalibrating engine operating parameters, and integrating the technology with other attributes of the vehicle. Manufacturers may also incur additional corporate overhead, marketing, or distribution and selling expenses as a consequence of their efforts to improve the fuel economy of individual vehicle models and their overall product lines.

In order to account for these additional costs, NHTSA has applied an indirect cost multiplier of 1.5 to its estimate of the vehicle manufacturers' direct costs for producing or acquiring each fuel economy-improving technology to arrive at a consumer cost. This estimate was developed by Argonne National Laboratory in a recent review of vehicle manufacturers' indirect costs. The Argonne study was specifically intended to improve the accuracy of future cost estimates for production of vehicles that achieve high fuel economy by employing many of the same advanced technologies considered in the agency's analysis.[55] Thus, its recommendation that a multiplier of 1.5 be applied to direct manufacturing costs to reflect manufacturers' increased indirect costs for deploying advanced fuel economy technologies appears to be appropriate for use in the current analysis. Historically, NHTSA has used almost the exact same multiplier, a multiplier of 1.51, as the markup from variable costs or direct manufacturing costs to consumer costs. This markup takes into account fixed costs, burden, manufacturer's profit, and dealers profit. Table VII-2 of the PRIA shows the estimated incremental consumer costs for each vehicle type.[56]

E. Ensuring sufficient lead time

In analyzing potential technological improvements to the product offerings for each manufacturer with a substantial share of the market, NHTSA added technologies based on our engineering judgment and expertise about possible adjustments to the detailed product plans submitted to NHTSA. Our decision whether and when to add a technology reflected our consideration of the practicability of applying a specific technology and the necessity for lead-time in its application. NHTSA recognizes that vehicle manufacturers must have sufficient lead time to incorporate changes and new features into their vehicles and hence added technologies in a cost-minimizing fashion. That is, we generally added technologies that were most cost-effective and took into account the year of availability of the technologies.

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[55] Vyas, Anant, Dan Santini, and Roy Cuenca, *Comparison of Indirect Cost Multipliers for Vehicle Manufacturing*, Center for Transportation Research, Argonne National Laboratory, April 2000.

[56] PRIA, VII-9.

NHTSA realizes that not all technologies will be available immediately or could be applied immediately and that there are different phase-in rates (how rapidly a technology is able to be applied across a manufacturer's fleet of vehicles) applicable to each technology as well as windows of opportunities when certain technologies could be applied (*i.e.*, when a product is redesigned or refreshed).

1. Linking to redesign and refresh

In the automobile industry there are two terms that describe when changes to vehicles occur: redesign and refresh. In projecting the technologies that could be applied to specific vehicle models, NHTSA tied the application of the majority of the technologies to a vehicle's refresh/redesign cycle. Vehicle redesign usually encompasses changes to a vehicle's appearance, shape, dimensions, and powertrain and is traditionally associated with the introduction of "new" vehicles into the market, and often is characterized as the next generation of a vehicle. In contrast vehicle refresh usually only encompasses changes to a vehicle's appearance, and may include an upgraded powertrain and is traditionally associated with mid-cycle cosmetic changes to a vehicle within its current generation to make it appear "fresh." Vehicle refresh traditionally occurs no earlier than two years after a vehicle redesign or at least two years before a scheduled redesign. Table 8 below contains a complete list of the technologies that were applied and whether NHTSA allowed them to be applied during a redesign year, a refresh year or during any model year is shown in the below table.

Table 8. Technology Refresh and Redesign Application

Technology	**Abbr.**	Can be applied during redesign model year only	Can be applied during a redesign or refresh model year	Can be applied during any model year
Low Friction Lubricants	LUB		X	X
Engine Friction Reduction	EFR		X	
Variable Valve Timing (ICP)	VVTI		X	
Variable Valve Timing (CCP)	VVTC		X	
Variable Valve Timing (DCP)	VVTD		X	
Cylinder Deactivation	DISP		X	
Variable Valve Lift & Timing (CVVL)	VVLTC	X		
Variable Valve Lift & Timing (DVVL)	VVLTD	X		
Cylinder Deactivation on OHV	DISPO		X	
Variable Valve Timing (CCP) on OHV	VVTO		X	
Multivalve Overhead Cam with CVVL	DOHC	X		
Variable Valve Lift & Timing (DVVL) on OHV	VVLTO	X		
Camless Valve Actuation	CVA	X		
Stoichiometric GDI	SIDI	X		
Lean Burn GDI	LBDI	X		
Turbocharging and Downsizing	TURB	X		
HCCI	HCCI	X		
Diesel with LNT	DSLL	X		

Diesel with SCR	DSLS	X		
5 Speed Automatic Transmission	5SP		X	
Aggressive Shift Logic	ASL		X	X
Early Torque Converter Lockup	TORQ		X	
6 Speed Automatic Transmission	6SP		X	
Automatic Manual Transmission	AMT	X		
Continuously Variable Transmission	CVT	X		
6 Speed Manual	6MAN	X		
Improved Accessories	IACC			X
Electronic Power Steering	EPS		X	
42-Volt Electrical System	42V	X		
Low Rolling Resistance Tires	ROLL			X
Low Drag Brakes	LDB			X
Secondary Axle Disconnect – Unibody	SAXU		X	
Secondary Axle Disconnect - Ladder Frame	SAXL		X	
Aero Drag Reduction	AERO		X	
Material Substitution (1%)	MS1	X		
Material Substitution (2%)	MS2	X		
Material Substitution (5%)	MS5	X		
ISG with Idle-Off	ISGO	X		
IMA/ISAD/BSG Hybrid (includes engine downsizing)	IHYB	X		
2-Mode Hybrid	2HYB	X		
Power Split Hybrid	PHYB	X		

As can be seen in the above table, most technologies would only be applied by the Volpe model when a specific vehicle was due for a redesign or refresh. However, for a limited set of technologies, the model was not restricted to applying them during a refresh/redesign year and thus they were made available for application at any time. These specific technologies are:

- Low Friction Lubricants
- Improved Accessories
- Low Rolling Resistance Tires
- Low Drag Brakes

All of these technologies are very cost-effective, can apply to multiple vehicle models/platforms and can be applied across multiple vehicle models/platforms in one year. Although they can also be applied during a refresh/redesign year, they are not restricted to that timeframe because their application is not viewed as necessitating a major engineering redesign and testing/calibration.

There is an additional technology whose application is not tied to refresh/redesign, which is Aggressive Shift Logic (ASL). ASL is accomplished through reprogramming the shift points for a transmission to be more like a manual transmission. Upgrading a transmission to utilize ASL can happen at refresh/redesign, but because it is not a hardware change, it can also occur at other points in a vehicle's design cycle. If a model that is scheduled for refresh/redesign has a transmission that is being upgraded to ASL, it is possible that all other vehicles that utilize the same transmission (which is usually produced at the same manufacturing plant) could be upgraded at the same time to incorporate ASL and that ASL could permeate other vehicle models in years other than a refresh/redesign year.

NHTSA based the redesign rates used in the Volpe Model on a combination of the manufacturers confidential product plans and on NHTSA's engineering judgment. In most instances, NHTSA has accepted the projected redesign periods from the companies who provided them through MY 2013. If companies did not provide product plan date, NHTSA used publicly available data about vehicle redesigns to establish the redesign rates for the vehicles produced by these companies.

NHTSA assumes that passenger cars will be redesigned every 5 years, based on the trend over the last 10-15 years for passenger cars to be redesigned every 5 years. These trends are reflected in the manufacturer production plans that NHTSA received in response to its request for product plan information and was confirmed by many automakers in meetings held with NHTSA to discuss various issues with manufacturers.

NHTSA believes that the vehicle design process has progressed and improved rapidly over the last decade and these improvements have resulted in the ability of manufacturers to shorten the design process and to introduce vehicles more frequently to respond to competitive market forces. Almost all passenger cars will be on a 5-year redesign cycle by the end of the decade, with the exception being some high performance vehicles and vehicles' with specific market niches.

Currently, light trucks are redesigned every 5 to 7 years, with some vehicles having longer redesign periods (*e.g.*, full-size vans). In the most competitive SUV and crossover vehicle segments, the redesign cycle currently averages slightly above 5 years. It is expected that the light truck redesign schedule will be shortened in the future due to competitive market forces and in response to fuel economy and other regulatory requirements. It is expected that by MY 2014, almost all light trucks will be redesigned on a 5-year cycle. Thus, for almost all vehicles scheduled for a redesign in model year 2014 and later, NHTSA estimated that all vehicles would be redesigned on a 5-year cycle. Exceptions were made for high performance vehicles and other vehicles that traditionally had longer than average design cycles (*e.g.*, 2-seater sports cars). For those vehicles, NHTSA attempted to preserve the historic redesign cycle rates.

2. Technology phase-in caps

In analyzing potential technological improvements to the product offerings for each manufacturer with a substantial share of the market, NHTSA added technologies based on our engineering judgment and expertise about possible adjustments to the detailed product plans submitted to NHTSA. Our decision whether and when to add a technology reflected our consideration of the practicability of applying a specific technology and the necessity for lead-time in its application.

NHTSA recognizes that vehicle manufacturers must have sufficient lead time to incorporate changes and new features into their vehicles and that these changes cannot occur all at once, but must be phased in over time. As discussed above, our analysis addresses these realities in part by timing the estimated application of most technologies to coincide with anticipated vehicle redesigns and/or freshenings. We have estimated that future vehicle redesigns can be implemented on a 5-year cycle with mid-cycle freshening, except where manufacturers have indicated plans for shorter redesign cycles.

However, the agency further recognizes that engineering, planning and financial constraints prohibit most technologies from being applied across an entire fleet of vehicles within a year. Thus, as for the analysis supporting its 2006 rulemaking regarding light truck CAFE, the agency is employing overall constraints on the rates at which each technology can penetrate a manufacturer's fleet. The Volpe model applies these "phase-in caps" by ceasing to add a given technology to a manufacturer's fleet in a specific model year once it has increased the corresponding penetration rate by at least amount of the cap. Having done so, the model proceeds to apply other technologies in lieu of the "capped" technology.

For its regulatory analysis in 2006, NHTSA applied phase-in caps expected to be consistent with NAS' indication in its 2002 report that even existing technologies would require 4 to 8 years to achieve widespread penetration of the fleet. The NAS report, which is believed to be the only peer-reviewed source which provides phase-in rates, was relied upon for establishing the phase-in caps that we used for all technologies, except diesels and hybrids, for which the report didn't include that information. Most of the phase-in caps applied by the agency in 2006 ranged from 25 percent (4 year introduction) to 17 percent (approximately 6 years, the midpoint of the NAS estimate). The agency assumed shorter implementation rates for technologies that did not require changes to the manufacturing line. For other technologies (e.g., hybrid and diesel powertrains), the agency employed phase-in caps as low as 3 percent, to reflect the major redesign efforts and capital investments required to implement these technologies.

Considerable changes have occurred since NHTSA's 2006 analysis, and even more since the 2002 NAS report. Not only have fuel prices increased, but official forecasts of future fuel prices have increased, as well. This suggests a market environment in which consumers are more likely to demand fuel-saving technologies than previously anticipated, and it suggests a financial environment in which investors are more likely to invest in companies developing and producing such technologies. Indeed, some technologies have penetrated the marketplace more quickly than projected in 2006. Confidential product plan information submitted to NHTSA in 2007 and information from suppliers confirm that the rate of technology penetration has increased as compared to 2006.

Also, the statutory environment has changed since 2006. With the enactment of EISA, Congress has adopted the specific objectives of increasing new vehicle fuel economy to at least 35 mpg by 2020 and making ratable progress toward that objective in earlier model years. This reduces manufacturers' uncertainty about the general direction of future fuel economy standards in the United States. Moreover, developments in other regions (*e.g.*, Europe) and countries (*e.g.*, Canada and China) suggest that the generalized expectation that future vehicles will perform well with respect to energy efficiency is not unique to the United States. Discussions with manufacturers in late 2007 and early 2008 indicate that the industry is highly sensitive to all of these developments and has been anticipating the need to accelerate the rate of technology deployment in response to the passage of major energy legislation in the U.S.

Considering these developments, the agency revisited the phase-in caps it had applied in 2006 and determined that it would be appropriate to relax many of them. In our judgment, most of the engine technologies could penetrate the fleet in as quickly as five years—rather than in the six we previously estimated—as long as they are applied during redesign. Low friction lubricants are already widely used, and our expectation is that they can quickly penetrate the remainder of the fleet. Therefore, we relaxed the 25 percent (4-year) phase-in cap to 50 percent (2 years). Similarly, product plans indicate that transmissions with 5 or more forward gears will widely penetrate the fleet even without the current proposal. Also, given the technology cost and effectiveness estimates discussed above, the Volpe model frequently estimates that manufacturers will "leapfrog" past 5-speed transmissions to apply more advanced transmissions (*e.g.*, 6-speed or AMT). We have therefore increased the phase-in cap for 5-speed transmissions from 25 percent (4 years) to 100 percent (1 year). However, in our judgment, phase-in caps of 17 percent (6 years) are currently still appropriate for most other transmission technologies.

Although NHTSA has applied phase-in caps of 25 percent (4 years) for most remaining technologies, we continue to anticipate that phase-in caps of 3 percent are appropriate for some advanced technologies, such as hybrids and diesels. Although engine, vehicle, and exhaust aftertreatment manufacturers have, more recently, expressed greater optimism than before regarding the outlook for light vehicle diesel engines, our expectation is that the phase-in cap that we have chosen is appropriate at this time. We also estimate that a 3 percent rate is appropriate for hybrid technologies, which are very complex, require significant engineering resources to implement, but are just now starting to penetrate the market.

Table 9 below presents the phase-in caps applied in the current analysis, with rates from the analysis of the 2006 final rule provided for comparison. NHTSA requests comments on the phase-in caps shown here, and on whether slower or faster rates would be more appropriate and, if so, why.

Table 9. Phase-in Cap Application

Technology	**2006 Final Rule**	**Current NPRM**
Low Friction Lubricants	25%	50%
Engine Friction Reduction	17%	20%
Variable Valve Timing (ICP)	17%	20%
Variable Valve Timing (CCP)	17%	20%
Variable Valve Timing (DCP)	17%	20%
Cylinder Deactivation	17%	20%
Variable Valve Lift & Timing (CVVL)	17%	20%
Variable Valve Lift & Timing (DVVL)	17%	20%
Cylinder Deactivation on OHV	17%	20%
Variable Valve Timing (CCP) on OHV	17%	20%
Multivalve Overhead Cam with CVVL	17%	20%
Variable Valve Lift & Timing (DVVL) on OHV	17%	20%
Camless Valve Actuation	10%	20%
Stoichiometric GDI	3%	20%
Diesel following GDI-S (SIDI)	3%	3%
Lean Burn GDI		20%

Turbocharging and Downsizing	17%	20%
Diesel following Turbo D/S	3%	3%
HCCI		13%
Diesel following HCCI	3%	3%
5 Speed Automatic Transmission	17%	100%
Aggressive Shift Logic	17%	25%
Early Torque Converter Lockup		25%
6 Speed Automatic Transmission	17%	17%
Automated Manual Transmission	17%	17%
Continuously Variable Transmission	17%	17%
6 Speed Manual		17%
Improved Accessories	25%	25%
Electric Power Steering	17%	25%
42-Volt Electrical System	17%	25%
Low Rolling Resistance Tires	25%	25%
Low Drag Brakes	17%	25%
Secondary Axle Disconnect – Unibody	17%	17%
Secondary Axle Disconnect - Ladder Frame	17%	17%
Aero Drag Reduction	17%	17%
Material Substitution (1%)	17%	17%
Material Substitution (2%)	17%	17%
Material Substitution (5%)	17%	17%
ISG with Idle-Off	5%	3%
IMA/ISAD/BSG Hybrid (includes engine downsizing)	5%	3%
2-Mode Hybrid	5%	3%
Power Split Hybrid	5%	3%
Plug-in Hybrid		3%

B. The Volpe model

1. What is the Volpe model?

As it did for the development and analysis of the April 2006 light truck final rule, in developing this proposal NHTSA made significant use of a peer-reviewed modeling system developed by the Department of Transportation’s Volpe National Transportation Systems Center (Volpe Center). The CAFE Compliance and Effects Modeling System (referred to herein as the Volpe model) serves two fundamental purposes: identifying technologies each manufacturer could apply in order to comply with a specified set of CAFE standards, and calculating the costs and effects of manufacturers’ application of technologies.

Before working with the Volpe Center to develop and apply this model, NHTSA had considered other options, including other modeling systems. NHTSA was unable to identify any other system that could operate at a sufficient level of detail with respect to manufacturers’ future products, which involve thousands of unique vehicle models using hundreds of unique engines and hundreds of unique transmissions. NHTSA was also unable to identify any other system that could simulate a range of different possible reforms to CAFE standards. The Volpe model provides these and other capabilities, and helps NHTSA examine potential regulatory options.

2. How does the Volpe model apply technologies to manufacturers' future fleets?

The Volpe model begins with an "initial state" of the domestic vehicle market, which in this case is the market for passenger cars and light trucks to be sold during the period covered by the proposed rule. The vehicle market is defined on a model-by-model, engine-by-engine, and transmission-by-transmission basis, such that each defined vehicle model refers to a separately-defined engine and a separately-defined transmission.

For the model years covered by the current proposal, the light vehicle (passenger car and light truck) market forecast included more than 3,000 vehicle models, more than 400 specific engines, and nearly 400 specific transmissions.[57] This level of detail in the representation of the vehicle market is vital to an accurate analysis of manufacturer-specific costs and the analysis of reformed CAFE standards, and is much greater than the level of detail used by many other models and analyses relevant to light vehicle fuel economy. Because CAFE standards apply to the average performance of each manufacturer's fleets of cars and light trucks, the impact of potential standards on individual manufacturers cannot be credibly estimated without analysis of manufacturers' planned fleets. NHTSA has used this level of detail in CAFE analysis throughout the history of the program. Furthermore, because required CAFE levels under an attribute-based CAFE standard depend on manufacturers' fleet composition, the stringency of an attribute-based standard cannot be predicted without performing analysis at this level of detail.

Examples of other models and analyses that NHTSA and Volpe Center staff have considered include DOE's NEMS, Oak Ridge National Laboratory's (ORNL) Transitional Alternative Fuels and Vehicles (TAFV) model, and the California Air Resources Board's (CARB) analysis supporting California's adopted greenhouse gas emissions standards for light vehicles.

DOE's NEMS represents the light-duty fleet in terms of four "manufacturers" (domestic cars, imported cars, domestic light trucks, and imported light trucks), twelve vehicle market classes (*e.g.*, "standard pickup"), and sixteen power train/fuel combinations (*e.g.*, methanol fuel-cell vehicle).[58] Therefore, as currently structured, NEMS is unable to estimate manufacturer-specific implications of attribute-based CAFE standards.

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[57] The market forecast is an input to the Volpe model developed by NHTSA using product plan information provided to the agency by individual vehicle manufacturers in response to NHTSA's requests. The submitted product plans contain confidential business information (CBI), which the agency is prohibited by federal law from disclosing. As the agency receives new product plan information in response to future requests, the market forecast is updated.

[58] U.S. Department of Energy, "Transportation Sector Module of the National Energy Modeling System: Model Documentation 2007," DOE/EIA-M070, May 2007. *Available at* http://tonto.eia.doe.gov/FTPROOT/modeldoc/m070(2007).pdf (last accessed Mar. 12, 2008). NEMS's Manufacturers Technology Choice Submodule (MTCS) is believed to have logical structures similar to those in Energy and Environmental Analysis, Inc.'s (EEA's) Fuel Economy Regulatory Analysis Model (FERAM). However, FERAM documentation and source code have not been made available to NHTSA or Volpe Center staff.

TAFV accounts for many power train/fuel combinations, having been originally designed to aid understanding of possible transitions to alternative fueled vehicles, but it represents the light-duty fleet as four aggregated (*i.e.*, industry-wide) categories of vehicles: small cars, large cars, small light trucks, and large light trucks.[59] Thus, again, as currently structure, TAFV is unable to estimate manufacturer-specific implications of attribute-based CAFE standards.

CARB's analysis of light vehicle GHG emissions standards uses two levels of accounting. First, based on a report prepared for Northeast States Center for a Clean Air Future (NESCCAF), CARB represents the light-duty fleet in terms of five "representative" vehicles. Use of these "representative" vehicles ignores the fact that the engineering characteristics of individual vehicle models vary widely both among manufacturers and within manufacturers' individual fleets. For each of these five vehicles, NESCCAF's report contains the results of full vehicle simulation given several pre-specified technology "packages."[60] Second, to evaluate manufacturer-specific regulatory costs, CARB essentially reduces each manufacturer's fleet to only two average test weights, one for each of California's two regulatory classes.[61] Even for a flat standard such as considered by California, NHTSA would not base its analysis of manufacturer-level costs on this level of aggregation. Use of CARB's methods would not enable NHTSA to estimate manufacturer-specific implications of the attribute-based CAFE standards proposed today.[62]

The Volpe model also uses several additional categories of data and estimates provided in various external input files:

One input file specifies the characteristics of fuel-saving technologies to be represented, and includes, for each technology, the first year in which the technology is expected to be ready for commercial application; upper and lower estimates of the effectiveness and cost (retail price equivalent) of the technology; coefficients defining the extent to which costs are expected to decline as a result of "learning effects" (discussed below); inclusion or exclusion of the technology on up to three technology "paths"; and constraints ("phase-in caps") on the annual rate at which manufacturers are estimated to be able to increase the technology's penetration rate. These technology characteristics and estimates are specified separately for each of the following categories of vehicles: small sport/utility vehicles (SUVs), midsize SUVs, large SUVs, small pickups, large pickups, minivans, subcompact cars, compact cars, midsize cars, and

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[59] Greene, David. "TAFV Alternative Fuels and Vehicles Choice Model Documentation," ORNL//TM—2001//134, July 2001. *Available at* http://www-cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2001_134.pdf (last accessed Mar. 12, 2008).

[60] Northeast States Center for a Clean Air Future (NESCCAF), Reducing Greenhouse Gases from Light-Duty Vehicles (2004). *Available at* http://bronze.nescaum.org/committees/mobile/rpt040923ghglightduty.pdf (last accessed Mar. 12, 2008).

[61] California Environmental Protection Agency, Air Resources Board, Staff Report: Initial Statement of Reasons (CARB ISOR) (2004), at 111-114. *Available at* http://www.arb.ca.gov/regact/grnhsgas/grnhsgas.htm (scroll down to "Public Hearing Notice and Related Material") (last accessed Sept. 11, 2007). We note that California has adopted these standards but is currently unable to enforce them, due to EPA's February 29, 2008 denial of California's request for waiver of federal preemption under Section 209 of the Clean Air Act. For information on EPA's decision, *see* http://www.epa.gov/otaq/ca-waiver.htm. California filed a petition in the 9th Circuit Court of Appeals challenging EPA's denial of the waiver on January 2, 2008.

[62] Although CARB's analysis covered a wider range of model years than does NHTSA's analysis, this does not lessen the importance of a detailed representation of manufacturers' fleets.

large cars. In addition, the input file defining technology characteristics can (but need not) contain specified "synergies" between technologies—that is, differences in a given technology's effect on fuel consumption that result from the presence of other technologies.

Another input file specifies vehicular emission rates for the following pollutants: carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NO_x), particulate matter (PM), and sulfur dioxide (SO_2). These rates are defined on a model year-by-model year and calendar year-by-calendar year basis, and are used to estimate changes in emissions that result from changes in vehicular travel (*i.e.*, vehicle-miles traveled or VMT).

A third input file specifies a variety of economic and other data and estimates. The model can accommodate vehicle survival (*i.e.*, percent of vehicles of a given vintage that remain in service) and mileage accumulation (*i.e.*, annual travel by vehicles of a given vintage) rates extending as many years beyond the year of sale as for which estimates are available and use those for estimating VMT, fuel consumption, and emissions. The model can also accommodate forecasts of price and fuel taxation rates for up to seven fuels (*e.g.*, gasoline, diesel) over a similar period. The model uses pump prices (*i.e.*, including taxes) to estimate the value manufacturers expect vehicle purchasers to place on saved fuel, because they indicate the amount by which the manufacturer is expected to consider itself able to increase the retail price of the vehicle based on the purchaser's consideration of the vehicle's increased fuel economy. However, the model uses pretax fuel prices to estimate the monetized societal benefits of reduced fuel consumption, because fuel taxes represent transfers of resources from fuel buyers to government agencies rather than real resources that are consumed in the process of supplying or using fuel, so their value must be deducted from retail fuel prices to determine the value of fuel savings to the U.S. economy.

Other economic inputs include the rebound effect coefficient (*i.e.*, the elasticity of VMT with respect to the per-mile cost of fuel); the discount rate; the "payback period" (*i.e.*, the number of years manufacturers are estimated to assume vehicle purchasers consider when taking into account fuel savings); the "gap" between laboratory and actual fuel economy; the per-vehicle value of travel time (in dollars per hour); the economic costs (in dollars per gallon) of petroleum consumption; various external costs (all in dollars per mile) associated with changes in vehicle use; damage costs (all on a dollar per ton basis) for each of the above-mentioned criteria pollutants; and the rate at which noncompliance causes civil penalties. Section V.A.4 below describes in much more detail how these inputs are included and used by the model.

The model also accommodates input data and estimates addressing the properties of different fuels. These include upstream carbon dioxide and criteria pollutant emission rates (*i.e.*, U.S. emissions resulting from the production and distribution of each fuel), density (pounds/gallon), energy density (BTU/gallon), carbon content, shares of fuel savings leading to reduced domestic refining, and relative shares of different gasoline blends. These fuel properties and related estimates are used to calculate changes in domestic upstream emissions resulting from changes in fuel consumption.

Coefficients defining the probability distributions to apply when performing sensitivity analysis (*i.e.*, Monte Carlo simulation) are also specified in this input file. These coefficients determine the likelihood that any given value will be selected when performing this type of analysis (*e.g.*, the likelihood that a rebound effect of -0.1 will be tested). High and low fuel price forecasts are also specified in this input file for this purpose.

The final input file contains CAFE scenarios to be examined. The model accommodates a baseline (*i.e.*, business-as-usual) scenario and different alternative scenarios. Effects of the alternative scenarios are calculated relative to results for the baseline scenario. Each scenario defines the coverage, structure, and stringency of CAFE standards for each of the covered model years.

With all of the above input data and estimates, the modeling system develops an estimate of a set of technologies each manufacturer *could* apply in response to each specified CAFE scenario. Because manufacturers have many choices regarding how to respond to CAFE standards, it is impossible to predict precisely how a given manufacturer *would* respond to a given set of standards. The modeling system begins with the "initial state" (*i.e.*, business-as-usual) of each manufacturer's future vehicles, and accumulates the estimated costs of progressive additions of fuel-saving technologies. Within a set of specified constraints, the system adds technologies following a cost-minimizing approach, because this is what NHTSA expects a manufacturer would do in real life. At each step, the system evaluates the effective cost of applying available technologies to individual vehicle models, engines, or transmissions, and selects the application of technology that produces the lowest effective cost. The effective cost estimated to be considered by the manufacturer is calculated by adding the total incurred technology costs (in retail price equivalent or RPE), subtracting the reduction in civil penalties owed for noncompliance with the CAFE standard, subtracting the estimated value[63] of the reduction in fuel costs, and dividing the result by the number of affected vehicles.

In representing manufacturer decision-making in response to a given CAFE standard, the modeling system accounts for the fact that historically some manufacturers have been unwilling to pay penalties and some have been willing to do so. Thus, the system applies technologies until any of the following conditions are met: the manufacturer no longer owes civil penalties for failing to meet the applicable standard, the manufacturer has exhausted technologies expected to be available in that model year, or the manufacturer is estimated to be willing to pay civil penalties, and doing so is estimated to be less expensive than continuing to add technologies. The system then progresses to the next model year (if included in the vehicle market and scenario input files), "carrying over" technologies where vehicle models are projected to be succeeded by other vehicle models.[64]

In the modeling system, this "compliance simulation" is constrained in several ways. First, technologies are defined as being applicable or not applicable to each of the ten vehicle categories listed above. The vehicle market forecast input file may also define some

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[63] The estimated value of the reduction in fuel costs represents the amount by which the manufacturer is expected to consider itself able to increase the retail price of the vehicle based on the purchaser's consideration of the vehicle's increased fuel economy. This calculation considers the change in the discounted outlays for fuel (and fuel taxes) during a "payback period" specified as an input to the model.

[64] For example, if Honda is expected to produce the Civic in 2012 and 2013, a version of the Civic estimated to be produced in 2013 may carry over technologies from a version of the Civic produced in 2012 if the latter is identified as a "predecessor" of the former.

technologies as being already present or not applicable to specific vehicles, engines or transmissions. For example, a manufacturer may have indicated it plans to use low-drag brakes on some specific vehicle model, or NHTSA may expect that another manufacturer is not likely to apply a 7- or 8-speed transmission after it installs a 6-speed transmission on a vehicle. Second, some technologies are subject to specific "engineering constraints." For example, secondary-axle disconnect can only be applied to vehicles with four-wheel (or all-wheel) drive. Third, some technologies (*e.g.*, conversion from pushrod valve actuation to overhead cam actuation) are nearly always applied only when the vehicle is expected to be redesigned and others (*e.g.*, cylinder deactivation) are applied only when the vehicle is expected to be refreshed or redesigned, so the model will only apply them at those particular points. Fourth, once the system applies a given technology to a percentage of a given manufacturers' fleet exceeding a specified phase-in cap, the system instead applies other technologies. The third and fourth of these constraints are intended to produce results consistent with manufacturers' product planning practices and with limitations on how quickly technologies can penetrate the fleet.

One important aspect of this compliance simulation is that it does not attempt to account for either CAFE credits or intentional over-compliance. In the real world, manufacturers may earn CAFE credits by selling flex-fueled vehicles (FFVs) and/or by exceeding CAFE standards, and may, within limitations, count those credits toward compliance in future or prior model years. However, EPCA and EISA do not allow NHTSA to consider these flexibilities in setting the standards. Therefore, the Volpe model does not attempt to account for these flexibilities.

Another possibility NHTSA and Volpe Center staff have considered, but do not yet know how to analyze, is the potential that manufacturers might "pull ahead" the implementation of some technologies in response to CAFE standards known to be increasing over time. For example, if a manufacturer plans to redesign many vehicles in MY2011 and not in MY2013, but the standard in MY2013 is considerably higher in MY2013 than in MY2011, the manufacturer might find it less expensive during MY2011-MY2013 (taken together) to apply more technology in MY2011 than is necessary for compliance with the MY2011 standard. Under some circumstances, doing so might make sense even setting aside the potential to earn and bank CAFE credits.

NHTSA and Volpe Center staff have discussed the potential to represent this type of response, but have thus far encountered two challenges. First, NHTSA is not certain that in determining the maximum feasible standard in a given model year, it would be appropriate to count on manufacturers overcomplying with standards in preceding model years. Second, considering other inter-model year dependencies (*e.g.*, technologies that carry over between model years, phase-in caps that accumulate across model years, volume-based learning curves), Volpe Center staff currently anticipate that some iterative procedure would likely be required. Also, the agency wonders whether trying to represent this type of response would require make undue implicit assumptions regarding manufacturers' ability to predict future market conditions. Although NHTSA and Volpe Center staff will continue to explore the potential to represent inter-model year timing, it is not yet clear that it will be appropriate and feasible to do so in the near term.

The agency requests comment on the appropriateness under EPCA of considering (in the standard-setting context) this type of anticipatory application of technology. The agency further requests comment on appropriate methodologies for representing such decisions by manufacturers.

3. What effects does the Volpe model estimate?

Having completed this compliance simulation for all manufacturers and all model years, the system calculates the total cost of all applied technologies, as well as a variety of effects of changes in fuel economy. The system calculates year-by-year mileage accumulation, taking into account any increased driving estimated to result from the rebound effect. Based on the calculated mileage accumulation and on fuel economy and the estimated gap between laboratory and actual fuel economy, the system calculates year-by-year fuel consumption. Based on calculated mileage accumulation and fuel consumption, and on specified emission factors, the system calculates future full fuel-cycle domestic carbon dioxide and criteria pollutant emissions. The system calculates total discounted and undiscounted national societal costs of year-by-year fuel consumption, taking into account estimated future fuel prices (before taxes) and the estimated economic externalities of fuel consumption. Based on changes in year-by-year mileage accumulation, the system calculates changes in consumer surplus related to additional travel, as well as economic externalities related to additional congestion, accidents, and noise stemming from additional travel. The system calculates the value of time saved because increases in fuel economy produce increases in driving range, thereby reducing the frequency with which some vehicles require refueling. The system calculates the monetary value of damages resulting from criteria pollutants. Finally, the system accumulates all discounted and undiscounted societal benefits of each scenario as compared to the baseline scenario. For each model year, the system compares total incurred technology costs to the total present value of societal benefits for each model year, calculating net societal benefits (*i.e.*, discounted societal benefits minus total incurred technology costs) and the benefit-cost ratio (*i.e.*, discounted societal benefits divided by total incurred technology costs).

One important effect not currently estimated by the Volpe model is the market response to CAFE-induced changes in vehicle prices and fuel economy levels. NHTSA and Volpe Center staff have considered developing and applying a market share model capable of estimating changes in sales of individual vehicle models. Doing so would allow estimation of the feedback between market shifts and CAFE requirements. For example, if the relative market share of vehicles with small footprints increases, the average required CAFE level under a footprint-based standard will also increase.

In an early experimental version of the Volpe model, Volpe Center staff included a market share model using a nested multinomial logit specification to calculate model-by-model changes in sales volumes. This allowed the Volpe model to calculate the resulting changes in manufacturers' required CAFE levels, and to seek iteratively a solution at which prices, fuel economy levels, sales volumes, and required CAFE levels converged to stable values. Although the market share model appeared to operate properly (and to converge rapidly), Volpe Center staff suspended its development because of three challenges:

First, Volpe Center staff were not successful in calibrating a logically consistent set of coefficients for the underlying multinomial logit model. The analysis, performed using information from a known (2002 model year) fleet, consistently yielded one or more coefficients that were either directionally incorrect (*e.g.*, indicating that some attributes actually detract from value) or implausibly large (*e.g.*, indicating that some attributes were of overwhelming value). Although Volpe Center staff tested many different specifications of the market share model, none produced results that appeared to merit further consideration.

Second, NHTSA and Volpe Center staff are not confident that baseline sales prices for individual vehicle models, which would be required by a market share model, can be reliably predicted. Although NHTSA requests that manufacturers include planned MSRPs in product plans submitted to NHTSA, MSRPs do not include the effect of various sales incentives that can change actual selling prices. The availability and dollar value of suchincentives have been observed to vary considerably, but not necessarily predictably.

Finally, before applying a market share model, it would be necessary to estimate how manufacturers would allocate compliance costs among vehicle models. Although one obvious approach would be to assume that all costs would be passed through in the form of higher prices for those vehicle models with improved fuel economy, other approaches are perhaps equally plausible. For example, a manufacturer might shift compliance costs toward high-demand vehicles in order to better compete in certain market segments. Although the above-mentioned experimental version of the Volpe model included a “cost allocation” model that offered several different allocation options, NHTSA and Volpe Center staff never achieved confidence that these aspects of manufacturer decisions could be reasonably estimated.

NHTSA and Volpe Center staff are continuing to explore options for including these types of effects. At the same time, EPA has contracted with Resources for the Future (RFF) to develop a potential market share model. Depending on the extent to which these efforts are successful, the Volpe model could at some point be modified to include cost allocation and market share models. NHTSA seeks comment on possible methodologies for incorporating market responses to CAFE-induced changes in vehicle price and fuel economy in the Volpe model. In particular, NHTSA seeks comments addressing the concerns identified above regarding the formulation and calibration of a market share model, the estimation of future vehicle prices, and the estimation of manufacturers’ decisions regarding the allocation of compliance costs.

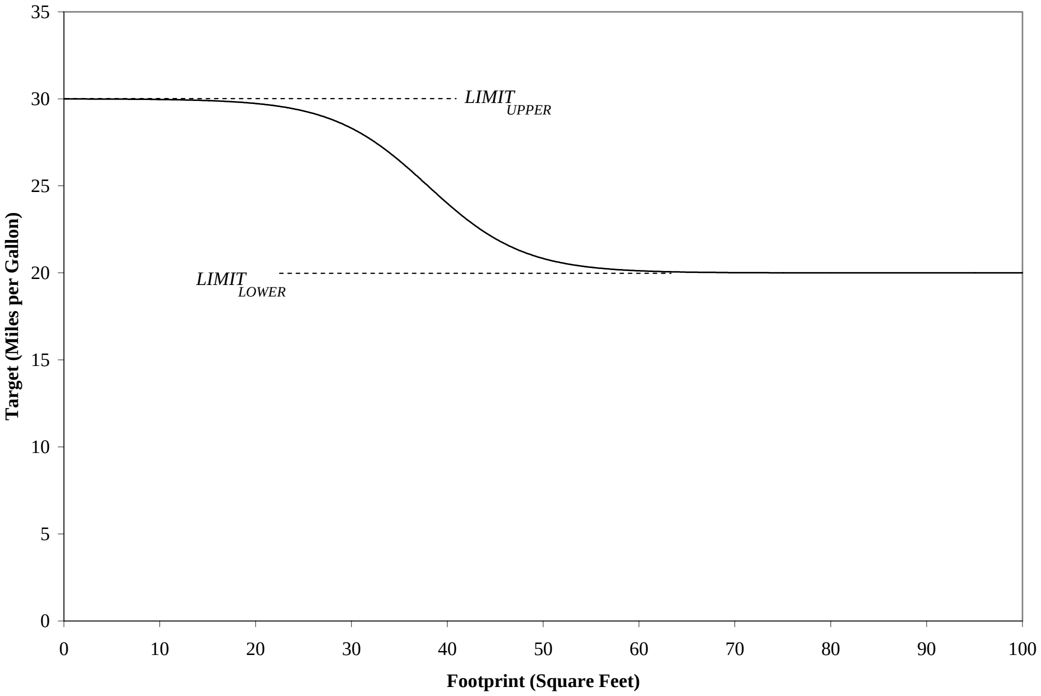
4. How can the Volpe model be used to calibrate and evaluate potential CAFE standards?

The modeling system can also be applied in a more highly-automated mode whereby the optimal shape of an attribute-based CAFE standard may be estimated and its stringency may be set at a level that produces a specified total technology cost or average required CAFE level among a specified set of manufacturers, or that is estimated to maximize net societal benefits. The first step in this operating mode involves identifying manufacturer-by-manufacturer CAFE levels at which societal benefits are estimated to be maximized. The second step involves combining the resultant fleets and statistically fitting a constrained logistic curve of the following form:

$$TARGET = \frac{1}{\frac{1}{LIMIT_{UPPER}} + \left(\frac{1}{LIMIT_{LOWER}} - \frac{1}{LIMIT_{UPPER}}\right)\frac{e^{(FOOTPRINT-MIDPOINT)/WIDTH}}{1+e^{(FOOTPRINT-MIDPOINT)/WIDTH}}}$$

Here, *TARGET* is the fuel economy target (in mpg) applicable to vehicles of a given footprint (*FOOTPRINT*, in square feet), $LIMIT_{LOWER}$ and $LIMIT_{UPPER}$ are the function's lower and upper asymptotes (also in mpg), *e* is approximately equal to 2.718,[65] *MIDPOINT* is the footprint (in square feet) at which the inverse of the fuel economy target falls halfway between the inverses of the lower and upper asymptotes, and *WIDTH* is a parameter (in square feet) that determines how gradually the fuel economy target transitions from the upper toward the lower asymptote as the footprint increases. Figure V-2 below shows an example of a logistic target function, where $LIMIT_{LOWER}$ = 20 mpg, $LIMIT_{UPPER}$ = 30 mpg, *MIDPOINT* = 40 square feet, and *WIDTH* = 5 square feet:

Figure V-2. Sample Logistic Curve



The lower asymptote is determined by calculating the average fuel economy of the largest vehicles in the "socially optimized" fleet discussed above, where the percentage of the fleet to consider is specified externally. Similarly, the upper asymptote is determined by calculating the average fuel economy of the smallest vehicles in the same fleet. Initial values of the other two

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[65] The number *e* is one of the most important numbers in mathematics and statistics. The function has a hockey stick appearance when plotted. The value of e itself is a never ending number whose first 8 digits equal 2.7182818. NHTSA uses it here because it occurs in many natural processes and tends to fit data well. In the last light truck rulemaking, NHTSA examined several functional forms that did not rely on e, but they were judged not to provide as good a fit for the data. We are using the same conclusion here.

coefficients of the logistic function are determined through a standard statistical technique (nonlinear least-square regression), except as discussed in sections V and VI below regarding the adjusting of the original curve for the passenger car function.

Following this initial calibration of the target function, the system adjusts the lower and upper asymptotes uniformly (on a gallon per mile basis) until one of the following externally specified conditions is met: the average CAFE level required of the included manufacturers approximately equals an externally specified goal; net societal benefits (i.e., total benefits minus total costs) are maximized, or total benefits are as close as observed (among evaluated stringency levels) to total costs. Due to rounding of fuel economy and CAFE levels, the first condition can only be satisfied on an approximate basis.

The modeling system provides another type of higher-level automation—the ability to perform uncertainty analysis, also referred to as Monte Carlo simulation. For some input parameters, such as technology costs, values can be tested over a specified continuous probability distribution. For others, such as fuel prices, discrete scenarios (*e.g.*, high, low, and reference cases), each with a specified probability, can be tested. The system performs sensitivity analysis by randomly selecting values for parameters to be varied, performing the compliance simulation and effects calculations, repeating these results many times and recording results for external analysis. This operating mode enables the examination of the uncertainty of high-level results (*e.g.*, total costs, fuel savings, or net societal benefits), as well as their sensitivity to variations in the model's input parameters.

5. How has the Volpe model been updated since the April 2006 light truck CAFE final rule?

Several changes were made to the Volpe model between the analysis reported in the April 2006 light truck final rule and the analysis of the current NPRM. As discussed above, the set of technologies represented was updated, the logical sequence for progressing through these technologies was changed, methods to account for "synergies" (*i.e.*, interactions) between technologies and technology cost reductions associated with a manufacturer's "learning" were added, the effective cost calculation used in the technology application algorithm was modified, and the procedure for calibrating a reformed standard was changed, as was the procedure for estimating the optimal stringency of a reformed standard.

As discussed in Section III above, the set of technologies considered by the agency has evolved since the previous light truck CAFE rulemaking. The set of technologies now included in the Volpe model is shown below in Table V-7, with codes used by the model to refer to each technology.

Table V-7. Revised Technology Set for Volpe Model

Technology	Code (for Model)
Low Friction Lubricants	LUB
Engine Friction Reduction	EFR
Variable Valve Timing (Intake Cam Phasing)	VVTI

Variable Valve Timing (Coupled Cam Phasing)	VVTC
Variable Valve Timing (Dual Cam Phasing)	VVTD
Cylinder Deactivation	DISP
Variable Valve Lift & Timing (Continuous VVL)	VVLTC
Variable Valve Lift & Timing (Discrete VVL)	VVLTD
Cylinder Deactivation on Overhead Valve (OHV)	DISPO
Variable Valve Timing (CCP) on OHV	VVTO
Multivalve Overhead Cam with CVVL	DOHC
Variable Valve Lift & Timing (DVVL) on OHV	VVLTO
Camless Valve Actuation	CVA
Stoichiometric Gasoline Direct Injection (GDI)	SIDI
Lean Burn GDI	LBDI
Turbocharging and Downsizing	TURB
Homogeneous Charge Compression Ignition	HCCI
Diesel with Lean NOx Trap (LNT)	DSLL
Diesel with Selective Catalytic Reduction (SCR)	DSLS
5 Speed Automatic Transmission	5SP
Aggressive Shift Logic	ASL
Early Torque Converter Lockup	TORQ
6 Speed Automatic Transmission	6SP
Automatic Manual Transmission	AMT
Continuously Variable Transmission	CVT
6 Speed Manual	6MAN
Improved Accessories	IACC
Electronic Power Steering	EPS
42-Volt Electrical System	42V
Low Rolling Resistance Tires	ROLL
Low Drag Brakes	LDB
Secondary Axle Disconnect – Unibody	SAXU
Secondary Axle Disconnect - Ladder Frame	SAXL
Aero Drag Reduction	AERO
Material Substitution (1%)	MS1
Material Substitution (2%)	MS2
Material Substitution (5%)	MS5
Integrated Starter/Generator (ISG) with Idle-Off	ISGO

IMA/ISAD/BSG Hybrid (includes engine downsizin	IHYB
2-Mode Hybrid	2HYB
Power Split Hybrid	PHYB
Full Diesel Hybrid	DHYB

The logical sequence for progressing between these technologies has also been changed. As in the previous version of the Volpe model, technologies are assigned to groups (*e.g.*, engine technologies) and the model follows a cost-minimizing approach to selecting technologies. However, the model now includes some "branch points" at which it selects from two or more technologies within the same group. This enables a more detailed representation of some technologies that have multiple variants (*e.g.*, variable valve timing) and, as relevant to the applicability of different technologies, more specific differentiation between technologies that have already been applied to vehicles (*e.g.*, single versus dual overhead cam engines). This revised logical sequencing is expected to produce results that are more realistic in terms of the application of technologies to different vehicle models. For example, in this analysis OHV engines and OHC engines were considered separately, and the model was generally not allowed to apply multivalve OHC technology to OHV engines (except where continuous variable valve timing and lift is applied to OHV engines, in which case the model assumes conversion to DOHC valvetrain).

Figure V-3 below shows the resultant "decision tree" for the group of engine technologies. As an example of the "branching" mentioned above, having applied cylinder deactivation and coupled cam phasing to an overhead valve engine, the Volpe model selects either discrete valve lift or an engine redesign to multivalve overhead cam with continuous variable valve Figure V-4 shows the decision tree for transmission technologies, and Figure V-5 shows the decision trees for other technologies.

Figure V-3. Engine Technology Decision Tree

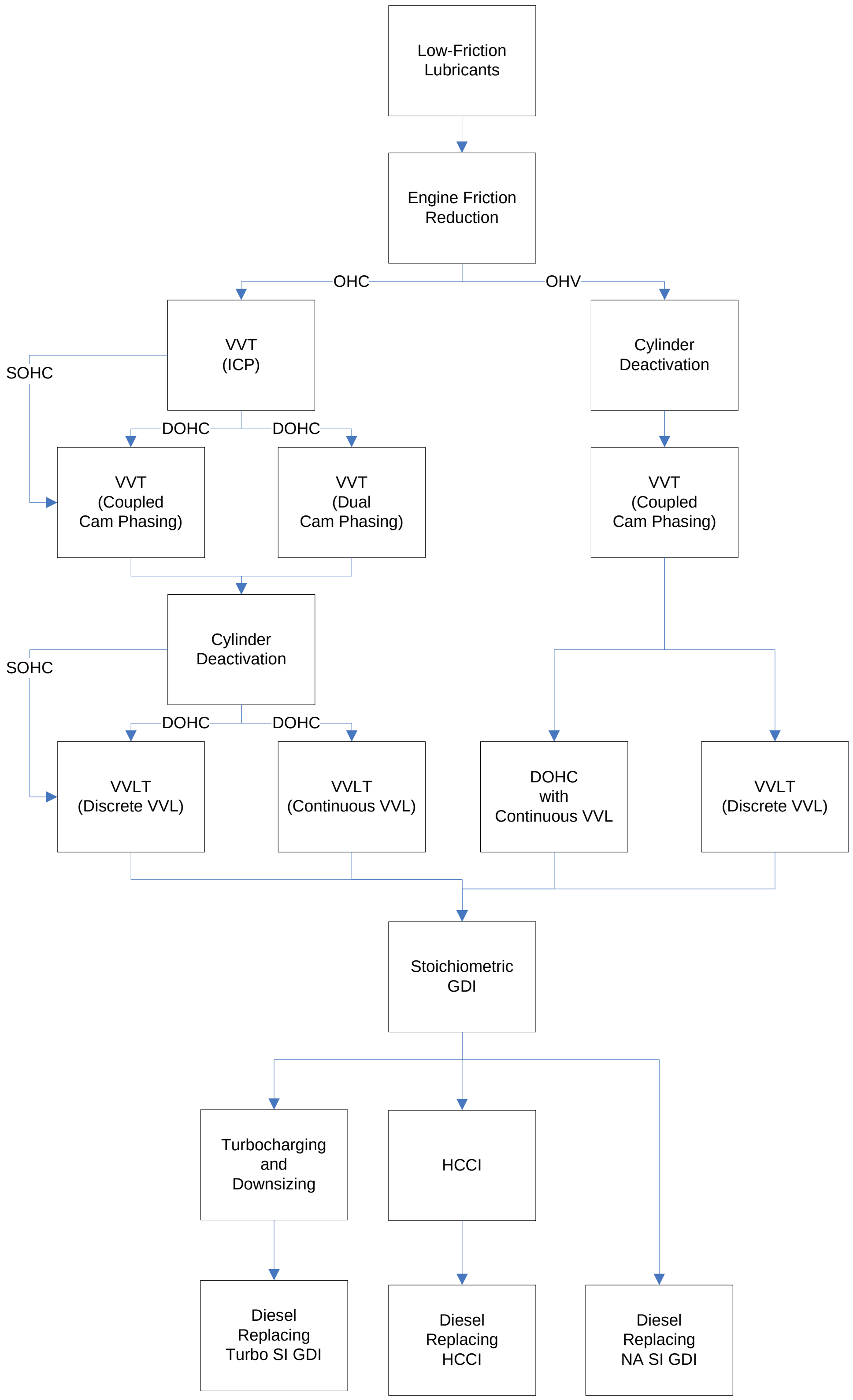

Low-Friction Lubricants
Engine Friction Reduction
OHC
OHV
VVT (ICP)
Cylinder Deactivation
SOHC
DOHC
DOHC
VVT (Coupled Cam Phasing)
VVT (Dual Cam Phasing)
VVT (Coupled Cam Phasing)
Cylinder Deactivation
SOHC
DOHC
DOHC
VVLT (Discrete VVL)
VVLT (Continuous VVL)
DOHC with Continuous VVL
VVLT (Discrete VVL)
Stoichiometric GDI
Turbocharging and Downsizing
HCCI
Diesel Replacing Turbo SI GDI
Diesel Replacing HCCI
Diesel Replacing NA SI GDI

Figure V-4. Transmission Technology Decision Tree

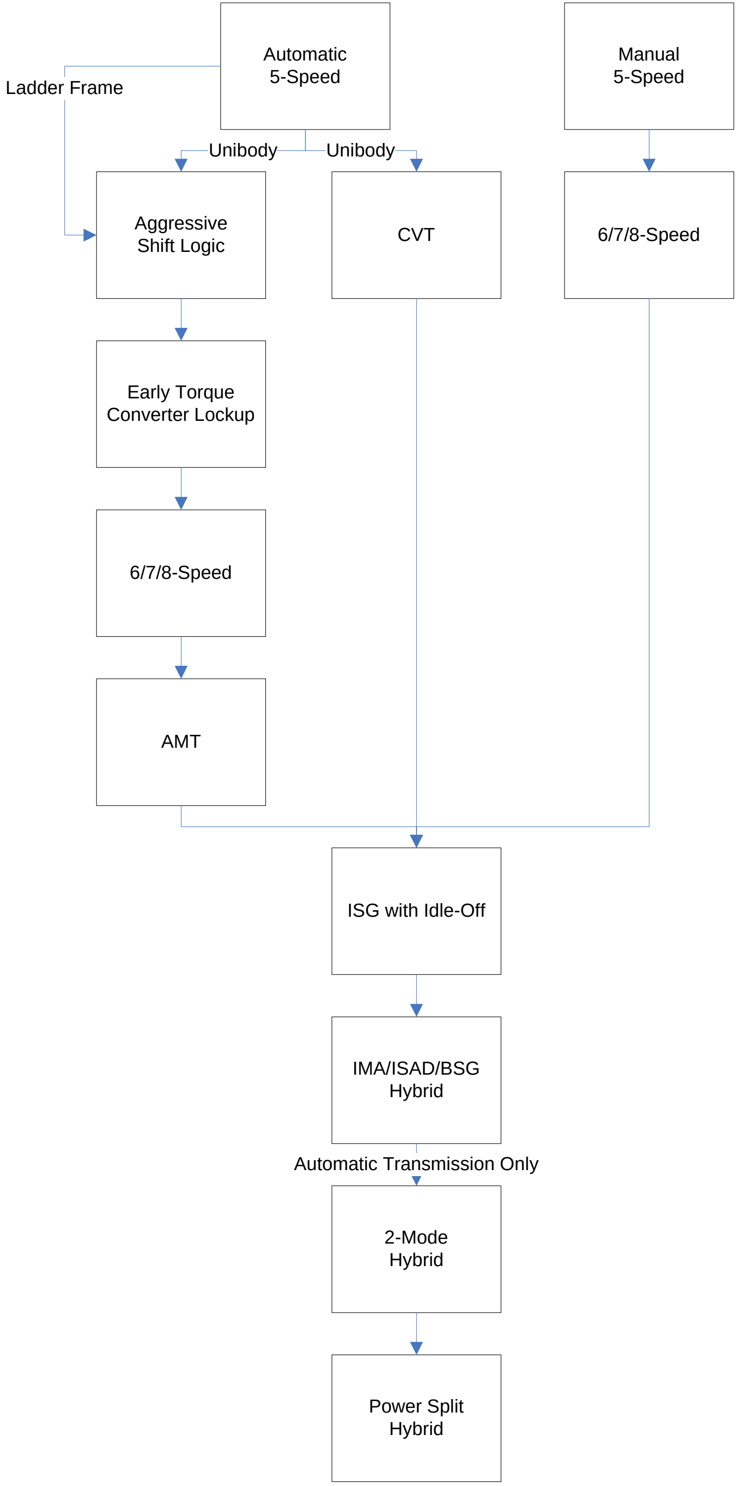
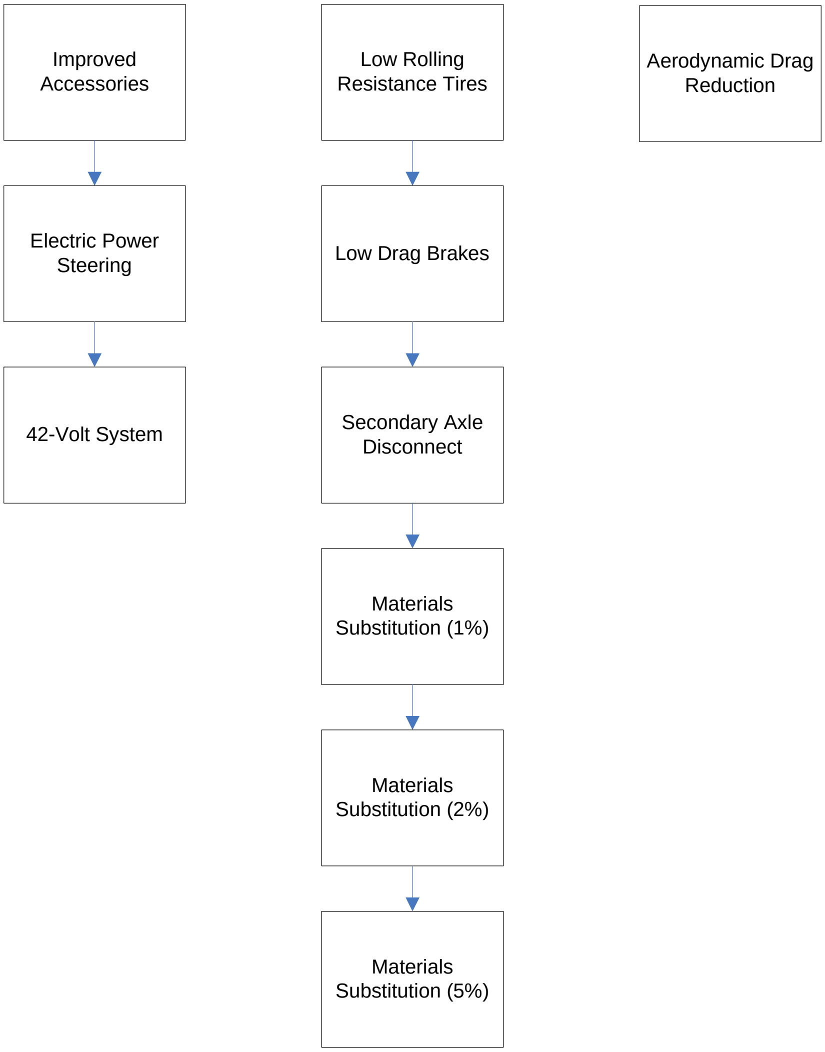


Figure V-5. Decision Trees for Other Technologies



Each time the model applies a technology to a vehicle in the fleet, it considers the next available technology on every available path. An available technology is one that is not included in the base vehicle, has not been applied by the model, and is not disqualified due to the vehicle's characteristics (discussed below). For a given path, the next available technology is the first available item (if no technologies on the path have yet been applied) or the first available item following the most recently applied technology on that path. An available path is any path that includes available technologies.

The engine and transmission paths contain several forks where the model may choose among two or more same-path items along with items from other paths. At some of these forks, conditions on the connecting arrows require the model to follow a particular branch. These conditions are based on previously applied technologies or vehicle characteristics. For example, ladder frame vehicles must follow the left branch of the transmission technology path, whereas unibody vehicles can follow either the right or left branch. The consequence is that the model considers both aggressive shift logic (ASL) and CVT for unibody vehicles, but only ASL for ladder frame vehicles. Conditions along the engine technologies path are based on valvetrain design (OHV, OHC, SOHC, and DOHC).

Other conditions require the model to discontinue considering technologies along a given path. For example, 2-Mode Hybrid and Power Split Hybrid drivetrains can be applied only to vehicles equipped with automatic transmissions. If the model has already chosen a manual transmission and IMA/ISAD/BSG Hybrid drivetrain (or if the base vehicle is equipped with these), the hybrid path becomes unavailable and the model must choose subsequent technologies from other paths.

a. Technology synergies

In some cases, the change in fuel economy achieved by applying a given technology depends on what other technologies are already present. The Volpe model has been modified to provide the ability to represent such "synergies" between technologies, as discussed above. These effects are specified in one of the model's input files. As shown below in Table V-8, which uses technology codes listed in Table V-7 above, most of the synergies represented in the analysis of this proposal are negative. In other words, most of the interactions are such that a given technology has a smaller effect on fuel economy if some other technologies have already been applied. The inclusion of such effects in the model is expected to produce more realistic estimates of the benefit of applying various technologies.

Table V-8. "Synergies" from Technology Input File for Volpe Model

Synergies		Synergy Values by Vehicle Class Positive values are synergies, negative values are dissynergies.				
Technology A	**Technology B**	**SUV-Small**	**SUV-Mid**	**SUV-Large**	**Minivan**	**Pickup-Small**
VVTI	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTI	ISGO	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTC	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTC	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTC	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISP	5SP	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DISP	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DISP	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISP	ISGO	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTC	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTC	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTC	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTC	6MAN	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTD	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTD	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISPO	5SP	-1.50%	-1.50%	-1.50%	-1.50%	-1.50%
DISPO	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DISPO	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISPO	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISPO	ISGO	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
VVTO	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTO	6MAN	0.50%	0.50%	0.50%	0.50%	0.50%
DOHC	5SP	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DOHC	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DOHC	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DOHC	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DOHC	6MAN	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DOHC	ISGO	0.50%	0.50%	0.50%	0.50%	0.50%
VVLTO	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTO	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTO	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%

Synergies		**Synergy Values by Vehicle Class** **Positive values are synergies, negative values are dissynergies.**				
Technology A	**Technology B**	**SUV-Small**	**SUV-Mid**	**SUV-Large**	**Minivan**	**Pickup-Small**
CVA	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
CVA	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
CVA	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
CVA	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
CVA	6MAN	0.50%	0.50%	0.50%	0.50%	0.50%
HCCI	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
HCCI	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
TURB	5SP	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
TURB	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
TURB	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
TURB	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
TURB	6MAN	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
ISGO	IACC	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
ISGO	EPS	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
ISGO	42V	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DSLT	5SP	0.50%	0.50%	0.50%	0.50%	0.50%
DSLT	CVT	0.50%	0.50%	0.50%	0.50%	0.50%
DSLT	ISGO	0.50%	0.50%	0.50%	0.50%	0.50%
DSLT	ASL	0.50%	0.50%	0.50%	0.50%	0.50%
DSLH	5SP	0.50%	0.50%	0.50%	0.50%	0.50%
DSLH	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DSLH	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DSLH	6MAN	0.50%	0.50%	0.50%	0.50%	0.50%
DSLH	ISGO	0.50%	0.50%	0.50%	0.50%	0.50%
DSLS	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DSLS	CVT	-2.50%	-2.50%	-2.50%	-2.50%	-2.50%
DSLS	6SP	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DSLS	6MAN	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DSLS	ISGO	0.50%	0.50%	0.50%	0.50%	0.50%

Synergies		Synergy Values by Vehicle Class Positive values are synergies, negative values are dissynergies.				
Technology A	**Technology B**	**Pickup-Large**	**Subcompact**	**Compact**	**Midsize**	**Large**
VVTI	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTI	ISGO	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTC	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTC	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTC	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISP	5SP	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DISP	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DISP	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISP	ISGO	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTC	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTC	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTC	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTC	6MAN	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTD	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTD	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISPO	5SP	-1.50%	-1.50%	-1.50%	-1.50%	-1.50%
DISPO	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DISPO	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISPO	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DISPO	ISGO	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
VVTO	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVTO	6MAN	0.50%	0.50%	0.50%	0.50%	0.50%
DOHC	5SP	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DOHC	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DOHC	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DOHC	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DOHC	6MAN	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DOHC	ISGO	0.50%	0.50%	0.50%	0.50%	0.50%
VVLTO	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTO	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
VVLTO	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%

Synergies		**Synergy Values by Vehicle Class** **Positive values are synergies, negative values are dissynergies.**				
Technology A	**Technology B**	**Pickup-Large**	**Subcompact**	**Compact**	**Midsize**	**Large**
CVA	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
CVA	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
CVA	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
CVA	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
CVA	6MAN	0.50%	0.50%	0.50%	0.50%	0.50%
HCCI	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
HCCI	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
TURB	5SP	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
TURB	CVT	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
TURB	ASL	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
TURB	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
TURB	6MAN	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
ISGO	IACC	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
ISGO	EPS	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
ISGO	42V	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DSLT	5SP	0.50%	0.50%	0.50%	0.50%	0.50%
DSLT	CVT	0.50%	0.50%	0.50%	0.50%	0.50%
DSLT	ISGO	0.50%	0.50%	0.50%	0.50%	0.50%
DSLT	ASL	0.50%	0.00%	0.00%	0.50%	0.50%
DSLH	5SP	0.50%	0.50%	0.50%	0.50%	0.50%
DSLH	CVT	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DSLH	6SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DSLH	6MAN	0.50%	0.50%	0.50%	0.50%	0.50%
DSLH	ISGO	0.50%	0.50%	0.50%	0.50%	0.50%
DSLS	5SP	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DSLS	CVT	-2.50%	-2.50%	-2.50%	-2.50%	-2.50%
DSLS	6SP	-1.00%	-1.00%	-1.00%	-1.00%	-1.00%
DSLS	6MAN	-0.50%	-0.50%	-0.50%	-0.50%	-0.50%
DSLS	ISGO	0.50%	0.50%	0.50%	0.50%	0.50%

b. Technology learning curves

The Volpe model has also been modified to provide the ability to account for cost reductions a manufacturer may realize through learning achieved from experience in actually applying a given technology. Thus, for some of the technologies, we have included a learning factor. Stated another way, the “learning curve” describes the reduction in unit production costs as a function of accumulated production volume and small redesigns that reduce costs.

As explained above, a typical learning curve can be described by three parameters: (1) the initial production volume before cost reductions begin to be realized; (2) the rate at which cost reductions occur with increases in cumulative production beyond this initial volume (usually referred to as the “learning rate”); and (3) the production volume after which costs reach a "floor," and further cost reductions no longer occur. Over the region where costs decline with accumulating production volume, an experience curve can be expressed as $C(Q) = aQ^{-b}$, where a is a constant coefficient, Q represents cumulative production, and b is a coefficient corresponding to the assumed learning rate. In turn, the learning rate L, which is usually expressed as the percent by which average unit cost declines with a doubling of cumulative production, and is related to the value of the coefficient b by $L = 100*(1 – 2^{-b})$.[66]

The new learning curves are described in greater detail above in the Proposed Technology Assumptions section, III. We seek comment on the new proposed learning curves.

c. Calibration of reformed CAFE standards

The procedure used by the Volpe model to develop (*i.e.*, calibrate) the initial shape of a reformed standard was also modified. In the version of the model used to analyze NHTSA's April 2006 light truck final rule, the asymptotes for the constrained logistic function defining fuel economy targets were assigned based on the set of vehicles that would have been assigned to the lowest and highest bins defined in that rule's 2005 NPRM. The Volpe model has been modified to accept specified percentages (in terms of either models or sales) of the fleet to include when assigning asymptotes.

The procedure used by the Volpe model to estimate the "socially optimized" stringency of a reformed standard was also modified. In the version of the model used to analyze the 2006 light truck final rule, the shape of the function (*i.e.*, the constrained logistic function) defining fuel economy targets was recalibrated every model year and then shifted up and down to estimate the stringency at which marginal costs begin to exceed marginal benefits or, equivalently, the point at which net societal benefits are maximized. However, analysis conducted by the agency to prepare for the current rulemaking revealed several opportunities to refine the procedure described above before applying it to an action that spans several model years. The first refinement is a method for gradually transforming the shape of the continuous function between model years and guarding against erratic fluctuations in the shape (though not necessarily the stringency) of the continuous function. The second is the implementation of several anti-backsliding measures that prevents the average required CAFE level from falling between model years and prevents the continuous function for a given model from crossing or falling below that of the preceding model year. The third, applied to passenger cars only, is an option to specify a fixed relationship between the function's midpoint and width coefficients. These refinements are discussed in greater detail in Section V.B below.

6. What manufacturer information does the Volpe model use?

For purposes of determining and analyzing CAFE standards, NHTSA has historically made significant use of detailed product plan information provided to the agency by individual manufacturers, supplementing this information where appropriate with information from other

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[66] *See, e.g.*, Robert H. Williams, "Toward Cost Buydown via Learning-by-Doing for Environmental Energy Technologies," paper presented at Workshop on Learning-by-Doing in Energy Technologies, Resources for the Future, Washington, DC, June 17-18, 2003, pp. 1-2. Another common but equivalent formulation of the relationship between L and b is $(1\text{-}L)=2^{-b}$, where (1-L) is referred to as the progress ratio; *see* Richard P. Rumelt, "Note on Strategic Cost Dynamics," POL 2001-1.1, Anderson School of Business, University of California, Los Angeles, California, 2001, pp. 4-5.

sources, such as data submitted to the agency in relation to CAFE compliance. Consistent with this practice, the Volpe model uses detailed representations of (i.e., model-by-model, linked to specific engines and transmissions) the fleets manufacturers are expected to produce for sale in the U.S. In preparation for today's action, the agency issued in the spring of 2006 a request that manufacturers provide updated product plans for passenger cars and light trucks.

NHTSA received product plan information from Chrysler, Ford, GM, Honda, Nissan, Mitsubishi, Porsche and Toyota. The agency didn't receive any product plan information from BMW, Ferrari, Hyundai, Mercedes or VW.

Chrysler, Ford, GM, Honda, Nissan, Mitsubishi, Porsche and Toyota provided information covering multiple model years. However, only Chrysler and Mitsubishi provided us with product plans that showed differing production quantities, vehicle introductions, vehicle redesigns/refreshes changes, without any carryover production quantities, from 2007 to MY 2015. The agency incorporated their product plan information as part of the input file to the model without the need to project or carryover any vehicle production data.

For the other companies which provided data, the agency carried over production quantities for their vehicles, allowing for growth, starting with the year after their product plan data showed changes in production quantities or showed the introduction or redesign/refresh of vehicles. Product plan information was provided until MY 2013 for Ford and Toyota, thus the first year that we started to carry over production quantities for those companies was MY 2014. Product plan information was provided until MY 2012 for GM and Nissan, thus the first year that we started to carry over production quantities for those companies was MY 2013. Product plan information was provided by Honda until MY 2008. Honda asked the agency to carry over those plans and also provided data for the last redesign of a vehicle and asked us to carry forward.

Product plan information was provided until MY 2008 for Porsche, thus the first year that we started to carry over production quantities for Porsche was MY 2009.

For Hyundai, given that it is one of the largest 7 manufacturers, the agency used the mid-year 2007 data contained in the agency's CAFE database to establish the baseline models and production quantities for their vehicles. For the other manufacturers, because of the time constraint the agency was under to meet the statutory deadline, we used the 2005 information from our database, which is the latest information used in the current analysis. To the extent possible , because, the CAFE database doesn't capture all of the product plan data that we request from companies, we supplemented the CAFE database information with information on public websites, from commercial information sources and for Hyundai, from the MY 2008 – 2011 light truck rule.

In all cases, manufacturers' respective sales volumes were normalized to produce passenger car and light truck fleets that reflected manufacturers' MY2006 market shares and to reflect passenger car and light truck fleets of projected aggregate volume consistent with forecasts in the EIA's 2007 Annual Energy Outlook. The agency requests comment on whether alternative methods should be used to estimate manufacturers' market shares and the overall sizes of the future passenger car and light truck fleets.

In a companion notice, the agency is requesting updated product plan information from all companies, and as in previous fuel economy rulemakings, we will be using those plans for the final rule. These plans will impact the standards for the final rule. To that end, the agency is requesting that these plans be as detailed and as accurate as possible.

7. What economic information does the Volpe model use?

NHTSA's preliminary analysis of alternative CAFE standards for the model years covered by this proposed rulemaking relies on a range of information, economic estimates, and input parameters. This section describes this information and each assumption and specific parameter values, and discusses the rationale for tentatively choosing each one. Similar to the product plan information, these economic assumptions play a role in the level of the standards, with some having a higher impacts than others. Outside of the cost of technologies and as discussed below, the price of gasoline and discount rate used for discounting future benefits account for the majority of the impacts. The agency seeks comment on the economic assumptions presented below. The agency seeks comment on the economic assumptions presented below. For the reader's reference, Table V-9 below summarizes the values used to calculate the impacts of each scenario:

Table V-9. Economic Values for Benefits Computations (2006$)

Rebound Effect (VMT Elasticity w/respect to Fuel Cost per Mile)	-0.15
Discount Rate Applied to Future Benefits	7%
Payback Period (years)	5.0
"Gap" between Test and On-Road mpg	20%
Value of Travel Time per Vehicle ($/hour)	$24.00
Economic Costs of Oil Imports ($/gallon)	
"Monopsony" Component	$0.176
Price Shock Component	$0.109
Military Security Component	$ -
Total Economic Costs ($/gallon)	$0.285
Total Economic Costs ($/BBL)	$11.97
External Costs from Additional Automobile Use Due to "Rebound" Effect ($/vehicle-mile)	
Congestion	$0.047
Accidents	$0.025
Noise	$0.001
External Costs from Additional Light Truck Use Due to "Rebound" Effect ($/vehicle-mile)	
Congestion	$0.052
Accidents	$0.023
Noise	$0.001
Emission Damage Costs	
Carbon Monoxide ($/ton)	$ -
Volatile Organic Compounds ($/ton)	$1,700
Nitrogen Oxides ($/ton)	$3,900

Particulate Matter ($/ton)	$164,000
Sulfur Dioxide ($/ton)	$16,000
Carbon Dioxide ($/metric ton)	$ 7.00
Annual Increase in CO2 Damage Cost	2.4%

a. Costs of fuel economy technologies

We developed detailed estimates of the costs of applying fuel economy-improving technologies to vehicle models for use in analyzing the impacts of alternative standards considered in this rulemaking. The estimates were based on those reported by the 2002 NAS Report analyzing costs for increasing fuel economy, but were modified for purposes of this analysis as a result of extensive consultations among engineers from NHTSA, EPA, and the Volpe Center. As part of this process, the agency also developed varying cost estimates for applying certain fuel economy technologies to vehicles of different sizes and body styles. We may adjust these cost estimates based on comments received to this NPRM.

The technology cost estimates used in this analysis are intended to represent manufacturers' direct costs for high-volume production of vehicles with these technologies and sufficient experience with their application so that all cost reductions due to "learning curve" effects have been fully realized. However, NHTSA recognizes that manufacturers' actual costs for applying these technologies to specific vehicle models are likely to include additional outlays for accompanying design or engineering changes to each model, development and testing of prototype versions, recalibrating engine operating parameters, and integrating the technology with other attributes of the vehicle. Manufacturers may also incur additional corporate overhead, marketing, or distribution and selling expenses as a consequence of their efforts to improve the fuel economy of individual vehicle models and their overall product lines.

In order to account for these additional costs, NHTSA applies an indirect cost multiplier of 1.5 to the estimate of the vehicle manufacturers' direct costs for producing or acquiring each fuel economy-improving/CO_2 emission-reducing technology. Historically, NHTSA has used an almost identical multiplier, 1.51, for the markup from variable costs or direct manufacturing costs to consumer costs. This markup takes into account fixed costs, burden, manufacturer's profit, and dealers' profit. NHTSA's methodology for determining this markup was recently peer reviewed.[67]

This estimate was confirmed by Argonne National Laboratory in a recent review of vehicle manufacturers' indirect costs. The Argonne study was specifically intended to improve the accuracy of future cost estimates for production of vehicles that achieve high fuel economy/low CO_2 emissions by employing many of the same advanced technologies considered in our analysis.[68] Thus, we believe that its recommendation that a multiplier of 1.5 be applied to direct

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[67] *See* Docket No. NHTSA-2007-27454, Item 4.

[68] Vyas, Anant, Dan Santini, and Roy Cuenca, *Comparison of Indirect Cost Multipliers for Vehicle Manufacturing*, Center for Transportation Research, Argonne National Laboratory, April 2000. *Available at* http://www.transportation.anl.gov/pdfs/TA/57.pdf (last accessed Oct. 23, 2007).

manufacturing costs to reflect manufacturers' increased indirect costs for deploying advanced fuel economy technologies is appropriate for use in the analysis for this rulemaking.

b. Potential opportunity costs of improved fuel economy

An important concern is whether achieving the fuel economy improvements required by alternative CAFE standards would require manufacturers to compromise the performance, carrying capacity, safety, or comfort of their vehicle models. If it did so, the resulting sacrifice in the value of these attributes to consumers would represent an additional cost of achieving the required improvements in fuel economy, and thus of manufacturers' compliance with stricter CAFE standards. While exact dollar values of these attributes to consumers are difficult to infer from vehicle purchase prices, changing vehicle attributes can affect the utility that vehicles provide to their owners, and thus their value to potential buyers.

NHTSA has approached this potential problem by developing tentative cost estimates for fuel economy-improving technologies that include any additional manufacturing costs that would be necessary to maintain the performance, comfort, capacity, or safety of any light-duty vehicle model to which those technologies are applied. In doing so, we primarily followed the precedent established by the 2002 NAS Report, although we updated its assumptions as necessary for the purposes of the current rulemaking. The NAS study estimated "constant performance and utility" costs for fuel economy technologies, and NHTSA has used these as the basis for their further efforts to develop the technology costs employed in analyzing manufacturer's costs for complying with alternative light truck standards.

NHTSA acknowledges the difficulty of estimating technology costs that include costs for the accompanying changes in vehicle design that are necessary to maintain performance, capacity, and utility. However, we believe that our tentative cost estimates for fuel economy/CO_2 emission-reduction technologies should be generally sufficient to prevent significant reductions in consumer welfare provided by vehicle models to which manufacturers apply those technologies.

c. The on-road fuel economy "gap"

Actual fuel economy levels achieved by light-duty vehicles in on-road driving fall somewhat short of their levels measured under the laboratory-like test conditions used by EPA to establish its published fuel economy ratings for different models. In analyzing the fuel savings from alternative CAFE standards, NHTSA has previously adjusted the actual fuel economy performance of each light truck model downward from its rated value to reflect the expected size of this on-road fuel economy "gap." On December 27, 2006, EPA adopted changes to its regulations on fuel economy labeling, which were intended to bring vehicles' rated fuel economy levels closer to their actual on-road fuel economy levels.[69]

In its Final Rule, EPA estimated that actual on-road fuel economy for light-duty vehicles averages 20 percent lower than published fuel economy levels. For example, if the overall EPA fuel economy rating of a light truck is 20 mpg, the on-road fuel economy actually achieved by a typical driver of that vehicle is expected to be 16 mpg (20*.80). NHTSA has employed EPA's

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[69] 71 FR 77871 (Dec. 27, 2006).

revised estimate of this on-road fuel economy gap in its analysis of the fuel savings resulting from alternative CAFE standards proposed in this rulemaking.

d. Fuel prices and the value of saving fuel

Projected future fuel prices are a critical input into the preliminary economic analysis of alternative CAFE standards, because they determine the value of fuel savings both to new vehicle buyers and to society. NHTSA relied on the most recent fuel price projections from the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook* (AEO) for this analysis. Specifically, we used the AEO 2008 Early Release forecasts of inflation-adjusted (constant-dollar) retail gasoline and diesel fuel prices, which represent the EIA's most up-to-date estimate of the most likely course of future prices for petroleum products.[70] Federal government agencies generally use EIA's projections in their assessments of future energy-related policies.

The retail fuel price forecasts presented in AEO 2008 span the period from 2008 through 2030. Measured in constant 2006 dollars, the Reference Case forecast of retail gasoline prices during calendar year 2020 is $2.30 per gallon, rising gradually to $2.49 by the year 2030. However, valuing fuel savings over the 36-year maximum lifetime of light trucks assumed in this analysis requires fuel price forecasts that extend through 2050, the last year during which a significant number of MY 2015 vehicles will remain in service.[71] To obtain fuel price forecasts for the years 2031 through 2050, the agency assumes that retail fuel prices forecast in the Reference Case for 2030 will remain constant (in 2006 dollars) through 2050.

The value of fuel savings resulting from improved fuel economy/reduced CO_2 emissions to buyers of light-duty vehicles is determined by the retail price of fuel, which includes federal, state, and any local taxes imposed on fuel sales. Total taxes on gasoline averaged $0.47 per gallon during 2006, while those levied on diesel averaged $0.53. State fuel taxes are weighted by sales. Because fuel taxes represent transfers of resources from fuel buyers to government agencies, however, rather than real resources that are consumed in the process of supplying or using fuel, their value must be deducted from retail fuel prices to determine the value of fuel savings resulting from more stringent CAFE standards to the U.S. economy as a whole.

In estimating the economy-wide or "social" value of fuel savings of increasing CAFE/reducing CO_2 emissions levels, NHTSA assumes that current fuel taxes will remain constant in real or inflation-adjusted terms over the lifetimes of the vehicles proposed to be regulated. In effect, this assumes that the average value per gallon of taxes on gasoline and diesel fuel levied by all levels of government will rise at the rate of inflation over that period. This value is deducted from each future year's forecast of retail gasoline and diesel prices reported in AEO 2008 to determine the social value of each gallon of fuel saved during that year as a result of improved fuel economy/reduced CO_2 emissions. Subtracting fuel taxes results in a projected value for saving gasoline of $1.83 per gallon during 2020, rising to $2.02 per gallon by the year 2030.

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[70] Energy Information Administration, *Annual Energy Outlook 2008, Early Release* Reference Case Table 12. *Available at* http://www.eia.doe.gov/oiaf/aeo/pdf/aeotab_12.pdf (last accessed Feb. 2, 2008).

[71] The agency defines the maximum lifetime of vehicles as the highest age at which more than 2 percent of those originally produced during a model year remain in service. In the case of light-duty trucks, for example, this age has typically been 36 years for recent model years.

In conducting the preliminary uncertainty analysis of benefits and costs from alternative CAFE standards required by OMB, NHTSA also considered higher and lower forecasts of future fuel prices. The results of the sensitivity runs can be found in the PRIA. EIA includes “High Price Case” and “Low Price Case” in AEO analyses that reflect uncertainties regarding future levels of oil production, but those cases are not meant to be probabilistic, and simply illustrate the range of uncertainty that exists. Because AEO 2008 Early Release included only a Reference Case of forecast of fuel prices and did not include the High and Low Price cases, the agency estimated high and low fuel prices corresponding to the AEO 2008 Reference Case forecast by assuming that high and low price forecasts would bear the same relationship to the Reference Case forecast as reported in AEO 2007.[72] These alternative scenarios project retail gasoline prices that range from a low of $1.94 per gallon to a high of $3.26 per gallon during 2020, and from $2.03 to $3.70 per gallon during 2030. In conjunction with our assumption that fuel taxes will remain constant in real or inflation-adjusted terms over this period, these forecasts imply social values of saving fuel ranging from $1.47 to $2.79 per gallon during 2020, and from $1.56 to $3.23 per gallon in 2030.

EIA is widely-recognized as an impartial and authoritative source of analysis and forecasts of U.S. energy production, consumption, and prices. The agency has published annual forecasts of energy prices and consumption levels for the U.S. economy since 1982 in its ***Annual Energy Outlook (AEO)***, and these forecasts have been widely relied upon by federal agencies for use in regulatory analysis and for other purposes. Since 1994, EIA’s annual forecasts have been based upon the agency’s National Energy Modeling System (NEMS), which includes detailed representation of supply pathways, sources of demand, and their interaction to determine prices for different forms of energy.

From 1982 through 1993, EIA’s forecasts of world oil prices – the primary determinant of prices for gasoline, diesel, and other transportation fuels derived from petroleum – consistently overestimated actual prices during future years, often very significantly. Of the total of 119 forecasts of future world oil prices for the years 1985 through 2005 that EIA reported in its 1982-1993 editions of ***AEO***, 109 overestimated the subsequent actual values for those years, on average exceeding their corresponding actual values by 75%.

Since that time, however, EIA’s forecasts of future world oil prices show a more mixed record for accuracy. The 1994-2005 editions of ***AEO*** reported 91 separate forecasts of world oil prices for the years 1995-2005, of which 33 have subsequently proven too high while the remaining 58 have underestimated actual prices. The average absolute error (i.e., regardless of its direction) of these forecasts has been 21%, but over- and underestimates have tended to offset one another, so that on average EIA’s more recent forecasts have underestimated actual world oil prices by 7%. Although both its overestimates and underestimates of future world oil prices for recent years have often been large, the most recent editions of AEO have significantly underestimated petroleum prices during those years for which actual prices are now available.

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[72] Energy Information Administration, *Annual Energy Outlook 2007* High Price Case, Table 12, http://www.eia.doe.gov/oiaf/aeo/pdf/aeohptab_12.pdf and Energy Information Administration, *Annual Energy Outlook 2007* Low Price Case, Table 12, http://www.eia.doe.gov/oiaf/aeo/pdf/aeolptab_12.pdf (last accessed Feb. 2, 2008).

However, NHTSA does not regard EIA's recent tendency to underestimate future prices for petroleum and refined products or the high level of current fuel prices as adequate justification to employ forecasts that differ from the Reference Case forecast presented in EIA's ***Annual Energy Outlook 2008*** Revised Early Release. This is particularly the case because this forecast has been revised upward significantly since the initial release of ***AEO 2008***, which in turn represented a major upward revision from EIA's fuel price forecast reported previously in AEO 2007. NHTSA also notes that retail gasoline prices across the U.S. have averaged $2.94 per gallon (expressed in 2005 dollars) for the first three months of 2008, slightly *below* EIA's recently revised forecast that gasoline prices will average $2.98 per gallon (also in 2005 dollars) throughout 2008.

Comparing different forecasts of world oil prices also shows that EIA's Reference Case forecast reported in Annual Energy Outlook 2007 (AEO 2007) was actually the *highest* of all six publicly-available forecasts of world oil prices over the 2010-30 time horizon.[73] Because world petroleum prices are the primary determinant of retail prices for refined petroleum products such as transportation fuels, this suggests that the Reference Case forecast of U.S. fuel prices reported in AEO 2007 is likely to be the highest of those projected by major forecasting services. Further, as indicated above, EIA's most recent fuel price forecasts have been revised significantly upward from those previously projected in AEO 2007.

e. Consumer valuation of fuel economy and payback period

In estimating the value of fuel economy improvements that would result from alternative CAFE standards to potential vehicle buyers, NHTSA assumes that buyers value the resulting fuel savings over only part of the expected lifetime of the vehicles they purchase. Specifically, we assume that buyers value fuel savings over the first five years of a new vehicle's lifetime, and that buyers behave as if they do not discount the value of these future fuel savings. The five-year figure represents the current average term of consumer loans to finance the purchase of new vehicles. We recognize that the period over which individual buyers finance new vehicle purchases may not correspond to the time horizons they apply in valuing fuel savings from higher fuel economy. However, NHTSA believes that five years represents a reasonable estimate of the average period over which buyers who finance their purchases of new vehicle receive – and thus must recognize – the monetary value of future fuel savings resulting from higher fuel economy.

The value of fuel savings over the first five years of a vehicle model's lifetime that would result under each alternative fuel economy standard is calculated using the projections of retail fuel prices described above. It is then deducted from the technology costs incurred by its manufacturer to produce the improvement in that model's fuel economy estimated for each alternative standard, to determine the increase in the "effective price" to buyers of that vehicle model. The Volpe model uses these estimates of effective costs for increasing the fuel economy of each vehicle model to identify the order in which manufacturers would be likely to select models for the application of fuel economy-improving technologies in order to comply with stricter standards. The average value of the resulting increase in effective cost from each

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[73] See http://www.eia.doe.gov/oiaf/archive/aeo07/pdf/forecast.pdf, Table 19, p. 106.

manufacturer's simulated compliance strategy is also used to estimate the impact of alternative standards on its total sales for future model years.

However, it is important to recognize that NHTSA estimates the aggregate value to the U.S. economy of fuel savings resulting from alternative standards – or their "social" value – over the *entire* expected lifetimes of vehicles manufactured under those standards, rather than over this shorter "payback period" we assume for their buyers. This is discussed directly below in section f on "Vehicle survival and use assumptions." As indicated previously, the maximum vehicle lifetimes used to analyze the effects of alternative fuel economy standards are estimated to be 25 years for automobiles and 36 years for light trucks.

f. Vehicle survival and use assumptions

NHTSA's preliminary analysis of fuel/CO_2 emissions savings and related benefits from adopting alternative standards for MY 2011-2015 passenger cars and light trucks is based on estimates of the resulting changes in fuel use over their entire lifetimes in the U.S. vehicle fleet. The first step in estimating lifetime fuel consumption by vehicles produced during a model year is to calculate the number that is expected to remain in service during each future year after they are produced and sold.[74] This number is calculated by multiplying the number of vehicles originally produced during a model year by the proportion expected to remain in service at the age they will have reached during each subsequent year, often referred to as a "survival rate."

The agency relies on projections of the number of passenger cars and light trucks that will be produced during future years reported by the EIA in its AEO Reference Case forecast.[75] It uses updated values of age-specific survival rates for cars and light trucks estimated from yearly registration data for vehicles produced during recent model years, to ensure that forecasts of the number of vehicles in use reflect recent increases in the durability and expected life spans of cars and light trucks.[76]

The next step in estimating fuel use is to calculate the total number of miles that the cars and light trucks produced in each model year affected by the proposed CAFE standards will be driven during each year of their lifetimes. To estimate total miles driven, the number of cars and light trucks projected to remain in use during each future year (calculated as described above) is

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[74] Vehicles are defined to be of age 1 during the calendar year corresponding to the model year in which they are produced; thus for example, model year 2000 vehicles are considered to be of age 1 during calendar year 2000, age 1 during calendar year 2001, and to reach their maximum age of 26 years during calendar year 2025. NHTSA considers the maximum lifetime of vehicles to be the age after which less than 2% of the vehicles originally produced during a model year remain in service. Applying these conventions to vehicle registration data indicates that passenger cars have a maximum age of 26 years, while light trucks have a maximum lifetime of 36 years. *See* Lu, S., NHTSA, Regulatory Analysis and Evaluation Division, "Vehicle Survivability and Travel Mileage Schedules," DOT HS 809 952, 8-11 (January 2006). *Available at* http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/Rpts/2006/809952.pdf (last accessed Feb. 2, 2008).

[75] The most recent edition is Energy Information Administration, *Annual Energy Outlook 2008: Early Release*. *Available at* http://www.eia.doe.gov/oiaf/aeo/index.html (last accessed Feb. 2, 2008).

[76] Lu, S., NHTSA, Regulatory Analysis and Evaluation Division, "Vehicle Survivability and Travel Mileage Schedules," DOT HS 809 952, 8-11 (January 2006). *Available at* http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/Rpts/2006/809952.pdf (last accessed Feb. 2, 2008). These updated survival rates suggest that the expected lifetimes of recent-model passenger cars and light trucks are 13.8 and 14.5 years.

multiplied by the average number of miles they are expected to be driven at the age they will have reached in that year. The agency estimated the average number of miles driven annually by cars and light trucks of each age using data from the Federal Highway Administration's 2001 National Household Transportation Survey (NHTS).[77]

Finally, fuel consumption during each year of a model year's lifetime is estimated by dividing the total number of miles its surviving vehicles are driven by the fuel economy they are expected to achieve under each alternative CAFE standard. Each model year's total lifetime fuel consumption is the sum of fuel use by the cars or light trucks produced during that model year that are projected to remain in use during each year of their maximum life spans. In turn, the *savings* in a model year's lifetime fuel use that will result from each alternative CAFE standard is the difference between its lifetime fuel use at the fuel economy level it attains under the Baseline alternative, and its lifetime fuel use at the higher fuel economy level it is projected to achieve under that alternative standard.

To illustrate these calculations, the most recent edition of the AEO projections that 8.52 million light trucks will be produced during 2012, and the agency's updated survival rates show that slightly more than half of these – 50.1 percent, or 4.27 million – are projected to remain in service during the year 2027, when they will have reached an age of 14 years. At that age, light trucks achieving the fuel economy level required under the Baseline alternative are driven an average of about 10,400 miles, so model year 2012 light trucks will be driven a total of 44.4 billion miles (= 4.27 million surviving vehicles x 10,400 miles per vehicle) during 2027. Summing the results of similar calculations for each year of their 36-year maximum lifetime, model year 2012 light trucks will be driven a total of 1,502 billion miles under the Baseline alternative. Under that alternative, they are projected to achieve a test fuel economy level of 23.8 mpg, which corresponds to actual on-road fuel economy of 19.0 mpg (= 23.8 mpg x 80%). Thus their lifetime fuel use under the Baseline alternative is projected to be 79.0 billion gallons (= 1,502 billion miles divided by 19.0 miles per gallon).

g. Growth in total vehicle use

By assuming that the annual number of miles driven by cars and light trucks at any age will remain constant over the future, NHTSA's procedure for estimating the number of miles driven by cars and light trucks over their lifetimes in effect assumes that all future growth in total vehicle-miles driven stems from increases in the *number* of vehicles in service, rather than from increases in the average number of miles they are driven each year. Similarly, because the survival rates used to estimate the number of cars and light trucks remaining in service to various ages are assumed to remain fixed for future model years, growth in the total number of cars and light trucks in use is effectively assumed to result only from increasing sales of new vehicles. In order to determine the validity of these assumptions, the agency conducted a detailed analysis of the causes of recent growth in car and light truck use.

From 1985 through 2005, the total number of miles driven (usually referred to as vehicle-miles traveled, or VMT) by passenger cars increased 35 percent, equivalent to a compound annual

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[77] For a description of the Survey, *see* http://nhts.ornl.gov/quickStart.shtml (last accessed Dec. 3, 2007).

growth rate of 1.5 percent.[78] During that time, the total number of passenger cars registered for in the U.S. grew by about 0.3 percent annually, almost exclusively as a result of increasing sales of new cars.[79] Thus growth in the average number of miles automobiles are driven each year accounted for the remaining 1.2 percent (= 1.5% - 0.3%) annual growth in total automobile use.[80]

Over this same period, total VMT by light trucks increased much faster, growing at an annual rate of 5.1 percent. In contrast to the causes of growth in automobile use, however, nearly all growth in light truck use over these two decades was attributable to rapid increases in the *number* of light trucks in use.[81] In turn, growth in the size of the nation's light truck fleet has resulted almost exclusively from rising sales of new light trucks, since the fraction of new light trucks remaining in service to various ages has remained stable or even declined slightly over the past two decades.[82]

On the basis of this analysis, the agency tentatively concludes that its projections of future growth in light truck VMT account fully for the primary cause of its recent growth, which has been the rapid increase in sales of new light trucks during recent model years. However, the assumption that average annual use of passenger cars will remain fixed over the future appears to ignore an important source of recent growth in their total use, the gradual increase in the average number of miles they are driven. To the extent that this factor continues to represent a significant source of growth in future passenger car use, the agency's analysis is likely to *underestimate* the reductions in fuel use and related environmental impacts resulting from stricter CAFE standards for passenger cars.[83] The agency plans to account explicitly for potential future growth in average annual use of *both* cars and light trucks in the analysis accompanying its Final Rule establishing CAFE standards for model years 2011-15.

h. Accounting for the rebound effect of higher fuel economy

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[78] Calculated from data reported in FHWA, Highway Statistics, Summary to 1995, Table vm201at http://www.fhwa.dot.gov/ohim/summary95/vm201a.xlw, and annual editions 1996-2005, Table VM-1 at http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.htm (last accessed Feb. 2, 2008).

[79] A slight increase in the fraction of new passenger cars remaining in service beyond age 10 has accounted for a small share of growth in the U.S. automobile fleet. The fraction of new automobiles remaining in service to various ages was computed from R.L. Polk vehicle registration data for 1977 through 2005 by the agency's Center for Statistical Analysis.

[80] *See supra* note [2 above here]

[81] FHWA data show that growth in total miles driven by "Two-axle, four-tire trucks," a category that includes most or all light trucks used as passenger vehicles, averaged 5.1% annually from 1985 through 2005. However, the number of miles light trucks are driven each year averaged 11,114 during 2005, almost unchanged from the average figure of 11,016 miles during 1985. *Id.*

[82] Unpublished analysis of R.L. Polk vehicle registration data conducted by NHTSA Center for Statistical Analysis, 2005.

[83] Assuming that average annual miles driven per automobile will continue to increase over the future would increase the agency's estimates of total lifetime mileage for MY 2011-18 passenger cars. Their estimated lifetime fuel use would also increase under each alternative standard considered in this analysis, but in inverse relation to their fuel economy. Thus lifetime fuel use will increase by more under the No Increase alternative than under any of the alternatives that would increase passenger car CAFE standards, and by progressively less for the alternatives that impose stricter standards. Taking account of this factor would thus increase the agency's estimates of fuel savings for those alternatives, and omitting it will cause the agency's analysis to underestimate those fuel savings.

The rebound effect refers to the tendency for owners to increase the number of miles they drive a vehicle in response to an increase in its fuel economy, as would result from more stringent fuel economy standards. The rebound effect occurs because an increase in a vehicle's fuel economy reduces its owner's fuel cost for driving each mile, which is typically the largest single component of the cost of operating a vehicle. Even with the vehicle's higher fuel economy, this additional driving uses some fuel, so the rebound effect will reduce the net fuel savings that result when the fuel economy standards require manufacturers to increase fuel economy. The rebound effect is usually expressed as the percentage by which annual vehicle use increases when average fuel cost per mile driven decreases in response to a change in the marginal cost of driving an extra mile, due either an increase in fuel economy or a reduction in the price of fuel.

The magnitude of the rebound effect is one of the determinants of the actual fuel savings that are likely to result from adopting stricter standards, and thus an important parameter affecting NHTSA's evaluation of alternative standards for future model years. The rebound effect can be measured directly by estimating the elasticity of vehicle use with respect to fuel economy itself, or indirectly by the elasticity of vehicle use with respect to fuel cost per mile driven.[84] When expressed as a positive percentage, either of these parameters gives the fraction of fuel savings that would otherwise result from adopting stricter standards, but is offset by the increase in fuel consumption that results when vehicles with increased fuel economy are driven more.

Research on the magnitude of the rebound effect in light-duty vehicle use dates to the early 1980s, and almost unanimously concludes that a statistically significant rebound effect occurs when vehicle fuel efficiency improves.[85] The most common approach to estimating its magnitude has been to analyze statistically household survey data on vehicle use, fuel consumption, fuel prices (often obtained from external sources), and other determinants of household travel demand to isolate the response of vehicle use to higher fuel economy. Other studies have relied on econometric analysis of annual U.S. data on vehicle use, fuel economy, fuel prices, and other variables to identify the response of total or average vehicle use to changes in fleet-wide average fuel economy and its effect of fuel cost per mile driven. Two recent studies analyzed yearly variation in vehicle ownership and use, fuel prices, and fuel economy among individual states over an extended time period in order to measure the response of vehicle use to changing fuel economy.[86]

An important distinction among studies of the rebound effect is whether they assume that the effect is constant, or varies over time in response to the absolute levels of fuel costs, personal income, or household vehicle ownership. Most studies using aggregate annual data for the U.S. assume a constant rebound effect, although some of these studies test whether the effect can vary as changes in retail fuel prices or average fuel economy alter fuel cost per mile driven. Many

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[84] Fuel cost per mile is equal to the price of fuel in dollars per gallon divided by fuel economy in miles per gallon, so this figure declines when a vehicle's fuel economy increases.

[85] Some studies estimate that the long-run rebound effect is significantly larger than the immediate response to increased fuel efficiency. Although their estimates of the adjustment period required for the rebound effect to reach its long-run magnitude vary, this long-run effect is most appropriate for evaluating the fuel savings and emissions reductions resulting from stricter standards that would apply to future model years.

[86] In effect, these studies treat U.S. states as a data "panel" by applying appropriate estimation procedures to data consisting of each year's average values of these variables for the separate states.

studies using household survey data estimate significantly different rebound effects for households owning varying numbers of vehicles, although they arrive at differing conclusions about whether the rebound effect is larger among households that own more vehicles. One recent study using state-level data concludes that the rebound effect varies directly in response to changes in personal income and the degree of urbanization of U.S. cities, as well as fuel costs.

In order to arrive at a preliminary estimate of the rebound effect for use in assessing the fuel savings, emissions reductions, and other impacts of alternative standards, NHTSA reviewed 22 studies of the rebound effect conducted from 1983 through 2005. We then conducted a detailed analysis of the 66 separate estimates of the long-run rebound effect reported in these studies, which is summarized in the table below.[87] As the table indicates, these 66 estimates of the long-run rebound effect range from as low as 7 percent to as high as 75 percent, with a mean value of 23 percent.

Limiting the sample to 50 estimates reported in the 17 published studies of the rebound effect yields the same range but a slightly higher mean (24 percent), while focusing on the authors' preferred estimates from published studies narrows this range and lowers its average only slightly. The median estimate of the rebound effect in all three samples, which is generally regarded as a more reliable indicator of their central tendency than the average because it is less influenced by unusually small and large estimates, is 22 percent. As Table V-10 indicates, approximately two-thirds of all estimates reviewed, of all published estimates, and of authors' preferred estimates fall in the range of 10-30 percent.

Table V-10. Summary of Rebound Effect Estimates

Category of Estimates	Number of Studies	Number of Estimates	Range		Distribution		
			Low	High	Median	Mean	Std. Dev.
All Estimates	22	66	7%	75%	22%	23%	14%
Published Estimates	17	50	7%	75%	22%	24%	14%
Authors' Preferred Estimates	17	17	9%	75%	22%	22%	15%
U.S. Time-Series Estimates	7	34	7%	45%	14%	18%	9%
Household Survey Estimates	13	23	9%	75%	31%	31%	16%
Pooled U.S. State Estimates	2	9	8%	58%	22%	25%	14%
Constant Rebound Effect (1)	15	37	7%	75%	20%	23%	16%
Variable Rebound Effect: (1) Reported Estimates	10	29	10%	45%	23%	23%	10%
Updated to 2006 (2)	10	29	6%	46%	16%	19%	12%

(1) Three studies estimate both constant and variable rebound effects.

(2) Reported estimates updated to reflect 2006 values of vehicle use, fuel prices, fleet fuel efficiency, household income, and household vehicle ownership.

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[87] In some cases, NHTSA derived estimates of the overall rebound effect from more detailed results reported in the studies. For example, where studies estimated different rebound effects for households owning different numbers of vehicles but did not report an overall value, we computed a weighted average of the reported values using the distribution of households among vehicle ownership categories.

The type of data used and authors' assumption about whether the rebound effect varies over time have important effects on its estimated magnitude. The 34 estimates derived from analysis of U.S. annual time-series data produce a median estimate of 14 percent for the long-run rebound effect, while the median of 23 estimates based on household survey data is more than twice as large (31 percent), and the median of 9 estimates based on pooled state data matches that of the entire sample (22 percent). The 37 estimates assuming a constant rebound effect produce a median of 20 percent, while the 29 originally reported estimates of a variable rebound effect have a slightly higher median value (23 percent).

In selecting a single value for the rebound effect to use in analyzing alternative standards for future model years, NHTSA tentatively attaches greater significance to studies that allow the rebound effect to vary in response to changes in the various factors that have been found to affect its magnitude. However, it is also important to update authors' originally-reported estimates of variable rebound effects to reflect current conditions. Recalculating the 29 original estimates of variable rebound effects to reflect current (2006) values for retail fuel prices, average fuel economy, personal income, and household vehicle ownership reduces their median estimate to 16 percent.[88] NHTSA also tentatively attaches greater significance to the recent study by Small and Van Dender (2005), which finds that the rebound effect tends to decline as average fuel economy, personal income, and suburbanization of U.S. cities increase, but – in accordance with previous studies – rises with increasing fuel prices.[89]

Considering the empirical evidence on the rebound effect as a whole, but according greater importance to the updated estimates from studies allowing the rebound effect to vary – particularly the Small and Van Dender study – NHTSA has selected a rebound effect of 15 percent to evaluate the fuel savings and other effects of alternative standards for the time period covered by this rulemaking. However, we do not believe that evidence of the rebound effect's dependence on fuel prices or household income is sufficiently convincing to justify allowing its future value to vary in response to forecast changes in these variables. A range extending from 10 percent to at least 20 percent -- and perhaps as high as 25 percent -- appears to be appropriate

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[88] As an illustration, Small and Van Dender (2005) allow the rebound effect to vary over time in response to changes in real per capita income as well as average fuel cost per mile driven. While their estimate for the entire interval (1966-2001) they analyze is 22 percent, updating this estimate using 2006 values of these variables reduces the rebound effect to approximately 10 percent. Similarly, updating Greene's 1992 original estimate of a 15 percent rebound effect to reflect 2006 fuel prices and average fuel economy reduces it to 6 percent. *See* David L. Greene, "Vehicle Use and Fuel Economy: How Big is the Rebound Effect?" The Energy Journal, 13:1 (1992), 117-143. In contrast, the distribution of households among vehicle ownership categories in the data samples used by Hensher et al. (1990) and Greene et al. (1999) are nearly identical to the most recent estimates for the U.S., so updating their original estimates to current U.S. conditions changes them very little. *See* David A. Hensher, Frank W. Milthorpe, and Nariida C. Smith, "The Demand for Vehicle Use in the Urban Household Sector: Theory and Empirical Evidence," Journal of Transport Economics and Policy, 24:2 (1990), 119-137; and David L. Greene, James R. Kahn, and Robert C. Gibson, "Fuel Economy Rebound Effect for Household Vehicles," The Energy Journal, 20:3 (1999), 1-21.

[89] In the most recent light truck CAFE rulemaking, NHTSA chose not to preference the Small and Van Dender study over other published estimates of the value of the rebound effect, stating that since it "remains an unpublished working paper that has not been subjected to formal peer review, …the agency does not yet consider the estimates it provides to have the same credibility as the published and widely-cited estimates it relied upon." *See* 71 FR 17633 (Apr. 6, 2006). The study has subsequently been published and peer-reviewed, so NHTSA is now prepared to "consider it in developing its own estimate of the rebound effect for use in subsequent CAFE rulemakings."

for the required analysis of the uncertainty surrounding these estimates. While the agency selected 15 percent, it also ran sensitivity analyses at 10 and 20 percent. The results are shown in the uncertainties analysis.

i. Benefits from increased vehicle use

The increase in vehicle use from the rebound effect provides additional benefits to their owners, who may make more frequent trips or travel farther to reach more desirable destinations. This additional travel provides benefits to drivers and their passengers by improving their access to social and economic opportunities away from home. As evidenced by their decisions to make more frequent or longer trips when improved fuel economy reduces their costs for driving, the benefits from this additional travel exceed the costs drivers and passengers incur in making more frequent or longer trips.

The amount by which the benefits from this additional travel exceed its costs (for fuel and other operating expenses) measures the net benefits that drivers receive from the additional travel, usually referred to as increased consumer surplus. NHTSA’s analysis estimates the economic value of the increased consumer surplus provided by added driving using the conventional approximation, which is one half of the product of the decline in vehicle operating costs per vehicle-mile and the resulting increase in the annual number of miles driven. The magnitude of these benefits represents a small fraction of the total benefits from the alternative fuel economy standards considered.

j. Added costs from congestion, crashes and noise

Although it provides some benefits to drivers, increased vehicle use associated with the rebound effect also contributes to increased traffic congestion, motor vehicle accidents, and highway noise. Depending on how the additional travel is distributed over the day and on where it takes place, additional vehicle use can contribute to traffic congestion and delays by increasing traffic volumes on facilities that are already heavily traveled during peak periods. These added delays impose higher costs on drivers and other vehicle occupants in the form of increased travel time and operating expenses. Because drivers do not take these added costs into account in deciding when and where to travel, they must be accounted for separately as a cost of the added driving associated with the rebound effect.

Increased vehicle use due to the rebound effect may also increase the costs associated with traffic accidents. Drivers may take account of the potential costs they (and their passengers) face from the possibility of being involved in an accident when they decide to make additional trips. However, they probably do not consider all of the potential costs they impose on occupants of other vehicles and on pedestrians when accidents occur, so any increase in these “external” accident costs must be considered as another cost of additional rebound-effect driving. Like increased delay costs, any increase in these external accident costs caused by added driving is likely to depend on the traffic conditions under which it takes place, since accidents are more frequent in heavier traffic (although their severity may be reduced by the slower speeds at which heavier traffic typically moves).

Finally, added vehicle use from the rebound effect may also increase traffic noise. Noise generated by vehicles causes inconvenience, irritation, and potentially even discomfort to occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of surrounding property. Because these effects are unlikely to be taken into account by the drivers whose vehicles contribute to traffic noise, they represent additional externalities associated with motor vehicle use. Although there is considerable uncertainty in measuring their value, any increase in the economic costs of traffic noise resulting from added vehicle use must be included together with other increased external costs from the rebound effect.

NHTSA relies on estimates of congestion, accident, and noise costs caused by automobiles and light trucks developed by the Federal Highway Administration to estimate the increased external costs caused by added driving due to the rebound effect.[90] These estimates are intended to measure the increases in costs from added congestion, property damages and injuries in traffic accidents, and noise levels caused by automobiles and light trucks that are borne by persons other than their drivers (or "marginal" external costs). Updated to 2006 dollars, FHWA's "Middle" estimates for marginal congestion, accident, and noise costs caused by automobile use amount to 5.2 cents, 2.3 cents, and 0.1 cents per vehicle-mile (for a total of 7.6 cents per mile), while those for pickup trucks and vans are 4.7 cents, 2.5 cents, and 0.1 cents per vehicle-mile (for a total of 7.3 cents per mile).[91, 92] These costs are multiplied by the annual increases in automobile and light truck use from the rebound effect to yield the estimated increases in congestion, accident, and noise externality costs during each future year.

k. Petroleum consumption and import externalities

U.S. consumption and imports of petroleum products also impose costs on the domestic economy that are not reflected in the market price for crude petroleum, or in the prices paid by consumers of petroleum products such as gasoline. In economics literature on this subject, these costs include (1) higher prices for petroleum products resulting from the effect of U.S. oil import demand on the world oil price; (2) the risk of disruptions to the U.S. economy caused by sudden reductions in the supply of imported oil to the U.S.; and (3) expenses for maintaining a U.S. military presence to secure imported oil supplies from unstable regions, and for maintaining the strategic petroleum reserve (SPR) to cushion against resulting price increases.[93] Higher U.S. imports of crude oil or refined petroleum products increase the magnitude of these external

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[90] These estimates were developed by FHWA for use in its 1997 *Federal Highway Cost Allocation Study*; *see* http://www.fhwa.dot.gov/policy/hcas/final/index.htm (last accessed Dec. 3, 2007).

[91] *See* Federal Highway Administration, 1997 *Federal Highway Cost Allocation Study*, http://www.fhwa.dot.gov/policy/hcas/final/index.htm, Tables V-22, V-23, and V-24 (last accessed Dec. 3, 2007).

[92] The Federal Highway Administration's estimates of these costs agree closely with some other recent estimates. For example, recent published research conducted by Resources for the Future (RFF) estimates marginal congestion and external accident costs for increased light-duty vehicle use in the U.S. to be 3.5 and 3.0 cents per vehicle-mile in year-2002 dollars. *See* Ian W.H. Parry and Kenneth A. Small, "Does Britain or the U.S. Have the Right Gasoline Tax?" Discussion Paper 02-12, Resources for the Future, 19 and Table 1 (March 2002). *Available at* http://www.rff.org/rff/Documents/RFF-DP-02-12.pdf (last accessed October 20, 2007).

[93] *See, e.g.*, Bohi, Douglas R. and W. David Montgomery (1982). Oil Prices, Energy Security, and Import Policy Washington, DC: Resources for the Future, Johns Hopkins University Press; Bohi, D. R., and M. A. Toman (1993). "Energy and Security: Externalities and Policies," Energy Policy 21:1093-1109; and Toman, M. A. (1993). "The Economics of Energy Security: Theory, Evidence, Policy," in A. V. Kneese and J. L. Sweeney, eds. (1993). Handbook of Natural Resource and Energy Economics, Vol. III. Amsterdam: North-Holland, pp. 1167-1218.

economic costs, thus increasing the true economic cost of supplying transportation fuels above the resource costs of producing them. Conversely, reducing U.S. imports of crude petroleum or refined fuels or reducing fuel consumption can reduce these external costs. Any reduction in their total value that results from improved light truck fuel economy represents an economic benefit of setting more stringent CAFE standards in addition to the value of fuel savings and emissions reductions itself.

Increased U.S. oil imports can impose higher costs on all purchasers of petroleum products, because the U.S. is a sufficiently large purchaser of foreign oil supplies that changes in U.S. demand can affect the world price. The effect of U.S. petroleum imports on world oil prices is determined by the degree of OPEC monopoly power over global oil supplies, and the degree of monopsony power over world oil demand exerted by the U.S. The combination of these two factors means that increases in domestic demand for petroleum products that are met through higher oil imports can cause the price of oil in the world market to rise, which imposes economic costs on all other purchasers in the global petroleum market in excess of the higher prices paid by U.S. consumers.[94] Conversely, reducing U.S. oil imports can lower the world petroleum price, and thus generate benefits to other oil purchasers by reducing these "monopsony costs."

Although the degree of current OPEC monopoly power is subject to debate, the consensus appears to be that OPEC remains able to exercise some degree of control over the response of world oil supplies to variation in world oil prices, so that the world oil market does not behave completely competitively.[95] The extent of U.S. monopsony power is determined by a complex set of factors including the relative importance of U.S. imports in the world oil market, and the sensitivity of petroleum supply and demand to its world price among other participants in the international oil market. Most evidence appears to suggest that variation in U.S. demand for imported petroleum continues to exert some influence on world oil prices, although this influence appears to be limited.[96]

The second component of external economic costs imposed by U.S. petroleum imports arises partly because an increase in oil prices triggered by a disruption in the supply of imported oil reduces the level of output that the U.S. economy can produce. The reduction in potential U.S. economic output depends on the extent and duration of the increases in petroleum product prices that result from a disruption in the supply of imported oil, as well as on whether and how rapidly these prices return to pre-disruption levels. Even if prices for imported oil return completely to their original levels, however, economic output will be at least temporarily reduced from the level that would have been possible without a disruption in oil supplies.

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[94] For example, if the U.S. imports 10 million barrels of petroleum per day at a world oil price of $20 per barrel, its total daily import bill is $200 million. If increasing imports to 11 million barrels per day causes the world oil price to rise to $21 per barrel, the daily U.S. import bill rises to $231 million. The resulting increase of $31 million per day ($231 million minus $200 million) is attributable to increasing daily imports by only 1 million barrels. This means that the incremental cost of importing each additional barrel is $31, or $10 more than the newly-increased world price of $21 per barrel. This additional $10 per barrel represents a cost imposed on all other purchasers in the global petroleum market by U.S. buyers, in excess of the price they pay to obtain those additional imports.

[95] For a summary *see* Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997, 17. *Available at* http://dmses.dot.gov/docimages/pdf93/343894_web.pdf (last accessed Dec. 2, 2007).

[96] *Id.*, 18-19.

Because supply disruptions and resulting price increases tend to occur suddenly rather than gradually, they can also impose costs on businesses and households for adjusting their use of petroleum products more rapidly than if the same price increase had occurred gradually over time. These adjustments impose costs because they temporarily reduce economic output even below the level that would ultimately be reached once the U.S. economy completely adapted to higher petroleum prices. The additional costs to businesses and households reflect their inability to adjust prices, output levels, and their use of energy and other resources quickly and smoothly in response to rapid changes in prices for petroleum products.

Since future disruptions in foreign oil supplies are an uncertain prospect, each of these disruption costs must be adjusted by the probability that the supply of imported oil to the U.S. will actually be disrupted. The "expected value" of these costs – the product of the probability that an oil import disruption will occur and the costs of reduced economic output and abrupt adjustment to sharply higher petroleum prices – is the appropriate measure of their magnitude. Any reduction in these expected disruption costs resulting from a measure that lowers U.S. oil imports represents an additional economic benefit beyond the direct value of savings from reduced purchases of petroleum products.

While the vulnerability of the U.S. economy to oil price shocks is widely thought to depend on total petroleum consumption rather than on the level of oil imports, variation in imports is still likely to have some effect on the magnitude of price increases resulting from a disruption of import supply. In addition, changing the quantity of petroleum imported into the U.S. may also affect the probability that such a disruption will occur. If either the size of the likely price increase or the probability that U.S. oil supplies will be disrupted is affected by oil imports, the expected value of the costs from a supply disruption will also depend on the level of imports.

Businesses and households use a variety of market mechanisms, including oil futures markets, energy conservation measures, and technologies that permit rapid fuel switching to "insure" against higher petroleum prices and reduce their costs for adjusting to sudden price increases. While the availability of these market mechanisms has likely reduced the potential costs of disruptions to the supply of imported oil, consumers of petroleum products are unlikely to take account of costs they impose on others, so these costs are probably not reflected in the price of imported oil. Thus changes in oil import levels probably continue to affect the expected cost to the U.S. economy from potential oil supply disruptions, although this component of oil import costs is likely to be significantly smaller than estimated by studies conducted in the wake of the oil supply disruptions during the 1970s.

The third component of the external economic costs of importing oil into the U.S. includes government outlays for maintaining a military presence to secure the supply of oil imports from potentially unstable regions of the world and to protect against their interruption. Some analysts also include outlays for maintaining the U.S. Strategic Petroleum Reserve (SPR), which is intended to cushion the U.S. economy against the consequences of disruption in the supply of imported oil, as additional costs of protecting the U.S. economy from oil supply disruptions.

NHTSA believes that while costs for U.S. military security may vary over time in response to long-term changes in the actual level of oil imports into the U.S., these costs are unlikely to decline in response to any reduction in U.S. oil imports resulting from raising future CAFE standards for passenger cars and light trucks. U.S. military activities in regions that represent vital sources of oil imports also serve a broader range of security and foreign policy objectives than simply protecting oil supplies, and as a consequence are unlikely to vary significantly in response to changes in the level of oil imports prompted by higher standards.

Similarly, while the optimal size of the SPR from the standpoint of its potential influence on domestic oil prices during a supply disruption may be related to the level of U.S. oil consumption and imports, its actual size has not appeared to vary in response to recent changes in oil imports. Thus while the budgetary costs for maintaining the Reserve are similar to other external costs in that they are not likely to be reflected in the market price for imported oil, these costs do not appear to have varied in response to changes in oil import levels.

In analyzing benefits from its recent actions to increase light truck CAFE standards for model years 2005-07 and 2008-11, NHTSA relied on a 1997 study by Oak Ridge National Laboratory (ORNL) to estimate the value of reduced economic externalities from petroleum consumption and imports.[97] More recently, ORNL updated its estimates of the value of these externalities, using the analytic framework developed in its original 1997 study in conjunction with recent estimates of the variables and parameters that determine their value.[98] These include world oil prices, current and anticipated future levels of OPEC petroleum production, U.S. oil import levels, the estimated responsiveness of oil supplies and demands to prices in different regions of the world, and the likelihood of oil supply disruptions. ORNL prepared its updated estimates of oil import externalities for use by EPA in evaluating the benefits of reductions in U.S. oil consumption and imports expected to result from its Renewable Fuel Standard Rule of 2007 (RFS).[99]

The updated ORNL study was subjected to a detailed peer review by experts selected by EPA, and its estimates of the value of oil import externalities were subsequently revised to reflect their comments and recommendations.[100] Specifically, reviewers recommended that ORNL increase its estimates of the sensitivity of oil supply by non-OPEC producers and oil demand by nations other than the U.S. to changes in the world oil price, as well as reduce its estimate of the sensitivity of U.S. gross domestic product (GDP) to potential sudden increases in world oil prices.

After making the revisions recommended by peer reviewers, ORNL's updated estimates of the monopsony cost associated with U.S. oil imports range from $5.22 to $9.68 per barrel, with a

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[97] Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997. *Available at* http://dmses.dot.gov/docimages/pdf93/343894_web.pdf (last accessed Dec. 2, 2007).

[98] Leiby, Paul N. "Estimating the Energy Security Benefits of Reduced U.S. Oil Imports," Oak Ridge National Laboratory, ORNL/TM-2007/028, Revised July 23, 2007. *Available at* http://pzl1.ed.ornl.gov/energysecurity.html (click on link below "Oil Imports Costs and Benefits") (last accessed Sept. 10, 2007).

[99] 72 FR 23899 (May 1, 2007).

[100] *Peer Review Report Summary: Estimating the Energy Security Benefits of Reduced U.S. Oil Imports*, ICF, Inc., September 2007.

most likely estimate of $7.41 per barrel. These estimates imply that each gallon of fuel saved as a result of adopting higher CAFE standards will reduce the monopsony costs of U.S. oil imports by $0.124 to $0.230 per gallon, with the actual value most likely to be $0.176 per gallon saved. ORNL's updated and revised estimates of the increase in the expected costs associated with oil supply disruptions to the U.S. and the resulting rapid increase in prices for petroleum products amount to $4.54 to $5.84 per barrel, although its most likely estimate of $4.59 per barrel is very close to the lower end of this range. According to these estimates, each gallon of fuel saved will reduce the expected costs disruptions to the U.S. economy by $0.108 to $0.139, with the actual value most likely to be $0.109 per gallon.

The updated and revised ORNL estimates suggest that the combined reduction in monopsony costs and expected costs to the U.S. economy from oil supply disruptions resulting from lower fuel consumption total $0.232 to $0.370 per gallon, with a most likely estimate of $0.286 per gallon. This represents the additional economic benefit likely to result from each gallon of fuel saved by higher CAFE standards, *beyond* the savings in resource costs for producing and distributing each gallon of fuel saved. NHTSA employs this midpoint estimate in its analysis of the benefits from fuel savings projected to result from alternative CAFE standards for model years 2011-15. It also analyzes the effect on these benefits estimates from variation in this value over the range from $0.232 to $0.370 per gallon of fuel saved.

NHTSA's analysis of benefits from alternative CAFE standards does not include cost savings from either reduced outlays for U.S. military operations or maintaining a smaller SPR among the external benefits of reducing gasoline consumption and petroleum imports by means of tightening future standards. This view concurs with that of both the original ORNL study of economic costs from U.S. oil imports and its recent update, which conclude that savings in government outlays for these purposes are unlikely to result form reductions in consumption of petroleum products and oil imports on the scale of those likely to result from the alternative increases in CAFE standards considered for model years 2011-15.

l. Air pollutant emissions

(i) Impacts on criteria air pollutant emissions

This section explains how NHTSA has monetized and modeled air pollutant emissions of criteria pollutants and CO_2 in developing the proposed standards using the EPCA factors. However, this section does not contain NHTSA's assessment of the potential environmental impacts of the proposed standards and reasonable alternatives for purposes of the National Environmental Policy Act (NEPA), 42 U.S.C. 4321-4347. On March 28, 2008, NHTSA published a notice of intent to prepare an environmental impact statement (EIS) and opened the NEPA scoping process (73 FR 16615). NHTSA will consider the potential environmental impacts of the proposed standards and reasonable alternatives, including impacts associated with CO_2 emissions and climate change, through the NEPA process. NHTSA's NEPA analysis will inform any further action on the proposed standards, consistent with NEPA and EPCA.

While reductions in domestic fuel refining and distribution that result from lower fuel consumption will reduce U.S. emissions of criteria pollutants, additional vehicle use associated with the rebound effect from higher fuel economy will increase emissions of these pollutants.

Thus the net effect of stricter CAFE standards on emissions of each criteria pollutant depends on the relative magnitudes of its reduced emissions in fuel refining and distribution, and increases in its emissions from vehicle use. Because the relationship between emission rates (emissions per gallon refined of fuel or mile driven) in fuel refining and vehicle use is different for each criteria pollutant, the net effect of fuel savings from the proposed standards on total emissions of each pollutant is likely to differ. Criteria air pollutants emitted by vehicles and during fuel production include carbon monoxide (CO), hydrocarbon compounds (usually referred to as "volatile organic compounds," or VOC), nitrogen oxides (NO_x), fine particulate matter (PM2.5), and sulfur oxides (SO_x).

The increase in emissions of these pollutants from additional vehicle use due to the rebound effect is estimated by multiplying the increase in total miles driven by vehicles of each model year and age by age-specific emission rates per vehicle-mile for each pollutant. NHTSA developed these emission rates using EPA's MOBILE6.2 motor vehicle emissions factor model.[101] Emissions of these pollutants also occur during crude oil extraction and transportation, fuel refining, and fuel storage and distribution. The reduction in total emissions from each of these sources thus depends on the extent to which fuel savings result in lower imports of refined fuel, or in reduced domestic fuel refining. To a lesser extent, they also depend on whether any reduction in domestic gasoline refining is translated into reduced imports of crude oil or reduced domestic extraction of petroleum.

Based on analysis of changes in U.S. gasoline imports and domestic gasoline consumption forecast in AEO's 2008 Early Release, NHTSA tentatively estimates that 50 percent of fuel savings resulting from higher CAFE standards will result in reduced imports of refined gasoline, while the remaining 50 percent will reduce domestic fuel refining.[102] The reduction in domestic refining is assumed to leave its sources of crude petroleum unchanged from the mix of 90 percent imports and 10 percent domestic production projected by AEO.

NHTSA proposes to estimate reductions in criteria pollutant emissions from gasoline refining and distribution using emission rates obtained from Argonne National Laboratories' Greenhouse Gases and Regulated Emissions in Transportation (GREET) model.[103] The GREET model provides separate estimates of air pollutant emissions that occur in four phases of fuel production and distribution: crude oil extraction, crude oil transportation and storage, fuel refining, and fuel distribution and storage.[104] We tentatively assume that reductions in imports of refined fuel

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[101] U.S. Environmental Protection Agency, MOBILE6 Vehicle Emission Modeling Software, *available at* http://www.epa.gov/otaq/m6.htm#m60 (last accessed Sept. 10, 2007).

[102] Estimates of the response of gasoline imports and domestic refining to fuel savings from stricter standards are variable and highly uncertain, but our preliminary analysis indicates that under any reasonable assumption about these responses, the magnitude of the net change in criteria pollutant emissions (accounting for both the rebound effect and changes in refining emissions) is extremely low relative to their current total.

[103] Argonne National Laboratories, *The Greenhouse Gas and Regulated Emissions from Transportation (GREET) Model*, Version 1.8, June 2007, *available at* http://www.transportation.anl.gov/software/GREET/index.html (last accessed Sept. 10, 2007).

[104] Emissions that occur during vehicle refueling at retail gasoline stations (primarily evaporative emissions of volatile organic compounds, or VOCs) are already accounted for in the "tailpipe" emission factors used to estimate the emissions generated by increased light truck use. GREET estimates emissions in each phase of gasoline production and distribution in mass per unit of gasoline energy content; these factors are then converted to mass per gallon of gasoline using the average energy content of gasoline.

would reduce criteria pollutant emissions during fuel storage and distribution only. Reductions in domestic fuel refining using imported crude oil as a feedstock are tentatively assumed to reduce emissions during crude oil transportation and storage, as well as during gasoline refining, distribution, and storage, because less of each of these activities would be occurring. Similarly, reduced domestic fuel refining using domestically-produced crude oil is tentatively assumed to reduce emissions during all phases of gasoline production and distribution.[105]

The net changes in emissions of each criteria pollutant are calculated by adding the increases in their emissions that result from increased vehicle use and the reductions that result from lower domestic fuel refining and distribution. The net change in emissions of each criteria pollutant is converted to an economic value using estimates of the economic costs per ton emitted (which result primarily from damages to human health) developed by EPA and submitted to the federal Office of Management and Budget for review. For certain criteria pollutants, EPA estimates different per-ton costs for emissions from vehicle use than for emissions of the same pollutant during fuel production, reflecting differences in their typical geographic distributions, contributions to ambient pollution levels, and resulting population exposure.

(ii) Reductions in CO_2 emissions

Fuel savings from stricter CAFE standards also result in lower emissions of carbon dioxide (CO_2), the main greenhouse gas emitted as a result of refining, distribution, and use of transportation fuels.[106] Lower fuel consumption reduces carbon dioxide emissions directly, because the primary source of transportation-related CO_2 emissions is fuel combustion in internal combustion engines. NHTSA tentatively estimates reductions in carbon dioxide emissions resulting from fuel savings by assuming that the entire carbon content of gasoline, diesel, and other fuels is converted to carbon dioxide during the combustion process.[107]

Reduced fuel consumption also reduces carbon dioxide emissions that result from the use of carbon-based energy sources during fuel production and distribution.[108] NHTSA currently

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[105] In effect, this assumes that the distances crude oil travels to U.S. refineries are approximately the same regardless of whether it travels from domestic oilfields or import terminals, and that the distances that gasoline travels from refineries to retail stations are approximately the same as those from import terminals to gasoline stations.

[106] Carbon dioxide emissions account for more than 97 percent of total greenhouse gas emissions from the refining and use of transportation fuels; *see* U.S. Environmental Protection Agency, *Draft Inventory of GHG Emissions and Sinks (1990-1999)*, Tables ES-1 and ES-4. *Available at* http://www.epa.gov/globalwarming/publications/emissions/us2001/energy.pdf (last accessed Sept. 10, 2007).

[107] This assumption results in a slight overestimate of carbon dioxide emissions, since a small fraction of the carbon content of gasoline is emitted in the forms of carbon monoxide and unburned hydrocarbons. However, the magnitude of this overestimate is likely to be extremely small. This approach is consistent with the recommendation of the Intergovernmental Panel on Climate Change for "Tier 1" national greenhouse gas emissions inventories. *Cf.* Intergovernmental Panel on Climate Change, *2006 Guidelines for National Greenhouse Gas Inventories*, Volume 2, Energy, p. 3.16.

[108] We note that NHTSA did not, for purposes of this proposed rulemaking, attempt to estimate changes in emissions of greenhouse gases (GHGs) other than carbon dioxide. This was because carbon dioxide itself accounts for more than 95 percent of the total CO_2-equivalent emissions of fuel production and use, even with other GHGs that result from those activities (principally methane and nitrous oxide) weighted by their higher global warming potentials (GWPs) relative to CO_2. Calculated from U.S. EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2005, EPA430-R-07-02, April 15, 2007. *Available at* http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf, Table ES-2.

estimates the reductions in CO_2 emissions during each phase of fuel production and distribution using carbon dioxide emission rates obtained from the GREET model, using the previous assumptions about how fuel savings are reflected in reductions in each phase. The total reduction in CO_2 emissions from the improvement in fuel economy under each alternative CAFE standard is the sum of the reductions in emissions from reduced fuel use and from lower fuel production and distribution.

iii) Economic value of reductions in CO_2 emissions

NHTSA has taken the economic benefits of reducing CO_2 emission into account in this rulemaking, both in developing proposed CAFE standards and in assessing the economic benefits of each alternative that was considered. As noted above, the 9th Circuit found in CBD that NHTSA had been arbitrary and capricious in deciding not to monetize the benefit of reducing CO_2 emissions, saying that the agency had not substantiated the conclusion in its April 2006 final rule that the appropriate course was not to monetize (i.e., quantify the value of) carbon emissions reduction at all.

To this end, NHTSA reviewed published estimates of the "social cost of carbon emissions" (SCC). The SCC refers to the marginal cost of additional damages caused by the increase in expected climate impacts resulting from the emission of each additional metric ton of carbon, which is emitted in the form of CO_2.[109] It is typically estimated as the net present value of the impact over some time period (100 years or longer) of one additional ton of carbon emitted into the atmosphere. Because accumulated concentrations of greenhouse gases in the atmosphere and the projected impacts on global climate are increasing over time, the economic damages resulting from each additional ton of CO_2 emissions in future years are believed to be greater as a result. Thus estimates of the SCC are typically reported for a specific year, and these estimates are generally larger for emissions in more distant future years.

There is substantial variation among different authors' estimates of the SCC, much of which can be traced to differences in their underlying assumptions about several variables. These include the sensitivity of global temperatures and other climate attributes to increasing atmospheric concentrations of greenhouse gases, discount rates applied to future economic damages from climate change, whether damages sustained by developing regions of the globe should be weighted more heavily than damages to developed nations, how long climate changes persist once they occur, and the economic valuation of specific climate impacts.[110]

Taken as a whole, recent estimates of the SCC may underestimate the true damage costs of carbon emissions because they often exclude damages caused by extreme weather events or

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[109] Carbon itself accounts for 12/44, or about 27%, of the mass of carbon dioxide (12/44 is the ratio of the molecular weight of carbon to that of carbon dioxide). Thus each ton of carbon emitted is associated with 44/12, or 3.67, tons of carbon dioxide emissions. Estimates of the SCC are typically reported in dollars per ton of carbon, and must be divided by 3.67 to determine their equivalent value per ton of carbon dioxide emissions.

[110] For a discussion of these factors, see Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez, 2007: Perspectives on climate change and sustainability. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, pp. 821-824.

climate response scenarios with low probabilities but potentially extreme impacts, and may underestimate the climate impacts and damages that could result from multiple stresses on the global climatic system. At the same time, however, many studies fail to consider potentially beneficial impacts of climate change, and do not adequately account for how future development patterns and adaptations could reduce potential impacts from climate change or the economic damages they cause.

Given the uncertainty surrounding estimates of the SCC, the use of any single study may not be advisable since its estimate of the SCC will depend on many assumptions made by its authors. The Working Group II's contribution to the Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC)[111] notes that:

> The large ranges of SCC are due in the large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses, and discount rates.

Although the IPCC does not recommend a single estimate of the SCC, it does cite the Tol (2005) study on four separate occasions (pages 17, 65, 813, 822) as the only available survey of the peer-reviewed literature that has itself been subjected to peer review. Tol developed a probability function using the SCC estimates of the peer reviewed literature and found estimates ranging from less than zero to over $200 per metric ton of carbon. In an effort to resolve some of the uncertainty in reported estimates of climate damage costs from carbon emissions, Tol (2005) reviewed and summarized one hundred and three estimates of the SCC from 28 published studies. He concluded that when only peer-reviewed studies published in recognized journals are considered, "…climate change impacts may be very uncertain but is unlikely that the marginal damage costs of carbon dioxide emissions exceed $50 per [metric] ton carbon [about $14 per metric ton of CO2]." [112] He also concluded that the costs may be less than $14.

Because of the number of assumptions required by each study, the wide range of uncertainty surrounding these assumptions, and their critical influence on the resulting estimates of climate damage costs, some studies have undoubtedly produced estimates of the SCC that are unrealistically high, while others are likely to have estimated values that are improbably low. Using a value for the SCC that reflects the central tendency of estimates drawn from many studies reduces the chances of relying on a single estimate that subsequently proves to be biased.

It is important to note that estimates of the SCC almost invariably include the value of worldwide damages from potential climate impacts caused by carbon dioxide emissions, and are not confined to damages likely to be suffered within the U.S. In contrast, the other estimates of costs and benefits of increasing fuel economy included in this proposal include only the economic values of impacts that occur within the U.S. For example, the economic value of reducing criteria air pollutant emissions from overseas oil refineries is not counted as a benefit resulting

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[111] Climate Change 2007 – Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the IPCC, 17. Available at http://www.ipcc-wg2.org (last accessed <Feb. 4, 2008>).

[112] Tol, Richard. The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties. Energy Policy 33 (2005) 2064–2074, 2072. The summary SCC estimates reported by Tol are assumed to be denominated in U.S. dollars of the year of publication, 2005.

from this rule, because any reduction in damages to health and property caused by overseas emissions are unlikely to be experienced within the U.S.

In contrast, the reduced value of transfer payments from U.S. oil purchasers to foreign oil suppliers that results when lower U.S. oil demand reduces the world price of petroleum (the reduced "monopsony effect") is counted as a benefit of reducing fuel use.[113] If the agency's analysis was conducted from a worldwide rather than a U.S. perspective, however, the benefit from reducing air pollution overseas would be included, while reduced payments from U.S. oil consumers to foreign suppliers would not.

In order to be consistent with NHTSA's use of exclusively domestic costs and benefits in prior CAFE rulemakings, the appropriate value to be placed on changes climate damages caused by carbon emissions should be one that reflects the change in damages to the United States alone. Accordingly, NHTSA notes that the value for the benefits of reducing CO_2 emissions might be restricted to the fraction of those benefits that are likely to be experienced within the United States.

Although no estimates of benefits to the U.S. itself that are likely to result from reducing CO_2 emissions are currently available, NHTSA expects that if such values were developed, the agency would employ those rather than global benefit estimates in its analysis. NHTSA also anticipates that if such values were developed, they would be lower than comparable global values, since the U.S. is likely to sustain only a fraction of total global damages resulting from climate change.

In the meantime, the agency has elected to use the IPCC estimate of $43 per metric ton of carbon as an upper bound on the benefits resulting from reducing each metric ton of U.S. emissions.[114] This corresponds to approximately $12 per metric ton of CO_2 when expressed in 2006 dollars. This estimate is based on the 2005 Tol study.[115] The Tol study is cited repeatedly as an authoritative survey in various IPCC reports, which are widely accepted as representing the general consensus in the scientific community on climate change science. Since the IPCC estimate includes the worldwide costs of potential damages from carbon dioxide emissions, NHTSA has elected to employ it as an upper bound on the estimated value of the reduction in U.S. domestic damage costs that is likely to result from lower CO_2 emissions.[116]

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[113] The reduction in payments from U.S. oil purchasers to domestic petroleum producers is not included as a benefit, since it represents a transfer that occurs entirely within the U.S. economy.

[114] The estimate of $43 per ton of carbon emissions is reported by Tol (p. 2070) as the mean of the "best" estimates reported in peer-reviewed studies (see fn. 4). It thus differs from the mean of all estimates reported in the peer-reviewed studies surveyed by Tol. The $43 per ton value is also attributed to Tol by IPCC Working Group II (2007), p. 822.

[115] Tol's more recent (2007) and inclusive survey has been published online with peer-review comments. The agency has elected not to rely on the estimates it reports, but will consider doing so in its analysis of the final rule if the survey has been published, and will also consider any other newly-published evidence.

[116] For purposes of comparison, we note that in the rulemaking to establish CAFE standards for MY 2008-11 light trucks, NRDC recommended a value of $10 to $25 per ton of CO2 emissions reduced by fuel savings and both Environmental Defense and Union of Concerned Scientists recommended a value of $50 per ton of carbon (equivalent to about $14 per ton of CO_2 emissions).

The IPCC Working Group II Fourth Assessment Report (2007, p. 822) further suggests that the SCC of carbon is growing at an annual 2.4 percent growth rate, based on estimated increases in damages from future emissions reported in published studies. NHTSA has also elected to apply this growth rate to Tol's original 2005 estimate. Thus by 2011, the agency estimates that the upper bound on the benefits of reducing CO_2 emissions will have reached about $14 per metric ton of CO_2, and will continue increase by 2.4 percent annually thereafter.

In setting a lower bound, the agency agrees with the IPCC Working Group II (2007) report that "significant warming across the globe and the locations of significant observed changes in many systems consistent with warming is very unlikely to be due solely to natural variability of temperatures or natural variability of the systems" (pp. 9). Although this finding suggests that the global value of economic benefits from reducing carbon dioxide emissions is unlikely to be zero, it does not necessarily rule out low or zero values for the benefit to the U.S. itself from reducing emissions.

For most of the analysis it performed to develop this proposal, NHTSA required a single estimate for the value of reducing CO_2 emissions. The agency thus elected to use the midpoint of the range from $0 to $14 (or $7.00) per metric ton of CO_2 as the initial value for the year 2011, and assumed that this value would grow at 2.4 percent annually thereafter. This estimate is employed for the analyses conducted using the Volpe CAFE model to support development of the proposed standards. The agency also conducted sensitivity analyses of the benefits from reducing CO_2 emissions using both the upper ($14 per metric ton) and lower ($0 per metric ton) bounds of this range.

NHTSA seeks comment on its tentative conclusions for the value of the SCC, the use of a domestic versus global value for the economic benefit of reducing CO_2 emissions, the rate at which the value of the SCC grows over time, the desirability of and procedures for incorporating benefits from reducing emissions of greenhouse gases other than CO_2, and any other aspects of developing a reliable SCC value for purposes of establishing CAFE standards.

m. The value of increased driving range

Improving vehicles' fuel economy may also increase their driving range before they require refueling. By reducing the frequency with which drivers typically refuel their vehicles, and by extending the upper limit of the range they can travel before requiring refueling, improving fuel economy thus provides some additional benefits to their owners. (Alternatively, if manufacturers respond to improved fuel economy by reducing the size of fuel tanks to maintain a constant driving range, the resulting cost saving will presumably be reflected in lower vehicle sales prices.)

No direct estimates of the value of extended vehicle range are readily available, so NHTSA's analysis calculates the reduction in the annual number of required refueling cycles that results from improved fuel economy, and applies DOT-recommended values of travel time savings to convert the resulting time savings to their economic value.[117] As an illustration of how the value

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[117] *See* Department of Transportation, Guidance Memorandum, "The Value of Saving Travel Time: Departmental Guidance for Conducting Economic Evaluations," Apr. 9, 1997. *Available at*

of extended refueling range is estimated, a typical small light truck model has an average fuel tank size of approximately 20 gallons. Assuming that drivers typically refuel when their tanks are 20 percent full (*i.e.*, 4 gallons in reserve), increasing this model's actual on-road fuel economy from 24 to 25 mpg would extend its driving range from 384 miles (= 16 gallons x 24 mpg) to 400 miles (= 16 gallons x 25 mpg). Assuming that it is driven 12,000 miles/year, this reduces the number of times it needs to be refueled each year from 31.3 (= 12,000 miles per year / 384 miles per refueling) to 30.0 (= 12,000 miles per year / 400 miles per refueling), or by 1.3 refuelings per year.

Weighted by the nationwide mix of urban (about 2/3) and rural (about 1/3) driving and average vehicle occupancy for all driving trips (1.6 persons), the DOT-recommended value of travel time per vehicle-hour is $24.00 (in 2006 dollars).[118] Assuming that locating a station and filling up requires ten minutes, the annual value of time saved as a result of less frequent refueling amounts to $5.20 (calculated as 10/60 x 1.3 x $24.00). This calculation is repeated for each future calendar year that vehicles of each model year affected by the alternative CAFE standards proposed in this rule would remain in service. Like fuel savings and other benefits, however, the value of this benefit declines over a model year's lifetime, because a smaller number of vehicles originally produced during that model year remain in service each year, and those remaining in service are driven fewer miles.

n. Discounting future benefits and costs

Discounting future fuel savings and other benefits is intended to account for the reduction in their value to society when they are deferred until some future date rather than received immediately. The discount rate expresses the percent decline in the value of these benefits – as viewed from today's perspective – for each year they are deferred into the future. NHTSA uses a rate of 7 percent per year to discount the value of future fuel savings and other benefits to analyze the potential impacts of alternative CAFE standards. However, the agency also performs an alternative analysis of benefits from alternative increases in CAFE standards using a 3 percent discount rate, and seeks comment on whether the standards should be set using a 3 percent rate instead of a 7 percent rate.

There are several reasons that NHTSA relies primarily on 7 percent as the appropriate rate for discounting future benefits from increased CAFE standards. First, OMB Circular A-4 indicates that this rate reflects the economy-wide opportunity cost of capital.[119] It also states that this "is the appropriate discount rate whenever the main effect of a regulation is to displace or alter the use of capital in the private sector."[120] We believe that a substantial portion of the cost of this

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http://ostpxweb.dot.gov/policy/Data/VOT97guid.pdf (last accessed October 20, 2007); update *available at* http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf (last accessed October 20, 2007).

[118] The hourly wage rate during 2006 is estimated to be $24.00. Personal travel (94.4 percent of urban travel) is valued at 50 percent of the hourly wage rate. Business travel (5.6 percent or urban travel) is valued at 100 percent of the hourly wage rate. For intercity travel, personal travel (87 percent) is valued at 70 percent of the wage rate, while business travel (13 percent) is valued at 100 percent of the wage rate. The resulting values of travel time are $12.67 for urban travel and $17.66 for intercity travel, and must be multiplied by vehicle occupancy (1.6) to obtain the estimate value of time per vehicle hour.

[119] Office of Management and Budget, Circular A-4, "Regulatory Analysis," September 17, 2003, 33. *Available at* http://www.whitehouse.gov/omb/circulars/a004/a-4.pdf (last accessed Feb. 14, 2008).

[120] *Id.*

regulation may come at the expense of other investments the auto manufacturers might otherwise make. Several large manufacturers are resource-constrained with respect to their engineering and product-development capabilities. As a result, other uses of these resources will be foregone while they are required to be applied to technologies that improve fuel economy.

Second, 7 percent also appears to be an appropriate rate to the extent that the costs of the regulation come at the expense of consumption as opposed to investment. NHTSA believes that financing rates on vehicle loans represent an appropriate discount rate, because they reflect the opportunity costs faced by consumers when buying vehicles with greater fuel economy and a higher purchase price. Most new and used vehicle purchases are financed, and because most of the benefits from higher fuel economy standards accrue to vehicle purchasers in the form of fuel savings, the appropriate discount rate is the interest rate buyers pay on loans to finance their vehicle purchases.[121]

According to the Federal Reserve, the interest rate on new car loans made through commercial banks has closely tracked the rate on 10-year treasury notes, but exceeded it by about 3 percent.[122] The official Administration forecast is that real (or inflation-adjusted) interest rates on 10-year treasury notes will average about 3 percent through 2016, implying that 6 percent is a reasonable forecast for the real interest rate on new car loans.[123] In turn, the interest rate on used car loans made through automobile financing companies has closely tracked the rate on new car loans made through commercial banks, but exceeded it by about 3 percent.[124] (We consider rates on loans that finance used car purchases, because some of the fuel savings resulting from improved fuel economy accrue to used car buyers.) Given the 6 percent estimate for new car loans, a reasonable forecast for used car loans is thus 9 percent.

Because the benefits of fuel economy accrue to both new and used car owners, a discount rate between 6 percent and 9 percent is thus appropriate for evaluating future benefits resulting from more stringent fuel economy standards. Assuming that new car buyers discount fuel savings at 6 percent for 5 years (the average duration of a new car loan) [125] and that used car buyers discount fuel savings at 9 percent for 5 years (the average duration of a used car loan),[126] the single constant discount rate that yields equivalent present value fuel savings is very close to 7 percent.

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[121] Some empirical evidence also demonstrates that used car purchasers are willing to pay higher prices for greater fuel economy; *see, e.g.*, James A. Kahn, "Gasoline Price Expectations and the Used Automobile Market: A Rational Expectations Asset Price Approach," *Quarterly Journal of Economics*, Vol. 101 (May 1986), 323-339.

[122] *See* Federal Reserve Bank, Statistical Release H.15, Selected Interest Rates (Weekly) (click on "Historical Data," then "Treasury constant maturities," then "10-year, monthly"), *available at* http://www.federalreserve.gov/Releases/H15/data/Monthly/H15_TCMNOM_Y10.txt (last accessed February 13, 2008); and Federal Reserve Bank, Statistical Release G.19, Consumer Credit, (click on "Historical Data," then "Terms of Credit") *available at* http://www.federalreserve.gov/releases/g19/hist/cc_hist_tc.html (last accessed February 13, 2008).

[123] See The White House, Joint Press Release of the Council of Economic Advisors, the Department of the Treasury, and the Office of Management and Budget, November 29, 2007, *available at* http://www.whitehouse.gov/news/releases/2007/11/20071129-4.html (last accessed February 13, 2008).

[124] See supra [2 above here] and Federal Reserve Bank, Statistical Release G.20, Finance Companies, (click on "Historical Data," then "Terms of Credit") *available at* http://www.federalreserve.gov/releases/g20/hist/fc_hist_tc.html (last accessed February 13, 2008).

[125] *Id.*

[126] *Id.*

However, NHTSA also seeks comment on whether a discount rate of 3 percent would be more appropriate for this proposed rulemaking. OMB Circular A-4 also states that when regulation primarily and directly affects private consumption (*e.g.*, through higher consumer prices for goods and services), instead of primarily affecting the allocation of capital, a lower discount rate may be appropriate. The alternative discount rate that is most appropriate in this case is the social rate of time preference, which refers to the rate at which society discounts future consumption to determine its value at the present time. The rate that savers are willing to accept to defer consumption into the future when there is no risk that borrowers will fail to pay them back offers one possible measure of the social rate of time preference. As noted above, the real rate of return on long-term government debt, which has averaged around 3 percent over the last 30 years, provides a reasonable estimate of this value.

In the context of CAFE standards for motor vehicles, the appropriate discount rate depends on one's view of how the costs and benefits of more stringent standards are distributed between vehicle manufacturers and consumers. Given that the discount rate plays a big role in the level of the standards under a "social optimization" context, NHTSA conducted an analysis of what the standards and associated costs and benefits would be if the future benefits are discounted at 3 percent.

o. Accounting for uncertainty in benefits and costs

In analyzing the uncertainty surrounding its estimates of benefits and costs from alternative CAFE standards, NHTSA has considered alternative estimates of those assumptions and parameters likely to have the largest effect. These include the projected costs of fuel economy-improving technologies and their expected effectiveness in reducing vehicle fuel consumption, forecasts of future fuel prices, the magnitude of the rebound effect, the reduction in external economic costs resulting from lower U.S. oil imports, the value to the U.S. economy of reducing carbon dioxide emissions, and the discount rate applied to future benefits and costs. The range for each of these variables employed in the uncertainty analysis is presented in the section of this notice discussing each variable.

The uncertainty analysis was conducted by assuming independent normal probability distributions for each of these variables, using the low and high estimates for each variable as the values below which 5 percent and 95 percent of observed values are believed to fall. Each trial of the uncertainty analysis employed a set of values randomly drawn from each of these probability distributions, assuming that the value of each variable is independent of the others. Benefits and costs of each alternative standard were estimated using each combination of variables. A total of 1,000 trials were used to establish the likely probability distributions of estimated benefits and costs for each alternative standard.

C. How has NHTSA used the Volpe model to select the proposed standards?

1. Establishing a continuous function standard

NHTSA's analysis supporting determination of the proposed continuous function standard builds on the analysis that supported the determination of the standards in NHTSA's 2006 light truck final rule. That process involved three steps.[127]

In "phase one," NHTSA added fuel saving technologies to each manufacturer's fleet, model by model, for a model year until the net benefit from doing so reached its maximum value (*i.e.*, until the incremental cost of improving its fuel economy further just equals the incremental value of fuel savings and other benefits from doing so). This was done for each of the seven largest manufacturers. Data points representing each vehicle's size and "optimized" fuel economy from the light truck fleets of those manufacturers were then combined into a single data set.

In "phase two," a preliminary continuous function was statistically fitted through these data points, subject to constraints at the upper and lower ends of the footprint range.

Once a preliminary continuous function was statistically fitted to the data for a model year, "phase three" was performed. In that phase, the level of the function was adjusted to maximize net benefits, that is, the preliminary continuous function was raised or lowered until industry-wide (limited to the seven largest manufacturers) benefits were maximized.

For NHTSA's 2006 light truck rulemaking, the optimization procedure was applied in its entirety only for MY 2011. The levels of the functions for MYs 2008-2010 were set at levels producing incremental costs approximately equivalent to those produced by the alternative Unreformed CAFE standards promulgated for those model years in the same rulemaking.

Analysis conducted by NHTSA to prepare for the current proposed rulemaking revealed several opportunities to refine the procedure described above before applying it to this action, which spans several model years. The resultant procedure is described below.

2. Calibration of initial continuous function standards

For the optimized standards, the first step in the current procedure involves all three phases described above. Separately, for each of the seven largest manufacturers, the agency determined the level of additional technology that would maximize net benefits. The agency then combined the resultant fleets and used standard statistical analysis procedures to specify a continuous function (*i.e.*, a function without abrupt changes) with asymptotes[128] set at the average fuel economy levels of the smallest and largest vehicles in this "optimized" fleet.[129]

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[127] *See* 71 FR 17596-97 (Apr. 6, 2006) for a more complete discussion of this process.

[128] Some functions are not bounded. For example, a line that is not flat will increase in one direction without limit and will, in the other direction, decrease without limit. The continuous function applied by the agency is of a form with upper and lower boundaries. Even as vehicle footprint declines or increases, the function's value (in mpg or grams/mile) will never exceed or fall below a specific value. These upper and lower limits are called asymptotes.

[129] Consistent with EPCA, the passenger car and light truck fleets were analyzed separately. For passenger cars, the agency determined the asymptotes of the continuous function by calculating the average fuel economy of the smallest 8 percent and the largest 5 percent of the fleet. For light trucks, the agency considered the smallest 11 percent and the largest 10 percent of the fleet. These cohorts were determined by identifying gaps in the distribution of vehicles according to footprint.

In the 2006 Light Truck Rule, NHTSA created an attribute-based fuel economy standard based upon a continuous function using a logistic curve. The 2006 rulemaking, and its antecedent advanced notice of proposed rulemaking, contains an extended discussion of alternative approaches, including a bin-based system and different potential curves.[130] As discussed below, the rulemaking explains NHTSA's decision to promulgate a standard based on a logistic ("S shaped") curve with constrained asymptotes (upper and lower limits).

Although we did not explicitly recognize it in the MY 2008-2011 light truck rulemaking, NHTSA now wishes to note that any continuous function with upper and lower asymptotes, as was promulgated in the last rulemaking and is proposed in this rulemaking, in fact has an absolute lower limit specified by the lower asymptote, which guards against the risk of upsizing to a great degree. As vehicle footprint continues to increase, decreases in the corresponding target become progressively smaller, such that the target approaches but never reaches the value of the lower asymptote. Because the required level of CAFE is the harmonic average of targets applicable to a manufacturer's vehicle models, the value of the standard can approach but will never fall to the value of this lower asymptote, no matter how far the manufacturer's product mix shifts toward larger vehicles. This will prevent loss of fuel savings due to manufacturer decisions to upsize their vehicles.

NHTSA has adopted the same approach for this proposed rulemaking. However, while the principles underlying the Agency's decision in 2006 continue to be compelling, the application of the logistic curve approach to passenger cars has persuaded us that it may be appropriate to reconsider the choice of the logistic curve for setting a continuous function, at least for passenger cars.

NHTSA would prefer to let vehicle data define the shape of the curve used for the continuous functions. However, NHTSA must also weigh certain practical public policy considerations in establishing the continuous function, including for regions where vehicles are not currently being built in significant numbers, but might become available in the future. In establishing footprint-based CAFE standards, the agency's objective is not to reflect a clear engineering relationship between footprint and fuel economy. Other attributes would be more closely correlated with fuel economy. The agency's objective is to make CAFE regulations more consistent with public policy goals, in particular (1) a rebalancing of requirements such that full-line manufacturers are not disproportionately burdened and (2) the establishment of an incentive that discourages manufacturers from responding to CAFE standards in ways that could compromise occupant protection and highway safety. While it is helpful that the attribute—in this case footprint—has an observed relationship to fuel economy, it is not necessary that this relationship be isolated from accompanying relationships (e.g., between weight and fuel economy) that can be better related to estimable physical processes. Similarly, it is more important that the functional form for the attribute-based standard yield desirable outcomes than that it have a clear foundation in estimable physical processes.

In general, public policy considerations and available vehicle data combine to suggest that the fuel economy standard should be generally downward sloping (on a fuel economy basis) with respect to NHTSA's chosen attribute, vehicle footprint. The arguments that favor an attribute-

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[130] FR

based system (maintaining consumer choice, protecting safety, more equitable distribution of costs, reducing the cost of regulation) all argue for a downward sloping curve. Larger vehicles should, in principle, have higher drag, weigh more, and therefore have greater inertia than otherwise identical smaller vehicles. Hence, all other factors remaining equal, larger vehicles should have lower fuel economy than smaller vehicles. Therefore, the selection of vehicle footprint as the reference attribute should produce downward sloping curves. Also, the tendency of larger vehicles to have lower fuel economy than smaller vehicles should provide some disincentive to shift to larger vehicles rather than adding technology; although doing so would tend to reduce the required CAFE level, it would also tend to reduce the achieved CAFE level.

However, vehicle data, by itself, does not necessarily define what functional form that the curve ought to take. In the 2006 light truck rulemaking, NHTSA considered a linear, quadratic, exponential, unconstrained logistic, and constrained logistic functions as possible alternatives. For light trucks, the various approaches produced broadly similar standards through the most commonly used vehicle sizes, but drastically different standards at the high and low ends of the range.

- Linear functions produced very high fuel economy standards for the smallest vehicles, and low standards for the largest vehicles.

- The quadratic function generated a minimum at about 75 square feet, and then perversely turned upward for vehicles with larger footprints. The standard for very small vehicles was unreasonably high.

- The exponential and unconstrained logistic functions produced unreasonably high standards for small vehicles, but flattened out for larger vehicles.

- The constrained logistic function provided a broadly linear downward-sloping through the most commonly used vehicle sizes, along with basically flat standards for very large and very small vehicles.

On this basis, NHTSA believed that, while the data did not dictate a particular functional form, public policy considerations made the constrained logistic function particularly attractive. The considerations include:

- A relatively flat standard for larger vehicles acts as a de facto ‘backstop’ for the standard in the event that future market conditions encourage manufacturers to build very large vehicles. Nothing prevents manufacturers from building larger vehicles. With a logistic curve, however, vehicles upsizing beyond some limit face a flat standard that is increasingly difficult to meet.

- A constrained logistic curve doesn’t impose unachievable fuel economy standards on vehicles that have unusually small footprints, thus continuing to keep manufacturing fuel-efficient small vehicles available as a compliance option.

- Infeasible sections of the curve can have may be unimportant for the industry at large while having a particular adverse impact on manufacturers that specialize in very large or small vehicles, for example, two-seater sports car.

- The transition from the ‘flat’ portions of the curve to the ‘slope’ portions of the curve is smooth and gradual, reducing the incentive for manufacturers to achieve compliance through marginal changes in vehicle size.

- The inflection points are set by the data and can potentially vary from year to year, rather than being chosen by NHTSA.

On the other hand, a constrained logistic curve shares with other functional forms a risk of an excessively steep or excessively flat slope. The slope of the compliance curve may be considered as ‘too steep’ for public policy purposes when manufacturers can achieve appreciable reductions in compliance costs by marginally increasing the size of a vehicle’s footprint—e.g., the cost of compliance from upsizing is lower than other cost-effective compliance methods open to manufacturers.

A slope is ‘too flat’ for public policy purposes when it negates the advantages of an attribute-based system: where the standard doesn’t meaningfully vary with respect to changes in the underlying attribute, it cannot be said to be an attribute-based system within the meaning of the statute.

NHTSA chose footprint as the best attribute for an attribute-based standard in part because we believed changing a vehicle’s footprint would involve significant costs for manufacturers, probably requiring a redesign of the vehicle.

While “too steep” or “too flat” inevitably cannot be defined with precision, they need to be kept in mind.

For the proposed standards, the agency defined the continuous function using the following formula:

$$T = \frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\frac{e^{(x-c)/d}}{1+e^{(x-c)/d}}}$$

where

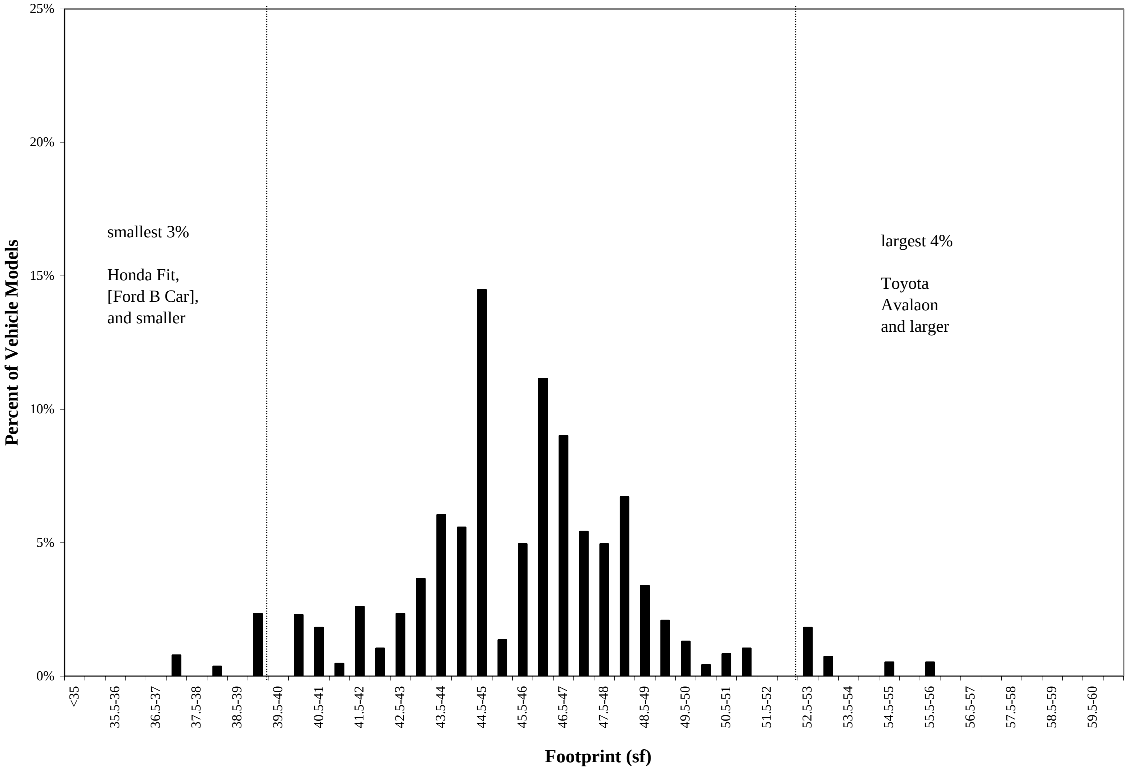
T = the fuel economy target (in mpg)
a = the maximum fuel economy target (in mpg)
b = the minimum fuel economy target (in mpg)

c = the footprint value (in square feet) at which the fuel economy target is midway between *a* and *b*[131]
d = the parameter (in square feet) defining the rate at which the value of targets decline from the largest to smallest values
e = 2.718[132]
x = footprint (in square feet, rounded to the nearest tenth) of the vehicle model

As for analysis of the light truck rule promulgated in 2006, NHTSA constrained this function by determining the maximum and minimum targets (*a* and *b*) and then holding those targets constant while using statistical techniques to fit the other two coefficients (*c* and *d*) in this equation.

In the current analysis for passenger cars, the upper and lower asymptotes are based on the smallest three percent and largest four percent, respectively, of the fleet. These reflect footprint values defining distinct cohorts outside the bulk of the fleet, and correspond to footprint values of less than 39.5 square feet (*i.e.*, up to the approximate size of a Honda Fit) and greater than 52.5 square feet (*i.e.*, at least as great as the approximate size of a Toyota Avalon), respectively:

Figure V-6. Passenger Automobile Footprint Distribution



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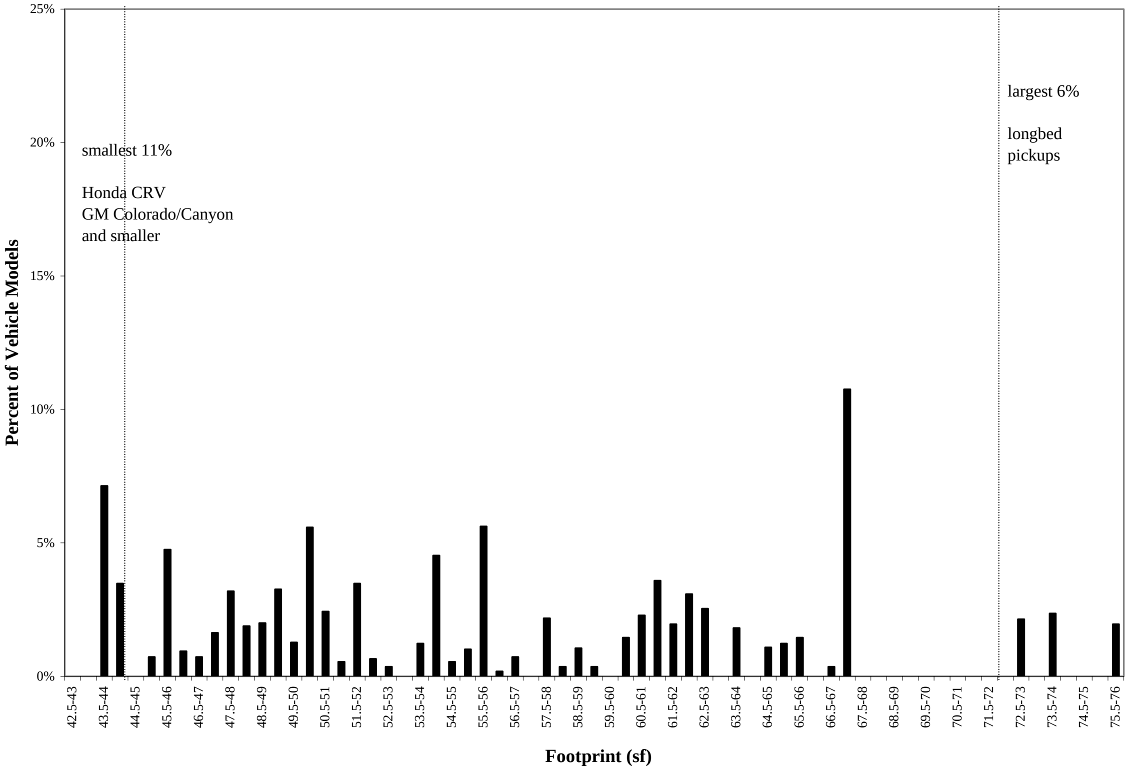
[131] That is, the midpoint.

[132] For the purpose of the Reformed CAFE standard, we are carrying *e* out to only three decimal places.

For light trucks, the upper asymptote (*i.e.*, the highest mpg value of the continuous function defining fuel economy targets) is based on the smallest (in terms of footprint) eleven percent of the fleet, and the lower asymptote is based on the largest six percent of the fleet. These cohorts correspond to footprint values of less than 44.5 square feet (*i.e.*, up to the approximate size of a Honda CR-V) and greater than 72.5 square feet (*i.e.*, comprised primarily of extended vans and long-bed pickup trucks), respectively:

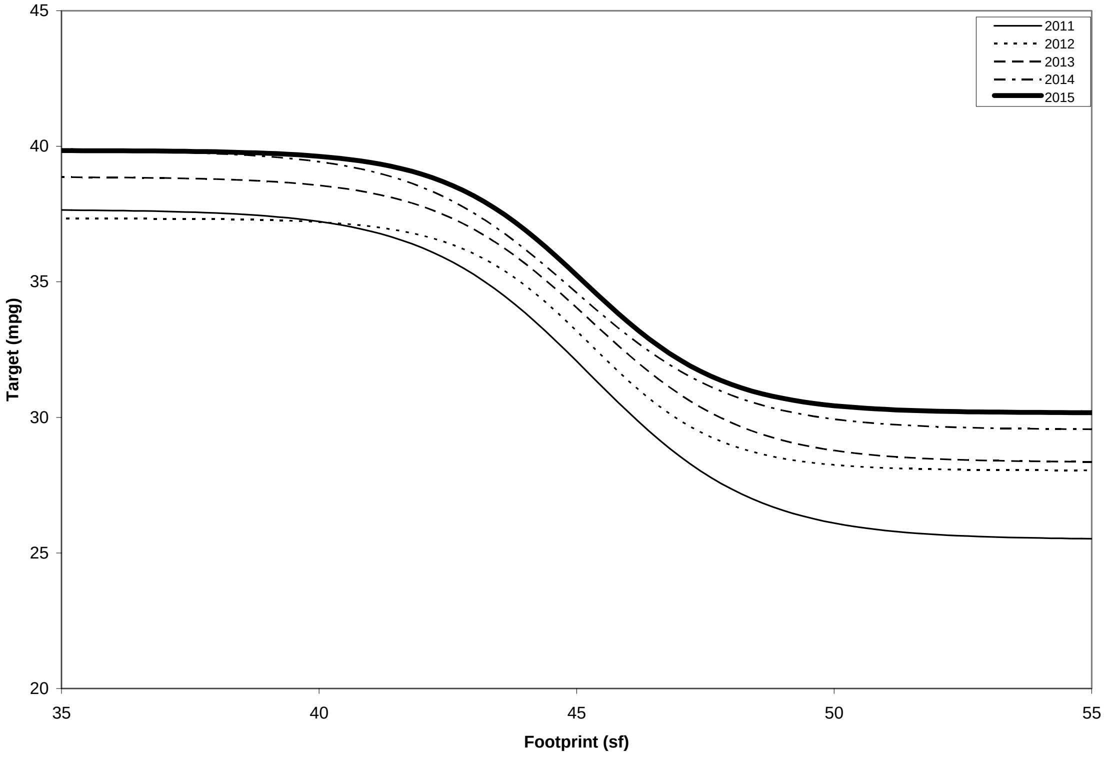
Figure V-7. Nonpassenger Automobile Footprint Distribution



NHTSA invites comment on the identification of vehicle cohorts for purposes of establishing upper and lower limits (asymptotes) bounding the attribute-based standard. After updating its baseline market forecast in consideration of new product plan information from manufacturers, the agency plans to reevaluate these cohorts for both passenger cars and light trucks before promulgating a final rule, and notes that changes in approach could lead to changes in stringency.

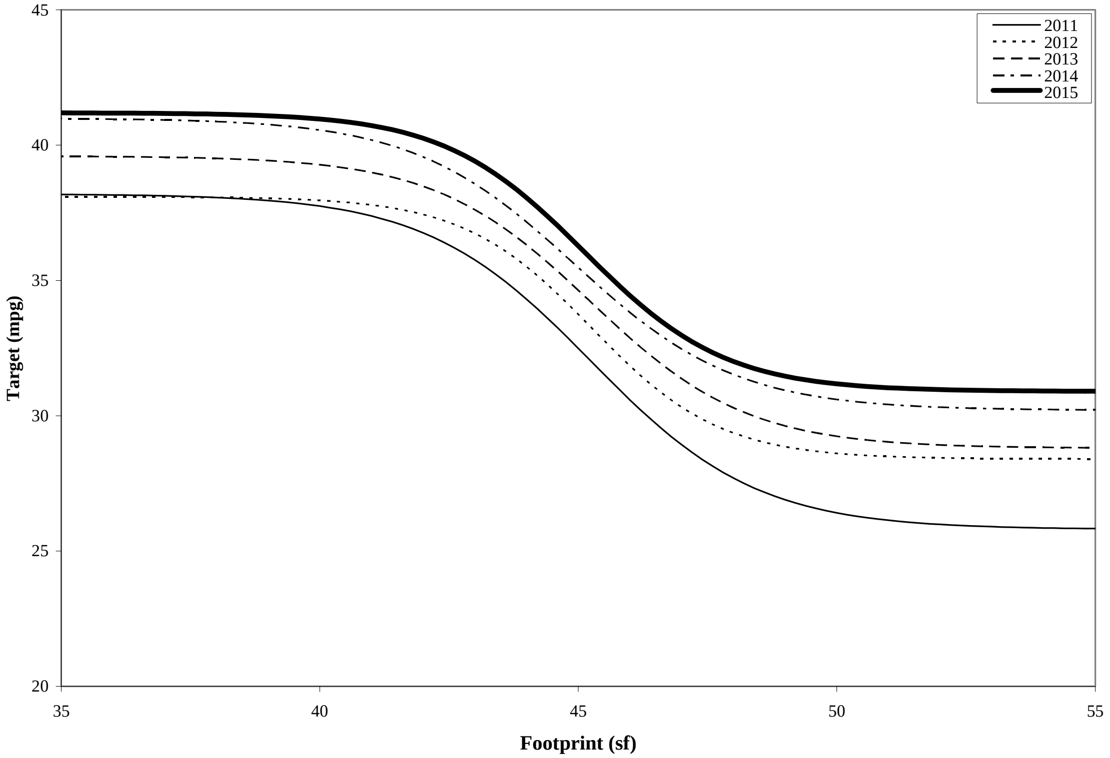
Given the above asymptotes, fitting the above functional form to the “optimized” passenger car fleet resulted in the following initial continuous functions:

Figure V-8. Initial Continuous Functions (Passenger Cars), Before Optimization



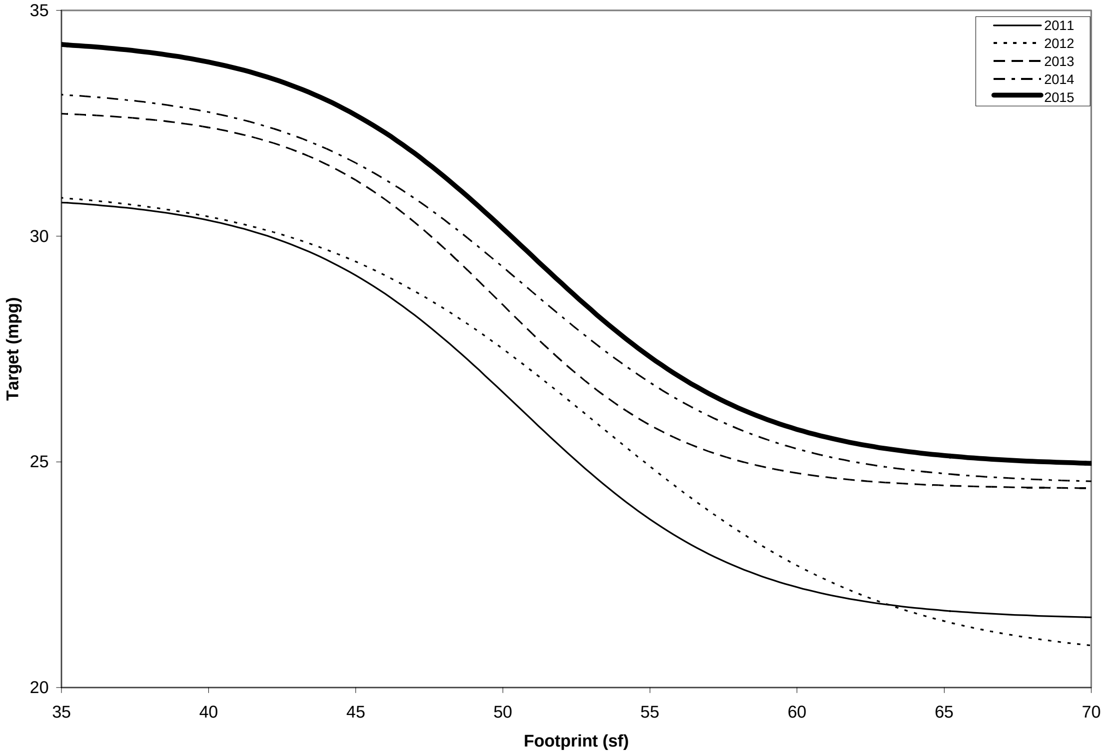
For each model year, NHTSA then raised or lowered the resultant continuous function until net benefits were maximized for the seven largest manufacturers (in total). Without subsequent recalibrations discussed below, this produced the following continuous functions for passenger cars:

Figure V-9. Initial Continuous Functions (Passenger Cars), After Optimization



The agency followed the same procedures for setting light truck standards and doing so resulted in the following continuous functions:

Figure V-10
Initial Continuous Functions (Light Trucks), After Optimization



In fitting the continuous function, NHTSA considered a range of statistical estimation techniques. In the 2006 light truck rulemaking, NHTSA estimated the parameters of the logistic function using fuel consumption (measured in gallons per mile) for each vehicle produced in a particular model year, weighted by sales

For this rulemaking, we observed that estimated fuel consumption functions for passenger cars were significantly affected by several outliers—a small number of popular vehicles that had significantly higher fuel economy than the fleet as a whole and, even more so, than vehicles of similar footprint. For passenger cars, the function, as estimated by weighted ordinary least squares, was exceptionally steep within the range considered. This observation, in turn, led NHTSA to consider alternative approaches to statistically fitting the continuous function.

Among the options considered by NHTSA were the following: dropping the outlying vehicles from the estimation process, weighted and unweighted ordinary least squares, and weighted and unweighted mean absolute deviation (MAD). MAD is a statistical procedure that has been demonstrated to produce more efficient parameter estimates in the presence of significant outliers.[133] As examples, the following two charts show the MY2015 passenger car and light

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[133] In the case of a dataset not drawn from a sample with a Gaussian, or normal, distribution, there is often a need to employ robust estimation methods rather than rely on least-squares approach to curve fitting. The least-squares approach has, as an underlying assumption, that the data are drawn from a normal distribution, and hence fits a curve using a sum-of-squares method to minimize errors. This approach will, in a sample drawn from a non-normal distribution, give excessive weight to outliers by making their presence felt in proportion to the square of their

truck fleets after the application of technologies to each manufacturers' fleet. These charts reveal numerous outliers for the passenger car fleet and, to a lesser extent, the light truck fleet:

Figure V-11. MY2015 Passenger Car Fleet after Technology Application

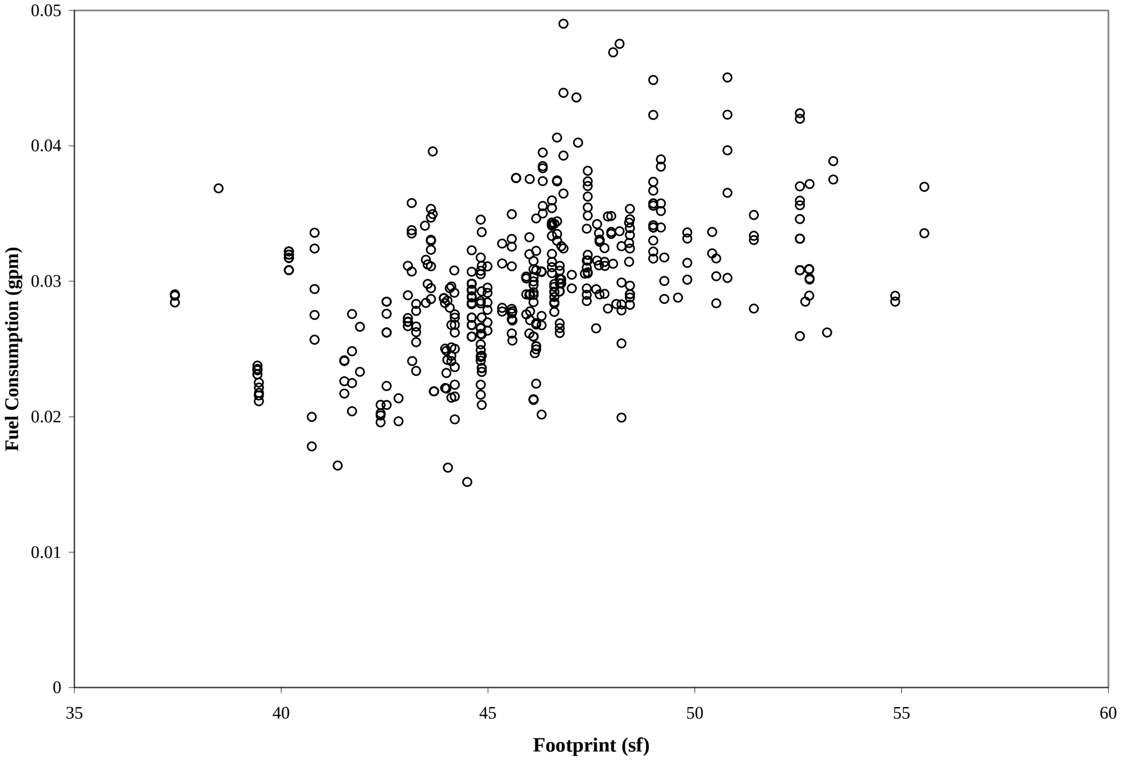

Figure V-12. MY2015 Light Truck Fleet after Technology Application

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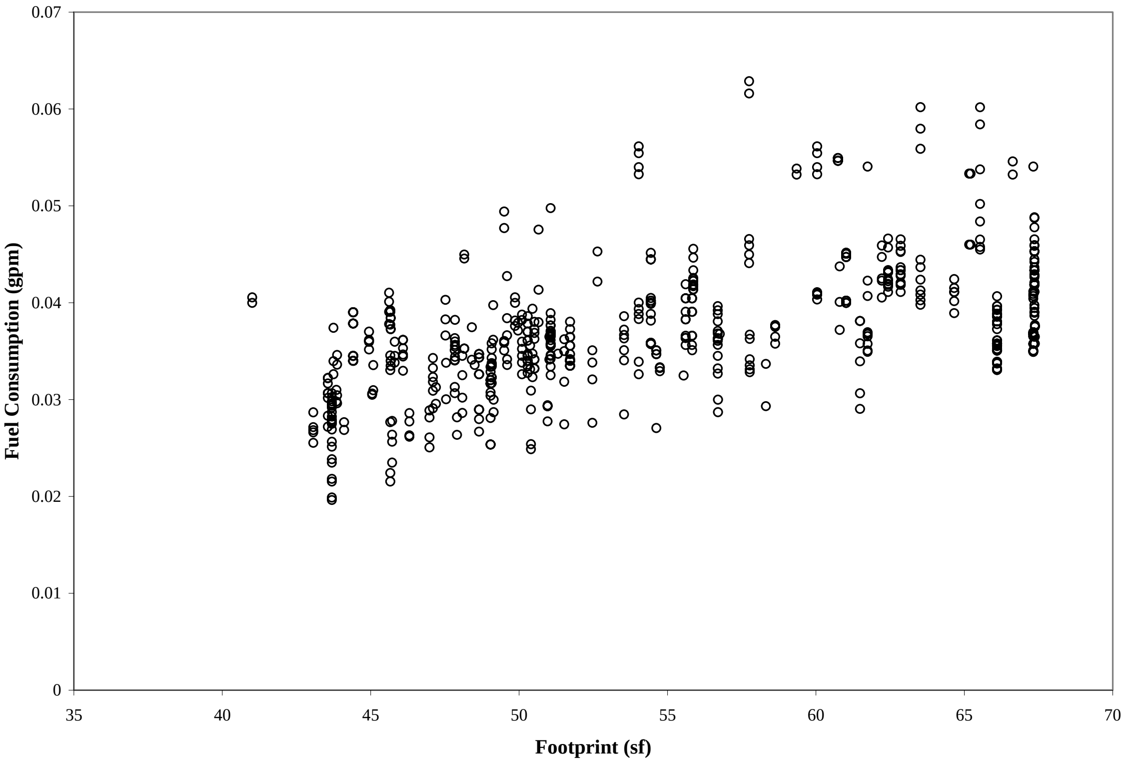
distance from the fitted curve, and, hence, distort the resulting fit. With outliers in the sample, the typical solution is to use a robust method such as a minimum absolute deviation, rather than a squared term, to estimate the fit (see, *e.g.*, "AI Access: Your Access to Data Modeling," at http://www.aiaccess.net/English/Glossaries/GlosMod/e_gm_O_Pa.htm#Outlier). The effect on the estimation is to let the presence of each observation be felt more uniformly, resulting in a curve more representative of the data (see, *e.g.*, Peter Kennedy, A Guide to Econometrics, 3rd edition, 1992, MIT Press, Cambridge, MA).



NHTSA requests comment on the best method for statistically fitting the continuous function.

There are strong theoretical arguments for using an unweighted (rather than weighted) analysis. Although the purpose of the attribute-based standard is to discourage downsizing and more equitably distribute compliance burdens among manufacturers, we expect the associated curve to be most successful if it is based on the observed physical relationship between vehicle size (i.e., footprint) and fuel economy. The curve reflects this relationship by depicting the variety of vehicle designs that have been produced in the real world for any given footprint. It is a measure of what is possible, not what consumers currently choose to buy.

Consider a scenario in which there are only 2 vehicle designs with exactly the same footprint, both from the same manufacturer. The manufacturer sells 1,000 units of design A and 100 units of design B. Either design could be produced in any number (no vehicle-specific resource constraint). The difference in sales is due to a variety of marketing considerations including vehicle styling, price, performance, fuel economy, etc., that have made one vehicle model more popular than the other. To describe the potential fuel economy capability at any given footprint, we want to recognize that both vehicles represent equally valid and viable designs. If we weight them according to sales, we will set standards that are biased towards existing fleet profiles rather than reflecting design potential.

However, the process by which we select the <u>stringency</u> (as distinct from the <u>form</u>) of the standard must consider sales volumes because the standards are based on sales-weighted average performance. Therefore, even if we use unweighted analysis develop the form of the standard, we would continue to evaluate the standard's stringency (and, therefore, its costs and benefits) based on sales-weighted average calculations done on a manufacturer-by-manufacturer basis.

There is already precedent for using unweighted data to produce curves that are descriptive of engineering relationships. In NHTSA's Preliminary Regulatory Impact Analysis for FMVSS 216 roof crush standards, a series of force-versus-deflection curves were produced for individual vehicle models and then averaged together. In that case, the agency was seeking observed relationships that reflect engineering possibilities, rather than a profile of the existing sales fleet.

In terms of relative emphasis on different vehicle models, the distinction between unweighted and weighted analysis is profound in the light vehicle market, in part because of the way "models" are defined for purposes of CAFE. The highest-selling passenger car model represents 356,000 units, and the lowest-selling model represents only 5 units. As a group, the five lowest-selling models represent only 305 units. Thus, weighted analysis places more than 1,000 times the emphasis on the highest-selling model than on the five lowest-selling models, and more than 70,000 times the emphasis than on the single lowest-selling model. The following histograms shows the broader distributions of models and sales with respect to model-level sales (first for passenger cars, then for light trucks):

Figure XX. Passenger Car Model Sales Volumes

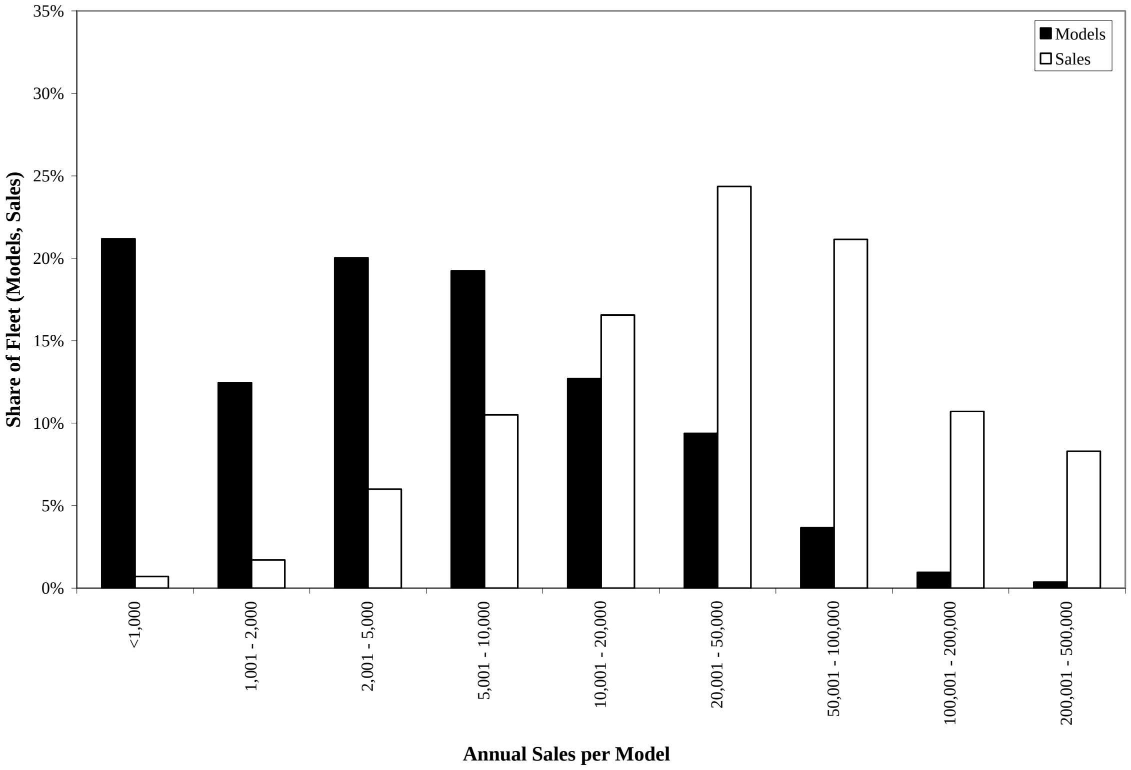
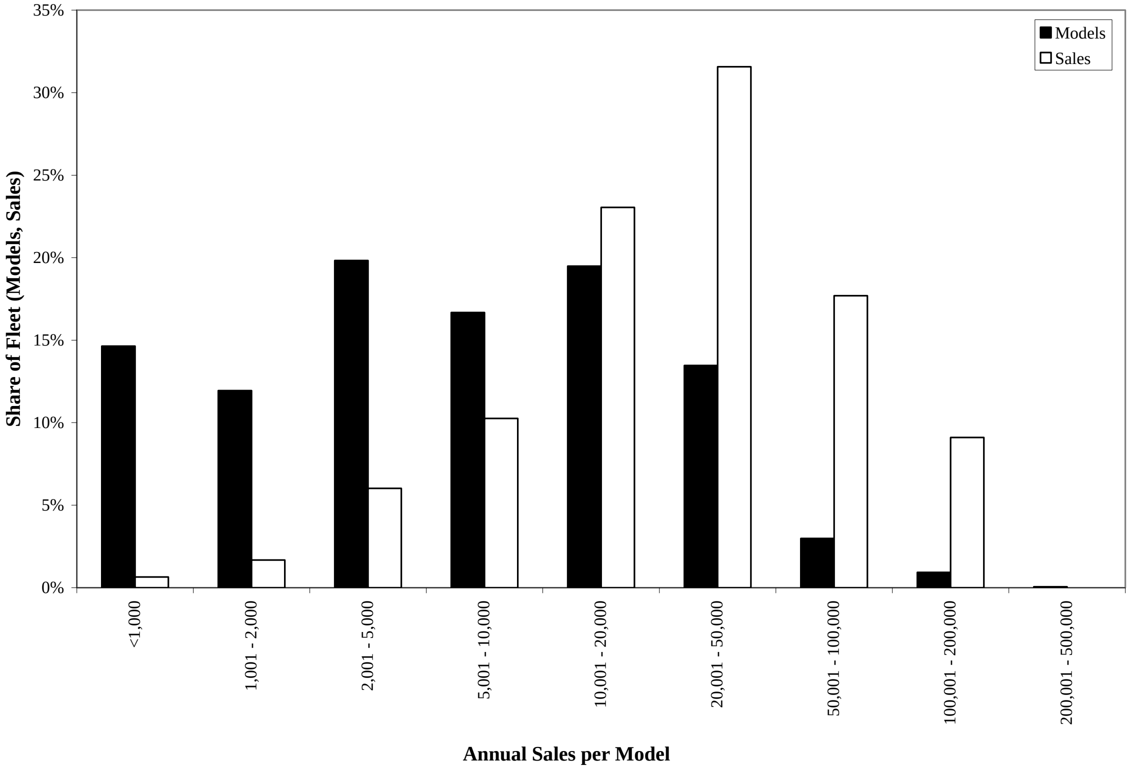


Figure V-13. Light Truck Model Sales Volumes



For purposes of setting the stringency of the corporate average fuel economy standard, this is vital because enforcement is based on the sales-weighted average. However, for purposes of developing a curve intended to represent fuel economy levels achieved at a given footprint, weighted analysis effectively ignores many models.

On the other hand, unweighted estimation is depending on the definition of a “model”. Manufacturers will sometimes offer substantially similar vehicles with different badges (i.e., Ford Taurus/Mercury Sable) as two different models. The distinction between differing ‘options packages’ on a single model and two distinct models is inevitably a bit blurry. When estimating fuel economy standards using a sales-weighted regression, this distinction is not material, since the estimation process will produce substantially the same results independently of the number of distribution of those sales into larger or smaller numbers of models. In unweighted estimation, however, dividing a particular vehicle family into a larger number of distinct models give that family some extra influence in the analysis. Nonetheless, considering that such parsing into similar “models” produces far less weighting disparity than does sales weighting (as illustrated by the 70,000-to-1 ratio mentioned above), NHTSA has tentatively concluded that unweighted estimation remains preferable to sales-weighted estimation.

The following charts shows, for MY2015 passenger cars and light trucks, how the use of sales-weighted least-squares estimation compares to the proposed approach, which uses unweighted mean absolute deviation. For passenger cars, the curve resulting from proposed approach is somewhat shallower than the curve resulting from sales-weighted least squares estimation. For light trucks, the curve resulting from proposed approach is somewhat steeper:

Figure V-14. Weighted Least Squares Regression Compared to Proposed Curve (Using Unweighted Mean Absolute Deviation) for MY2015 Passenger Cars with Technologies

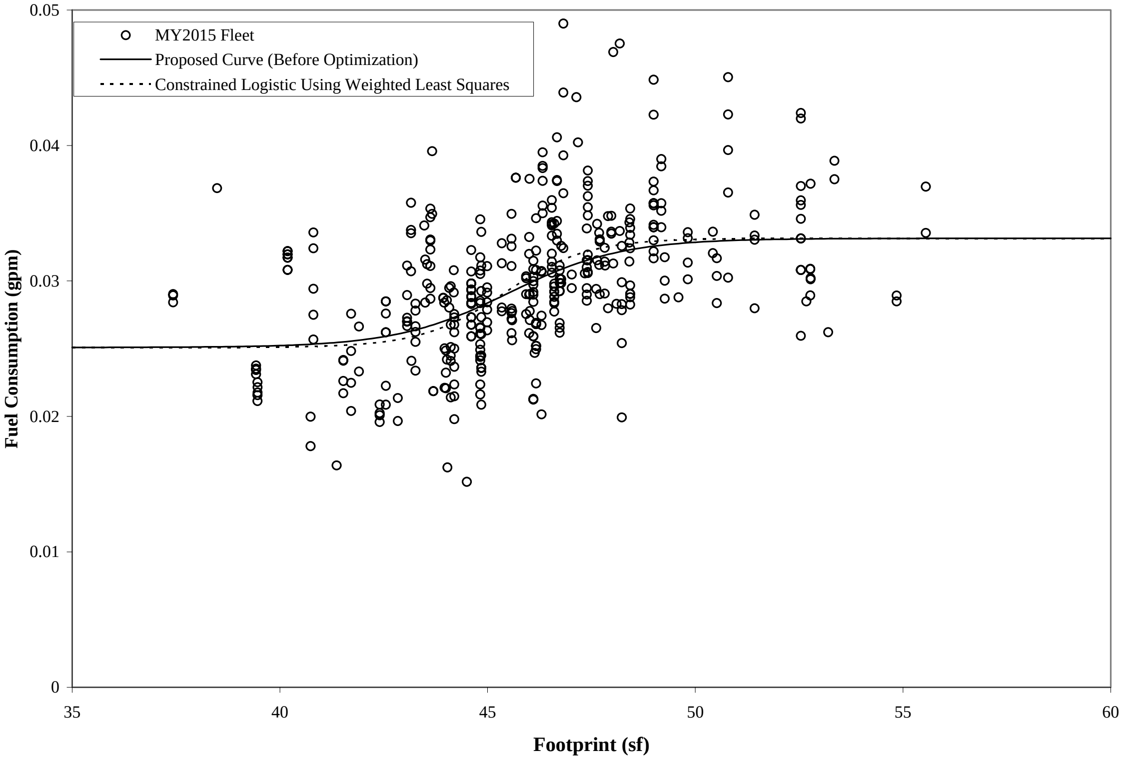
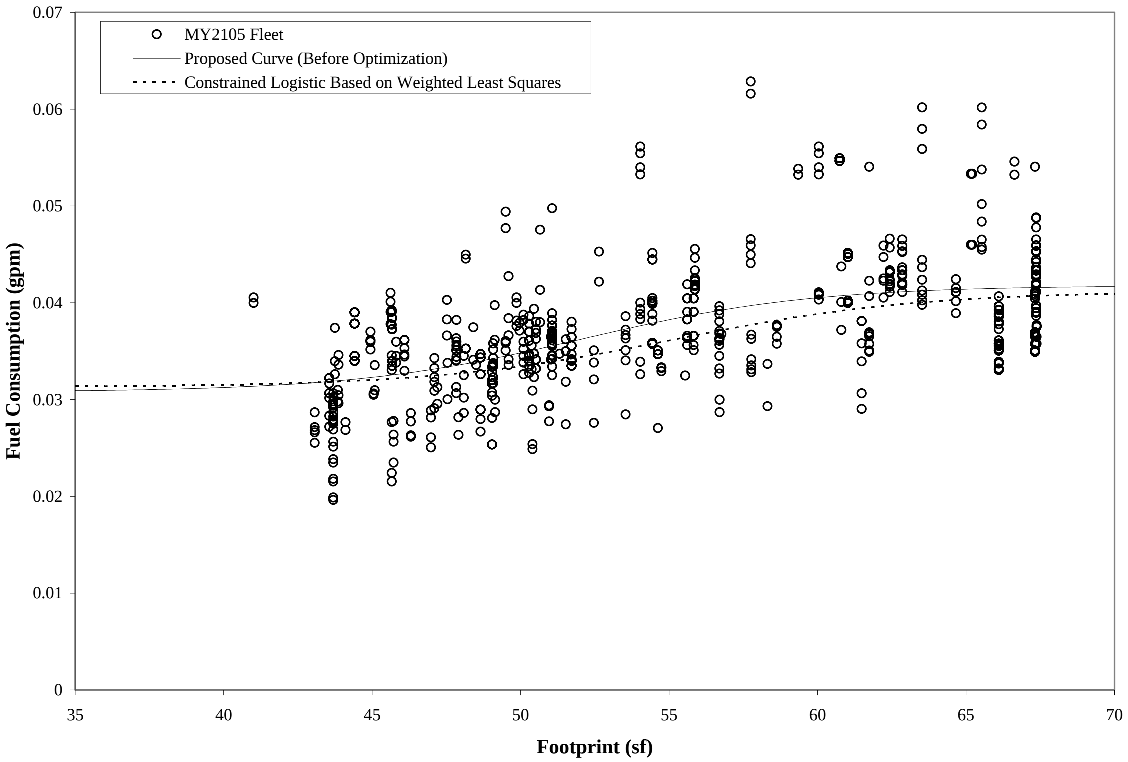


Figure V-15. Weighted Least Squares Regression Compared to Proposed Curve (Using Unweighted Mean Absolute Deviation) for MY2015 Light Trucks with Technologies



NHTSA invites comment on the relative merits of unweighted and weighted estimation, as well as on the other curve fitting options (e.g., the use of mean absolute deviation) raised here. The agency plans to reevaluate curve fitting approaches for both passenger cars and light trucks before promulgating a final rule, and notes that changes in approach could lead to changes in stringency and impacts on different manufacturers.]

3. Adjustments to address policy considerations

NHTSA believes that the resultant curve characteristics discussed above are empirically correct in that they correspond to the footprint and fuel economy values of the fleet obtained by adding fuel saving technologies to each manufacturer’s fleet until the net benefit from doing so reached its maximum value.

However, there are three issues (described above) which may tend to reduce the effectiveness of fuel economy regulation over time. These concerns are:

- curve crossings;
- excessive steepness of the passenger car curve;
- risk of upsizing.

In this rule, NHTSA proposes a solution to the curve crossing issue, requests comment on various methods of reducing the steepness of the passenger car, and examines the potential for upsizing generally under the provisions of this proposed rule.

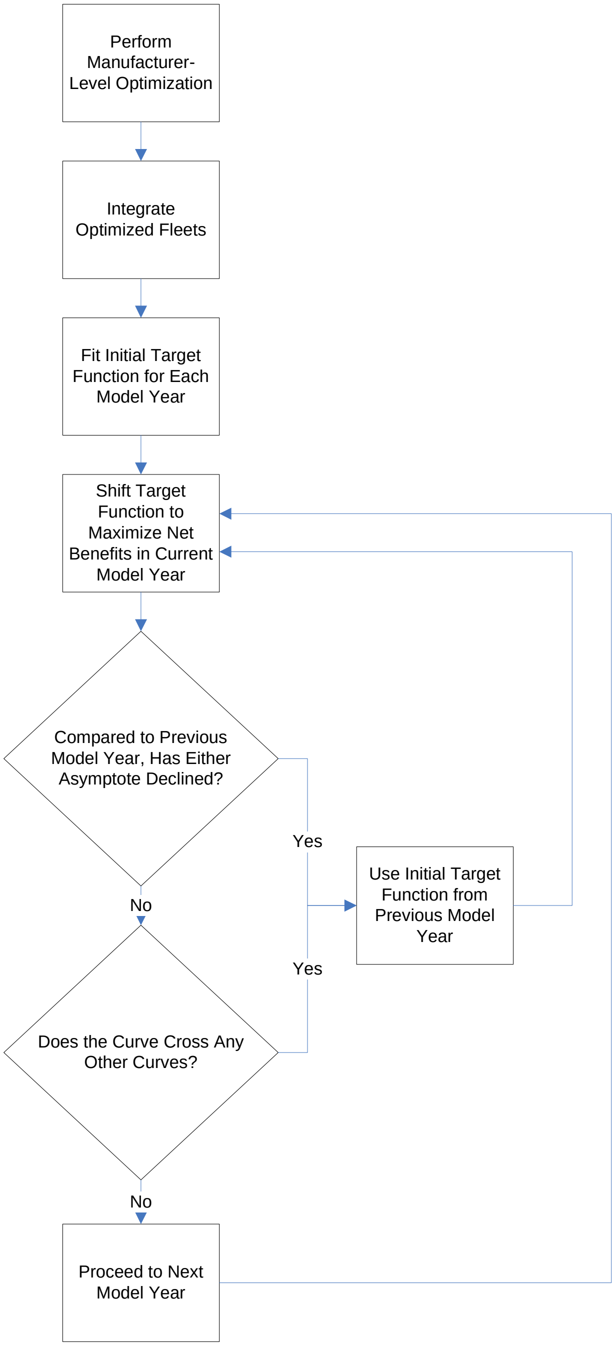
a. Curve crossings

For both passenger cars and light trucks, NHTSA observed some curve crossings from one model year to the next (*i.e.*, for the same footprint, some targets fell below the levels attained in the previous model year), as revealed in the above charts. The upper limit of the MY2012 passenger car curve falls slightly (about 0.1 mpg) below the MY2011 value. For light trucks, the lower asymptote in MY2012 is 0.9 mpg below the lower asymptote in MY2011. This was not observed during the last round of light truck rulemaking because reformed CAFE was fully implemented only in MY 2011. During the transition period (MYs 2008-2010), the standards were set at levels equivalent in cost to unreformed CAFE. However, for this rulemaking, because the projected fleet composition changes between model years and the fuel economy target function is optimized in every model year, the initial continuous functions do not change monotonically (*i.e.*, in only one direction—increasing) from year to year at every footprint value. Given the availability of lead time and the importance of improving fuel economy, NHTSA has decided that, in the setting of the standards, we should ensure that the fuel economy targets do not fall from one year to the next at any footprint value.

To address the year-to-year fluctuations in the functions, which may lead to these curve crossings, NHTSA recalibrated each continuous function to prevent it from crossing the continuous function from any previous model year. In doing so, the agency attempted to avoid continuous functions that would artificially encourage the product mix to approximate that of earlier years. Instead, the agency recalibrated by gradually shifting the initial continuous functions for each model year toward the initial continuous function determined above for the product mix for MY 2015. For both passenger cars and light trucks, the agency adjusted each of the four coefficients in the formula determining the continuous function such that regular steps were taken year by year between the values determined above for MY 2011 and those for MY 2015. For example, the inflection point (the coefficient determining the footprint at which the target falls halfway between its minimum and maximum values) defining the light truck target function was increased by 0.034 square feet annually from 51.9 square feet in MY 2011 to 52.1 square feet in MY 2015.

NHTSA also recalibrated the continuous function for each model year by adding, as needed, anti-backsliding constraints that prevent the function from either (a) yielding an industry wide average level of CAFE lower than that for the preceding model year, (b) for a given footprint, having targets that fall below the level of previous year, and (c) having an asymptote lower than that of the preceding model year. The “decision tree” for determining for each model year the need for each of these constraints is summarized below in Figure 12.

Figure V-16. Anti-backsliding Decision Tree



The industry-wide average CAFE is prevented from decreasing between model years in order to prevent standards from falling below the level that was determined to be achievable for the model year before. To allow the industry-wide CAFE level to fall between successive model years would be to promulgate a standard that, notwithstanding maximizing net benefits, falls below what the agency has determined to be feasible in previous years. In a model year in which simple maximization of net benefits would have caused this to occur, NHTSA shifted the resultant curve upward (without changing the curve’s shape) in order to produce an industry-wide CAFE equal to that of the preceding model year.

b. Steep curves for passenger cars

NHTSA has developed a set of attribute-based curves for passenger cars for this proposal consistent with the methodology used in the 2008-2011 light duty truck rule. However, unlike the relatively gradually sloped curve relating fuel economy to footprint for trucks, our analysis for cars when utilizing a constrained logistic curve produces a comparatively steep “S”-shaped curve for passenger cars. This occurs primarily because – unlike trucks – current passenger car sales include vehicles with a wide range of fuel economy spanning a relatively narrow footprint range. Consequently, there is a relatively steep curve applied to the middle range of footprint values with a more rapid change of slope in the tails to flatten the curve and thus satisfy the constrained logistic functional form.

In this Rule, NHTSA is proposing a relatively “steep” curve. The agency has considered and experimented with several methods of reducing the steepness of the passenger car curve. However, each of these approaches has created challenges that may potentially be worse than the problem they are trying to cure.

However, any attempt to ‘fix’ the steepness of the passenger car curve appears to come at a price: First, flattening the curve by any particular method will move the curve away from the actual vehicle data. Second, flatter curves are generally place greater compliance burdens on full-line manufacturers than comparatively stringent (in terms of average require CAFE) standards. This tends to increase the overall costs required to achieve a given amount of fuel savings and societal benefits, and it increases the risk that NHTSA would need to return to a “least capable manufacturer” approach in order to ensure economic practicability. Doing so would likely reduce stringency, and reduce fuel savings. In deciding on a particular approach, NHTSA must balance the certainty of high costs and lost fuel savings through a less “efficient” standard against the risk that the steepness of the curve might stimulate manufacturers to evade the standard over time by redesigning their vehicles over time.

In proposing steep curve for this rule, NHTSA has tentatively decided that the cures that we have identified come at too high a price is lost stringency or undesirable side effects. However, NHTSA requests comment on these and other potential solutions to reduce the steepness of the proposed car curves.

Some of the approaches considered or tested by NHTSA include:

Linear standards. When the fuel consumption of vehicles with added technologies is plotted against footprint, we note a roughly linear relationship over the existing range of footprint values. Hence, a simple alternative to the current constrained logistic function would be to estimate a linear form of the curve with the sales data. However, NHTSA is concerned that such an approach may result in very low fuel economy standards for the largest footprint vehicles, very high fuel economy standards for the smallest vehicles, and loss of the inherent backstop properties of the constrained logistic function.

In addition, the slope of a line estimated through a ‘cloud’ of data may be very sensitive to the exact characteristics of vehicles with the largest and smallest footprints. It may turn out that small changes in vehicle characteristics in the tails could shift the slope of a linear estimate. Further, it may be impossible to materially adjust the slope of a linear standard in future years without accepting curve crossing. The following two charts compare linear regression results for MY2015 to the curves proposed today by NHTSA. The result for passenger cars illustrates the concern regarding behavior at large and small footprints. Over the range of footprints in which light trucks are expected to be offered in MY2015, the result for light trucks shows less difference from the proposed curve.

Figure V-17. Linear Fit to MY2015 Passenger Cars with Technologies

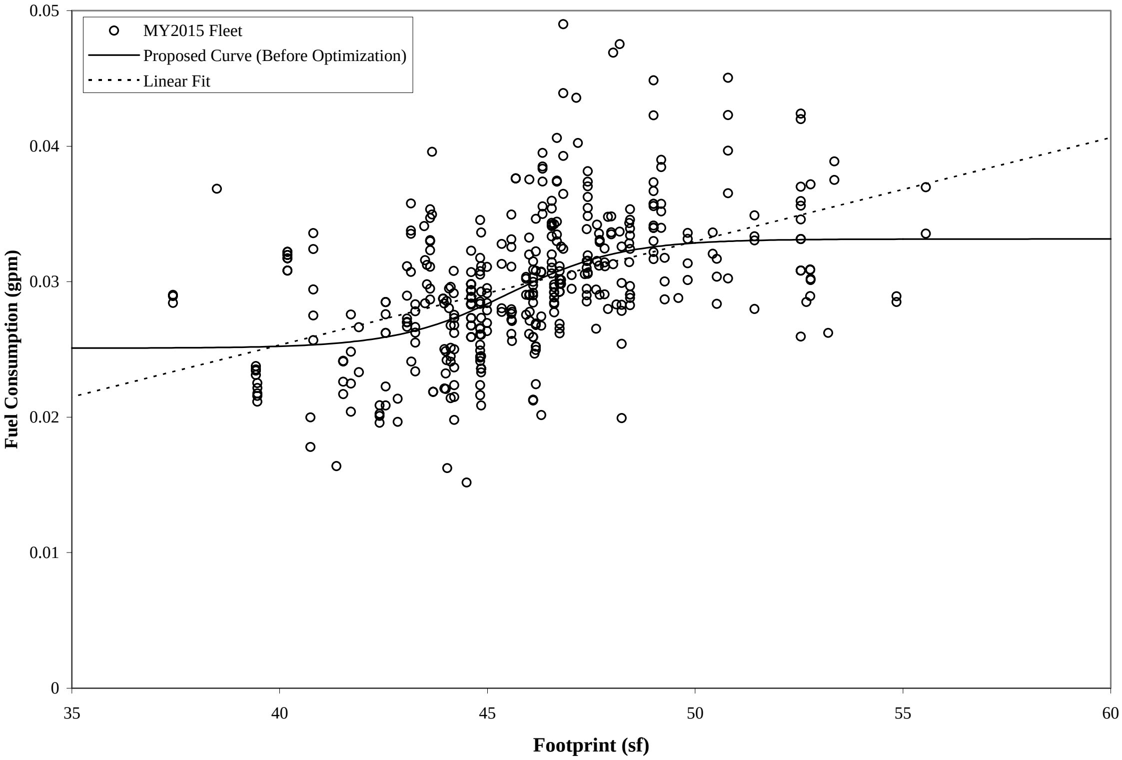
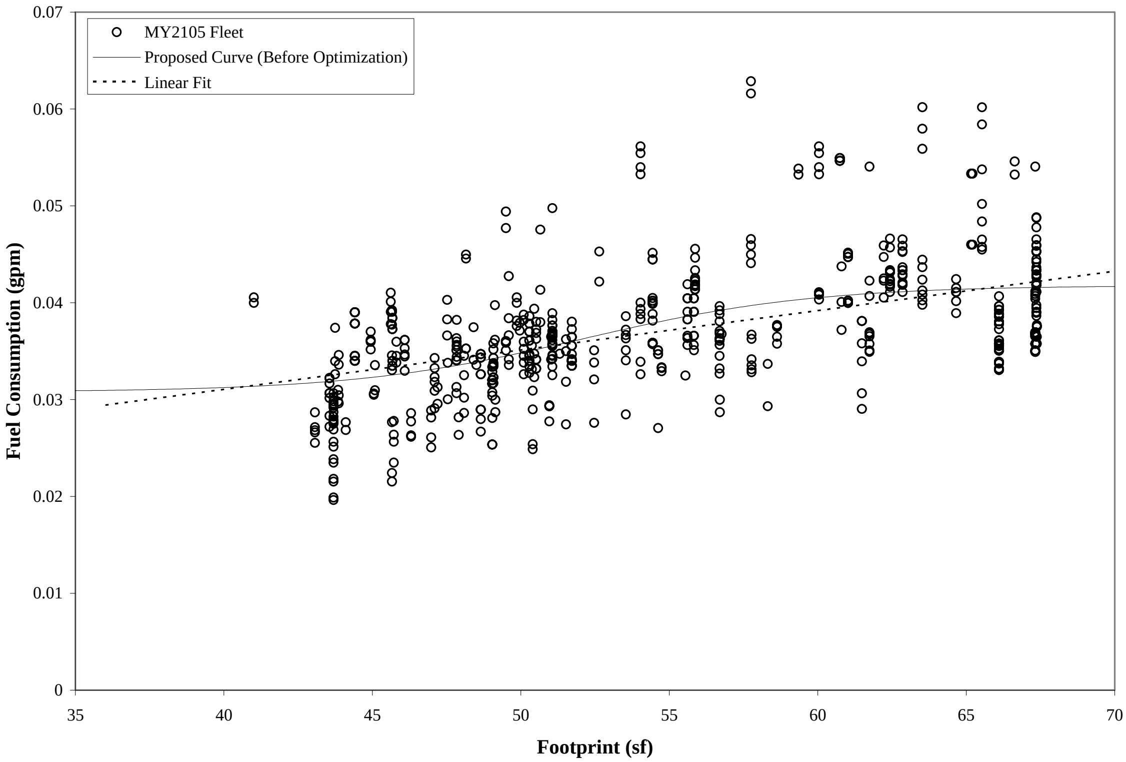


Figure V-18. Linear Fit to MY2015 Light Trucks with Technologies



Constrained linear standards. Another possible approach would be to retain the flattened tails proposed today but reduce the steepness of the middle portion by allowing it to directly reflect a linear relationship. This approach could be likened to a simplification or linearization of the constrained logistic function. The same minima and maxima would be used to bound the vertical extent of the linear form. The following two charts suggest that, at least for the MY2015 passenger car and light truck fleets considered today, a constrained linear standard would, compared to the standard proposed today, likely result in a similar distribution of compliance burdens among manufacturers (because the stringency at each footprint would be similar):

Figure V-19. Constrained Linear Fit to MY2015 Passenger Cars with Technologies

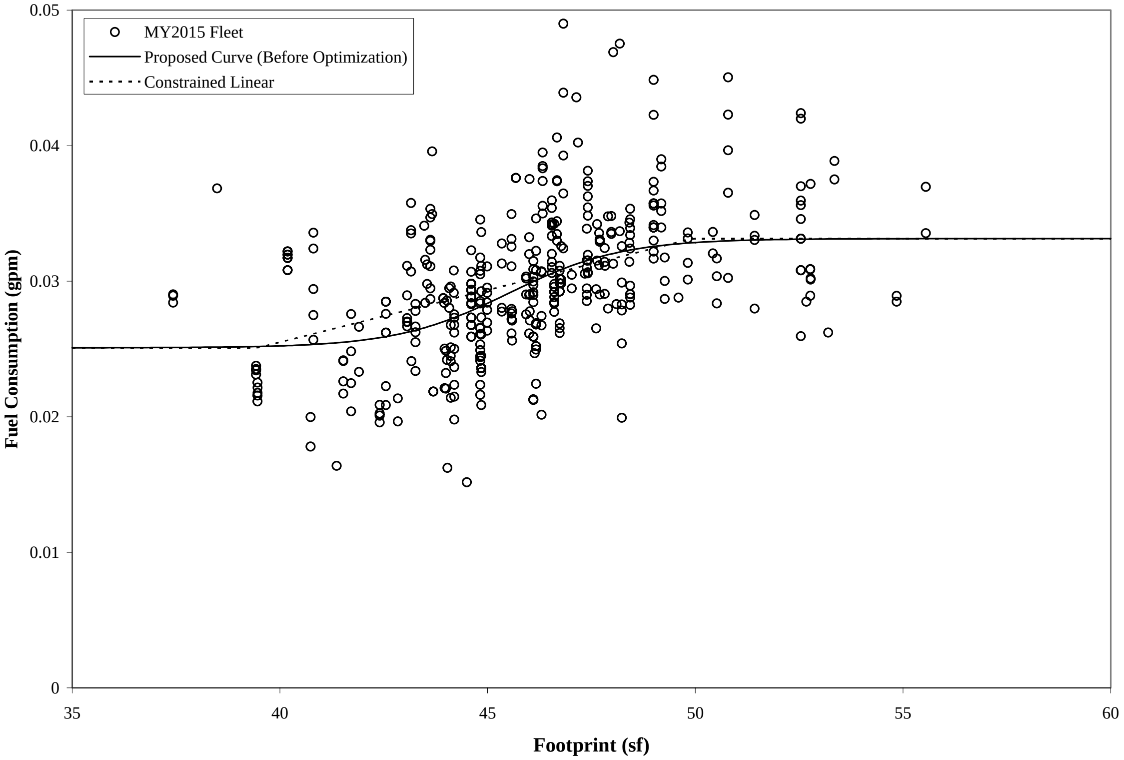
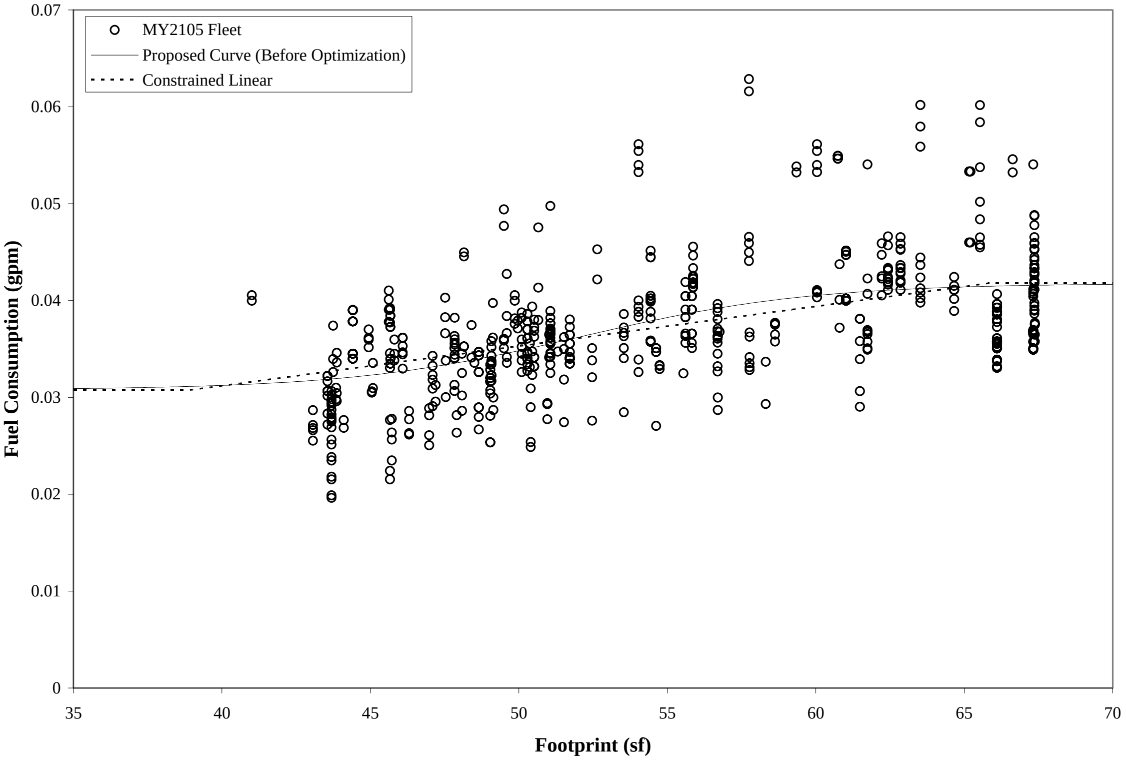


Figure V-20. Constrained Linear Fit to MY2015 Light Trucks with Technologies



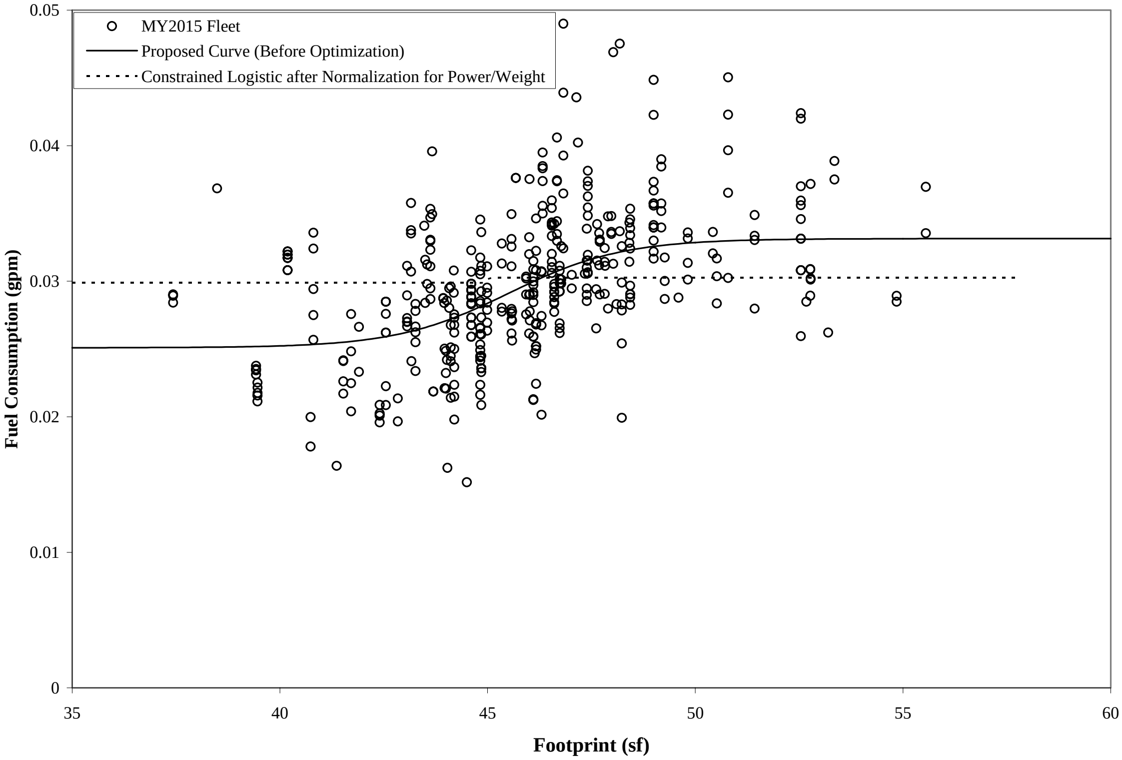
However, the agency remains concerned that the slope could exhibit greater year-to-year variation than the proposed logistic form (although further analysis would be required in order to address this concern). Also, as discussed in the preamble to the 2006 Federal Register notice regarding light truck CAFE standards, the agency remains concerned that the upper and lower “kinks” in the function could offer unexpected incentives for manufacturers to redesign vehicles with footprints close to the kink-point.

Dual Attribute Approaches. A third possible solution would be to use additional attribute-based information to spread out the distribution of passenger cars across the x-axis. In effect, this approach uses a second attribute to normalize the footprint-fuel economy relationship. This second attribute might be horsepower, weight, or horsepower-to-weight.

In analyzing the expected passenger car market, NHTSA observes that the ratio of engine horsepower to vehicle weight generally increases with increasing footprint. Higher power-to-weight ratios tend to imply lower fuel economy, as the engine is typically larger and operating less efficiently under driving conditions applicable to certification. Thus, the fuel consumption versus footprint curves for passenger cars reflect this relationship. For trucks, there does not appear to be a relationship between footprint and the power-to-weight ratio. For passenger cars, then, adjusting fuel consumption values to normalize for differences in power-to-weight ratio may produce a flatter curve providing less of an upsizing incentive for middle footprint values.

NHTSA has experimented with normalizing footprint by horsepower-to-weight ratio. The result was a nearly flat standard with respect to footprint across the most popular size ranges. This did not appear to deliver the benefits of an attribute-based system. In addition, it involves significant downward adjustments to the fuel economy of hybrid electric vehicles (such as the Toyota Prius), for which the engine is not the sole source of motive power. Also, it involves significant upward adjustments to the fuel economy of vehicles with high power-to-weight ratios (such as the Chevrolet Corvette). Some of these upward and downward adjustments are large enough to suggest radical changes in the nature of the original vehicles. Furthermore, insofar as such normalization implies that NHTSA should adopt a two-attributed standard (*e.g.,* in which the target depends on footprint and power-to-weight ratio), it may be challenging and time consuming to come up with a sufficiently precise vehicle-by-vehicle definition of horsepower or horsepower-to-weight to be used for regulatory purposes.

Figure V-21. Constrained Logistic Curve after Normalization for Differences in Power-to-Weight Ratio (MY2015 Passenger Cars with Technologies)



Shape Based on Combined Fleet. A fourth possible solution would be to combine the passenger car and light truck fleet to determine the shape of the constrained logistic curve, and then determine the stringency (i.e., height) of that curve separately for each fleet. On one hand, this approach would base the curve's shape on the widest available range of information. On the other, the resultant initial shape for each fleet would be based on vehicles from the other fleet. For example, the initial shape applied to passenger cars would be based, in part, on large SUVs and pickup trucks, and the initial shape applied to light trucks would be based, in part, on subcompact cars. Stringency would still be determined separately for passenger cars and light trucks, NHTSA invites comments on the consistency of this approach with the requirement in EPCA to establish separate standards for passenger cars and light trucks.

NHTSA performed a preliminary analysis of this approach. Considering the very wide range of fuel consumption levels in the combined fleet, NHTSA developed the asymptotes based on the average fuel consumption of all passenger cars and light trucks, respectively, rather than on the smallest passenger cars and the largest light trucks. The resultant MY2015 curve, shown below, is similar in curvature to the proposed curve for passenger cars and notably steeper than the proposed curve for light trucks.

Figure V-22. Constrained Logistic Curve Based on Combined Fleet (as Compared to MY2015 Passenger Cars with Technologies)

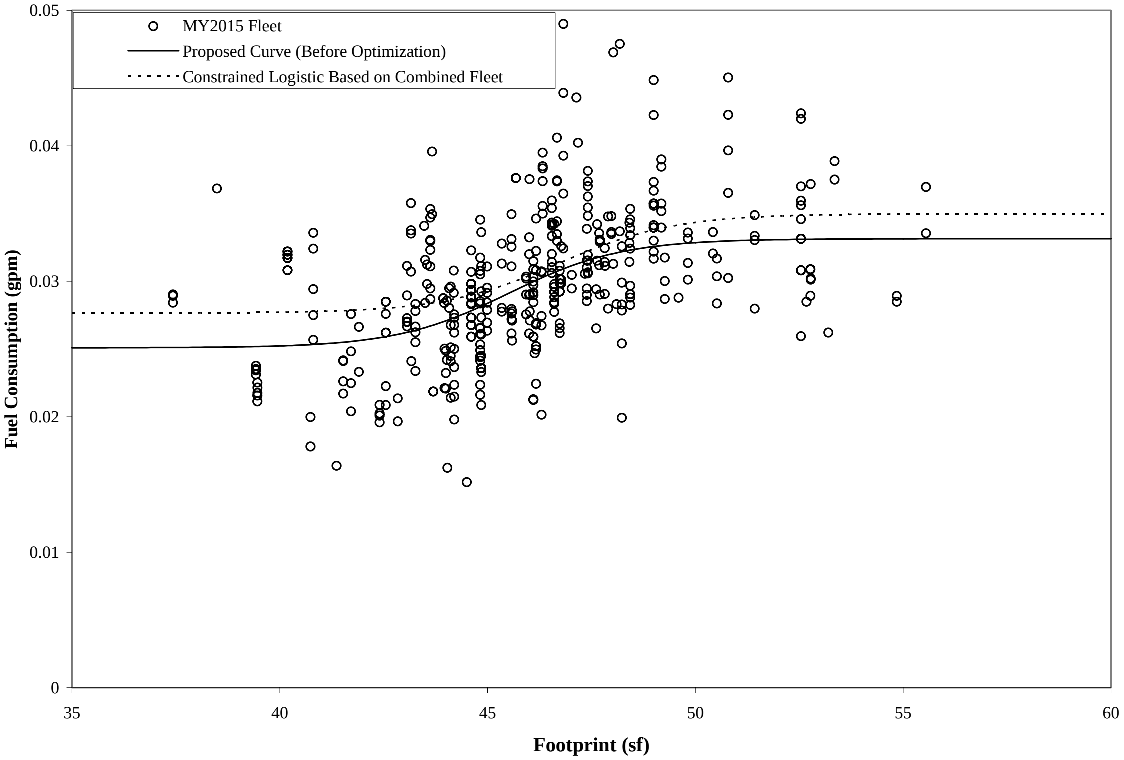
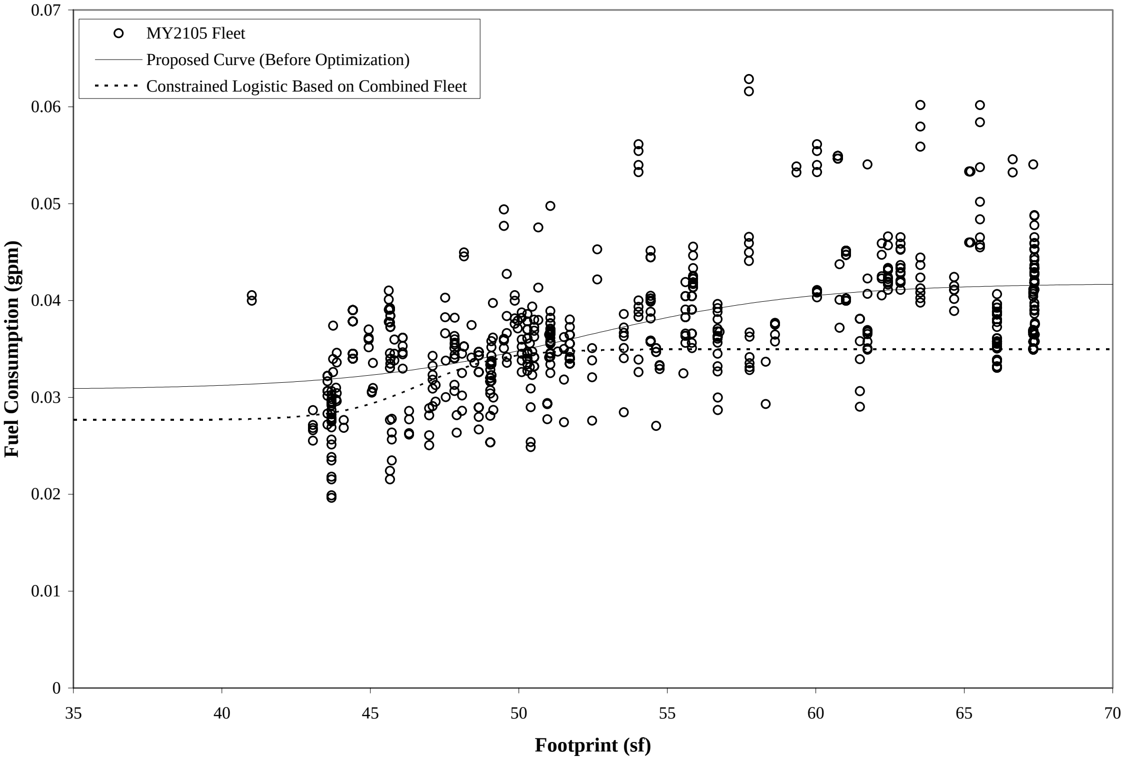


Figure V-23. Constrained Logistic Curve Based on Combined Fleet (as Compared to MY2015 Light Trucks with Technologies)



Ignoring Outliers. A fifth possible solution would be to ignore outliers. Lacking an objective means of classifying specific vehicle models as outliers that should be excluded from the analysis, NHTSA explored the possibility of excluding all hybrid electric vehicles (HEVs). The Japanese government also excluded HEVs for purposes of developing Japan's light vehicle efficiency standards. However, doing so yield initial curves of shape similar to those proposed, but displaced slightly in the direction of lower fuel consumption. The similarity of the shapes of these curves suggests that optimization against the full fleet (with HEVs) would produce standards of stringency similar to those proposed today.

Figure V-24. Constrained Logistic Curve Based on MY2015 Passenger Car Fleet with Technologies and Excluding HEVs

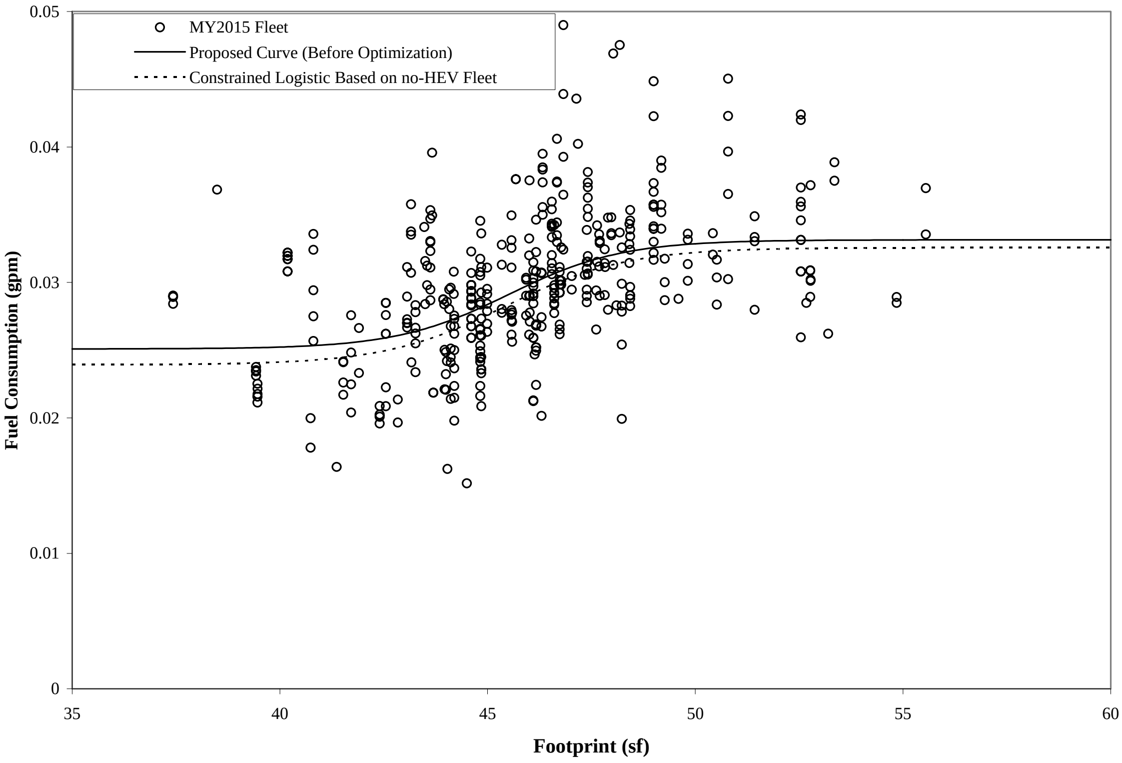
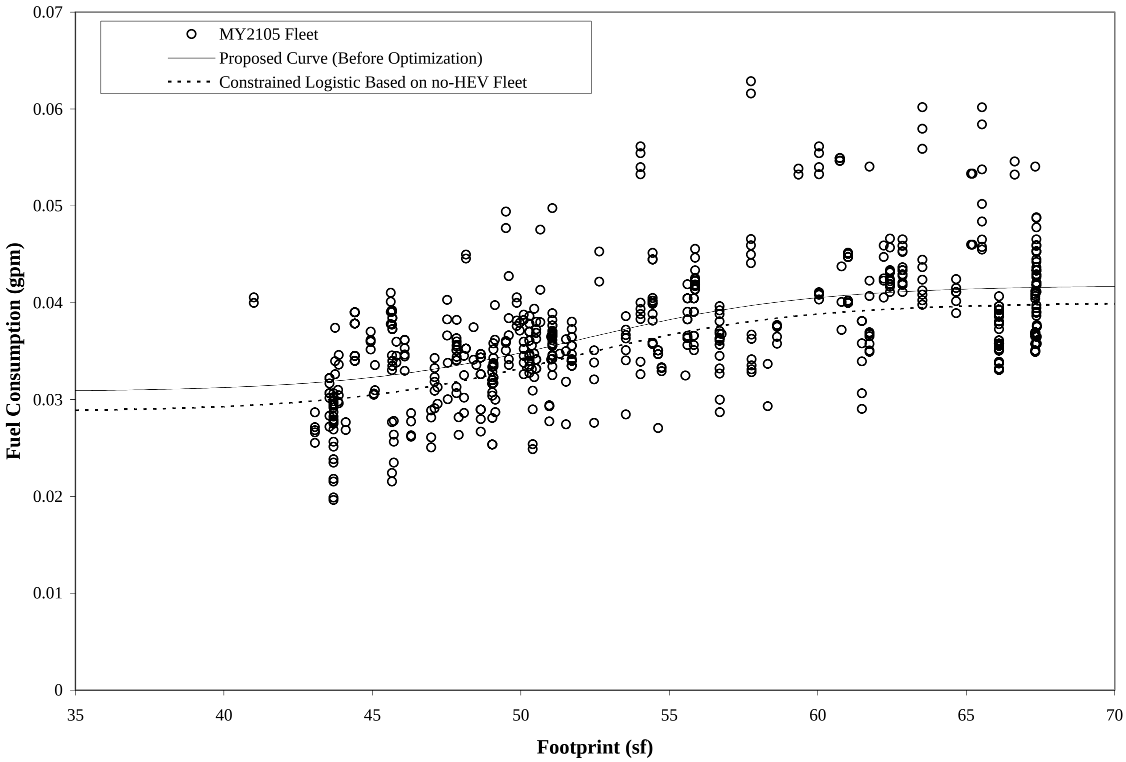


Figure V-25. Constrained Logistic Curve Based on MY2015 Passenger Car Fleet with Technologies and Excluding HEVs



NHTSA invites comments on the importance of addressing the relative steepness of the proposed curves for passenger cars, and on the feasibility of, technical basis for, and implications of any options for doing so. The agency plans to reevaluate standards for both passenger cars and light trucks before promulgating a final rule, and notes that changes in approach—including measures to address the steepness of the passenger car curves—could lead to changes in stringency as well as different impacts on different manufacturers.

c. Risk of upsizing

The steepness of the proposed curve for passenger cars presents a localized risk that manufacturers will respond in ways that compromise expected fuel savings. That is, although the constrained logistic curve has a steep region, that region does not cover a wide range of footprints. However, any attribute-based system involves the broader risk that manufacturers will shift toward vehicles with the lowest fuel economy targets. As mentioned above, the constrained logistic curve proposed by NHTSA provides an absolute floor. That is, even manufacturers discontinue all but the very largest known passenger cars and light trucks, they would still be required to meet CAFE standards no lower than the lower asymptote (on an mpg basis) of the constrained logistic curve. Also, for domestic passenger cars, EISA establishes a floor or “backstop” equal to 92% of the average required CAFE level for passenger cars. This backstop is discussed below in Section VI.

It is difficult to assess the risk that manufacturers may shift the mix of vehicles enough to approach the EISA floor for domestic passenger cars, or to approach the lower asymptotes for light trucks or imported passenger cars. However, considering the footprint distribution of vehicles (as indicated by the various histograms and scatter plots shown above in this section) expected to be covered by the proposed rule, NHTSA anticipates that manufacturers would not be able to approach these reductions in stringency without dramatically altering product mix. The agency doubts that manufacturers could do so unless consumer preferences also shift dramatically.

NHTSA also notes that under attribute-based CAFE standards such as the agency is proposing today, shifts in consumer preferences could cause manufacturers' required CAFE levels and, therefore, achieved fuel savings (and perhaps costs) to increase. For example, if changes in fuel prices combine with demographic and/or other factors to cause market preferences to shift significantly toward vehicles with smaller footprints, manufacturers shifting (relative to current estimates) in that direction will face higher required CAFE levels than the agency has estimated.

C. Penetration of Technologies by Alternative

Tables V-11a through V-11g show the penetration of technologies by year for passenger cars and Tables V-12a through V-12g show the penetration of technologies by year for light trucks for the alternatives. These tables are for the whole fleet combined, not by specific manufacturers. They allow the reader to see the progression of technologies applied as the standards get stricter. The baseline shown here is the adjusted baseline for MY 2011.

Table V-11a
Penetration Rate of New Technologies to Passenger Cars – 25% Below Optimized

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	78%	81%	100%	100%	100%	100%
2. EFR	14%	20%	26%	38%	58%	71%
3. VVTI	80%	80%	83%	88%	89%	91%
4. VVTC	8%	9%	10%	13%	19%	28%
5. VVTD	27%	26%	29%	31%	32%	34%
6. DISP	4%	4%	7%	10%	15%	16%
7. VVLTC	1%	1%	2%	5%	6%	9%
8. VVLTD	12%	15%	18%	22%	22%	24%
9. DISPO	2%	2%	2%	2%	3%	3%
10. VVTO	6%	6%	6%	5%	5%	5%
11. DOHC	6%	6%	5%	6%	7%	7%
12. VVLTO	0%	0%	0%	0%	0%	0%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	11%	13%	15%	18%	19%	21%
15. DSLS	0%	0%	0%	0%	0%	0%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	8%	8%	9%	9%	9%	11%
18. DSLT	1%	3%	2%	2%	3%	5%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	22%	22%	23%	21%	20%	18%
22. ASL	7%	12%	21%	25%	22%	26%
23. TORQ	4%	5%	6%	10%	16%	14%
24. 6SP	26%	26%	26%	27%	22%	20%
25. AMT	9%	9%	15%	19%	25%	30%
26. CVT	11%	11%	10%	10%	10%	10%
27. 6MAN	7%	8%	8%	8%	9%	9%
28. IACC	20%	27%	27%	38%	39%	44%
29. EPS	14%	16%	20%	27%	28%	34%
30. 42V	0%	2%	1%	1%	2%	8%
31. ROLL	5%	18%	29%	51%	62%	63%
32. LDB	21%	21%	21%	21%	21%	21%
33. SAXU	0%	0%	0%	1%	1%	1%
34. SAXL	0%	0%	0%	0%	0%	0%
35. AERO	7%	12%	20%	31%	42%	47%
36. MS1	0%	0%	0%	0%	0%	0%
37. MS2	0%	0%	0%	0%	0%	0%
38. MS5	0%	0%	0%	0%	0%	0%
39. ISGO	0%	2%	3%	3%	8%	10%
40. IHYB	1%	1%	1%	1%	1%	2%
41. 2HYB	0%	0%	0%	0%	1%	1%
42. PHYB	3%	3%	3%	3%	3%	3%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-11b
Penetration Rate of New Technologies to Passenger Cars – Optimized 7%

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	78%	93%	100%	100%	100%	100%
2. EFR	14%	27%	49%	69%	82%	82%
3. VVTI	80%	80%	86%	91%	92%	91%
4. VVTC	8%	9%	20%	28%	34%	34%
5. VVTD	27%	27%	30%	34%	35%	36%
6. DISP	4%	6%	11%	15%	20%	20%
7. VVLTC	1%	1%	1%	4%	7%	15%
8. VVLTD	12%	18%	27%	33%	34%	36%
9. DISPO	2%	3%	4%	3%	3%	3%
10. VVTO	6%	6%	6%	5%	5%	5%
11. DOHC	6%	6%	5%	6%	7%	7%
12. VVLTO	0%	1%	2%	2%	2%	2%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	11%	15%	21%	24%	25%	28%
15. DSLS	0%	0%	0%	0%	0%	0%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	8%	10%	13%	14%	15%	19%
18. DSLT	1%	3%	3%	3%	3%	4%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	22%	21%	22%	19%	16%	15%
22. ASL	7%	17%	29%	29%	21%	19%
23. TORQ	4%	6%	9%	16%	15%	8%
24. 6SP	26%	23%	21%	22%	17%	9%
25. AMT	9%	13%	22%	27%	34%	43%
26. CVT	11%	11%	12%	11%	12%	12%
27. 6MAN	7%	8%	8%	8%	9%	9%
28. IACC	20%	36%	41%	48%	51%	64%
29. EPS	14%	21%	33%	41%	44%	51%
30. 42V	0%	7%	14%	15%	19%	26%
31. ROLL	5%	23%	42%	57%	62%	74%
32. LDB	21%	21%	21%	21%	21%	21%
33. SAXU	0%	0%	0%	1%	1%	1%
34. SAXL	0%	0%	0%	0%	0%	0%
35. AERO	7%	18%	31%	40%	52%	56%
36. MS1	0%	0%	0%	0%	0%	0%
37. MS2	0%	0%	0%	0%	0%	0%
38. MS5	0%	0%	0%	0%	0%	0%
39. ISGO	0%	3%	4%	5%	8%	11%
40. IHYB	1%	1%	1%	1%	1%	2%
41. 2HYB	0%	1%	1%	1%	1%	1%
42. PHYB	3%	4%	3%	3%	4%	4%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-11c
Penetration Rate of New Technologies to Passenger Cars – 25% Above Optimized

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	78%	93%	100%	100%	100%	100%
2. EFR	14%	33%	55%	73%	85%	87%
3. VVTI	80%	79%	84%	88%	88%	87%
4. VVTC	8%	14%	27%	37%	40%	41%
5. VVTD	27%	27%	29%	33%	36%	36%
6. DISP	4%	9%	15%	19%	23%	23%
7. VVLTC	1%	1%	1%	4%	7%	13%
8. VVLTD	12%	19%	29%	36%	38%	38%
9. DISPO	2%	3%	4%	3%	3%	3%
10. VVTO	6%	6%	6%	5%	4%	4%
11. DOHC	6%	6%	6%	7%	8%	8%
12. VVLTO	0%	1%	2%	2%	2%	2%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	11%	14%	25%	29%	32%	34%
15. DSLS	0%	0%	0%	0%	0%	0%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	8%	12%	23%	27%	30%	31%
18. DSLT	1%	5%	6%	6%	8%	9%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	22%	19%	16%	14%	13%	13%
22. ASL	7%	22%	31%	33%	24%	12%
23. TORQ	4%	10%	14%	23%	21%	9%
24. 6SP	26%	26%	25%	25%	18%	5%
25. AMT	9%	14%	27%	29%	38%	50%
26. CVT	11%	13%	13%	12%	12%	12%
27. 6MAN	7%	8%	9%	9%	9%	10%
28. IACC	20%	42%	56%	59%	60%	74%
29. EPS	14%	24%	44%	51%	56%	59%
30. 42V	0%	9%	22%	26%	32%	39%
31. ROLL	5%	23%	48%	63%	86%	88%
32. LDB	21%	21%	21%	21%	21%	21%
33. SAXU	0%	0%	0%	1%	2%	2%
34. SAXL	0%	0%	0%	0%	0%	0%
35. AERO	7%	18%	34%	45%	57%	68%
36. MS1	0%	0%	0%	0%	0%	0%
37. MS2	0%	0%	0%	0%	0%	0%
38. MS5	0%	0%	0%	0%	0%	0%
39. ISGO	0%	1%	3%	3%	6%	9%
40. IHYB	1%	1%	1%	1%	2%	2%
41. 2HYB	0%	2%	4%	3%	4%	4%
42. PHYB	3%	5%	5%	6%	7%	7%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-11d
Penetration Rate of New Technologies to Passenger Cars – 50% Above Optimized

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	78%	93%	100%	100%	100%	100%
2. EFR	14%	33%	63%	83%	91%	91%
3. VVTI	80%	79%	81%	84%	83%	82%
4. VVTC	8%	17%	29%	37%	42%	41%
5. VVTD	27%	26%	26%	30%	34%	34%
6. DISP	4%	9%	17%	21%	25%	25%
7. VVLTC	1%	1%	2%	5%	8%	21%
8. VVLTD	12%	19%	29%	35%	37%	37%
9. DISPO	2%	3%	4%	3%	3%	3%
10. VVTO	6%	6%	6%	5%	4%	4%
11. DOHC	6%	6%	5%	5%	6%	7%
12. VVLTO	0%	1%	2%	2%	2%	2%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	11%	15%	26%	31%	35%	44%
15. DSLS	0%	0%	0%	0%	0%	0%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	8%	12%	24%	27%	31%	38%
18. DSLT	1%	5%	9%	10%	13%	14%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	22%	19%	15%	9%	5%	5%
22. ASL	7%	20%	29%	30%	18%	16%
23. TORQ	4%	8%	12%	21%	18%	5%
24. 6SP	26%	24%	23%	28%	19%	7%
25. AMT	9%	16%	28%	32%	44%	56%
26. CVT	11%	13%	12%	11%	10%	11%
27. 6MAN	7%	8%	9%	9%	10%	10%
28. IACC	20%	45%	64%	71%	72%	74%
29. EPS	14%	26%	50%	62%	66%	67%
30. 42V	0%	10%	26%	30%	38%	54%
31. ROLL	5%	23%	56%	79%	85%	88%
32. LDB	21%	21%	21%	21%	21%	21%
33. SAXU	0%	0%	0%	1%	2%	2%
34. SAXL	0%	0%	0%	0%	0%	0%
35. AERO	7%	22%	43%	53%	64%	67%
36. MS1	0%	0%	0%	0%	0%	0%
37. MS2	0%	0%	0%	0%	0%	0%
38. MS5	0%	0%	0%	0%	0%	0%
39. ISGO	0%	1%	2%	2%	5%	7%
40. IHYB	1%	1%	2%	2%	2%	3%
41. 2HYB	0%	2%	4%	4%	5%	5%
42. PHYB	3%	6%	8%	8%	12%	13%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-11e
Penetration Rate of New Technologies to Passenger Cars – Optimized (3%)

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	78%	93%	100%	100%	100%	100%
2. EFR	14%	37%	62%	81%	89%	89%
3. VVTI	80%	77%	81%	84%	83%	82%
4. VVTC	8%	19%	31%	38%	42%	42%
5. VVTD	27%	26%	27%	30%	34%	34%
6. DISP	4%	10%	18%	21%	25%	25%
7. VVLTC	1%	1%	2%	5%	12%	25%
8. VVLTD	12%	18%	31%	36%	38%	38%
9. DISPO	2%	3%	4%	3%	3%	3%
10. VVTO	6%	6%	6%	5%	4%	4%
11. DOHC	6%	6%	5%	5%	6%	7%
12. VVLTO	0%	1%	2%	2%	2%	2%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	11%	20%	33%	37%	41%	52%
15. DSLS	0%	0%	0%	0%	0%	0%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	8%	16%	29%	34%	37%	49%
18. DSLT	1%	7%	9%	11%	13%	14%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	22%	12%	5%	3%	1%	1%
22. ASL	7%	33%	30%	32%	17%	4%
23. TORQ	4%	14%	17%	23%	14%	2%
24. 6SP	26%	30%	27%	28%	15%	2%
25. AMT	9%	17%	36%	39%	54%	67%
26. CVT	11%	14%	14%	12%	12%	12%
27. 6MAN	7%	8%	9%	9%	10%	10%
28. IACC	20%	51%	62%	68%	75%	77%
29. EPS	14%	30%	54%	62%	66%	67%
30. 42V	0%	14%	32%	35%	45%	60%
31. ROLL	5%	33%	56%	74%	88%	88%
32. LDB	21%	21%	21%	21%	21%	21%
33. SAXU	0%	0%	0%	1%	2%	2%
34. SAXL	0%	0%	0%	0%	0%	0%
35. AERO	7%	26%	41%	50%	58%	61%
36. MS1	0%	0%	0%	0%	0%	0%
37. MS2	0%	0%	0%	0%	0%	0%
38. MS5	0%	0%	0%	0%	0%	0%
39. ISGO	0%	2%	4%	4%	6%	8%
40. IHYB	1%	1%	2%	2%	2%	3%
41. 2HYB	0%	3%	5%	5%	6%	8%
42. PHYB	3%	6%	8%	8%	12%	13%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-11f
Penetration Rate of New Technologies to Passenger Cars – TC = TB

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	78%	93%	100%	100%	100%	100%
2. EFR	14%	37%	62%	81%	89%	89%
3. VVTI	80%	77%	81%	84%	83%	82%
4. VVTC	8%	19%	31%	38%	42%	42%
5. VVTD	27%	26%	27%	30%	34%	34%
6. DISP	4%	10%	18%	21%	25%	25%
7. VVLTC	1%	1%	2%	5%	12%	25%
8. VVLTD	12%	18%	31%	36%	38%	38%
9. DISPO	2%	3%	4%	3%	3%	3%
10. VVTO	6%	6%	6%	5%	4%	4%
11. DOHC	6%	6%	5%	5%	6%	7%
12. VVLTO	0%	1%	2%	2%	2%	2%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	11%	20%	33%	37%	41%	52%
15. DSLS	0%	0%	0%	0%	0%	0%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	8%	16%	29%	34%	37%	49%
18. DSLT	1%	7%	9%	11%	13%	14%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	22%	12%	5%	3%	1%	1%
22. ASL	7%	33%	30%	32%	17%	4%
23. TORQ	4%	14%	17%	23%	14%	2%
24. 6SP	26%	30%	27%	28%	15%	2%
25. AMT	9%	17%	36%	39%	54%	67%
26. CVT	11%	14%	14%	12%	12%	12%
27. 6MAN	7%	8%	9%	9%	10%	10%
28. IACC	20%	51%	62%	68%	75%	77%
29. EPS	14%	30%	54%	62%	66%	67%
30. 42V	0%	14%	32%	35%	45%	60%
31. ROLL	5%	33%	56%	74%	88%	88%
32. LDB	21%	21%	21%	21%	21%	21%
33. SAXU	0%	0%	0%	1%	2%	2%
34. SAXL	0%	0%	0%	0%	0%	0%
35. AERO	7%	26%	41%	50%	58%	61%
36. MS1	0%	0%	0%	0%	0%	0%
37. MS2	0%	0%	0%	0%	0%	0%
38. MS5	0%	0%	0%	0%	0%	0%
39. ISGO	0%	2%	4%	4%	6%	8%
40. IHYB	1%	1%	2%	2%	2%	3%
41. 2HYB	0%	3%	5%	5%	6%	8%
42. PHYB	3%	6%	8%	8%	12%	13%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-11g
Penetration Rate of New Technologies to Passenger Cars – Tech exhaustion

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	78%	93%	100%	100%	100%	100%
2. EFR	14%	37%	66%	88%	96%	96%
3. VVTI	80%	76%	77%	79%	74%	72%
4. VVTC	8%	18%	29%	37%	36%	35%
5. VVTD	27%	26%	26%	29%	33%	34%
6. DISP	4%	10%	18%	22%	26%	27%
7. VVLTC	1%	1%	2%	5%	8%	22%
8. VVLTD	12%	17%	33%	40%	41%	43%
9. DISPO	2%	3%	4%	3%	3%	3%
10. VVTO	6%	6%	6%	5%	4%	4%
11. DOHC	6%	6%	5%	5%	5%	7%
12. VVLTO	0%	1%	2%	2%	2%	2%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	11%	18%	36%	42%	50%	61%
15. DSLS	0%	0%	0%	0%	0%	0%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	8%	15%	32%	38%	46%	58%
18. DSLT	1%	9%	13%	15%	22%	24%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	22%	12%	5%	2%	0%	0%
22. ASL	7%	33%	30%	30%	15%	2%
23. TORQ	4%	14%	17%	24%	15%	2%
24. 6SP	26%	30%	27%	28%	15%	2%
25. AMT	9%	17%	36%	40%	56%	69%
26. CVT	11%	13%	13%	11%	11%	11%
27. 6MAN	7%	8%	10%	10%	12%	12%
28. IACC	20%	59%	75%	84%	88%	88%
29. EPS	14%	34%	66%	76%	87%	88%
30. 42V	0%	14%	40%	46%	65%	81%
31. ROLL	5%	33%	57%	80%	88%	88%
32. LDB	21%	21%	21%	21%	21%	21%
33. SAXU	0%	0%	1%	2%	3%	3%
34. SAXL	0%	0%	0%	0%	0%	0%
35. AERO	7%	26%	41%	53%	60%	69%
36. MS1	0%	0%	0%	0%	0%	0%
37. MS2	0%	0%	0%	0%	0%	0%
38. MS5	0%	0%	0%	0%	0%	0%
39. ISGO	0%	1%	1%	1%	2%	4%
40. IHYB	1%	1%	2%	2%	3%	3%
41. 2HYB	0%	3%	9%	9%	11%	12%
42. PHYB	3%	7%	11%	11%	16%	19%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-12a
Penetration Rate of New Technologies to Light Trucks – 25% Below Optimized

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	73%	85%	100%	100%	100%	100%
2. EFR	59%	71%	79%	93%	92%	90%
3. VVTI	63%	66%	69%	71%	72%	73%
4. VVTC	6%	14%	30%	39%	36%	35%
5. VVTD	17%	18%	20%	25%	30%	30%
6. DISP	13%	19%	31%	43%	44%	45%
7. VVLTC	0%	0%	0%	2%	2%	3%
8. VVLTD	10%	11%	14%	20%	20%	21%
9. DISPO	14%	16%	14%	19%	18%	17%
10. VVTO	9%	9%	13%	19%	18%	17%
11. DOHC	11%	11%	18%	19%	21%	22%
12. VVLTO	1%	1%	1%	1%	1%	1%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	12%	12%	19%	23%	26%	30%
15. DSLS	3%	5%	5%	5%	5%	5%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	10%	10%	19%	21%	21%	21%
18. DSLT	0%	0%	0%	0%	0%	0%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	34%	24%	13%	10%	12%	11%
22. ASL	25%	41%	43%	44%	46%	47%
23. TORQ	2%	11%	19%	26%	28%	26%
24. 6SP	36%	40%	40%	36%	36%	38%
25. AMT	11%	19%	33%	47%	45%	44%
26. CVT	4%	4%	3%	3%	3%	3%
27. 6MAN	1%	1%	2%	2%	2%	2%
28. IACC	28%	50%	63%	71%	71%	71%
29. EPS	10%	16%	36%	58%	58%	57%
30. 42V	5%	5%	14%	27%	29%	29%
31. ROLL	7%	28%	31%	34%	34%	34%
32. LDB	26%	32%	35%	36%	36%	36%
33. SAXU	0%	0%	1%	3%	3%	3%
34. SAXL	1%	1%	8%	12%	12%	12%
35. AERO	10%	18%	38%	62%	60%	62%
36. MS1	1%	1%	6%	6%	6%	6%
37. MS2	1%	1%	6%	6%	6%	6%
38. MS5	1%	1%	6%	6%	6%	6%
39. ISGO	2%	2%	3%	5%	5%	5%
40. IHYB	1%	3%	5%	7%	7%	7%
41. 2HYB	0%	1%	1%	1%	1%	1%
42. PHYB	2%	3%	3%	3%	3%	3%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-12b
Penetration Rate of New Technologies to Light Trucks – Optimized 7%

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	73%	85%	100%	100%	100%	100%
2. EFR	59%	71%	79%	92%	91%	93%
3. VVTI	63%	66%	69%	71%	71%	73%
4. VVTC	6%	15%	31%	39%	35%	38%
5. VVTD	17%	18%	22%	26%	30%	31%
6. DISP	13%	22%	35%	46%	47%	49%
7. VVLTC	0%	0%	0%	2%	2%	3%
8. VVLTD	10%	11%	15%	23%	23%	23%
9. DISPO	14%	16%	14%	19%	18%	17%
10. VVTO	9%	10%	13%	19%	18%	17%
11. DOHC	11%	11%	18%	19%	21%	22%
12. VVLTO	1%	1%	1%	1%	1%	1%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	12%	12%	24%	32%	34%	39%
15. DSLS	3%	5%	5%	5%	5%	5%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	10%	10%	22%	30%	30%	30%
18. DSLT	0%	0%	0%	0%	0%	0%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	34%	24%	13%	10%	12%	9%
22. ASL	25%	41%	42%	43%	39%	36%
23. TORQ	2%	11%	24%	33%	29%	29%
24. 6SP	36%	40%	38%	36%	29%	28%
25. AMT	11%	19%	36%	48%	53%	57%
26. CVT	4%	4%	3%	3%	3%	3%
27. 6MAN	1%	1%	2%	2%	2%	2%
28. IACC	28%	57%	70%	80%	84%	86%
29. EPS	10%	22%	43%	66%	69%	74%
30. 42V	5%	8%	23%	44%	48%	50%
31. ROLL	7%	28%	31%	34%	34%	34%
32. LDB	26%	35%	37%	37%	37%	37%
33. SAXU	0%	0%	1%	3%	3%	3%
34. SAXL	1%	1%	9%	12%	13%	14%
35. AERO	10%	18%	38%	60%	68%	80%
36. MS1	1%	2%	7%	13%	13%	14%
37. MS2	1%	2%	7%	10%	11%	11%
38. MS5	1%	1%	6%	6%	7%	7%
39. ISGO	2%	2%	3%	4%	5%	7%
40. IHYB	1%	3%	5%	8%	11%	15%
41. 2HYB	0%	1%	1%	1%	1%	1%
42. PHYB	2%	3%	3%	3%	4%	4%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-12c
Penetration Rate of New Technologies to Light Trucks – 25% Above Optimized

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	73%	85%	100%	100%	100%	100%
2. EFR	59%	71%	79%	93%	92%	90%
3. VVTI	63%	66%	69%	71%	72%	73%
4. VVTC	6%	14%	30%	39%	36%	35%
5. VVTD	17%	18%	20%	25%	30%	30%
6. DISP	13%	19%	31%	43%	44%	45%
7. VVLTC	0%	0%	0%	2%	2%	3%
8. VVLTD	10%	11%	14%	20%	20%	21%
9. DISPO	14%	16%	14%	19%	18%	17%
10. VVTO	9%	9%	13%	19%	18%	17%
11. DOHC	11%	11%	18%	19%	21%	22%
12. VVLTO	1%	1%	1%	1%	1%	1%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	12%	12%	19%	23%	26%	30%
15. DSLS	3%	5%	5%	5%	5%	5%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	10%	10%	19%	21%	21%	21%
18. DSLT	0%	0%	0%	0%	0%	0%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	34%	24%	13%	10%	12%	11%
22. ASL	25%	41%	43%	44%	46%	47%
23. TORQ	2%	11%	19%	26%	28%	26%
24. 6SP	36%	40%	40%	36%	36%	38%
25. AMT	11%	19%	33%	47%	45%	44%
26. CVT	4%	4%	3%	3%	3%	3%
27. 6MAN	1%	1%	2%	2%	2%	2%
28. IACC	28%	50%	63%	71%	71%	71%
29. EPS	10%	16%	36%	58%	58%	57%
30. 42V	5%	5%	14%	27%	29%	29%
31. ROLL	7%	28%	31%	34%	34%	34%
32. LDB	26%	32%	35%	36%	36%	36%
33. SAXU	0%	0%	1%	3%	3%	3%
34. SAXL	1%	1%	8%	12%	12%	12%
35. AERO	10%	18%	38%	62%	60%	62%
36. MS1	1%	1%	6%	6%	6%	6%
37. MS2	1%	1%	6%	6%	6%	6%
38. MS5	1%	1%	6%	6%	6%	6%
39. ISGO	2%	2%	3%	5%	5%	5%
40. IHYB	1%	3%	5%	7%	7%	7%
41. 2HYB	0%	1%	1%	1%	1%	1%
42. PHYB	2%	3%	3%	3%	3%	3%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-12d
Penetration Rate of New Technologies to Light Trucks – 50% Above Optimized

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	73%	85%	100%	100%	100%	100%
2. EFR	59%	71%	79%	89%	89%	91%
3. VVTI	63%	66%	65%	67%	65%	62%
4. VVTC	6%	15%	30%	33%	29%	34%
5. VVTD	17%	19%	21%	22%	26%	25%
6. DISP	13%	22%	36%	44%	46%	50%
7. VVLTC	0%	3%	2%	5%	6%	5%
8. VVLTD	10%	11%	13%	23%	23%	24%
9. DISPO	14%	16%	14%	19%	18%	17%
10. VVTO	9%	10%	13%	19%	18%	17%
11. DOHC	11%	11%	18%	19%	22%	21%
12. VVLTO	1%	1%	1%	3%	3%	3%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	12%	16%	25%	36%	38%	41%
15. DSLS	3%	5%	6%	5%	5%	5%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	10%	10%	22%	32%	33%	37%
18. DSLT	0%	0%	4%	5%	8%	13%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	34%	24%	13%	11%	12%	7%
22. ASL	25%	41%	41%	41%	40%	33%
23. TORQ	2%	11%	22%	28%	22%	23%
24. 6SP	36%	40%	37%	37%	28%	26%
25. AMT	11%	19%	37%	45%	53%	60%
26. CVT	4%	4%	3%	3%	3%	2%
27. 6MAN	1%	1%	2%	2%	2%	2%
28. IACC	28%	61%	78%	85%	96%	97%
29. EPS	10%	26%	53%	73%	78%	86%
30. 42V	5%	12%	30%	51%	62%	71%
31. ROLL	7%	28%	31%	33%	34%	34%
32. LDB	26%	36%	38%	39%	39%	39%
33. SAXU	0%	0%	4%	11%	14%	17%
34. SAXL	1%	3%	10%	14%	14%	14%
35. AERO	10%	18%	38%	56%	64%	79%
36. MS1	1%	3%	8%	13%	17%	17%
37. MS2	1%	2%	7%	13%	17%	17%
38. MS5	1%	2%	7%	13%	14%	15%
39. ISGO	2%	2%	3%	4%	5%	6%
40. IHYB	1%	3%	7%	9%	12%	13%
41. 2HYB	0%	1%	1%	1%	1%	1%
42. PHYB	2%	3%	4%	4%	7%	10%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-12e
Penetration Rate of New Technologies to Light Trucks – Optimized (3%)

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	73%	85%	100%	100%	100%	100%
2. EFR	59%	71%	79%	95%	94%	95%
3. VVTI	63%	66%	69%	71%	71%	72%
4. VVTC	6%	15%	32%	39%	36%	38%
5. VVTD	17%	19%	23%	26%	31%	31%
6. DISP	13%	22%	36%	49%	50%	53%
7. VVLTC	0%	0%	0%	2%	2%	3%
8. VVLTD	10%	11%	15%	24%	24%	28%
9. DISPO	14%	16%	14%	19%	18%	17%
10. VVTO	9%	10%	13%	19%	18%	17%
11. DOHC	11%	11%	18%	18%	20%	21%
12. VVLTO	1%	1%	1%	2%	2%	2%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	12%	12%	23%	33%	35%	41%
15. DSLS	3%	5%	5%	5%	5%	5%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	10%	10%	20%	29%	29%	34%
18. DSLT	0%	0%	0%	1%	3%	4%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	34%	24%	13%	10%	12%	7%
22. ASL	25%	41%	42%	42%	37%	30%
23. TORQ	2%	11%	24%	31%	27%	23%
24. 6SP	36%	40%	38%	33%	26%	24%
25. AMT	11%	19%	36%	50%	56%	63%
26. CVT	4%	4%	3%	3%	3%	2%
27. 6MAN	1%	1%	2%	2%	2%	2%
28. IACC	28%	57%	70%	80%	87%	90%
29. EPS	10%	22%	43%	68%	71%	79%
30. 42V	5%	8%	23%	45%	49%	57%
31. ROLL	7%	28%	31%	34%	34%	34%
32. LDB	26%	35%	37%	37%	38%	38%
33. SAXU	0%	0%	1%	8%	9%	9%
34. SAXL	1%	1%	9%	12%	13%	14%
35. AERO	10%	18%	38%	60%	68%	82%
36. MS1	1%	2%	7%	13%	13%	14%
37. MS2	1%	2%	7%	13%	13%	14%
38. MS5	1%	1%	6%	12%	12%	13%
39. ISGO	2%	2%	3%	4%	5%	7%
40. IHYB	1%	3%	5%	8%	12%	14%
41. 2HYB	0%	1%	1%	1%	1%	1%
42. PHYB	2%	3%	3%	3%	4%	4%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-12f
Penetration Rate of New Technologies to Light Trucks – TC = TB

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	73%	85%	100%	100%	100%	100%
2. EFR	59%	71%	79%	93%	94%	94%
3. VVTI	63%	61%	59%	61%	58%	56%
4. VVTC	6%	13%	27%	30%	24%	26%
5. VVTD	17%	16%	19%	22%	25%	27%
6. DISP	13%	23%	37%	43%	44%	48%
7. VVLTC	0%	1%	3%	7%	8%	11%
8. VVLTD	10%	11%	16%	25%	25%	26%
9. DISPO	14%	16%	14%	19%	18%	17%
10. VVTO	9%	10%	13%	19%	18%	17%
11. DOHC	11%	8%	16%	23%	27%	30%
12. VVLTO	1%	1%	1%	3%	3%	3%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	12%	15%	27%	45%	50%	58%
15. DSLS	3%	5%	5%	5%	5%	5%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	10%	13%	27%	43%	46%	53%
18. DSLT	0%	4%	10%	12%	16%	19%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	34%	24%	13%	11%	12%	7%
22. ASL	25%	41%	41%	41%	41%	33%
23. TORQ	2%	11%	22%	29%	22%	22%
24. 6SP	36%	40%	37%	37%	29%	25%
25. AMT	11%	19%	37%	45%	53%	61%
26. CVT	4%	4%	3%	3%	3%	2%
27. 6MAN	1%	1%	2%	2%	3%	3%
28. IACC	28%	63%	79%	85%	99%	99%
29. EPS	10%	28%	55%	76%	79%	89%
30. 42V	5%	14%	34%	54%	67%	79%
31. ROLL	7%	28%	31%	33%	34%	34%
32. LDB	26%	36%	38%	39%	39%	39%
33. SAXU	0%	0%	7%	15%	20%	22%
34. SAXL	1%	3%	10%	14%	14%	14%
35. AERO	10%	18%	38%	56%	64%	79%
36. MS1	1%	3%	8%	13%	17%	17%
37. MS2	1%	3%	8%	13%	17%	17%
38. MS5	1%	3%	8%	13%	17%	17%
39. ISGO	2%	2%	2%	2%	3%	5%
40. IHYB	1%	3%	4%	5%	5%	5%
41. 2HYB	0%	1%	1%	1%	1%	1%
42. PHYB	2%	4%	8%	10%	16%	20%
43. PLUG	0%	0%	0%	0%	0%	0%

Table V-12g
Penetration Rate of New Technologies to Light Trucks – Tech exhaustion

	Baseline	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
1. LUB	73%	85%	100%	100%	100%	100%
2. EFR	59%	71%	79%	95%	96%	95%
3. VVTI	63%	61%	59%	58%	56%	55%
4. VVTC	6%	13%	27%	33%	29%	28%
5. VVTD	17%	16%	19%	22%	25%	27%
6. DISP	13%	23%	37%	51%	52%	55%
7. VVLTC	0%	1%	3%	9%	11%	14%
8. VVLTD	10%	11%	16%	27%	26%	27%
9. DISPO	14%	16%	14%	19%	18%	17%
10. VVTO	9%	10%	13%	19%	18%	17%
11. DOHC	11%	8%	16%	23%	27%	30%
12. VVLTO	1%	1%	1%	3%	3%	3%
13. CVA	0%	0%	0%	0%	0%	0%
14. SIDI	12%	15%	27%	52%	58%	67%
15. DSLS	3%	5%	5%	5%	5%	5%
16. LBDI	0%	0%	0%	0%	0%	0%
17. TURB	10%	13%	27%	51%	56%	63%
18. DSLT	0%	4%	10%	15%	18%	20%
19. HCCI	0%	0%	0%	0%	0%	0%
20. DSLH	0%	0%	0%	0%	0%	0%
21. 5SP	34%	24%	13%	5%	6%	3%
22. ASL	25%	41%	41%	38%	31%	23%
23. TORQ	2%	11%	22%	31%	25%	20%
24. 6SP	36%	40%	37%	34%	26%	21%
25. AMT	11%	19%	37%	55%	63%	71%
26. CVT	4%	4%	3%	2%	2%	2%
27. 6MAN	1%	1%	2%	3%	3%	3%
28. IACC	28%	63%	79%	92%	99%	99%
29. EPS	10%	28%	55%	88%	92%	98%
30. 42V	5%	14%	34%	68%	81%	93%
31. ROLL	7%	28%	31%	34%	34%	34%
32. LDB	26%	36%	38%	39%	39%	39%
33. SAXU	0%	0%	7%	17%	21%	22%
34. SAXL	1%	3%	10%	15%	15%	15%
35. AERO	10%	18%	38%	61%	68%	83%
36. MS1	1%	3%	8%	17%	21%	21%
37. MS2	1%	3%	8%	17%	21%	21%
38. MS5	1%	3%	8%	17%	21%	21%
39. ISGO	2%	2%	2%	2%	2%	3%
40. IHYB	1%	3%	4%	5%	5%	7%
41. 2HYB	0%	1%	1%	1%	1%	1%
42. PHYB	2%	5%	9%	12%	16%	20%
43. PLUG	0%	0%	0%	0%	0%	0%

VI. MANUFACTURER SPECIFIC CAFE CAPABILITIES

Table VI-1a for passenger cars and Table VI-2a for light trucks shows the CAFE product plans for each of the manufacturers, based on the manufacturer's plans without taking into account any alternative or dual fuel vehicle attributes.

Table VI-1b for passenger cars and Table VI-2b for light trucks shows the **ADJUSTED BASELINE**. Note that when we do cost and benefit analyses, we use the **ADJUSTED BASELINE** throughout the analysis. The adjusted baseline assumes for the analysis that each manufacturer, below the MY 2010 standard applicable to that manufacturer, (except Ferrari, Lotus, Maserati, Mercedes, Porsche and Volkswagen) would apply technology to achieve the MY 2010 standard. Those mpg levels of those manufacturers with product plans above the MY 2010 standard, or above their required reform level standard in any model year, are retained for the adjusted baseline. Our rationale for this adjustment of the baseline is that the costs and benefits of achieving MY 2010 mpg levels for light trucks have already been analyzed and estimated in previous analyses. The methodology in this analysis is to apply technologies to the manufacturers' plans and increase them to the adjusted baseline. The costs of these technologies are estimated, but they are not considered part of this rule. We then estimate the costs and benefits of going from the adjusted baseline to the level of the alternatives.[134]

The required standard levels for only the proposal are shown in Table VI-1d for passenger cars and VI-2d for light trucks. For the other tables in the group from Tables VI-1c through VI-1j for passenger cars and Tables VI-2c through VI-2j for light trucks shows what we believe the manufacturers' fuel economy could be for "meeting" the alternative levels analyzed in this analysis. They include in some cases manufacturers' plans at levels higher than the alternative standards would require. Note that not all manufacturers are assumed to attempt to "meet" the alternatives. We assume that Ferrari, Lotus, Maserati, Mercedes, Porsche and Volkswagen would not meet these levels because, for them, the cost of meeting these levels is more than the cost of paying penalties. These manufacturers have shown, in the past, the willingness to pay penalties rather than spend more money to improve the fuel economy of their products.

The agency has performed an analysis of how manufacturers could respond to changes in the proposed CAFE levels. The "Technology Application Analysis" (or the "Volpe Analysis") uses a technology application algorithm to systematically apply consistent cost and performance assumptions to the entire industry, as well as consistent assumptions regarding economic decision-making by manufacturers. The resulting computer model (the CAFE Compliance and Effects Model), developed by technical staff of the DOT Volpe National Transportation Systems Center in consultation with NHTSA staff, is used to help estimate the overall economic impact of the alternative CAFE standards. The Volpe analysis shows the economic impact of the standards in terms of increases in new vehicle prices on a manufacturer-wide, industry-wide, and average per-vehicle basis. Based on these estimates and corresponding estimates of net economic and

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[134] Some manufacturer's plans are above the level of the standard already and are assumed to remain at that level. Some manufacturer's levels go slightly above the proposed mark for them since some technologies are applied to all models of a particular manufacturer so that the exact level for each manufacturer may be slightly higher than the level of the standard and costs and benefits are estimated to that level.

other benefits, the agency is able to consider alternatives that are economically practicable and technologically feasible.

We note that the Volpe model has been updated and refined with respect to its representation of some fuel-saving technologies, but the model remains fundamentally unchanged. The model has been peer reviewed. The model documentation, including a description of the input assumptions and process, as well as peer review reports, was made available in the rulemaking docket for the August 2005 NPRM.[135]

Our analyses of the potential effects of alternative CAFE standards were founded on two major elements: (1) projections of the technical characteristics and sales volumes of future product offerings and (2) estimates of the applicability and incremental cost and fuel savings associated with different hardware changes—technologies—that might be utilized in response to alternative CAFE standards.

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[135] *See* Docket Nos. NHTSA-20005-22223-3, 4, 5.

Table VI-1a
Manufacturers Production Plans
Estimated mpg
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	26.9	26.9	26.9	26.9	26.9
Chrysler	28.2	28.2	31.3	31.2	31.3
Ferrari	14.6	14.6	14.6	14.6	14.6
Ford	28.2	30.5	30.5	30.5	30.5
Fuji (Subaru)	27.1	27.1	27.1	27.1	27.1
General Motors	28.2	27.8	27.8	27.8	27.8
Honda	34.8	34.8	34.8	34.8	34.8
Hyundai	32.7	32.7	32.7	32.7	32.7
Lotus	29.2	29.2	29.2	29.2	29.2
Maserati	15.9	15.9	15.9	15.9	15.9
Mercedes	25.1	25.1	25.1	25.1	25.1
Mitsubishi	29.8	30.2	30.4	30.6	30.6
Nissan	30.6	31.2	31.2	31.2	31.2
Porsche	24.5	24.5	24.5	24.5	24.5
Suzuki	29.6	29.6	29.6	29.6	29.6
Toyota	34.3	34.3	34.4	34.4	34.4
Volkswagen	28.8	28.8	28.8	28.8	28.8
Total/Average	30.0	30.3	30.5	30.5	30.6

Table VI-1b
Adjusted Baseline
Passenger Cars
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	27.5	27.5	27.5	27.5	27.5
Chrysler	28.2	28.2	31.3	31.2	31.3
Ferrari	14.6	14.6	14.6	14.6	14.6
Ford	28.2	30.5	30.5	30.5	30.5
Fuji (Subaru)	27.6	27.6	27.6	27.6	27.6
General Motors	28.2	27.8	27.8	27.8	27.8
Honda	34.8	34.8	34.8	34.8	34.8
Hyundai	32.7	32.7	32.7	32.7	32.7
Lotus	29.2	29.2	29.2	29.2	29.2
Maserati	15.9	15.9	15.9	15.9	15.9
Mercedes	26.2	27.0	27.4	27.5	27.5
Mitsubishi	29.8	30.2	30.4	30.6	30.6
Nissan	30.6	31.2	31.2	31.2	31.2
Porsche	25.4	25.5	25.5	26.5	26.5
Suzuki	29.6	29.6	29.6	29.6	29.6
Toyota	34.3	34.3	34.4	34.4	34.4
Volkswagen	28.8	28.8	28.8	28.8	28.8
Total/Average	30.1	30.4	30.7	30.7	30.7

Table VI-1c
Estimated Achievable Fuel Economy Levels
25% Below Optimized
Passenger Cars
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	28.7	29.0	29.6	30.1	30.1
Chrysler	28.2	28.2	31.3	31.2	32.0
Ferrari	14.6	14.6	14.6	14.6	14.6
Ford	29.4	31.4	31.5	32.5	33.7
Fuji (Subaru)	28.6	28.7	29.8	34.1	37.5
General Motors	28.6	29.5	30.4	31.9	33.0
Honda	34.8	34.8	34.8	34.8	34.8
Hyundai	32.7	32.7	33.5	34.5	35.6
Lotus	29.2	29.2	29.2	29.2	29.2
Maserati	15.9	15.9	15.9	15.9	15.9
Mercedes	26.2	27.0	27.4	29.8	30.1
Mitsubishi	31.2	32.2	33.4	34.7	35.8
Nissan	30.6	31.2	31.9	32.9	34.0
Porsche	25.4	25.5	25.5	26.5	26.5
Suzuki	31.3	34.8	34.8	37.6	39.4
Toyota	34.3	34.3	34.4	34.4	34.4
Volkswagen	29.5	29.7	31.2	31.3	32.3
Total/Average	30.5	31.2	31.9	32.8	33.5

Table VI-1d
Required Fuel Economy Levels
Proposed Optimized (7%) Standard
Passenger Cars
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	33.3	35.0	36.0	36.8	37.7
Chrysler	28.7	29.3	32.2	32.6	33.6
Ferrari	30.4	32.0	33.1	33.9	34.9
Ford	31.0	32.7	33.7	34.5	35.5
Fuji (Subaru)	36.9	38.7	39.6	40.1	40.8
General Motors	30.0	31.7	32.8	33.7	34.7
Honda	32.1	33.8	34.8	35.5	36.4
Hyundai	33.4	35.1	36.0	36.7	37.5
Lotus	38.1	40.0	40.8	41.2	41.7
Maserati	28.9	30.6	31.8	32.8	34.0
Mercedes	31.7	33.3	34.4	35.3	36.2
Mitsubishi	33.0	35.1	35.9	37.0	37.9
Nissan	31.2	33.2	34.2	35.0	35.9
Porsche	37.6	39.4	40.3	40.7	41.3
Suzuki	37.3	39.2	40.1	40.6	41.2
Toyota	30.1	31.5	32.7	33.6	34.6
Volkswagen	35.4	37.2	38.2	38.8	39.5
Total/Average	31.2	32.8	34.0	34.8	35.7

Table VI-1e
Estimated Achievable Fuel Economy Levels
Proposed Optimized (7%) Standard
Passenger Cars
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	28.7	29.0	29.6	30.1	30.1
Chrysler	28.7	29.3	32.3	32.6	33.1
Ferrari	14.6	14.6	14.6	14.6	14.6
Ford	29.5	32.7	33.7	34.5	35.6
Fuji (Subaru)	28.6	28.7	29.8	34.1	37.5
General Motors	30.0	31.7	32.3	33.7	34.7
Honda	34.8	34.8	34.8	35.5	36.4
Hyundai	33.4	35.1	36.0	36.7	37.1
Lotus	29.2	29.2	29.2	29.2	29.2
Maserati	15.9	15.9	15.9	15.9	15.9
Mercedes	26.2	27.0	27.4	29.8	30.1
Mitsubishi	33.5	35.1	35.9	37.0	37.9
Nissan	31.2	33.2	34.2	35.0	35.9
Porsche	25.4	25.5	25.5	26.5	26.5
Suzuki	31.3	34.8	34.8	37.6	41.8
Toyota	34.3	34.3	34.4	34.4	34.6
Volkswagen	29.5	29.7	31.2	31.3	32.3
Total/Average	31.0	32.3	33.1	33.9	34.7

Table VI-1f
Estimated Achievable Fuel Economy Levels
25% Above Optimized
Passenger Cars
(mpg)

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	28.7	29.0	29.6	30.1	30.1
Chrysler	30.2	31.4	34.2	34.4	34.1
Ferrari	14.6	14.6	14.6	14.6	14.6
Ford	29.5	33.1	34.3	35.8	37.3
Fuji (Subaru)	28.6	28.7	29.8	34.1	37.5
General Motors	30.4	32.9	33.6	35.6	36.4
Honda	34.8	36.4	37.0	37.7	38.3
Hyundai	35.6	37.9	38.5	39.0	39.3
Lotus	29.2	29.2	29.2	29.2	29.2
Maserati	15.9	15.9	15.9	15.9	15.9
Mercedes	26.2	27.0	27.4	29.8	30.1
Mitsubishi	34.3	37.3	38.6	39.3	39.6
Nissan	32.8	35.7	36.5	37.0	37.7
Porsche	25.4	25.5	25.5	26.5	26.5
Suzuki	31.3	34.8	34.8	37.6	45.2
Toyota	34.3	34.3	34.6	35.5	36.3
Volkswagen	29.5	29.7	31.2	31.3	32.3
Total/Average	31.5	33.3	34.2	35.3	36.1

Table VI-1g
Estimated Achievable Fuel Economy Levels
50% Above Optimized
Passenger Cars
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	28.7	29.0	29.6	30.1	30.1
Chrysler	31.0	33.3	36.0	36.1	35.2
Ferrari	14.6	14.6	14.6	14.6	14.6
Ford	29.5	33.1	34.3	35.8	39.2
Fuji (Subaru)	28.6	28.7	29.8	34.1	37.5
General Motors	30.4	32.9	33.6	35.9	37.4
Honda	35.5	38.2	39.2	40.6	40.8
Hyundai	37.0	41.2	41.5	42.0	42.4
Lotus	29.2	29.2	29.2	29.2	29.2
Maserati	15.9	15.9	15.9	15.9	15.9
Mercedes	26.2	27.0	27.4	29.8	30.1
Mitsubishi	34.3	37.3	41.1	41.3	41.9
Nissan	32.9	35.9	38.0	39.4	40.0
Porsche	25.4	25.5	25.5	26.5	26.5
Suzuki	31.3	34.8	34.8	37.6	49.8
Toyota	34.3	36.1	36.7	37.1	37.7
Volkswagen	29.5	29.7	31.2	31.3	32.3
Total/Average	31.7	34.0	35.1	36.4	37.6

Table VI-1h
Estimated Achievable Fuel Economy Levels
Optimized (3%)
Passenger Cars
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	28.7	29.0	29.6	30.1	30.1
Chrysler	31.0	34.1	36.7	37.6	36.4
Ferrari	14.6	14.6	14.6	14.6	14.6
Ford	29.5	33.1	34.3	35.8	39.8
Fuji (Subaru)	28.6	28.7	29.8	34.1	37.5
General Motors	30.4	32.9	33.6	35.9	37.4
Honda	38.5	40.3	40.6	41.9	42.0
Hyundai	39.6	42.5	42.5	43.5	43.7
Lotus	29.2	29.2	29.2	29.2	29.2
Maserati	15.9	15.9	15.9	15.9	15.9
Mercedes	26.2	27.0	27.4	29.8	30.1
Mitsubishi	34.3	37.3	41.1	41.3	41.9
Nissan	32.9	35.9	38.0	39.9	40.5
Porsche	25.4	25.5	25.5	26.5	26.5
Suzuki	31.3	34.8	34.8	37.6	49.8
Toyota	35.6	37.7	37.9	39.0	39.2
Volkswagen	29.5	29.7	31.2	31.3	32.3
Total/Average	32.2	34.5	35.5	37.0	38.2

Table VI-1i
Estimated Achievable Fuel Economy Levels
Total Cost = Total Benefit
Passenger Cars
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	28.7	29.0	29.6	30.1	30.1
Chrysler	31.0	34.4	38.0	38.4	36.8
Ferrari	14.6	14.6	14.6	14.6	14.6
Ford	29.5	33.1	34.3	35.8	39.8
Fuji (Subaru)	28.6	28.7	29.8	34.1	37.5
General Motors	30.4	32.9	33.6	35.9	37.4
Honda	39.0	40.6	41.0	43.7	43.8
Hyundai	39.6	44.2	45.0	47.6	47.6
Lotus	29.2	29.2	29.2	29.2	29.2
Maserati	15.9	15.9	15.9	15.9	15.9
Mercedes	26.2	27.0	27.4	29.8	30.1
Mitsubishi	34.3	37.3	41.1	41.3	41.9
Nissan	32.9	35.9	38.0	39.9	40.5
Porsche	25.4	25.5	25.5	26.5	26.5
Suzuki	31.3	34.8	34.8	37.6	51.6
Toyota	36.0	40.7	40.9	40.9	41.0
Volkswagen	29.5	29.7	31.2	31.3	32.3
Total/Average	32.3	35.0	36.1	37.6	38.8

Table VI-1j
Estimated Achievable Fuel Economy Levels
Technology Exhaustion
Passenger Cars
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	28.7	29.0	29.6	30.1	30.1
Chrysler	31.0	34.4	38.0	38.4	36.8
Ferrari	14.6	14.6	14.6	14.6	14.6
Ford	29.5	33.1	34.3	35.8	39.8
Fuji (Subaru)	28.6	28.7	29.8	34.1	37.5
General Motors	30.4	32.9	33.6	35.9	37.4
Honda	39.7	41.4	41.7	44.5	44.7
Hyundai	39.6	44.2	45.0	48.5	48.7
Lotus	29.2	29.2	29.2	29.2	29.2
Maserati	15.9	15.9	15.9	15.9	15.9
Mercedes	26.2	27.0	27.4	29.8	30.1
Mitsubishi	34.3	37.3	41.1	41.3	41.9
Nissan	32.9	35.9	38.0	39.9	40.5
Porsche	25.4	25.5	25.5	26.5	26.5
Suzuki	31.3	34.8	34.8	37.6	51.6
Toyota	36.0	42.0	44.5	46.9	48.7
Volkswagen	29.5	29.7	31.2	31.3	32.3
Total/Average	32.3	35.2	36.6	38.5	39.9

Table VI-2a
Manufacturers Production Plans
Estimated mpg
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	21.3	21.3	21.3	21.3	21.3
Chrysler Ferrari	23.5	23.8	24.4	25.0	25.4
Ford	23.6	24.1	25.3	25.3	25.3
Fuji (Subaru)	27.1	27.1	27.1	27.1	27.0
General Motors	21.6	21.8	21.8	21.8	21.8
Honda	25.0	25.0	25.0	25.0	25.0
Hyundai Lotus Maserati	24.5	24.5	24.5	24.5	24.5
Mercedes	18.7	18.7	18.7	18.7	18.7
Mitsubishi	24.9	23.8	26.6	26.7	26.7
Nissan	20.9	21.0	21.0	21.0	21.0
Porsche	17.3	17.3	17.3	17.3	17.3
Suzuki	22.8	22.8	22.8	22.8	22.8
Toyota	23.3	23.1	23.4	23.4	23.4
Volkswagen	20.1	20.1	20.1	20.1	20.1
Total/Average	22.9	23.1	23.5	23.6	23.7

Table VI-2b
Adjusted Baseline
Light Trucks
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	22.4	23.8	23.8	23.8	23.8
Chrysler	23.6	23.9	24.5	25.1	25.6
Ferrari					
Ford	23.6	24.1	25.3	25.3	25.3
Fuji (Subaru)	27.5	27.5	27.5	27.5	27.5
General Motors	22.9	23.0	23.0	23.0	23.0
Honda	25.0	25.0	25.0	25.0	25.0
Hyundai	25.2	25.2	25.2	25.2	25.2
Lotus					
Maserati					
Mercedes	19.1	19.6	23.4	23.4	23.4
Mitsubishi	25.5	26.7	29.8	29.9	29.9
Nissan	23.7	24.5	24.5	24.5	24.5
Porsche	17.3	17.3	17.3	17.3	17.3
Suzuki	23.4	23.7	26.4	26.6	28.3
Toyota	23.4	23.2	23.5	23.5	23.5
Volkswagen	20.1	20.1	20.1	20.1	20.1
Total/Average	23.5	23.7	24.2	24.3	24.4

Table VI-2c
Estimated Achievable Fuel Economy Levels
25% Below Optimized
Light Trucks
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	22.4	23.8	23.8	23.8	23.8
Chrysler	25.0	25.6	27.7	27.8	28.0
Ferrari					
Ford	24.6	25.7	27.7	27.7	27.7
Fuji (Subaru)	27.8	29.0	32.7	32.6	32.8
General Motors	23.0	24.7	26.3	26.3	26.3
Honda	26.0	27.2	28.6	28.6	28.6
Hyundai	26.1	28.7	30.0	30.0	30.3
Lotus					
Maserati					
Mercedes	19.1	19.6	23.4	23.4	23.4
Mitsubishi	25.5	33.1	36.9	37.1	37.2
Nissan	23.8	25.8	27.1	27.1	27.1
Porsche	17.3	17.3	17.3	17.3	17.3
Suzuki	23.4	23.7	26.4	26.6	33.6
Toyota	24.7	25.6	26.9	26.9	26.9
Volkswagen	20.1	20.1	20.1	20.1	20.1
Total/Average	24.3	25.5	27.3	27.3	27.4

Table VI-2d
Required Fuel Economy Levels
Proposed Optimized (7%) Standard
Light Trucks
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	28.2	29.9	31.2	31.4	31.7
Chrysler	25.2	26.6	28.0	28.5	29.1
Ferrari					
Ford	24.7	26.1	28.0	28.3	28.8
Fuji (Subaru)	30.0	31.7	33.1	33.2	33.4
General Motors	23.9	25.4	26.5	27.0	27.4
Honda	26.1	27.7	28.9	29.2	29.6
Hyundai	27.5	29.1	30.4	30.6	31.0
Lotus					
Maserati					
Mercedes	28.4	30.1	31.4	31.6	31.9
Mitsubishi	29.4	30.8	32.2	32.3	32.6
Nissan	24.9	26.2	27.3	27.7	28.2
Porsche	25.9	27.4	28.7	29.0	29.4
Suzuki	30.3	32.1	33.5	33.5	33.7
Toyota	24.9	26.0	27.2	27.6	28.0
Volkswagen	26.2	27.8	29.0	29.3	29.7
Total/Average	25.0	26.4	27.8	28.2	28.6

Table VI-2e
Estimated Achievable Fuel Economy Levels
Proposed Optimized (7%) Standard
Light Trucks
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	22.4	23.8	23.8	23.8	23.8
Chrysler	25.2	25.7	28.0	28.7	29.1
Ferrari					
Ford	24.7	26.1	28.0	28.3	28.8
Fuji (Subaru)	27.8	29.0	32.7	33.2	33.5
General Motors	23.0	24.7	26.5	27.0	27.4
Honda	26.1	27.7	28.9	29.2	29.6
Hyundai	26.1	29.1	30.4	30.5	31.0
Lotus					
Maserati					
Mercedes	19.1	19.6	23.4	23.4	23.4
Mitsubishi	25.5	33.1	36.9	37.1	37.2
Nissan	23.8	26.2	27.6	27.7	28.2
Porsche	17.3	17.3	17.3	17.3	17.3
Suzuki	23.4	23.7	26.4	26.6	34.8
Toyota	24.9	26.0	27.2	27.6	28.0
Volkswagen	20.1	20.1	20.1	20.1	20.1
Total/Average	24.4	25.8	27.5	28.0	28.4

Table VI-2f
Estimated Achievable Fuel Economy Levels
25% Above Optimized
Light Trucks
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	22.4	23.8	23.8	23.8	23.8
Chrysler	25.3	25.8	28.2	29.2	30.3
Ferrari					
Ford	24.8	26.6	28.2	29.1	29.9
Fuji (Subaru)	27.8	29.0	32.7	35.1	35.1
General Motors	23.0	24.7	26.8	27.4	28.2
Honda	26.3	29.1	29.1	29.9	30.9
Hyundai	26.1	30.2	30.7	30.8	32.4
Lotus					
Maserati					
Mercedes	19.1	19.6	23.4	23.4	23.4
Mitsubishi	25.5	32.9	36.6	36.7	36.7
Nissan	23.8	26.5	27.9	28.1	29.1
Porsche	17.3	17.3	17.3	17.3	17.3
Suzuki	23.4	23.7	26.4	26.6	34.8
Toyota	25.0	26.5	27.4	27.9	29.2
Volkswagen	20.1	20.1	20.1	20.1	20.1
Total/Average	24.4	26.1	27.8	28.5	29.5

Table VI-2g
Estimated Achievable Fuel Economy Levels
50% Above Optimized
Light Trucks
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	22.4	23.8	23.8	23.8	23.8
Chrysler	25.4	25.9	28.6	29.9	30.6
Ferrari					
Ford	25.0	27.0	28.5	29.7	30.5
Fuji (Subaru)	27.8	29.0	32.7	35.0	36.5
General Motors	23.0	24.7	27.0	27.6	28.4
Honda	26.3	29.2	29.6	30.7	32.6
Hyundai	26.1	30.2	31.0	31.1	34.0
Lotus					
Maserati					
Mercedes	19.1	19.6	23.4	23.4	23.4
Mitsubishi	25.5	33.1	36.9	37.1	37.2
Nissan	23.8	27.1	27.9	28.1	29.2
Porsche	17.3	17.3	17.3	17.3	17.3
Suzuki	23.4	23.7	26.4	26.6	34.8
Toyota	25.3	26.9	27.7	28.1	29.8
Volkswagen	20.1	20.1	20.1	20.1	20.1
Total/Average	24.6	26.3	28.0	28.9	30.0

Table VI-2h
Estimated Achievable Fuel Economy Levels
Optimized (3%)
Light Trucks
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	22.4	23.8	23.8	23.8	23.8
Chrysler	25.2	25.7	28.2	28.9	29.5
Ferrari					
Ford	24.7	26.1	28.2	28.7	29.2
Fuji (Subaru)	27.8	29.0	32.7	33.6	33.9
General Motors	23.0	24.7	26.7	27.2	27.7
Honda	26.2	27.7	29.1	29.6	30.1
Hyundai	26.1	29.2	30.3	30.4	31.7
Lotus					
Maserati					
Mercedes	19.1	19.6	23.4	23.4	23.4
Mitsubishi	25.5	33.1	36.9	37.1	37.2
Nissan	23.8	26.2	27.6	27.7	28.7
Porsche	17.3	17.3	17.3	17.3	17.3
Suzuki	23.4	23.7	26.4	26.6	34.8
Toyota	24.9	26.0	27.5	27.9	28.5
Volkswagen	20.1	20.1	20.1	20.1	20.1
Total/Average	24.4	25.8	27.7	28.2	28.8

Table VI-2i
Estimated Achievable Fuel Economy Levels
Total Cost = Total Benefit
Light Trucks
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	22.4	23.8	23.8	23.8	23.8
Chrysler	25.8	26.2	29.1	30.8	31.0
Ferrari					
Ford	25.1	27.6	29.0	30.4	31.0
Fuji (Subaru)	27.8	29.0	32.7	36.1	40.9
General Motors	23.0	24.7	27.1	27.7	28.5
Honda	26.3	30.0	30.0	32.1	34.5
Hyundai	26.1	30.3	31.5	31.6	34.6
Lotus					
Maserati					
Mercedes	19.1	19.6	23.4	23.4	23.4
Mitsubishi	25.5	34.4	38.5	38.6	38.7
Nissan	23.8	27.4	28.9	29.1	30.2
Porsche	17.3	17.3	17.3	17.3	17.3
Suzuki	23.4	23.7	26.4	26.6	34.8
Toyota	25.4	26.9	28.2	28.7	30.0
Volkswagen	20.1	20.1	20.1	20.1	20.1
Total/Average	24.7	26.5	28.5	29.5	30.5

Table VI-2j
Estimated Achievable Fuel Economy Levels
Technology Exhaustion
Light Trucks
(mpg)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	22.4	23.8	23.8	23.8	23.8
Chrysler	25.8	26.3	29.1	30.8	31.0
Ferrari					
Ford	25.1	27.6	31.1	31.9	32.6
Fuji (Subaru)	27.8	29.0	32.7	36.1	40.9
General Motors	23.0	24.7	27.1	27.7	28.5
Honda	26.3	30.0	32.5	34.7	36.9
Hyundai	26.1	30.3	31.5	31.6	34.6
Lotus					
Maserati					
Mercedes	19.1	19.6	23.4	23.4	23.4
Mitsubishi	25.5	34.4	38.5	38.7	39.0
Nissan	23.8	27.4	29.1	29.3	30.4
Porsche	17.3	17.3	17.3	17.3	17.3
Suzuki	23.4	23.7	26.4	26.6	34.8
Toyota	25.4	26.9	31.1	31.4	32.5
Volkswagen	20.1	20.1	20.1	20.1	20.1
Total/Average	24.7	26.6	29.4	30.3	31.3

VII. COST IMPACTS

Technology Costs

Table V-1 provides the technology cost estimates used in this analysis. These are meant to represent consumer costs for high-volume production of these technologies after sufficient experience with their application have resulted in all "learning curve" effects being fully realized. The method taken to get to this consumer cost estimate starts with an initial estimate of the incremental manufacturers' direct costs (or variable costs) for high-volume production of these technologies. In the case of some very new technologies, the agency may have only had cost estimates from low volume products and has assumed that the products have not matured in the development production cycle and that a "learning curve" will result in a reduction in the variable cost of the product by 20 percent. The technologies to which the learning curve factors were applied are shown in Table V-3. The variable costs are marked up by a factor of 1.5 to take into account fixed costs of R&D, burden, manufacturer's profits, and dealer's profits. The final results are shown in Table V-1.

The variable costs are incremental costs in material, labor, and variable burden for the product. For example, if a vehicle already has a 4-speed automatic transmission, the cost of applying a 5-speed transmission is assumed to be the incremental cost, calculated as the cost of applying a 5-speed transmission less the cost of applying the previously applied 4-speed automatic transmission.

The learning curve

For some of the technologies, we have included a learning factor. The "learning curve" describes the reduction in unit production costs as a function of accumulated production volume and small redesigns that reduce costs.

A typical learning curve can be described by three parameters: (1) the initial production volume before cost reductions begin to be realized; (2) the rate at which cost reductions occur with increases in cumulative production beyond this initial volume (usually referred to as the "learning rate"); and (3) the production volume after which costs reach a "floor," and further cost reductions no longer occur. Over the region where costs decline with accumulating production volume, an experience curve can be expressed as $C(Q) = aQ^{-b}$, where a is a constant coefficient, Q represents cumulative production, and b is a coefficient corresponding to the assumed learning rate. In turn, the learning rate L, which is usually expressed as the percent by which average unit cost declines with a doubling of cumulative production, and is related to the value of the coefficient b by $L = 100*(1 - 2^{-b})$[136].

Figure VII-1 illustrates a learning curve for a vehicle technology with an initial average unit cost of $100 and a learning rate of approximately 20 percent. In this hypothetical example, the initial

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[136] See, for example, Robert H. Williams, "Toward Cost Buydown via Learning-by-Doing for Environmental Energy Technologies," paper presented at Workshop on Learning-by-Doing in Energy Technologies, Resources for the Future, Washington, D.C., June 17-18, 2003, pp. 1-2. Another common but equivalent formulation of the relationship between L and b is $(1-L)=2^{-b}$, where (1-L) is referred to as the progress ratio; see Richard P. Rumelt, "Note on Strategic Cost Dynamics," POL 2001-1.1, Anderson School of Business, University of California, Los Angeles, California, 2001, pp. 4-5.

production volume before cost reductions begin to be realized is set at 12,000 units and the production volume at the cost floor is set at roughly 50,000 units.

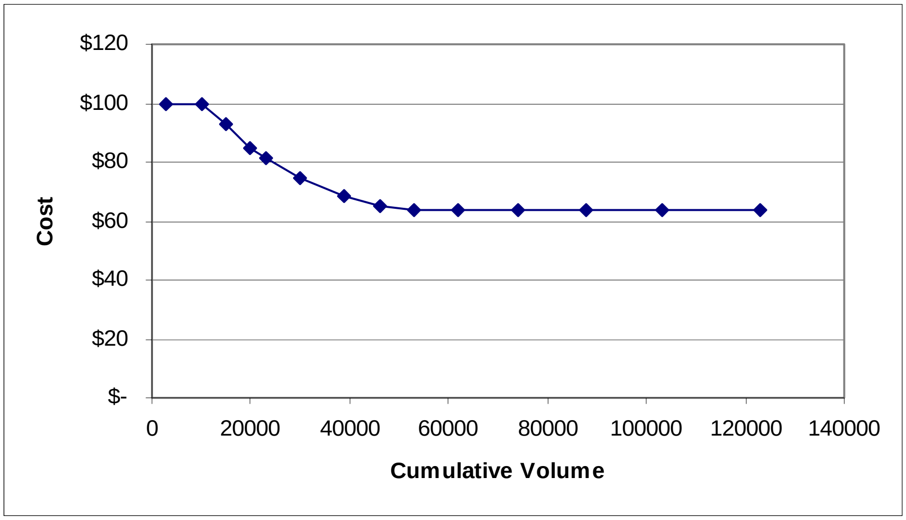

Figure VII-1 Typical Experience Curve

Most studies of the effect of the learning curve on production costs appear to assume that cost reductions begin only after some initial volume threshold has been reached, but not all of these studies specify the threshold volume. The rate at which costs decline beyond the initial threshold is usually expressed as the percent reduction in average unit cost that results from each successive doubling of cumulative production volume, sometimes referred to as the learning rate. Many estimates of learning experience curves do not specify a cumulative production volume beyond which cost reductions no longer occur, instead depending on the asymptotic behavior of the above expression of (CQ) for learning rates below 100 percent to establish a floor on costs.

Table VII-1 summarizes estimates of learning rates derived from studies of production costs for various products.[137]

Table VII-1
Estimated Learning Rates and Associated Volumes for Various Products

Product(s)	Costs Affected	Threshold Volume	Learning Rate
Photovoltaic cells	Total costs	Not reported	20%
Wind turbines	Total costs	100 MW	20%
Gas turbines	Total costs	100 MW	10%
Semiconductors	Total costs	Not reported	13-24%
Automobile assembly	Assembly labor	Not reported	16%
Truck manufacturing	Total costs	Not reported	10%
Battery-electric LDV	Total costs	10,000 units	10%
Fuel cell hybrid LDV	Total costs	10,000 units	16%
Fuel cell LDV powertrain	Total costs	10,000 units	19%

In past rulemaking analyses, EPA has used a learning curve factor of 20 percent for each doubling of production volume. For this analysis, however, NHTSA has applied learning curve cost reductions on a manufacturer-specific basis, and have assumed that learning-based reductions in technology costs occur once during the time that a manufacturer applies the given technology to 25,000 cars or trucks, and are repeated a second time as it produces another 25,000 cars or trucks for the second learning step (car and truck volumes are treated separately for determining these sales volumes). The volumes chosen represent our best estimate for where learning would occur. As such, NHTSA believes that these estimates are better suited to this analysis than the more general approach used by EPA in past rules, because each manufacturer would be implementing technologies at its own pace in this rule, rather than assuming that all manufacturers implement each identical technology at the same time. The volumes chosen represent our best estimate for where learning would occur.

For this analysis, the agency has used engineering judgment to estimate the development production cycle and maturity level for each technology. After having produced 25,000 cars or trucks with a specific part or system, we believe that sufficient learning will have taken place such that costs will be lower by 20 percent for some technologies and 10 percent for others. After another 25,000 units for some technologies, another cost reduction will have been realized. When we applied a learning curve, we applied a 20 percent learning factor for all newly applied technologies except for diesel engines. We have applied a 10 percent factor for diesel costs here because we believe that the diesel technologies being considered are reaching their "learned" limit and, therefore, less learning reductions are available.[138]

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[137] Adapted from Williams, Figure 1, p. 14; Rumelt, Exhibit 5, p. 5; Linda Argote and Dennis Epple, "Learning Curves in Manufacturing," *Science*, Vol. 247 (1990), pp. 920-924; and Philip Auerswald et al., "The Production Recipes Approach to Modeling Technological Innovation: An Application to Learning by Doing," Journal of Economic Dynamics and Control, Vol. 24 (2000), pp. 389-450.

[138] Importantly, diesel technologies can still be considered to have some learning left given recent announcements by General Motors stating potential cost savings associated with their new 4.5 liter Duramax diesel V8 engine (see *Automotive News*, September 24, 2007).

For each of the technologies, we have considered whether we could project future cost reductions due to manufacturer learning. In making this determination, we considered whether or not the technology was in wide-spread use today or expected to be by the model year 2011 time frame, in which case no future learning curve would apply because the technology is already in wide-spread production by the automotive industry today, e.g., on the order of multi-millions of units per year. (Examples of these include 5-speed automatic transmissions and intake-cam phasing variable valve timing. These technologies have been in production for light-duty vehicles for more than 10 years.) In addition, we carefully considered the underlying source data for our cost estimate. If the source data specifically stated that manufacturer cost reduction from future learning would occur, we took that information into account in determining whether we would apply manufacturer learning in our cost projections. Thus, for many of the technologies, we have not applied any future cost reduction learning curve.

However, there are a number of technologies which are not yet in mass production for which we have estimated the initial cost will be reduced in the time frame of this rule due to manufacturer production learning. As indicated in Table V-3, we have applied the learning curve beginning in 2011 to one set of technologies, and for a number of additional technologies we did not apply manufacturer learning until 2014. The distinction between 2011 and 2014 is due to our source data for our cost estimates. For those technologies where we have applied manufacturer learning in 2011, the source of our cost estimate did not rely on manufacturer learning to develop the initial cost estimate we have used – therefore we apply the manufacturer learning methodology beginning in 2011.

The technologies for which we do not begin applying learning until 2014 all have the same reference source, the 2004 NESCCAF study, for which the sub-contractor was The Martec Group. In the work done for the 2004 NESCCAF report, Martec relied upon actual price quotes from Tier 1 automotive suppliers to develop automotive manufacturer cost estimates. Based on information presented by Martec to the National Academy of Sciences (NAS) Committee during their January 24, 2008 public meeting in Dearborn, Michigan[1], the agency understands that the Martec cost estimates done for the NESCCAF report incorporated some element of manufacturer learning. Martec informed stated that the Tier 1 suppliers were specifically requested to provide price quotes which would be valid for three years (2009-2011), and that for some components the Tier 1 supplier included cost reductions in years two and three which the supplier anticipated could occur, and which they anticipated would be necessary in order for their quote to be competitive with other suppliers. Therefore, for this analysis, we did not apply any learning curve to any of the Martec-sourced costs for the first three years of this proposal (2011-2013). However, the theory of manufacturer learning is that it is a continuous process, though the rate of improvement decreases as the number of units produced increases. While we were not able to gain access to the detailed submissions from Tier 1 suppliers which Martec relied upon for their estimates, we do believe that additional cost reductions will occur in the future for a number of the technologies for which we relied upon the Martec cost estimates for the reasons stated above in reference to the general learning curve effect. For those technologies we applied a learning

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[1] "Variable Costs of Fuel Economy Technologies" Martec Group, Inc Report Presented to: Committee to Assess Technologies for Improving Light-Duty Vehicle Fuel Economy. Division on Engineering and Physical Systems, Board on Energy and Environmental Systems, the National Academy of Sciences, January 24, 2008.

curve beginning in 2014. Martec has recently submitted a study to the NAS Committee comparing the 2004 NESCAF study with new updated cost information. Given that this study had just been completely, the agency could not take it into consideration for the NPRM. However, the agency will review the new study and consider its findings in time for the final rule.

Manufacturers' actual costs for applying these technologies to specific vehicle models are likely to include significant additional outlays for accompanying design or engineering changes to each model, development and testing of prototype versions, recalibrating engine operating parameters, and integrating the technology with other attributes of the vehicle. Manufacturers may also incur additional corporate overhead, marketing, or distribution and selling expenses as a consequence of their efforts to improve the fuel economy of individual vehicle models and their overall product lines.

In order to account for these additional costs, the agency applies an indirect cost multiplier of 1.5 to its estimate of the vehicle manufacturers' direct costs for producing or acquiring each fuel economy-improving technology to arrive at a consumer cost. This estimate was developed by Argonne National Laboratory in a recent review of vehicle manufacturers' indirect costs. The Argonne study was specifically intended to improve the accuracy of future cost estimates for production of vehicles that achieve high fuel economy by employing many of the same advanced technologies considered in the agency's analysis.[139] Thus, its recommendation that a multiplier of 1.5 be applied to direct manufacturing costs to reflect manufacturers' increased indirect costs for deploying advanced fuel economy technologies appears to be appropriate for use in the agency's current analysis. Historically, NHTSA has used almost the exact same multiplier, a multiplier of 1.51, as the markup from variable costs or direct manufacturing costs to consumer costs. This markup takes into account fixed costs, burden, manufacturer's profit, and dealers profit. NHTSA's methodology for developing this markup factor was recently peer reviewed (see Docket No.27453-4).

Potential opportunity costs of improved fuel economy

An important concern is whether achieving the fuel economy improvements required by alternative CAFE standards would require manufacturers to compromise the performance, carrying capacity, safety, or comfort of their vehicles. If it did so, the resulting sacrifice in the value of these attributes to vehicle buyers would represent an additional cost of achieving the required improvements in fuel economy, and thus of manufacturers' compliance with stricter CAFE standards. While exact dollar values of these attributes to buyers are extremely difficult to infer from vehicle purchase prices, it is nevertheless clear that changes in these attributes can affect the utility that vehicle provide to their owners, and thus their value to potential buyers.

The agency has approached this potential problem by developing cost estimates for fuel economy-improving technologies that include any additional manufacturing costs that would be necessary to maintain the performance, comfort, capacity, or safety of any vehicle to which those technologies are applied. In doing so, the agency followed the precedent established by NAS in

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[139] Vyas, Anant, Dan Santini, and Roy Cuenca, ***Comparison of Indirect Cost Multipliers for Vehicle Manufacturing***, Center for Transportation Research, Argonne National Laboratory, April 2000.

its 2002 analysis of the costs and benefits of improving fuel economy by raising CAFE standards.[140] The NAS study estimated "constant performance and utility" costs for fuel economy technologies, and the agency has used these as the basis for developing the technology costs it employed in analyzing manufacturer's costs for complying with alternative standards.

NHTSA fully acknowledges the difficulty of estimating technology costs that include costs for the accompanying changes in vehicle design that are necessary to maintain performance, capacity, and utility. However, the agency believes its cost estimates for fuel economy technologies are generally sufficient to prevent significant reductions in consumer welfare.

The technology application algorithm implemented with the Volpe model was used as the basis for estimating costs for the fleet. We applied the technology application algorithm described in Chapter VI.

The agency did estimate the costs or fines to bring passenger car manufacturers up to the 27.5 mpg level in place for MY 2010 as shown in Table VII-2. Table VII-3 shows the estimates for those light truck manufacturers that are not planning on meeting the CAFE reform level for MY 2011, without using fuel economy adjustments for alternative fueled vehicles, up to the level required for them for MY 2011. These costs have been estimated, but they are not considered to be part of the costs of meeting the proposed requirements. Those costs, and commensurate benefits, are considered part of the costs and benefits of complying with previously issued rules.

Tables VII-4a through 4n for passenger cars and Tables VII-5a through 5n show the costs for light trucks (on an average cost-per-vehicle basis and on a total cost basis) of applying technology necessary to move each manufacturer's planned fuel economy levels up to the level of the alternative. Thus, if a manufacturer's product plans resulted in a fuel economy level of 22.2 mpg during each model year, the cost represents the cumulative cost of technologies necessary to bring that manufacturer's fleet average up to the levels of the alternative. The costs for several manufacturers are the fines that these manufacturers would have to pay on an average vehicle basis. We assume that the costs of fines will be passed on to consumers. The second part of each of these tables shows the estimated total manufacturer costs in millions of dollars. Fines are not included in the second part of these tables, since these are transfer payments and not technology costs.

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[140] National Academy of Sciences, ***Costs and Effectiveness of Increasing Corporate Average Fuel Economy Standards***, 2002.

Table VII-2

Estimated Incremental Costs or Fines over Manufacturer's Plans To get to Adjusted Baseline - Average Cost per Vehicle (2006$) Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	58	59	60	61	61
Chrysler	-	-	-	-	-
Ferrari	710	710	710	710	710
Ford	-	-	-	-	-
Fuji (Subaru)	39	40	40	41	41
General Motors	-	-	-	-	-
Honda	-	-	-	-	-
Hyundai	-	-	-	-	-
Lotus	-	-	-	-	-
Maserati	638	638	638	638	638
Mercedes	255	323	328	356	359
Mitsubishi	-	-	-	-	-
Nissan	-	-	-	-	-
Porsche	334	353	355	454	458)
Suzuki	-	-	-	-	-
Toyota	-	-	-	-	-
Volkswagen	-	-	-	-	-
Total/Average	11	13	13	14	14

Table VII-3

Estimated Incremental Costs or Fines over Manufacturer's Plans
To get to Adjusted Baseline - Average Cost per Vehicle (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	499	761	745	727	720
Chrysler	9	9	9	9	9
Ferrari					
Ford	-	-	-	-	-
Fuji (Subaru)	35	34	33	32	32
General Motors	647	645	630	612	606
Honda	-	-	-	-	-
Hyundai	106	103	101	98	97
Lotus					
Maserati					
Mercedes	433	586	1,152	1,124	1,113
Mitsubishi	153	444	419	408	403
Nissan	1,105	1,181	1,147	1,111	1,097
Porsche	363	363	363	363	363
Suzuki	321	377	1,081	1,070	1,101
Toyota	6	5	5	5	5
Volkswagen	220	220	220	220	220
Total/Average	240	244	248	241	239

Table VII-4a
Estimated Incremental Costs or Fines over Adjusted Baseline
25% Below Optimized
Average Cost per Vehicle (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	456	513	611	710	781
Chrysler	-	-	-	-	109
Ferrari	77	116	193	248	314
Ford	439	240	239	312	411
Fuji (Subaru)	509	537	912	2,825	3,764
General Motors	42	150	323	453	750
Honda	-	-	-	-	-
Hyundai	-	-	45	92	173
Lotus	363	391	462	506	556
Maserati	6	50	127	193	264
Mercedes	138	176	253	439	528
Mitsubishi	109	159	290	533	1,127
Nissan	-	-	24	116	219
Porsche	435	457	528	578	627
Suzuki	416	615	697	2,087	2,160
Toyota	-	-	-	-	-
Volkswagen	299	332	440	489	614
Total/Average	126	126	187	294	428

Table VII-4b
Estimated Incremental Costs or Fines over Adjusted Baseline
25% Below Optimized
Total Incremental Costs in Millions (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	104.6	117.3	134.8	154.4	156.3
Chrysler	-	-	-	-	61.2
Ferrari	-	-	-	-	-
Ford	570.2	307.9	304.6	390.5	509.1
Fuji (Subaru)	23.1	23.8	70.5	339.2	472.6
General Motors	75.9	270.7	548.2	795.4	1,305.7
Honda	-	-	-	-	-
Hyundai	-	-	23.6	47.2	88.0
Lotus	-	-	-	-	-
Maserati	-	-	-	-	-
Mercedes	-	-	-	52.1	59.8
Mitsubishi	12.5	18.0	32.7	58.9	122.7
Nissan	-	-	16.4	79.1	147.6
Porsche	-	-	-	-	-
Suzuki	16.4	44.7	44.7	157.5	162.9
Toyota	-	-	-	-	-
Volkswagen	32.2	36.1	77.8	78.3	122.7
Total/Average	834.8	818.4	1,253.3	2,152.6	3,208.7

Table VII-4c
Estimated Incremental Costs or Fines over Adjusted Baseline
Proposed Optimized (7%)
Average Cost per Vehicle (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	555	672	748	831	891
Chrysler	29	135	151	228	401
Ferrari	160	248	308	352	407
Ford	782	560	627	691	790
Fuji (Subaru)	630	730	1,077	2,968	3,890
General Motors	338	535	644	767	988
Honda	-	-	-	23	55
Hyundai	21	175	390	442	530
Lotus	490	594	638	660	688
Maserati	77	171	237	292	358
Mercedes	231	319	380	554	627
Mitsubishi	1,113	1,585	1,589	1,850	2,303
Nissan	37	164	259	331	575
Porsche	556	655	704	726	759
Suzuki	537	813	868	2,236	2,521
Toyota	-	-	-	-	5
Volkswagen	409	508	594	627	735
Total/Average	276	334	404	512	649

Table VII-4d
Estimated Incremental Costs or Fines over Adjusted Baseline
Proposed Optimized (7%)
Total Incremental Costs in Millions (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	104.6	117.3	134.8	154.4	156.3
Chrysler	16.8	78.5	87.1	129.0	209.1
Ferrari	-	-	-	-	-
Ford	908.5	719.3	798.5	863.9	978.9
Fuji (Subaru)	23.1	23.8	70.5	339.2	472.6
General Motors	617.6	965.9	1,103.2	1,346.4	1,720.2
Honda	-	-	-	20.5	48.6
Hyundai	11.2	92.5	204.1	226.8	258.3
Lotus	-	-	-	-	-
Maserati	-	-	-	-	-
Mercedes	-	-	-	52.1	59.8
Mitsubishi	127.7	179.9	178.9	204.3	252.1
Nissan	26.1	114.9	179.6	225.2	387.6
Porsche	-	-	-	-	-
Suzuki	16.4	44.7	44.7	157.5	190.1
Toyota	-	-	-	-	5.9
Volkswagen	32.2	36.1	77.8	78.3	122.7
Total/Average	1,884.4	2,372.6	2,879.1	3,797.5	4,862.2

Table VII-4e
Estimated Incremental Costs or Fines over Adjusted Baseline
25% Above Optimized
Average Cost per Vehicle (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	654	832	886	958	1,001
Chrysler	328	462	738	849	753
Ferrari	248	380	418	462	501
Ford	870	942	1,103	1,492	1,539
Fuji (Subaru)	751	922	1,242	3,122	4,022
General Motors	814	1,510	1,594	1,913	2,028
Honda	-	115	148	193	357
Hyundai	245	513	673	704	742
Lotus	622	798	814	820	825
Maserati	154	286	336	391	446
Mercedes	319	462	501	670	732
Mitsubishi	2,091	3,326	3,307	3,633	3,847
Nissan	520	1,065	1,142	1,195	1,394
Porsche	682	858	875	886	891
Suzuki	664	1,011	1,033	2,390	3,945
Toyota	-	-	7	42	83
Volkswagen	525	690	743	764	856
Total/Average	494	778	871	1,078	1,185

Table VII-4f
Estimated Incremental Costs or Fines over Adjusted Baseline
25% Above Optimized
Total Cost in Millions (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	104.6	117.3	134.8	154.4	156.3
Chrysler	192.2	268.0	424.4	479.1	384.7
Ferrari	-	-	-	-	-
Ford	908.5	1,062.3	1,300.5	1,817.6	1,907.6
Fuji (Subaru)	23.1	23.8	70.5	339.2	472.6
General Motors	1,374.8	2,606.9	2,734.2	3,359.4	3,530.5
Honda	-	105.4	133.6	171.3	315.0
Hyundai	130.7	270.9	351.8	361.5	371.7
Lotus	-	-	-	-	-
Maserati	-	-	-	-	-
Mercedes	-	-	-	52.1	59.8
Mitsubishi	236.7	373.2	372.1	401.2	418.7
Nissan	367.3	744.8	791.4	812.9	939.8
Porsche	-	-	-	-	-
Suzuki	16.4	44.7	44.7	157.5	297.4
Toyota	-	-	9.4	54.9	107.0
Volkswagen	32.2	36.1	77.8	78.3	122.7
Total/Average	3,386.6	5,653.1	6,445.3	8,239.5	9,083.9

Table VII-4g
Estimated Incremental Costs or Fines over Adjusted Baseline
50% Above Optimized
Average Cost per Vehicle (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	753	991	1,051	1,117	1,166
Chrysler	1,045	1,478	1,475	1,442	1,137
Ferrari	325	512	539	561	594
Ford	952	1,079	1,230	1,608	2,009
Fuji (Subaru)	872	1,120	1,468	3,364	4,297
General Motors	891	1,636	1,709	2,152	2,505
Honda	19	769	880	946	981
Hyundai	421	1,895	1,916	1,971	2,035
Lotus	754	1,012	1,062	1,100	1,155
Maserati	226	407	435	451	484
Mercedes	407	605	638	791	847
Mitsubishi	2,184	3,485	4,115	4,466	4,765
Nissan	753	1,492	2,005	2,343	2,498
Porsche	814	1,067	1,111	1,150	1,205
Suzuki	790	1,215	1,269	2,648	5,019
Toyota	-	115	138	172	223
Volkswagen	635	871	941	973	1,092
Total/Average	620	1,133	1,251	1,501	1,694

Table VII-4h
Estimated Incremental Costs or Fines over Adjusted Baseline
50% Above Optimized
Total Incremental Costs in Millions (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	104.6	117.3	134.8	154.4	156.3
Chrysler	593.5	857.9	848.6	813.9	611.4
Ferrari	-	-	-	-	-
Ford	908.5	1,062.3	1,300.5	1,817.6	2,489.5
Fuji (Subaru)	23.1	23.8	70.5	339.2	472.6
General Motors	1,374.8	2,606.9	2,734.2	3,634.7	4,313.3
Honda	17.9	657.7	772.0	840.9	864.4
Hyundai	224.6	999.7	1,002.0	1,011.6	1,026.8
Lotus	-	-	-	-	-
Maserati	-	-	-	-	-
Mercedes	-	-	-	52.1	59.8
Mitsubishi	236.7	373.2	461.8	487.1	513.2
Nissan	478.1	951.1	1,355.5	1,593.9	1,684.4
Porsche	-	-	-	-	-
Suzuki	16.4	44.7	44.7	157.5	378.4
Toyota	-	154.4	183.8	225.5	288.5
Volkswagen	32.2	36.1	77.8	78.3	122.7
Total/Average	4,010.5	7,884.7	8,986.1	11,206.8	12,981.4

Table VII-4i
Estimated Incremental Costs or Fines over Adjusted Baseline
Optimized (3%)
Average Cost per Vehicle (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	923	1,068	1,089	1,200	1,215
Chrysler	1,182	1,684	1,753	1,982	1,611
Ferrari	473	589	589	671	677
Ford	1,095	1,156	1,274	1,707	2,328
Fuji (Subaru)	1,092	1,225	1,523	3,414	4,308
General Motors	1,028	1,708	1,753	2,256	2,593
Honda	667	1,198	1,229	1,298	1,336
Hyundai	1,875	2,287	2,308	2,401	2,429
Lotus	963	1,095	1,095	1,111	1,122
Maserati	363	457	468	572	583
Mercedes	561	682	682	890	924
Mitsubishi	2,371	3,584	4,176	4,560	4,826
Nissan	907	1,574	2,054	2,661	2,824
Porsche	1,018	1,150	1,150	1,172	1,183
Suzuki	1,010	1,314	1,319	2,687	5,019
Toyota	78	232	234	350	373
Volkswagen	844	970	1,001	1,039	1,120
Total/Average	896	1,284	1,376	1,706	1,915

Table VII-4j
Estimated Incremental Costs or Fines over Adjusted Baseline
Optimized 3%
Total Incremental Costs in Millions (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	104.6	117.3	134.8	154.4	156.3
Chrysler	593.5	977.3	1,008.6	1,116.0	861.3
Ferrari	-	-	-	-	-
Ford	908.5	1,062.3	1,300.5	1,817.6	2,831.4
Fuji (Subaru)	23.1	23.8	70.5	339.2	472.6
General Motors	1,374.8	2,606.9	2,734.2	3,634.7	4,313.3
Honda	616.0	1,079.8	1,113.3	1,154.4	1,177.7
Hyundai	976.4	1,206.9	1,206.9	1,232.4	1,235.9
Lotus	-	-	-	-	-
Maserati	-	-	-	-	-
Mercedes	-	-	-	52.1	59.8
Mitsubishi	236.7	373.2	461.8	487.1	513.2
Nissan	478.1	951.1	1,355.5	1,765.4	1,878.4
Porsche	-	-	-	-	-
Suzuki	16.4	44.7	44.7	157.5	378.4
Toyota	106.3	312.3	312.2	458.0	483.4
Volkswagen	32.2	36.1	77.8	78.3	122.7
Total/Average	5,466.7	8,791.5	9,820.9	12,447.1	14,484.5

Table VII-4k
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Cost = Total Benefit
Average Cost per Vehicle (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	956	1,310	1,331	1,381	1,402
Chrysler	1,204	2,062	2,734	2,766	2,299
Ferrari	490	765	765	776	781
Ford	1,123	1,349	1,466	1,828	2,449
Fuji (Subaru)	1,136	1,538	1,836	3,711	4,611
General Motors	1,050	1,889	1,935	2,355	2,692
Honda	978	1,548	1,594	2,071	2,115
Hyundai	1,891	3,371	3,529	4,003	4,039
Lotus	1,040	1,463	1,463	1,480	1,496
Maserati	385	633	649	660	666
Mercedes	583	886	886	1,022	1,056
Mitsubishi	2,382	3,804	4,396	4,741	5,013
Nissan	929	1,772	2,252	2,793	2,961
Porsche	1,089	1,502	1,502	1,518	1,529
Suzuki	1,060	1,644	1,649	3,006	6,030
Toyota	195	1,143	1,152	1,174	1,187
Volkswagen	871	1,245	1,276	1,287	1,373
Total/Average	966	1,685	1,829	2,159	2,367

Table VII-4l
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Cost = Total Benefit
Total Incremental Costs in Millions (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	104.6	117.3	134.8	154.4	156.3
Chrysler	593.5	1,113.5	1,515.9	1,527.5	1,200.0
Ferrari	-	-	-	-	-
Ford	908.5	1,062.3	1,300.5	1,817.6	2,831.4
Fuji (Subaru)	23.1	23.8	70.5	339.2	472.6
General Motors	1,374.8	2,606.9	2,734.2	3,634.7	4,313.3
Honda	903.8	1,224.0	1,274.4	1,797.9	1,815.9
Hyundai	976.4	1,706.0	1,796.7	2,054.8	2,054.8
Lotus	-	-	-	-	-
Maserati	-	-	-	-	-
Mercedes	-	-	-	52.1	59.8
Mitsubishi	236.7	373.2	461.8	487.1	513.2
Nissan	478.1	951.1	1,355.5	1,765.4	1,878.4
Porsche	-	-	-	-	-
Suzuki	16.4	44.7	44.7	157.5	440.9
Toyota	265.1	1,537.1	1,535.9	1,535.9	1,538.2
Volkswagen	32.2	36.1	77.8	78.3	122.7
Total/Average	5,913.2	10,795.8	12,302.7	15,402.5	17,397.6

Table VII-4m
Estimated Incremental Costs or Fines over Adjusted Baseline Technology Exhaustion
Average Cost per Vehicle (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	1,017	1,475	1,683	1,788	1,969
Chrysler	1,254	2,155	3,026	3,102	2,739
Ferrari	556	919	1,084	1,155	1,287
Ford	1,172	1,503	1,791	2,213	2,961
Fuji (Subaru)	1,213	1,758	2,260	4,156	5,265
General Motors	1,105	2,027	2,243	2,735	3,187
Honda	1,180	1,855	2,083	2,605	2,788
Hyundai	1,968	3,558	3,892	4,728	4,934
Lotus	1,089	1,661	1,870	1,892	2,134
Maserati	435	743	919	1,012	1,133
Mercedes	644	1,045	1,227	1,423	1,595
Mitsubishi	2,470	4,008	4,770	5,165	5,607
Nissan	990	1,932	2,582	3,183	3,484
Porsche	1,139	1,700	1,903	1,936	2,167
Suzuki	1,131	1,864	2,072	3,446	6,684
Toyota	239	2,408	2,913	3,487	3,825
Volkswagen	948	1,449	1,678	1,721	1,994
Total/Average	1,038	2,032	2,406	2,889	3,264

Table VII-4n
Estimated Incremental Costs or Fines over Adjusted Baseline
Technology Exhaustion
Total Incremental Costs in Millions (2006$)
Passenger Cars

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	104.6	117.3	134.8	154.4	156.3
Chrysler	593.5	1,113.5	1,515.9	1,527.5	1,200.0
Ferrari	-	-	-	-	-
Ford	908.5	1,062.3	1,300.5	1,817.6	2,831.4
Fuji (Subaru)	23.1	23.8	70.5	339.2	472.6
General Motors	1,374.8	2,606.9	2,734.2	3,634.7	4,313.3
Honda	1,069.9	1,389.2	1,444.0	1,964.1	1,982.1
Hyundai	976.4	1,706.0	1,796.7	2,263.1	2,266.7
Lotus	-	-	-	-	-
Maserati	-	-	-	-	-
Mercedes	-	-	-	52.1	59.8
Mitsubishi	236.7	373.2	461.8	487.1	513.2
Nissan	478.1	951.1	1,355.5	1,765.4	1,878.4
Porsche	-	-	-	-	-
Suzuki	16.4	44.7	44.7	157.5	440.9
Toyota	265.1	3,171.3	3,764.8	4,517.6	4,872.6
Volkswagen	32.2	36.1	77.8	78.3	122.7
Total/Average	6,079.4	12,595.2	14,701.1	18,758.8	21,110.1

Table VII-5a
Estimated Incremental Costs or Fines over Adjusted Baseline
25% Below Optimized
Average Cost per Vehicle (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	149	220	303	297	303
Chrysler	251	396	682	599	563
Ferrari					
Ford	147	218	281	273	270
Fuji (Subaru)	160	618	2,088	2,031	2,016
General Motors	113	1,030	1,205	1,173	1,160
Honda	141	271	492	478	473
Hyundai	664	898	1,101	1,066	1,067
Lotus					
Maserati					
Mercedes	149	220	303	297	303
Mitsubishi	149	2,838	2,630	2,558	2,530
Nissan	177	340	1,049	1,016	1,003
Porsche	99	171	248	242	248
Suzuki	121	198	286	281	2,877
Toyota	202	367	477	464	459
Volkswagen	110	182	253	253	253
Total/Average	185	526	738	705	708

Table VII-5b
Estimated Incremental Costs or Fines over Adjusted Baseline
25% Below Optimized
Total Incremental Costs in Millions (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	0	0	0	0	0
Chrysler	417	618	1,193	1,077	1,023
Ferrari					
Ford	230	351	463	463	463
Fuji (Subaru)	5	54	232	232	232
General Motors	140	2,124	2,589	2,589	2,589
Honda	103	204	379	379	379
Hyundai	157	243	304	304	308
Lotus					
Maserati					
Mercedes	0	0	0	0	0
Mitsubishi	0	107	101	101	101
Nissan	57	149	474	474	474
Porsche	0	0	0	0	0
Suzuki	0	0	0	0	163
Toyota	239	447	594	594	594
Volkswagen	0	0	0	0	0
Total/Average	1,349	4,296	6,329	6,212	6,326

Table VII-5c
Estimated Incremental Costs or Fines over Adjusted Baseline
Proposed Optimized (7%)
Average Cost per Vehicle (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	154	248	319	330	347
Chrysler	329	439	905	838	815
Ferrari					
Ford	195	288	332	365	425
Fuji (Subaru)	171	646	2,110	2,061	2,108
General Motors	118	1,052	1,276	1,453	1,487
Honda	175	512	668	700	769
Hyundai	675	1,082	1,243	1,270	1,293
Lotus					
Maserati					
Mercedes	154	248	319	330	347
Mitsubishi	160	2,838	2,630	2,558	2,530
Nissan	182	596	1,283	1,251	1,307
Porsche	110	193	264	281	303
Suzuki	132	231	308	308	3,977
Toyota	262	522	603	774	815
Volkswagen	116	204	270	286	308
Total/Average	224	617	861	924	979

Table VII-5d
Proposed Optimized (7%)
Total Incremental Costs in Millions (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	-	-	-	-	-
Chrysler	546.1	663.6	1,583.3	1,507.1	1,481.1
Ferrari					
Ford	305.2	463.5	546.8	618.1	728.7
Fuji (Subaru)	5.2	53.8	231.5	235.0	242.9
General Motors	140.4	2,123.6	2,739.4	3,207.7	3,319.3
Honda	128.2	384.5	514.4	554.3	615.6
Hyundai	157.4	293.1	344.9	360.9	373.1
Lotus					
Maserati					
Mercedes	-	-	-	-	-
Mitsubishi	-	106.8	101.5	101.5	101.5
Nissan	57.0	261.4	579.5	583.6	617.3
Porsche	-	-	-	-	-
Suzuki	-	-	-	-	224.7
Toyota	309.6	635.3	752.1	991.8	1,056.5
Volkswagen	-	-	-	-	-
Total/Average	1,649.3	4,985.5	7,393.6	8,159.9	8,760.6

Table VII-5e
Estimated Incremental Costs or Fines over Adjusted Baseline
25% Above Optimized
Average Cost per Vehicle (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	171	286	336	374	429
Chrysler	490	610	1,162	1,173	1,541
Ferrari					
Ford	233	459	451	797	1,079
Fuji (Subaru)	187	690	2,126	3,316	3,280
General Motors	129	1,080	1,512	1,831	2,125
Honda	228	1,307	1,275	1,306	1,400
Hyundai	686	1,750	1,749	1,804	1,927
Lotus					
Maserati					
Mercedes	171	286	336	374	429
Mitsubishi	176	3,173	2,880	2,801	2,771
Nissan	193	882	1,551	1,529	1,995
Porsche	121	226	275	319	374
Suzuki	149	275	325	363	4,010
Toyota	312	1,020	1,028	1,335	1,628
Volkswagen	127	237	286	330	380
Total/Average	279	873	1,141	1,352	1,655

Table VII-5f
Estimated Incremental Costs or Fines over Adjusted Baseline
25% Above Optimized
Total Cost in Millions (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	0	0	0	0	0
Chrysler	813	919	2,032	2,109	2,800
Ferrari					
Ford	364	739	744	1,351	1,839
Fuji (Subaru)	5	54	232	378	378
General Motors	140	2,124	3,246	4,018	4,705
Honda	167	982	982	1,035	1,122
Hyundai	157	474	485	505	556
Lotus					
Maserati					
Mercedes	0	0	0	0	0
Mitsubishi	0	119	111	111	111
Nissan	57	382	700	705	937
Porsche	0	0	0	0	0
Suzuki	0	0	0	0	225
Toyota	369	1,241	1,282	1,690	2,109
Volkswagen	0	0	0	0	0
Total/Average	2,072	7,034	9,815	11,903	14,781

Table VII-5g
Estimated Incremental Costs or Fines over Adjusted Baseline
50% Above Optimized
Average Cost per Vehicle (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	176	314	358	424	501
Chrysler	597	731	1,408	1,657	1,932
Ferrari					
Ford	462	770	639	1,144	1,418
Fuji (Subaru)	193	723	2,148	2,982	3,376
General Motors	135	1,102	1,875	2,206	2,518
Honda	257	1,329	1,325	1,506	2,197
Hyundai	691	1,750	1,784	1,866	2,439
Lotus					
Maserati					
Mercedes	176	314	358	424	501
Mitsubishi	182	2,838	2,630	2,558	2,530
Nissan	199	1,028	1,337	1,355	1,963
Porsche	127	248	292	358	435
Suzuki	154	308	352	418	4,092
Toyota	563	1,279	1,276	1,535	2,033
Volkswagen	132	259	303	369	446
Total/Average	385	1,008	1,347	1,644	2,041

Table VII-5h
Estimated Incremental Costs or Fines over Adjusted Baseline
50% Above Optimized
Total Incremental Costs in Millions (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	0	0	0	0	0
Chrysler	990	1,097	2,463	2,979	3,432
Ferrari					
Ford	723	1,237	1,053	1,939	2,372
Fuji (Subaru)	5	54	232	340	389
General Motors	140	2,124	4,026	4,798	5,485
Honda	184	999	1,021	1,193	1,760
Hyundai	157	474	495	515	704
Lotus					
Maserati					
Mercedes	0	0	0	0	0
Mitsubishi	0	107	101	101	101
Nissan	57	451	604	609	896
Porsche	0	0	0	0	0
Suzuki	0	0	0	0	225
Toyota	666	1,555	1,591	1,911	2,605
Volkswagen	0	0	0	0	0
Total/Average	2,922	8,098	11,586	14,386	17,969

Table VII-5i
Estimated Incremental Costs or Fines over Adjusted Baseline
Optimized (3%)
Average Cost per Vehicle (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	160	253	336	363	380
Chrysler	329	439	1,092	1,022	1,095
Ferrari					
Ford	195	288	344	398	468
Fuji (Subaru)	176	651	2,121	2,326	2,362
General Motors	124	1,052	1,435	1,609	1,720
Honda	192	497	711	775	803
Hyundai	675	1,078	1,249	1,288	1,356
Lotus					
Maserati					
Mercedes	160	253	336	363	380
Mitsubishi	165	2,838	2,630	2,558	2,530
Nissan	182	596	1,283	1,276	1,765
Porsche	110	198	275	303	325
Suzuki	138	237	319	336	3,977
Toyota	262	522	668	837	891
Volkswagen	121	204	281	308	336
Total/Average	227	616	955	1,028	1,145

Table VII-5j
Estimated Incremental Costs or Fines over Adjusted Baseline
Optimized 3%
Total Incremental Costs in Millions (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	0	0	0	0	0
Chrysler	546	664	1,909	1,837	1,991
Ferrari					
Ford	305	463	567	675	801
Fuji (Subaru)	5	54	232	265	272
General Motors	140	2,124	3,081	3,552	3,840
Honda	141	374	548	614	644
Hyundai	157	292	341	357	391
Lotus					
Maserati					
Mercedes	0	0	0	0	0
Mitsubishi	0	107	101	101	101
Nissan	57	261	580	585	834
Porsche	0	0	0	0	0
Suzuki	0	0	0	0	225
Toyota	310	635	832	1,072	1,154
Volkswagen	0	0	0	0	0
Total/Average	1,662	4,974	8,190	9,058	10,253

Table VII-5k
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Cost = Total Benefit
Average Cost per Vehicle (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	198	369	391	512	649
Chrysler	857	1,012	1,880	2,348	2,225
Ferrari					
Ford	647	1,388	1,201	1,772	1,965
Fuji (Subaru)	215	789	2,187	3,884	5,451
General Motors	151	1,140	2,178	2,475	2,834
Honda	279	2,295	2,238	2,850	3,630
Hyundai	713	1,907	1,984	2,096	2,929
Lotus					
Maserati					
Mercedes	198	374	391	512	655
Mitsubishi	204	3,743	3,513	3,417	3,380
Nissan	215	1,352	1,977	1,992	2,517
Porsche	143	297	325	435	567
Suzuki	182	374	385	517	4,263
Toyota	705	1,407	1,415	1,700	2,174
Volkswagen	154	308	330	446	578
Total/Average	501	1,325	1,770	2,171	2,509

Table VII-5l
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Cost = Total Benefit
Total Incremental Costs in Millions (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	0	0	0	0	0
Chrysler	1,422	1,529	3,288	4,182	3,773
Ferrari					
Ford	995	2,213	1,979	2,948	3,150
Fuji (Subaru)	5	54	232	438	628
General Motors	140	2,124	4,631	5,258	5,944
Honda	184	1,725	1,725	2,258	2,907
Hyundai	157	502	549	564	818
Lotus					
Maserati					
Mercedes	0	0	0	0	0
Mitsubishi	0	141	136	136	136
Nissan	57	581	893	898	1,129
Porsche	0	0	0	0	0
Suzuki	0	0	0	0	225
Toyota	828	1,657	1,764	2,080	2,653
Volkswagen	0	0	0	0	0
Total/Average	3,788	10,525	15,196	18,762	21,364

Table VII-5m
Estimated Incremental Costs or Fines over Adjusted Baseline Technology Exhaustion
Average Cost per Vehicle (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	220	407	638	704	781
Chrysler	961	1,119	2,093	2,479	2,348
Ferrari					
Ford	664	1,410	1,912	2,127	2,299
Fuji (Subaru)	242	827	2,467	4,109	5,511
General Motors	168	1,162	2,349	2,585	2,905
Honda	301	2,300	3,049	3,499	4,076
Hyundai	735	1,940	2,220	2,266	3,045
Lotus					
Maserati					
Mercedes	220	413	644	710	787
Mitsubishi	231	3,743	3,513	3,505	3,755
Nissan	237	1,380	2,287	2,263	2,743
Porsche	165	325	528	578	660
Suzuki	209	413	671	743	4,400
Toyota	722	1,429	2,519	2,595	2,930
Volkswagen	176	341	545	594	677
Total/Average	536	1,364	2,255	2,507	2,785

Table VII-5n
Estimated Incremental Costs or Fines over Adjusted Baseline
Technology Exhaustion
Total Incremental Costs in Millions (2006$)
Light Trucks

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	0	0	0	0	0
Chrysler	1,567	1,674	3,323	4,180	3,827
Ferrari					
Ford	995	2,213	3,025	3,465	3,721
Fuji (Subaru)	5	54	232	438	628
General Motors	140	2,124	4,631	5,258	5,944
Honda	184	1,725	2,299	2,773	3,264
Hyundai	157	502	549	564	818
Lotus					
Maserati					
Mercedes	0	0	0	0	0
Mitsubishi	0	141	136	137	146
Nissan	57	581	968	973	1,202
Porsche	0	0	0	0	0
Suzuki	0	0	0	0	225
Toyota	828	1,657	3,113	3,263	3,703
Volkswagen	0	0	0	0	0
Total/Average	3,933	10,670	18,275	21,051	23,479

Financial Impacts of Raising CAFE Standards

The agency does not have the capability to predict the capital investment needs of the automobile industry to install fuel economy technologies, nor the capability to determine the level of capital investments available to specific manufacturers in the future. The analysis estimates the price increases in total for each manufacturer, under the assumption that prices would be increased and the manufacturer would get back that investment when the vehicles are sold. However, that methodology does not determine whether automobile manufacturers can pay for research and development, plant changes, and tooling necessary to get the technology into the vehicles in the first place. In essence this is a cash flow question. Do they have the cash reserves or can they borrow enough money to fund this process? The implicit assumption in the analysis is yes.

A significant portion of the capital needs will fall upon suppliers to the automobile manufacturers, those companies that develop and sell engines, transmissions, and other fuel economy technologies. So, the capital needs are spread out to both the suppliers and original equipment manufacturers.

The agency would like to have a more informed opinion on the ability of manufacturers to provide the capital investment needs for the various alternatives. In light of these unknowns, the agency is seeking information regarding the manufacturers financial capabilities in meeting this proposal and the alternatives examined. Specific questions are as follows:

QUESTIONS FOR VEHICLE MANUFACTURERS AND SUPPLIERS

1. For each of the model years 2011-2015, please provide the best possible estimate of the incremental capital investments required for your company to comply with the alternatives discussed in this analysis (25% Below Optimized, Optimized (7%), 25% Above Optimized, 50% Above Optimized, Optimized (3%), TC = TB, and Technology Exhaustion. Capital investments are defined here by asset class and consist of outlays for property, plant, machinery, equipment, and special tools used in the production process by vehicle manufacturers and suppliers. Incremental investments are defined as those directly attributed to the fuel economy improvements and would not be incurred in the absence of the new requirements.

2. To the degree possible, please provide the above utilizing the elements below for each model year presenting passenger cars and LTV'S separately (suppliers can supply data by model year). NHTSA understands that the adoption of flexible assembly in which production of passenger cars and many LTV'S are integrated onto the same line may make such distinctions infeasible, particularly in the out-years. In such cases, a combined PC/ LTV estimate for each element below will suffice. The agency further acknowledges that estimates of capital requirements for the out-years must contain, by nature, a high degree of uncertainty.

Asset Classification	**Capital Investment** (Incremental)	**Write-off Period**
New Property	$-	In years
Plant	$-	In years
Machinery& Equipment	$-	In years
Special Tooling	$-	In years

3. Please discuss whether you anticipate that your firm will to be able to raise the incremental capital investments necessary to meet the levels predicted in answer to the questions above. If the answer is no, what level appears likely to be achievable. What alternatives are available to raise the incremental capital investments necessary?

The Impact of Higher Prices on Sales

Higher fuel economy standards are expected to increase the price of passenger cars and light trucks. The potential impact of higher vehicle prices on sales was examined on a manufacturer-specific basis, since the estimated cost of improving fuel economy and the fuel economy improvement is different for each manufacturer. There is a broad consensus in the economic literature that the price elasticity for demand for automobiles is approximately –1.0.[141,142,143] Thus, every one percent increase in the price of the vehicle would reduce sales by one percent. Elasticity estimates assume no perceived change in the quality of the product. However, in this case, vehicle price increases result from adding technologies that improve fuel economy. If consumers do not value improved fuel economy at all, and consider nothing but the increase in price in their purchase decisions, then the estimated impact on sales from price elasticity could be applied directly. However, we believe that consumers do value improved fuel economy, because they reduce the operating cost of the vehicles. We also believe that consumers consider other factors that affect their costs and have included these in the analysis.

To estimate the average value consumers place on fuel savings at the time of purchase, we assume that the average purchaser considers the fuel savings they would receive over a 5 year timeframe. We chose 5 years because this is the average length of time of a financing agreement.[144] The present values of these savings were calculated using a 3 percent discount rate, which is more consistent with the real (after-inflation) rate that consumers receive from their own personal savings in banks, etc, than the 7 percent discount factor. We used a fuel price forecast (see Table VIII-3) that included taxes, because this is what consumers must pay. Fuel savings were calculated over the first 5 years and discounted back to a present value.

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[141] Kleit, A.N. (1990). "The Effect of Annual Changes in Automobile Fuel Economy Standards." *Journal of Regulatory Economics*, vol. 2, pp 151-172.

[142] Bordley, R. (1994). "An Overlapping Choice Set Model of Automotive Price Elasticities," *Transportation Research B*, vol 28B, no 6, pp 401-408.

[143] McCarthy , P.S. (1996). "Market Price and Income Elasticities of New Vehicle Demands," *The Review of Economics and Statistics*, vol. LXXVII, no. 3, pp. 543-547.

[144] National average financing terms for automobile loans are available from the Board of Governors of the Federal Reserve System G.19 "Consumer Finance" release. See: http://www.federalreserve.gov/releases/g19/

The agency believes that consumers may consider several other factors over the 5 year horizon when contemplating the purchase of a new vehicle. The agency added these factors into the calculation to represent how an increase in technology costs might affect consumers' buying considerations.

First, consumers might consider the sales taxes they have to pay at the time of purchasing the vehicle. We took sales taxes in 2007 by state and weighted them by population by state to determine a national weighted-average sales tax of 5.5 percent.

Second, we considered insurance costs over the 5 year period. More expensive vehicles will require more expensive collision and comprehensive (e.g., theft) car insurance. According to the National Association of Insurance Commissioners (NAIC) the national average premium for collision + comprehensive insurance in 2000 was $389 while the average new car transaction price was $20,600. If we assume that this premium is proportional to the new car price, it represents about 1.9 percent of the new car price and insurance is paid each year for the five year period we are considering for payback. Discounting that stream of insurance costs back to present value using a 3 percent discount rate suggests that the present value of the component of insurance costs that vary with vehicle price is equal to about 8.0 percent of the vehicle's price.

Third, we considered that 70 percent of new vehicle purchasers take out loans to finance their purchase. The average new vehicle loan is for 5 years at a 6 percent rate[145]. At these terms the average person taking a loan will pay 16 percent more for their vehicle over the 5 years than a consumer paying cash for the vehicle at the time of purchase[146]. Discounting the additional 3.2 percent (16 percent / 5 years) per year over the 5 years using a 3 percent mid-year discount rate[147] results in a discounted present value of 14.87 percent higher for those taking a loan. Multiplying that by the 70 percent that take a loan, means that the average consumer would pay 10.4 percent more than the retail price for loans.

Fourth, we considered the residual value (or resale value) of the vehicle after 5 years and expressed this as a percentage of the new vehicle price. In other words, if the price of the vehicle increases due to fuel economy technologies, the resale value of the vehicle will go up proportionately. To estimate that value, we looked at 138 model year 2002 vehicles to compare their original MSRP values (based on www.nadaguides.com) to their current trade-in values (5 years later in 2007 based on www.edmunds.com). The sales weighted average residual value for this group of vehicles was 37.5 percent. Discounting the residual value back 5 years using a 3 percent discount rate (37.5 percent * .8755) gives an effective residual value at new of 32.8 percent.

These four factors together, the consumer considering he could get 32.8 percent back upon resale in 5 years, but will pay 10.4 percent more for loans, 5.5 percent more for taxes and 8.0 percent

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[145] New car loan rates in 2007 average about 7.8 percent at commercial banks and 4.5 percent at auto finance companies, so their average is close to 7 percent

[146] Based on www.bankrate.com auto loan calculator for a 5 year loan at 6 percent.

[147] The summation of 3.2 percent x 0.9853 in year one, 3.2 x 0.9566 in year two, 3.2 x 0.9288 in year three, 3.2 x 0.9017 in year 4, and 3.2 x 0.8755 in year five.

more in insurance, results in a 8.9 percent return on the increase in price for fuel economy technology (32.8 percent – 10.4 percent - 5.5 percent – 8.0 percent). Thus, the increase in price per vehicle is multiplied by 0.911 (1 – 0.089) before subtracting the fuel savings to determine the overall net consumer valuation the increase of costs on his purchase decision.

Using sales volumes from Automotive News and the Automotive News 2006 Market Data Book for base vehicle average prices for MY 2006, we determined an average passenger car and an average light truck price per manufacturer. The average base price for all passenger cars using this method was $22,857 and for all light trucks was $26,090. While this method does not give an exact price, the results are reasonable and specific to individual manufacturers[148]. These prices are in 2006 dollars. Average prices and estimated sales volumes are needed because price elasticity is an estimate of how a percent increase in price affects the percent decrease in sales.

A sample calculation for Ford passenger cars under the Optimized 7% alternative in MY 2011 is an estimated retail price increase of $782, which is multiplied by 0.911 to get a residual price increase of $712. The estimated fuel savings over the 5 years of $281 at a 3 percent discount rate results in a net cost to consumers of $431. Comparing that to the $21,821 average price is 2.39 percent price increase. Ford sales were estimated to be about 1,300,000 passenger cars for MY 2011. With a price elasticity of –1.0, a 2.39 percent increase in sales could result in an estimated loss in sales of 3,104 passenger cars at a 3 percent discount rate.

Sales increases occur when the value of improved fuel economy exceeds the consumer cost of added technology. Overall, the 25% Below Optimized and the proposed Optimized (7%) alternatives result in a gain in sales, while the other alternatives result in almost progressively larger losses in sales. Tables VII-6a through 6g show the estimated impact on sales for passenger cars and light trucks combined.

Our projections indicate that CAFE standards will result in sales increases for some manufacturers under some scenarios. These results rest on several assumptions about consumer behavior, in particular, how consumers value fuel economy increases. If consumers are completely unable to perceive any increases in fuel economy, then they would treat the vehicle price increases resulting from CAFE standards as pure price increases without any corresponding quality increase. Under those circumstances, one would expect vehicle sales to fall in accordance with the price elasticity of demand discussed earlier. Our projections of sales increases rest on the assumption that consumers will correctly perceive at least some of the increase in fuel economy and therefore be willing to pay somewhat more for a vehicle with greater fuel economy. Even if consumers value only a portion of the resulting fuel savings, there are instances where those fuel savings are nonetheless projected to be large enough to exceed the increased vehicle price, thus leading to an increase in sales. However, this assumption raises the following question: If some fraction of fuel economy improvements (as perceived and valued by vehicle purchasers) is large enough to exceed the increased vehicle cost (and result in an increase in vehicle sales), then what would be the nature of the market failure such that those levels of fuel economy would not exist but for a CAFE mandate? To better understand this issue, NHTSA

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[148] The base price does not include the more expensive lines of a model or purchased optional equipment; nor does it count discounts given. Thus, it is not an average light truck purchase transaction price, but a price that we can track.

seeks comment on the following questions: What evidence or data exist that indicate the extent to which consumers undervalue fuel economy improvements? Under what circumstances is it reasonable to expect that a mandated increase in fuel economy would lead to an increase in vehicle sales?

Note that there is no feedback loop between this sales analysis and the Volpe model. These sales estimates are not used to determine additional or less mileage traveled or fuel consumed. Also, see the earlier discussion about a market share model in Chapter V.

Table VII-6a
Potential Impact on Sales by Manufacturer
Passenger Cars and Light Trucks Combined
25% Below Optimized

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	-1,408	-1,528	-1,520	-1,497	-2,038
Chrysler	17,429	14,748	20,295	12,675	8,732
Ferrari	-5	-8	-13	-17	-21
Ford	10,813	16,693	24,406	25,835	26,704
Fuji (Subaru)	-1,913	-2,454	-5,948	-11,872	-14,118
General Motors	-3,797	-10,067	12,302	23,018	16,005
Honda	4,820	10,573	14,410	14,877	15,049
Hyundai	-4,103	1,475	4,404	7,216	9,698
Lotus	-32	-34	-40	-43	-46
Maserati	0	-3	-7	-11	-14
Mercedes	-864	-1,159	-1,645	-222	-328
Mitsubishi	29	-1,468	-1,456	-1,537	-2,044
Nissan	-2,089	1,330	132	2,673	5,279
Porsche	-512	-543	-631	-675	-725
Suzuki	-321	-50	-373	-1,497	-4,764
Toyota	11,977	20,734	26,551	27,361	27,659
Volkswagen	-2,195	-1,979	912	329	980
Total/Average	27,828	46,262	91,779	96,615	86,009

Table VII-6b
Potential Impact on Sales by Manufacturer
Passenger Cars and Light Trucks Combined
Proposed Optimized (7%) Alternative

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	-2,258	-2,910	-2,691	-2,540	-3,000
Chrysler	17,331	14,665	10,741	13,423	9,536
Ferrari	-11	-17	-21	-24	-27
Ford	8,551	19,365	26,032	29,032	33,226
Fuji (Subaru)	-2,629	-3,623	-6,938	-12,359	-14,611
General Motors	-2,230	-8,057	14,642	17,547	17,554
Honda	4,764	7,891	11,720	16,296	20,396
Hyundai	-2,120	5,283	4,690	5,361	5,893
Lotus	-43	-51	-55	-55	-57
Maserati	-4	-10	-13	-16	-20
Mercedes	-1,290	-1,837	-2,228	-779	-831
Mitsubishi	-719	-2,662	-2,588	-2,751	-3,134
Nissan	230	5,842	3,615	5,338	2,525
Porsche	-652	-771	-831	-845	-878
Suzuki	-485	-349	-616	-1,726	-6,925
Toyota	12,245	19,544	24,826	22,455	26,886
Volkswagen	-3,840	-4,587	-1,350	-1,659	-763
Total/Average	26,839	47,716	78,935	86,698	85,769

Table VII-6c
Potential Impact on Sales by Manufacturer
Passenger Cars and Light Trucks Combined
25% Supra Alternative

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	-3,123	-4,309	-3,862	-3,644	-4,025
Chrysler	9,912	6,334	-6,223	-6,195	-24,075
Ferrari	-17	-26	-29	-31	-33
Ford	7,370	16,682	19,573	12,529	7,087
Fuji (Subaru)	-3,367	-4,857	-7,907	-16,928	-19,038
General Motors	-30,508	-61,856	-45,558	-58,594	-66,337
Honda	4,722	1,920	3,970	9,350	9,244
Hyundai	1,088	1,979	830	612	2,889
Lotus	-54	-69	-70	-69	-69
Maserati	-9	-16	-19	-21	-24
Mercedes	-1,711	-2,535	-2,786	-1,355	-1,428
Mitsubishi	-1,815	-4,997	-4,703	-5,029	-5,234
Nissan	-5,783	-13,221	-16,419	-15,875	-22,833
Porsche	-799	-1,006	-1,025	-1,027	-1,033
Suzuki	-666	-672	-840	-2,024	-8,197
Toyota	11,809	5,470	10,213	10,327	16,675
Volkswagen	-5,569	-7,281	-3,531	-3,651	-2,513
Total/Average	-18,519	-68,461	-58,385	-81,627	-118,944

Table VII-6d
Potential Impact on Sales by Manufacturer
Passenger Cars and Light Trucks Combined
50% Supra Alternative

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	-3,972	-5,691	-5,271	-5,028	-5,478
Chrysler	-558	-7,331	-20,508	-31,632	-49,142
Ferrari	-23	-35	-37	-38	-39
Ford	-1,342	4,579	12,174	-1,025	-7,272
Fuji (Subaru)	-4,062	-6,079	-9,228	-16,956	-19,945
General Motors	-36,279	-72,169	-75,782	-95,110	-114,136
Honda	8,507	-14,076	-12,017	-6,609	-15,842
Hyundai	1,587	-19,379	-18,338	-19,135	-19,963
Lotus	-66	-87	-91	-92	-96
Maserati	-13	-23	-24	-25	-26
Mercedes	-2,113	-3,214	-3,427	-1,965	-2,052
Mitsubishi	-1,943	-4,681	-4,943	-5,341	-5,587
Nissan	-12,560	-25,212	-34,257	-39,264	-47,405
Porsche	-951	-1,247	-1,293	-1,324	-1,386
Suzuki	-824	-977	-1,170	-2,439	-9,160
Toyota	6,218	11,832	16,778	11,296	8,569
Volkswagen	-7,214	-9,970	-6,437	-6,670	-5,907
Total/Average	-55,606	-153,761	-163,872	-221,357	-294,866

Table VII-6e
Potential Impact on Sales by Manufacturer
Passenger Cars and Light Trucks Combined
Optimized (3%)

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	-5,396	-6,246	-5,557	-5,605	-5,683
Chrysler	10,327	7,841	-7,235	-6,240	-10,436
Ferrari	-33	-41	-40	-45	-45
Ford	6,495	16,042	25,196	27,749	30,897
Fuji (Subaru)	-5,227	-6,376	-9,419	-15,516	-17,566
General Motors	-45,165	-73,656	-53,602	-66,812	-74,776
Honda	37	-9,614	-6,242	-2,122	-840
Hyundai	-22,801	-20,020	-20,005	-20,067	-17,556
Lotus	-84	-95	-94	-93	-93
Maserati	-21	-26	-26	-31	-32
Mercedes	-2,772	-3,449	-3,581	-2,279	-2,156
Mitsubishi	-2,161	-4,807	-5,020	-5,457	-5,661
Nissan	-17,337	-25,420	-36,520	-47,914	-54,454
Porsche	-1,182	-1,333	-1,334	-1,340	-1,344
Suzuki	-1,043	-933	-1,151	-2,291	-8,889
Toyota	21,822	41,006	46,381	44,740	49,292
Volkswagen	-10,333	-11,415	-7,316	-7,598	-6,260
Total/Average	-74,873	-98,542	-85,566	-110,920	-125,605

Table VII-6f
Potential Impact on Sales by Manufacturer
Passenger Cars and Light Trucks Combined
Total Costs = Total Benefit Alternative

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	-5,733	-8,456	-7,659	-7,327	-7,635
Chrysler	-10,937	-23,499	-54,877	-75,745	-73,164
Ferrari	-34	-53	-52	-52	-52
Ford	-9,599	-21,475	-14,836	-30,982	-35,388
Fuji (Subaru)	-5,618	-8,643	-11,398	-21,785	-27,766
General Motors	-48,581	-92,408	-109,370	-126,542	-148,076
Honda	-10,825	-53,233	-53,413	-66,008	-77,005
Hyundai	-23,599	-46,485	-46,833	-53,290	-57,145
Lotus	-91	-126	-125	-124	-125
Maserati	-22	-36	-36	-36	-36
Mercedes	-2,935	-4,557	-4,569	-3,118	-3,226
Mitsubishi	-2,226	-5,991	-6,195	-6,590	-6,807
Nissan	-18,595	-37,982	-48,329	-58,123	-65,615
Porsche	-1,269	-1,746	-1,737	-1,742	-1,761
Suzuki	-1,194	-1,612	-1,674	-3,066	-10,532
Toyota	6,846	-26,703	-20,917	-30,747	-38,504
Volkswagen	-10,754	-15,514	-11,362	-11,204	-9,951
Total/Average	-145,167	-348,520	-393,382	-496,484	-562,788

Table VII-6g
Potential Impact on Sales by Manufacturer
Passenger Cars and Light Trucks Combined
Technology Exhaustion Alternative

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
BMW	-6,280	-9,901	-10,977	-10,963	-12,440
Chrysler	-16,765	-30,229	-71,831	-89,064	-85,899
Ferrari	-39	-63	-74	-77	-85
Ford	-10,835	-23,723	-30,037	-35,235	-38,953
Fuji (Subaru)	-6,152	-10,007	-14,838	-25,105	-31,500
General Motors	-53,560	-103,483	-142,788	-160,265	-186,507
Honda	-16,012	-62,105	-76,863	-88,495	-101,441
Hyundai	-25,559	-50,981	-57,543	-69,209	-75,562
Lotus	-95	-144	-160	-159	-178
Maserati	-25	-42	-52	-56	-62
Mercedes	-3,242	-5,328	-6,511	-5,204	-5,764
Mitsubishi	-2,376	-6,250	-6,667	-7,222	-8,018
Nissan	-20,935	-43,571	-63,048	-74,077	-84,875
Porsche	-1,328	-1,975	-2,219	-2,226	-2,474
Suzuki	-1,335	-1,948	-2,798	-4,077	-11,575
Toyota	2,665	-115,685	-147,858	-175,571	-195,117
Volkswagen	-11,912	-18,533	-17,317	-17,503	-18,843
Total/Average	-173,784	-483,968	-651,580	-764,510	-859,291

Table VII-6h
Potential Impact on Sales
Passenger Cars versus Light Trucks by Alternative
MY 2015

	Passenger Cars	Light Trucks	Total
25% Below Optimized	22,237	63,773	86,009
Optimized (7%)	21,482	64,288	85,769
25% Above Optimized	-48,921	-70,024	-118,944
50% Above Optimized	-138,449	-156,417	-294,866
Optimized (3%)	-170,031	44,426	-125,605
TC = TB	-293,326	-269,462	-562,788
Technology Exhaustion	-557,905	-301,386	-859,291

Potential Impact on Employment

There are three potential areas of employment that fuel economy standards could impact. The first is the hiring of additional engineers by automobile companies and their suppliers to do research and development and testing on new technologies to determine their capabilities, durability, platform introduction, etc. The agency does not anticipate a huge number of incremental jobs in the engineering field. Often people would be diverted from one area to another and the incremental number of jobs might be a few thousand.

The second area is the impact that new technologies would have on the production line. Again, we don't anticipate a large number of incremental workers, as for the most part you are replacing one engine with another or one transmission with another. In some instances the technology is more complex, requiring more parts and there would be a small increase in the number of production employees, but we don't anticipate a large change.

The third area is the potential impact that sales gains or losses could have on production employment. This area is potentially much more sensitive to change than the first two areas discussed above. In the past, the agency and others have made estimates of the impact of sales losses on employment. In the final rule reducing the light truck fuel economy standard for MY 1985, the agency concluded that sales losses of 100,000 to 180,000 would result in employment losses of 12,000 to 23,000 (49 FR 41252, October 22, 1984).[149] In the final rule reducing the MY 1986 passenger car fuel economy standard, the agency concluded that while it was difficult to precisely estimate the impacts, "there would be a likelihood of sales losses well into the hundreds of thousands of units and job losses well into the tens of thousands. Sales and employment losses of these magnitudes would have significant adverse effects on the economy … " (50 FR 40538, October 4, 1985). In the final rule amending the passenger car standards for MY 1987 and 1988, the agency said that "… domestic car production may fall by more than 900,000 units. The short employment effects are substantial: over 130,000 jobs…" (51 FR 35598, October 6, 1986). These estimates imply a ratio between the number of vehicles sales lost and the number of employees laid off in the 1980s of between 6.9 (900,000/130,000) and 8.3 (100,000/12,000).

Certainly productivity has increased since that time. In order to get an estimate of potential job losses per sales loss, we examined more recent U.S. employment (original equipment manufacturers and suppliers) and U.S. production. Total employment in 2000 reached a peak in the Motor Vehicle and Equipment Manufacturing sector of the economy at 1,313,600. Since then there has been a decline to 1,108,000 in 2003 and to 1,098,000 in 2005[150]. Averaging those three years, the average U.S. domestic employee produces 10.5 vehicles. Thus, one could assume that projected sales loss divided by 10.5 would give an estimate of the potential employment loss.

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[149] The agency's decision to lower standards based on that amount of impacts identified in the 1985 rule was upheld by the DC Circuit in Public Citizen v. NHTSA, 848 F.2d 256.

[150] Based on "U.S. Automotive Industry Employment Trends", Office of Aerospace and Automotive Industries, U.S. Department of Commerce, March 30, 2005, and Ward's Automotive Yearbook, 2006, pgs. 215, 222, and 270.

Table VII-7
U.S. Light Duty Vehicle Production and Employment

	U.S. Light Vehicle Production	U.S. Employment	Production per Employee
2000	12,773,714	1,313,600	9.7
2003	12,087,028	1,108,000	10.9
2005	11,946,653	1,098,000	10.9
Total/Average	36,807,396	3,519,600	10.5

At this time, the agency considers these effects to occur in the short to medium term (meaning up to 5 years). Over the next few years, consumers can elect to defer vehicle purchases by continuing to operate existing vehicles. Eventually, however, the rising maintenance costs for aging vehicles will make replacements look more attractive.

However, vehicle owners may also react to persistently higher vehicle costs by permanently owning fewer vehicles, and keeping existing vehicles in service for somewhat longer. In this case, the possibility exists that there may be permanent sales losses, compared with a situation in which vehicle prices are lower.

The 25% Sub Optimizes and the proposed Optimized (7%) alternative would have positive impacts on employment. The other alternatives have negative impacts on employment. Combining the sales effect on passenger cars and light trucks, the impact on employment is estimated in the following table.

Table VII-8
Impact on Auto Industry Employment by Alternative
(Jobs)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
25% Below Optimized	-409	1,151	1,835	2,632	2,118
Optimized (7%)	-327	1,941	2,148	2,689	2,046
25% Above Optimized	-25,822	-33,273	-31,777	-31,082	-32,614
50% Above Optimized	-5,407	-10,527	-10,782	-11,887	-13,186
Optimized (3%)	-9,972	-12,054	-12,381	-14,919	-16,193
TC = TB	-11,760	-22,413	-23,420	-26,578	-27,936
Technology Exhaustion	-13,587	-34,289	-40,892	-47,829	-53,134
Light Trucks					
25% Below Optimized	3,059	3,255	6,906	6,569	6,074
Optimized (7%)	2,883	2,604	5,370	5,568	6,123
25% Above Optimized	1,925	-1,767	-1,021	-3,334	-6,669
50% Above Optimized	111	-4,117	-4,825	-9,195	-14,897
Optimized (3%)	2,841	2,669	4,232	4,356	4,231
TC = TB	-2,066	-10,779	-14,045	-20,706	-25,663
Technology Exhaustion	-2,964	-11,803	-21,163	-24,982	-28,703
Passenger Cars and Light Trucks Combined					
25% Below Optimized	2,650	4,406	8,741	-9,201	8,191
Optimized (7%)	2,556	4,544	7,518	-8,257	8,169
25% Above Optimized	-1,764	-6,520	-5,561	7,774	-11,328
50% Above Optimized	-5,296	-14,644	-15,607	21,082	-28,082
Optimized (3%)	-7,131	-9,385	-8,149	10,564	-11,962
TC = TB	-13,825	-33,192	-37,465	47,284	-53,599
Technology Exhaustion	-16,551	-46,092	-62,055	72,810	-81,837

Table VII-9 provides further information relating to the stringency of the different alternatives. It looks at the largest 7 manufacturers and examines whether or not they run out of technologies that the agency believes they have available. As the alternatives get more stringent, more manufacturers run out of technologies.

Table VII-9
Number of Manufacturers That Run out of Technology

	Cars: Number of Manufacturers Exhausting Technology				
	2011	2012	2013	2014	2015
-25%	0	0	1	0	0
MC=MB	1	0	1	0	2
+25%	2	2	2	1	2
+50%	4	4	4	2	3
TC=TB	5	6	6	5	5
Technology Exhaustion	6	6	6	6	7

	Trucks: Number of Manufacturers Exhausting Technology				
	2011	2012	2013	2014	2015
-25%	3	2	0	1	0
MC=MB	3	2	0	1	0
+25%	3	3	0	4	3
+50%	4	3	0	4	5
TC=TB	6	6	2	6	6
Technology Exhaustion	7	6	6	6	6

VIII. BENEFITS

Economic Impacts from Higher CAFE Standards

Economic impacts from adopting a more stringent CAFE standard for passenger cars and light trucks were estimated separately for each model year over the lifespan of those vehicles in the U.S. vehicle fleet, extending from the initial year when a model is offered for sale through the year when nearly all vehicles from that model year have been retired or scrapped (assumed to be 26 years for passenger cars and 36 years for light trucks in this analysis). The principal source of the economic and environmental impacts considered in this analysis is the reduction in gasoline use resulting from the improvement in fuel economy of new light-duty vehicles produced. Reducing gasoline consumption provides consumer benefits through decreased fuel costs, through reduced costs for externalities such as demand price inflation, economic disruption, and military security, through reduced economic and health impacts from criteria pollutants and green house gas emissions, through increased driving ranges for vehicles, and through consumer surplus from added driving. Offsetting a part of these benefits are added costs from congestion, crashes, and noise, as well as some offset to fuel consumption and pollution savings, all due to an increase in driving that results from lower driving costs (the rebound effect). Each of these impacts is measured by comparing their value under each alternative approach to their value under the adjusted baseline. Future impacts are estimated after discounting to the year the vehicle is sold to determine their present value.[151]

Basic Inputs for Analysis of Economic Impacts

The variety of impacts discussed above are a function of basic factors which determine their magnitude and define their value. These include the discount rate, the level of vehicle sales, the magnitude of the rebound effect, and the relationship between EPA measured fuel efficiency and actual on-road fuel efficiency.

The Discount Rate

Discounting future fuel savings and other benefits is intended to account for the reduction in their value to society when they are deferred until some future date rather than received immediately. The discount rate expresses the percent decline in the value of these benefits – as viewed from today's perspective – for each year they are deferred into the future. Discount rates are used in a variety of analyses that address different aspects of benefit valuation. These include: 1) selecting a set of standards 2) analyzing the impact of those standards 3) examining the impact of uncertainty surrounding our choice of rates used to analyze impacts, and 4) determining the sensitivity of standards selection to the discount rate. However, the agency must select one specific rate to set the standards. The agency uses a rate of 7 percent per year to discount the value of future fuel savings and other benefits when it analyzes the potential impacts of alternative passenger car and light truck CAFE standards. OMB Circular A-4 requires that the agency examine costs and benefits of proposed standards using discount rates of both 3 percent and 7 percent. The 3 percent rate generally represents the consumer rate of time preference while the 7 percent rate generally represents the economy-wide opportunity cost of capital. Benefits based on both of these rates are presented to value the benefits that are associated with the standards set in this proposal. The agency

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[151] Discounting to the year when each model year was produced allows future economic benefits from improving each model year's fuel economy to be compared to added production costs for making those vehicles more fuel-efficient, which are assumed to be incurred at the time those vehicles are manufactured.

uses discount rates ranging from 3 percent to 10 percent per year to analyze the uncertainty surrounding the future impacts of alternative standards.

There are several reasons for the agency's choice of 7 percent as the appropriate discount rate to determine the standards. First, OMB Circular A-4 indicates that this rate reflects the economy-wide opportunity cost of capital. The agency believes that a substantial portion of the cost of this regulation may come at the expense of other investments the auto manufacturers might otherwise make. Several large manufacturers are resource-constrained with respect to their engineering and product-development capabilities. As a result, other uses of these resources will be foregone while they are required to be applied to technologies that improve fuel economy.

Second, 7 percent also appears to be an appropriate rate to the extent that the costs of the regulation come at the expense of consumption as opposed to investment. The agency believes that financing rates on vehicle loans represent an appropriate discount rate, because they reflect the opportunity costs faced by consumers when buying vehicles with greater fuel economy and a higher purchase price. Most new and used vehicle purchases are financed, and because most of the benefits from higher fuel economy standards accrue to vehicle purchasers in the form of fuel savings, the appropriate discount rate is the interest rate buyers pay on loans to finance their vehicle purchases.[152]

According to the Federal Reserve, the interest rate on new car loans made through commercial banks has closely tracked the rate on 10-year treasury notes, but exceeded it by about 3 percent.[153] The official Administration forecast is that real interest rates on 10-year treasury notes will average about 3 percent through 2016, implying that 6 percent is a reasonable forecast for the real interest rate on new car loans.[154] In turn, the interest rate on used car loans made through automobile financing companies has closely tracked the rate on new car loans made through commercial banks, but exceeded it by about 3 percent.[155] (The agency believes it is important to consider rates on loans that finance used car purchases, because some of the fuel savings resulting from improved fuel economy accrue to used car buyers.) Given the 6 percent estimate for new car loans, a reasonable forecast for used car loans is thus 9 percent.

Because the benefits of fuel economy accrue to both new and used car owners, a discount rate between 6 percent and 9 percent is thus appropriate for evaluating future benefits resulting from higher fuel economy. Assuming that new car buyers discount fuel savings at 6 percent for 5 years (the average duration of a new car loan) [156] and that used car buyers discount fuel savings at 9 percent for 5 years (the average duration of a used car loan)[157], the single constant discount rate that yields equivalent present value fuel savings is very close to 7 percent.

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[152] Empirical evidence also demonstrates that used car purchasers do pay for greater fuel economy (Kahn, Quarterly Journal of Economics, 1986).

[153] See, http://www.federalreserve.gov/releases/g20/hist/fc_hist_tc.txt.

[154] See, http://www.federalreserve.gov/releases/h15/data/Monthly/H15_TCMNOM_Y10.txt.

[155] See, http://www.federalreserve.gov/releases/g20/hist/fc_hist_tc.txt.

[156] Id.

[157] Id.

However, the Agency recognizes that there are arguments for using 3 percent as well. Namely that OMB requests benefits to be estimated at both 3 percent as well as 7 percent and that the official Administration forecast is that real interest rates on 10-year treasury notes will average about 3 percent through 2016. Although the agency feels that the arguments for 7% are stronger, we have calculated results under both 3% and 7% to demonstrate the impact of the lower discount rate on the resulting standards.

Sales Projections

A critical variable affecting the total economic benefits from improving light truck fuel economy is the number of vehicles likely to be produced under stricter fuel economy. Projections of total passenger cars and light truck sales for future years (see Table VIII-1a and VIII-1b) were obtained from the Energy Information Administration’s (EIA) *Annual Energy Outlook 2007* (*AEO 2007*), a standard government reference for projections of energy production and consumption in different sectors of the U.S. economy.[158] NHTSA estimated the sales by manufacturer, based on their market shares in the NHTSA MY2006 CAFE data base. These values will be used as multipliers to estimate the overall impacts (both costs and benefits) of changes in fuel economy standards.

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[158] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2007*, Supplemental Table 47, http://www.eia.doe.gov/oiaf/aeo/supplement/suptab_47.xls.

Table VIII-1a
Sales Projections – Passenger Cars
(1,000s of vehicles)

	2011	2012	2013	2014	2015
BMW	187.2	185.2	183.6	180.2	178.6
Mercedes	184.9	182.9	181.3	177.9	176.3
Chrysler	571.9	551.9	569.0	554.0	546.7
Ferrari	1.7	1.7	1.7	1.7	1.6
Ford	1,430.5	1,415.3	1,402.9	1,376.8	1,364.7
Fuji (Subaru)	137.3	135.8	134.7	132.2	131.0
General Motors	2,014.0	2,000.9	1,985.3	1,951.0	1,935.0
Honda	916.6	906.8	898.9	882.2	874.4
Hyundai/Kia	477.5	472.4	468.3	459.6	455.5
Lotus	3.7	3.6	3.6	3.5	3.5
Maserati	2.3	2.3	2.3	2.2	2.2
Mitsubishi	75.7	74.9	74.2	72.8	72.2
Nissan	721.6	713.9	707.7	694.5	688.4
Porsche	16.1	15.9	15.7	15.5	15.3
Suzuki	64.5	63.8	63.2	62.0	61.5
Toyota	1,500.4	1,483.3	1,470.3	1,443.0	1,430.2
Volkswagen	274.0	271.1	268.7	263.7	261.4
Total	8,579.6	8,481.7	8,431.2	8,272.8	8,198.5

Table VIII-1b
Sales Projections – Light Trucks
(1,000s of vehicles)

	2011	2012	2013	2014	2015
BMW	66.5	68.4	70.1	72.1	72.9
Mercedes	21.4	22.0	22.6	23.2	23.5
Chrysler	1899.9	1,953.4	2,002.6	2,058.9	2,081.3
Ford	1559.6	1,644.6	1,686.0	1,733.4	1,752.3
Fuji (Subaru)	84.6	86.9	89.0	91.4	92.4
General Motors	2159.2	2,213.6	2,269.3	2,333.0	2,358.4
Honda	570.7	586.8	601.5	618.4	625.2
Hyundai	298.5	306.9	314.6	323.5	327.0
Mitsubishi	40.4	41.5	42.5	43.7	44.2
Nissan	446.3	417.3	429.6	443.6	449.2
Porsche	14.6	15.0	15.4	15.9	16.0
Suzuki	25.0	25.7	26.3	27.1	27.3
Toyota	963.1	990.2	1,015.2	1,043.7	1,055.1
Volkswagen	23.4	24.0	24.6	25.3	25.6
Total	8213.1	8,396.4	8,609.4	8,853.2	8,950.3

The “Rebound Effect”

The rebound effect refers to the tendency for owners to increase the number of miles they drive a vehicle in response to an increase in its fuel economy, as would result from more stringent fuel economy standards. The rebound effect occurs because an increase in a vehicle’s fuel economy reduces its owner’s fuel cost for driving each mile, which is typically the largest single component of the cost of operating a vehicle. Even with the vehicle’s higher fuel economy, this additional driving uses some fuel, so the rebound effect will reduce the net fuel savings that result when the fuel economy standards require manufacturers to increase fuel economy. The rebound effect is usually expressed as the percentage by which annual vehicle use increases when average fuel cost per mile driven decreases in response to a change in the marginal cost of driving an extra mile, due either an increase in fuel economy or a reduction in the price of fuel.

The magnitude of the rebound effect is one of the determinants of the actual fuel savings that are likely to result from adopting stricter standards, and thus an important parameter affecting NHTSA's evaluation of alternative standards for future model years. The rebound effect can be measured directly by estimating the elasticity of vehicle use with respect to fuel economy itself, or indirectly by the elasticity of vehicle use with respect to fuel cost per mile driven.[159] When expressed as a positive percentage, either of these parameters gives the fraction of fuel savings that would otherwise result from adopting stricter standards, but is offset by the increase in fuel consumption that results when vehicles with increased fuel economy are driven more.

Research on the magnitude of the rebound effect in light-duty vehicle use dates to the early 1980s, and almost unanimously concludes that a statistically significant rebound effect occurs when vehicle fuel efficiency improves.[160] The most common approach to estimating its magnitude has been to analyze statistically household survey data on vehicle use, fuel consumption, fuel prices (often obtained from external sources), and other determinants of household travel demand to isolate the response of vehicle use to higher fuel economy. Other studies have relied on econometric analysis of annual U.S. data on vehicle use, fuel economy, fuel prices, and other variables to identify the response of total or average vehicle use to changes in fleet-wide average fuel economy and its effect of fuel cost per mile driven. Two recent studies analyzed yearly variation in vehicle ownership and use, fuel prices, and fuel economy among individual states over an extended time period in order to measure the response of vehicle use to changing fuel economy.[161]

An important distinction among studies of the rebound effect is whether they assume that the effect is constant, or varies over time in response to the absolute levels of fuel costs, personal income, or household vehicle ownership. Most studies using aggregate annual data for the U.S. assume a constant rebound effect, although some of these studies test whether the effect can vary as changes in retail fuel prices or average fuel economy alter fuel cost per mile driven. Many studies using household survey data estimate significantly different rebound effects for households owning varying numbers of vehicles, although they arrive at differing conclusions about whether the rebound effect is larger among households that own more vehicles. One recent study using state-level data concludes that the rebound effect varies directly in response to changes in personal income and the degree of urbanization of U.S. cities, as well as fuel costs.

In order to arrive at a preliminary estimate of the rebound effect for use in assessing the fuel savings, emissions reductions, and other impacts of alternative standards, NHTSA reviewed 22 studies of the rebound effect conducted from 1983 through 2005. We then conducted a detailed analysis of the 66 separate estimates of the long-run rebound effect reported in these studies,

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[159] Fuel cost per mile is equal to the price of fuel in dollars per gallon divided by fuel economy in miles per gallon, so this figure declines when a vehicle's fuel economy increases.

[160] Some studies estimate that the long-run rebound effect is significantly larger than the immediate response to increased fuel efficiency. Although their estimates of the adjustment period required for the rebound effect to reach its long-run magnitude vary, this long-run effect is most appropriate for evaluating the fuel savings and emissions reductions resulting from stricter standards that would apply to future model years.

[161] In effect, these studies treat U.S. states as a data "panel" by applying appropriate estimation procedures to data consisting of each year's average values of these variables for the separate states.

which is summarized in the table below.[162] As the table indicates, these 66 estimates of the long-run rebound effect range from as low as 7 percent to as high as 75 percent, with a mean value of 23 percent.

Limiting the sample to 50 estimates reported in the 17 published studies of the rebound effect yields the same range but a slightly higher mean (24 percent), while focusing on the authors' preferred estimates from published studies narrows this range and lowers its average only slightly. The median estimate of the rebound effect in all three samples, which is generally regarded as a more reliable indicator of their central tendency than the average because it is less influenced by unusually small and large estimates, is 22 percent. As Table 13 indicates, approximately two-thirds of all estimates reviewed, of all published estimates, and of authors' preferred estimates fall in the range of 10-30 percent.

Table VIII-1c
Summary of Rebound Effect Estimates

Category of Estimates	Number of Studies	Number of Estimates	Range		Distribution		
			Low	High	Median	Mean	Std. Dev.
All Estimates	22	66	7%	75%	22%	23%	14%
Published Estimates	17	50	7%	75%	22%	24%	14%
Authors' Preferred Estimates	17	17	9%	75%	22%	22%	15%
U.S. Time-Series Estimates	7	34	7%	45%	14%	18%	9%
Household Survey Estimates	13	23	9%	75%	31%	31%	16%
Pooled U.S. State Estimates	2	9	8%	58%	22%	25%	14%
Constant Rebound Effect (1)	15	37	7%	75%	20%	23%	16%
Variable Rebound Effect: (1)							
Reported Estimates	10	29	10%	45%	23%	23%	10%
Updated to 2006 (2)	10	29	6%	46%	16%	19%	12%

(3) Three studies estimate both constant and variable rebound effects.

(4) Reported estimates updated to reflect 2006 values of vehicle use, fuel prices, fleet fuel efficiency, household income, and household vehicle ownership.

The type of data used and authors' assumption about whether the rebound effect varies over time have important effects on its estimated magnitude. The 34 estimates derived from analysis of U.S. annual time-series data produce a median estimate of 14 percent for the long-run rebound effect, while the median of 23 estimates based on household survey data is more than twice as large (31 percent), and the median of 9 estimates based on pooled state data matches that of the entire sample (22 percent). The 37 estimates assuming a constant rebound effect produce a median of 20 percent, while the 29 originally reported estimates of a variable rebound effect have a slightly higher median value (23 percent).

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[162] In some cases, NHTSA derived estimates of the overall rebound effect from more detailed results reported in the studies. For example, where studies estimated different rebound effects for households owning different numbers of vehicles but did not report an overall value, we computed a weighted average of the reported values using the distribution of households among vehicle ownership categories.

In selecting a single value for the rebound effect to use in analyzing alternative standards for future model years, NHTSA tentatively attaches greater significance to studies that allow the rebound effect to vary in response to changes in the various factors that have been found to affect its magnitude. However, it is also important to update authors' originally-reported estimates of variable rebound effects to reflect current conditions. Recalculating the 29 original estimates of variable rebound effects to reflect current (2006) values for retail fuel prices, average fuel economy, personal income, and household vehicle ownership reduces their median estimate to 16 percent.[163] NHTSA also tentatively attaches greater significance to the recent study by Small and Van Dender (2005), which finds that the rebound effect tends to decline as average fuel economy, personal income, and suburbanization of U.S. cities increase, but – in accordance with previous studies – rises with increasing fuel prices.[164]

Considering the empirical evidence on the rebound effect as a whole, but according greater importance to the updated estimates from studies allowing the rebound effect to vary – particularly the Small and Van Dender study – NHTSA has selected a rebound effect of 15 percent to evaluate the fuel savings and other effects of alternative standards for the time period covered by this rulemaking. However, we do not believe that evidence of the rebound effect's dependence on fuel prices or household income is sufficiently convincing to justify allowing its future value to vary in response to forecast changes in these variables. A range extending from 10 percent to at least 20 percent -- and perhaps as high as 25 percent -- appears to be appropriate for the required analysis of the uncertainty surrounding these estimates.

On-Road Fuel Economy Adjustment

Actual fuel economy levels achieved by vehicles in on-road driving fall significantly short of their levels measured under the laboratory-like test conditions used by EPA to establish its

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[163] As an illustration, Small and Van Dender (2005) allow the rebound effect to vary over time in response to changes in real per capita income as well as average fuel cost per mile driven. While their estimate for the entire interval (1966-2001) they analyze is 22 percent, updating this estimate using 2006 values of these variables reduces the rebound effect to approximately 10 percent. Similarly, updating Greene's 1992 original estimate of a 15 percent rebound effect to reflect 2006 fuel prices and average fuel economy reduces it to 6 percent. *See* David L. Greene, "Vehicle Use and Fuel Economy: How Big is the Rebound Effect?" The Energy Journal, 13:1 (1992), 117-143. In contrast, the distribution of households among vehicle ownership categories in the data samples used by Hensher et al. (1990) and Greene et al. (1999) are nearly identical to the most recent estimates for the U.S., so updating their original estimates to current U.S. conditions changes them very little. *See* David A. Hensher, Frank W. Milthorpe, and Nariida C. Smith, "The Demand for Vehicle Use in the Urban Household Sector: Theory and Empirical Evidence," Journal of Transport Economics and Policy, 24:2 (1990), 119-137; and David L. Greene, James R. Kahn, and Robert C. Gibson, "Fuel Economy Rebound Effect for Household Vehicles," The Energy Journal, 20:3 (1999), 1-21.

[164] In the most recent light truck CAFE rulemaking, NHTSA chose not to preference the Small and Van Dender study over other published estimates of the value of the rebound effect, stating that since it "remains an unpublished working paper that has not been subjected to formal peer review, …the agency does not yet consider the estimates it provides to have the same credibility as the published and widely-cited estimates it relied upon." *See* 71 FR 17633 (Apr. 6, 2006). The study has subsequently been published and peer-reviewed, so NHTSA is now prepared to "consider it in developing its own estimate of the rebound effect for use in subsequent CAFE rulemakings."

published fuel economy ratings for different models. In analyzing the fuel savings from alternative passenger car and light truck CAFE standards, the agency adjusts the actual fuel economy performance of each passenger car and light truck model downward from its rated value to reflect the expected size of this on-road fuel economy "gap." In December 2006, EPA adopted changes to its regulations on fuel economy labeling, which were intended to bring vehicles' rated fuel economy levels closer to their actual on-road fuel economy levels.[165]

Supplemental analysis reported by EPA as part of its Final Rule indicates that actual on-road fuel economy for light-duty vehicles averages 20 percent lower than published fuel economy levels.[166] For example, if the overall EPA fuel economy rating of a light truck is 20 mpg, the on-road fuel economy actually achieved by a typical driver of that vehicle is expected to be 16 mpg (20*.80). The agency has employed EPA's revised estimate of this on-road fuel economy gap in its analysis of the fuel savings resulting from alternative CAFE standards for MY 2011-2018 passenger cars and MY 2012-18 light trucks.

Benefits from Fuel Savings

The main source of economic benefits from a fuel economy standard is the value of the resulting fuel savings over the lifetimes of vehicles that are required to comply with the stricter standards. These fuel savings for each scenario are measured by the difference between the adjusted baseline fuel economy for each model year and the fuel economy levels corresponding to that alternative. The sum of these annual fuel savings over each calendar year that a vehicle remains in service represents the cumulative fuel savings resulting from applying the alternative to vehicles produced during that model year.

As previously noted, actual fuel economy levels achieved by vehicles in on-road driving fall significantly short of their levels measured under the laboratory-like test conditions used by EPA to establish its published fuel economy ratings for different models. In analyzing the fuel savings from alternative passenger car and light truck CAFE standards, the agency adjusts the actual fuel economy performance of each passenger car and light truck model downward from its rated value to reflect the expected size of this on-road fuel economy "gap." In December 2006, EPA adopted changes to its regulations on fuel economy labeling, which were intended to bring vehicles' rated fuel economy levels closer to their actual on-road fuel economy levels.[167]

Supplemental analysis reported by EPA as part of its Final Rule indicates that actual on-road fuel economy for light-duty vehicles averages 20 percent lower than published fuel economy

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[165] EPA, Fuel Economy Labeling of Motor Vehicles: Revisions To Improve Calculation of Fuel Economy Estimates; Final Rule, 40 CFR Parts 86 and 600, Federal Register, December 27, 2006, pp. 77872-77969, http://www.epa.gov/fedrgstr/EPA-AIR/2006/December/Day-27/a9749.pdf.

[166] EPA, *Final Technical Support Document: Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates*, Office of Transportation and Air Quality EPA420-R-06-017 December 2006, Chapter II, http://www.epa.gov/fueleconomy/420r06017.pdf.

[167] EPA, Fuel Economy Labeling of Motor Vehicles: Revisions To Improve Calculation of Fuel Economy Estimates; Final Rule, 40 CFR Parts 86 and 600, Federal Register, December 27, 2006, pp. 77872-77969, http://www.epa.gov/fedrgstr/EPA-AIR/2006/December/Day-27/a9749.pdf.

levels.[168] The agency has employed EPA's revised estimate of this on-road fuel economy gap in its analysis of the fuel savings resulting from alternative CAFE standards for MY 2011-2018 passenger cars and MY 2012-18 light trucks.

The number of light vehicles manufactured during each model year that remains in service during each subsequent calendar year is estimated by multiplying the estimated proportions of vehicles expected to survive to each age up to 26 years for passenger cars (Table VIII-2a) and 36 years for light trucks (Table VIII-2b) by the number of cars and light trucks forecast to be produced during each year. These "survival rates," which are estimated from experience with recent model-year vehicles, are slightly different than the survival rates used in past NHTSA analyses since they reflect recent increases in durability and usage of more recent passenger car and light truck models.[169] Updated estimates of average annual miles driven by vehicle age were developed from the Federal Highway Administration's 2001 National Household Transportation Survey, and these also differ from the estimates of annual mileage employed in past NHTSA analyses.[170] The total number of miles driven by vehicles of a single model year during each year of its life span in the fleet in effect is estimated by multiplying these age-specific estimates of annual miles driven per vehicle by the number of vehicles projected to remain in service at each age.

Table VIII-2a and VIII-2b provide the new schedules of vehicle miles traveled and survivability based on updated analyses performed by NHTSA. These were developed from registration data for 1977 through 2003, and from a 2001 survey of household vehicle use. In this analysis, the maximum vehicle age was defined as the age when the number remaining in service has declined to approximately two percent of the vehicles originally produced. Based on and examination of recent registration data for older model years, typical maximum ages appear to be 26 years for passenger cars and 36 years for light trucks. Using the 36-year estimate of the maximum lifetimes of light trucks results in survival-weighted or "expected" lifetime mileage of 190,066 miles. Fuel savings and other benefits resulting from higher light truck CAFE standards are calculated over this expected 36 year lifetime and total mileage. In contrast, NHTSA's previous estimate of lifetime VMT in the 2006 final rule was 179,954 miles over a 36-year lifetime for light trucks. The resulting survival-weighted mileage over the 26-year maximum lifetime of passenger cars is 161,847 miles, and fuel savings and other benefits resulting from higher passenger car CAFE standards are calculated over this 26-year lifetime and total mileage. It should be noted, however, that survival-weighted VMT is extremely low (less than 1,000 miles per year) after age 20 for cars and age 25 for light trucks, and thus has little impact on lifetime fuel savings or other benefits from higher fuel economy, particularly after discounting those benefits to their present values.

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[168] EPA, *Final Technical Support Document: Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates*, Office of Transportation and Air Quality EPA420-R-06-017 December 2006, Chapter II, http://www.epa.gov/fueleconomy/420r06017.pdf.

[169] The survival rates were calculated from R.L. Polk, National Vehicle Population Profile, 1977-2003; see NHTSA, "Vehicle Survivability and Travel Mileage Schedules," Office of Regulatory Analysis and Evaluation, NCSA, January 2006, pp. 9-11, Docket No. 22223-2218.

[170] See also NHTSA, "Vehicle Survivability and Travel Mileage Schedules," Office of Regulatory Analysis and Evaluation, January 2006, pp. 15-17.

The primary source of data for determining vehicles in operation is the National Vehicle Population Profile (NVPP) compiled by R.L. Polk and Company. The NVPP is an annual census, as of July 1 of each year, of passenger cars and light trucks registered for on-road operation in the United States. NVPP registration data was used from vehicle model years 1977 to 2003. Survival rates were averaged for the five most recent model years for vehicles up to 20 years old, and regression models were fitted to these data to develop smooth relationships between age and the proportion of cars or light trucks surviving to that age. The survival rates predicted by these models are used to develop the estimates of annual mileage and fuel consumption used to calculate fuel savings and other impacts of higher fuel economy.

The 2001 National Household Travel Survey (NHTS) sponsored by the Federal Highway Administration, Bureau of Transportation Statistics, and the National Highway Traffic Safety Administration attempted to develop up-to-date information on household vehicle ownership and use. The NHTS is the integration of two previous national travel surveys: the Federal Highway Administration-sponsored Nationwide Personal Transportation Survey (NPTS) and the Bureau of Transportation Statistics-sponsored American Travel Survey (ATS).[171] The 2001 NHTS was the source of updated information on annual miles driven by age for passenger cars and light trucks.

Finally, it should be noted that the estimates of average annual miles driven by passenger cars and light trucks, while new for NHTSA, are based on data collected during 2001-2002, and reflect the historically low gasoline prices that prevailed at the time the survey was conducted. To account for the effect on vehicle use of subsequent increases in fuel prices, the estimates of annual vehicle use derived from the NHTS are adjusted to reflect projected future gasoline prices using the rebound effect, which is discussed in detail later in this chapter. Two factors affect the cost of gasoline per mile driven - fuel prices per gallon, and fuel economy in miles-per-gallon. Because the intensity of vehicle use depends partly on the cost per mile of driving, the estimates of vehicle use developed from NHTS data reflect both fuel prices and fuel economy levels that prevailed during 2001 and 2002, when the survey was conducted. In analyzing the final rule, the agency adjusted the annual usage estimates derived from the NHTS data to reflect the effect of the higher EIA fuel prices that are forecast over the covered vehicles' expected lifetimes, which exceed those that existed during 2001-2002.

Specifically, the adjustment accounted for the difference between the average price per gallon of fuel forecast over the expected lifetimes of model year 2011-2015 passenger cars and light trucks and the average price that prevailed during 2000 and 2001. When expressed in percentage terms, this difference was assumed to represent the percent increase in fuel cost per mile driven between the time the survey was conducted and the time period when model year 2011-2015 passenger cars and light trucks would be in service.

The same elasticity of annual vehicle use with respect to fuel cost per mile that was used to estimate the increase in vehicle use resulting from improved fuel economy (see detailed discussion of the "rebound effect" earlier in this chapter), assumed to be –0.15, was applied to this percent difference to adjust the estimates of vehicle use derived from the survey to reflect the effect of higher future fuel prices. In contrast, this adjustment reduces model year 2011-2015 passenger cars' and light trucks' average annual usage at each age to account for the fact that fuel cost per mile driven is expected to be

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[171] For details on survey coverage and procedures, see http://nhts.ornl.gov/quickStart.shtml.

higher throughout their expected lifetimes than at the time the NHTS was conducted. The results of this adjustment are shown in Table VIII-2c for passenger cars and in Table VIII-2d for light trucks. The unadjusted average lifetime mileage is estimated to be 161,847 for passenger cars and 190,066 for light trucks. After adjusting for the rebound effect, the average lifetime mileage is estimated to be 152,274 for passenger cars and 178,824 for light trucks.

Table VIII-2a
Survival Rates and Unadjusted Annual Vehicle-Miles Traveled (VMT)
by Age for Passenger Cars

Vehicle Age	**Estimated Survivability (1977 to 2002 NVPP)**	**Estimated VMT (2001 NHTS)**	**Weighted Yearly Travel Miles**
1	0.9950	14,231	14,160
2	0.9900	13,961	13,821
3	0.9831	13,669	13,438
4	0.9731	13,357	12,998
5	0.9593	13,028	12,497
6	0.9413	12,683	11,938
7	0.9188	12,325	11,324
8	0.8918	11,956	10,662
9	0.5604	11,578	9,961
10	0.8252	11,193	9,237
11	0.7866	10,804	8,499
12	0.7170	10,413	7,466
13	0.6125	10,022	6,138
14	0.5094	9,633	4,907
15	0.4142	9,249	3,831
16	0.3308	8,871	2,934
17	0.2604	8,502	2,214
18	0.2028	8,144	1,652
19	0.1565	7,799	1,220
20	0.1200	7,469	896
21	0.0916	7,157	656
22	0.0696	6,866	478
23	0.0527	6,596	348
24	0.0399	6,350	253
25	0.0301	6,131	185
26	0.0227	5,940	135
Estimated Passenger Car Lifetime VMT			161,847

Table VIII-2b
Survival Rates and Unadjusted Annual Vehicle-Miles Traveled (VMT)
by Age for Light Trucks

Vehicle Age	**Estimated Survivability (1977 to 2002 NVPP)**	**Estimated VMT (2001 NHTS)**	**Weighted Yearly Travel Miles**
1	0.9950	16,085	16,004
2	0.9741	15,782	15,374
3	0.9603	15,442	14,829
4	0.9420	15,069	14,195
5	0.9190	14,667	13,479
6	0.8913	14,239	12,691
7	0.8590	13,790	11,845
8	0.8226	13,323	10,960
9	0.7827	12,844	10,053
10	0.7401	12,356	9,145
11	0.6956	11,863	8,252
12	0.6501	11,369	7,391
13	0.6042	10,879	6,573
14	0.5517	10,396	5,735
15	0.5009	9,924	4,971
16	0.4522	9,468	4,281
17	0.4062	9,032	3,669
18	0.3633	8,619	3,131
19	0.3236	8,234	2,665
20	0.2873	7,881	2,264
21	0.2542	7,565	1,923
22	0.2244	7,288	1,635
23	0.1975	7,055	1,393
24	0.1735	6,871	1,192
25	0.1522	6,739	1,026
26	0.1332	6,663	887
27	0.1165	6,648	774
28	0.1017	6,648	676
29	0.0887	6,648	590
30	0.0773	6,648	514
31	0.0673	6,648	447
32	0.0586	6,648	390
33	0.0509	6,648	338
34	0.0443	6,648	294
35	0.0385	6,648	256
36	0.0334	6,648	222
Estimated Lifetime Light Truck VMT			190,066

Table VIII-2c
Survival Rates and Adjusted Annual Vehicle-Miles Traveled (VMT)
by Age for Passenger Cars

Vehicle Age	Estimated Survivability	Adjusted VMT	Weighted Yearly Travel Miles
1	0.9950	13,389	13,322
2	0.9900	13,135	13,004
3	0.9831	12,860	12,643
4	0.9731	12,567	12,229
5	0.9593	12,257	11,758
6	0.9413	11,933	11,232
7	0.9188	11,596	10,654
8	0.8918	11,248	10,031
9	0.5604	10,893	9,372
10	0.8252	10,531	8,690
11	0.7866	10,165	7,996
12	0.7170	9,797	7,025
13	0.6125	9,429	5,775
14	0.5094	9,063	4,617
15	0.4142	8,702	3,604
16	0.3308	8,346	2,761
17	0.2604	7,999	2,083
18	0.2028	7,662	1,554
19	0.1565	7,337	1,148
20	0.1200	7,028	843
21	0.0916	6,734	617
22	0.0696	6,459	450
23	0.0527	6,206	327
24	0.0399	5,974	238
25	0.0301	5,768	174
26	0.0227	5,589	127
Adjusted Lifetime Passenger Car VMT			152,274

Table VIII-2d
Survival Rates and Adjusted Annual Vehicle-Miles Traveled (VMT)
by Age for Light Trucks

Vehicle Age	**Estimated Survivability**	**Adjusted VMT**	**Weighted Yearly Travel Miles**
1	0.9950	15,133	15,058
2	0.9741	14,849	14,464
3	0.9603	14,529	13,952
4	0.9420	14,178	13,356
5	0.9190	13,799	12,681
6	0.8913	13,396	11,940
7	0.8590	12,974	11,145
8	0.8226	12,535	10,312
9	0.7827	12,084	9,458
10	0.7401	11,625	8,604
11	0.6956	11,161	7,764
12	0.6501	10,697	6,954
13	0.6042	10,235	6,184
14	0.5517	9,781	5,396
15	0.5009	9,337	4,677
16	0.4522	8,908	4,028
17	0.4062	8,498	3,452
18	0.3633	8,109	2,946
19	0.3236	7,747	2,507
20	0.2873	7,415	2,130
21	0.2542	7,117	1,809
22	0.2244	6,857	1,539
23	0.1975	6,638	1,311
24	0.1735	6,464	1,122
25	0.1522	6,340	965
26	0.1332	6,269	835
27	0.1165	6,254	729
28	0.1017	6,254	636
29	0.0887	6,254	555
30	0.0773	6,254	483
31	0.0673	6,254	421
32	0.0586	6,254	367
33	0.0509	6,254	318
34	0.0443	6,254	277
35	0.0385	6,254	241
36	0.0334	6,254	209
Adjusted Lifetime Light Truck VMT			178,824

In interpreting the survivability and annual mileage estimates reported in Tables VIII-2a through VIII-2d, it is important to understand that vehicles are considered to be of age 1 during the calendar year that coincides with their model year   Thus for example, model year 2010 vehicles will be considered to be of age 1 during calendar year 2010. This convention is used in order to account for the fact that vehicles produced during a model year typical are first offered for sale in June through September of the preceding calendar year (for example, sales of a model year typically begin in June through September of the previous calendar year, depending on manufacturer). Thus virtually all of the vehicles produced during a model year will be in use for some or all of the calendar year coinciding with their model year, and they are considered to be of age 1 during that year.[172] As an illustration, virtually the entire production of model year 2008 vehicles will have been sold and placed in service by the end of calendar year 2008, so model year 2008 vehicles are defined to be of age 1 during calendar year 2008.Model year 2008 vehicles are subsequently defined to be of age 2 during calendar year 2009, age 3 during calendar year 2010, and so on, until they reach their maximum age of 36 years in calendar year 2043 (2008 + 35 = 2043).

To determine the impact of improved CAFE standards, fuel consumption is calculated using both current and revised CAFE levels. The difference between these estimates represents the net savings from increased CAFE standards. With the current CAFE standard assumed to remain in effect, total fuel consumption by each model year's vehicles during each calendar year they remain in service is calculated by dividing the total number of miles they are driven during that year by the average on-road fuel economy level they would achieve under the higher of either the manufacturer-specific standard or their production plans. With the final rule in effect, total fuel consumption by each model year's vehicles during each future calendar year is calculated by dividing the total number of miles they are driven by the higher on-road fuel economy level associated with that stricter CAFE standard. The total number of miles that vehicles are driven each year is different under the final rule than with the current standards remaining in effect as a result of the fuel economy "rebound effect," which is discussed in detail later in this chapter.

The economic benefits to vehicle owners that result from future fuel savings are valued in this analysis over the complete expected lifetimes of the vehicles affected by the final rule. This reflects the assumption that while the purchaser and first owner of a new vehicle might not realize the full lifetime benefits of improved fuel economy, subsequent owners of that same vehicle will continue to experience the resulting fuel savings until the vehicle is retired from service. It is important to note, however, that not all vehicles produced during a model year remain in service for the complete lifetime (26-year for passenger cars or 36 –year for light trucks) of each model year assumed in this analysis. Due to the pattern of vehicle retirement over this period, the expected or average lifetime of a representative vehicle is approximately half of that figure.

CAFE's most immediate impacts are on individual consumers, but regulating fuel economy also has a broader societal impact that must be considered. The agency believes that CAFE standards should reflect the true economic value of resources that are saved when less fuel is produced and

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[172] One complication arises because registration data are typically collected for July 1 of each calendar year, so not all vehicles produced during a model year will appear in registration data until the calendar year when they have reached age 2 (and sometimes age 3) under this convention.

consumed, higher vehicle prices, and, to the extent possible, any externalities that impact the broader society. Consumers' perceptions of these values may differ from their actual impacts, but they will nonetheless experience the full value of actual fuel savings just as they will pay the full increased cost when the vehicle is purchased.

Moreover, the first and any subsequent owners of a vehicle will together realize these savings throughout its entire on-road lifetime. While a vehicle's buyer may only experience fuel savings for the limited time he or she typically owns that vehicle, any subsequent purchasers and owners of that used vehicle will continue to experience the fuel savings resulting from its higher fuel economy throughout the remainder of its useful life. The agency restricts its analysis of the sales impacts of higher new vehicle prices to the length of time the buyers of new vehicles typically own the vehicles they purchase, under the assumption that their purchase decisions will be influenced only by the benefits they receive during the time they expect to own the vehicles they purchase new. The agency estimates the length of this period using the average term of new car loans, which has recently averaged almost exactly 5 years.[173] However, the agency believes that the value of fuel savings resulting from more efficient operation over the entire lifetime of vehicles should be reflected in its analysis of the societal impacts that will determine fuel economy standards.

The economic value of fuel savings resulting from the final rule is estimated by applying the forecast of future fuel prices from the Reference Case of the Energy Information Administration's *Annual Energy Outlook 2008 Early Release* to each future year's estimated fuel savings.[174] (The uncertainty analysis reported in Chapter X uses fuel price forecasts from the High and Low Oil Price Scenarios included in *AEO 2007* to examine the effects a range of possible fuel price scenarios, since High and Low Oil Price Scenario forecasts for AEO 2008 were not available at the time this analysis was conducted.) The *AEO 2008 Early Release* forecast of future fuel prices, which is reported in Table VIII-3, represents retail prices per gallon of fuel, which including Federal, State, and any applicable local taxes. While the retail price of fuel is the proper measure for valuing fuel savings from the perspective of vehicle owners, two adjustments to the retail price are necessary in order to reflect the economic value of fuel savings to society as a whole.

First, Federal and State taxes are excluded from the social value of fuel savings because these do not reflect costs of resources used in fuel production, and thus do not reflect resource savings that would result from reducing fuel consumption. Instead, fuel taxes simply represent resources that are transferred from one segment of the population to another. Any reduction in State and Federal fuel tax payments by consumers will reduce government revenues by the same amount, thus ultimately reducing the value of government-financed services by approximately that same amount. The benefit derived from lower taxes to individuals is thus likely to be offset exactly by a reduction in the value of services provided to society.

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[173] This estimate is derived from Federal Reserve Board, Federal Reserve Statistical Release G. 19: Consumer Credit, November 7, 2007, http://www.federalreserve.gov/releases/g19/Current/.

[174] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2008 Early Release*, Reference Case Table 12, http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_12.xls.

Second, the economic cost of externalities generated by imports and consumption of petroleum products will be reduced in proportion to gasoline savings resulting from the final rule. The estimated economic value of these externalities is converted into its per-gallon equivalent and added to the pre-tax price of gasoline in order to measure this additional benefit to society for each gallon of fuel saved. This also allows the magnitude of these externalities to be easily compared to the value of the resources saved from reduced fuel production and use, which represents the most important component of the social benefits from saving gasoline. A discussion of these externality values is included in the next section of this chapter

Table VIII-3 illustrates the adjustment of forecast retail fuel prices to remove the value of fuel taxes and add the value of economic externalities from petroleum imports and use. The derivation of the estimated value of reduced economic externalities from petroleum use shown in the table is explained in detail in the following section. While the Reference Case fuel price forecasts reported in *AEO 2008 Early Release* extend through 2030, the agency's analysis of the value of fuel savings over the 26-year maximum lifetimes of MY 2011-15 passenger cars and 36-year maximum lifetimes MY 2011-15 light trucks requires forecasts extending through calendar year 2050. The agency assumes that retail fuel prices will remain at the 2030 forecast values reported in the *AEO 2008* Reference Case forecast over the period from 2030 through 2052 (in constant-dollar terms). As Table VIII-3 shows, the projected retail price of gasoline expressed in 2006 dollars varies over the forecast period, declining from $2.69 in 2008 to $2.20 in 2016, and then increasing to $2.49 by 2030 and as assumed previously, remaining at that level through 2052.

Since gasoline taxes are a transfer payment and not a societal cost, the value of gasoline taxes is subtracted from the estimated gasoline price to estimate the value to society of saving gasoline. The agency has updated its estimates of gasoline taxes, using updated State tax rates reported for January 1, 2006. Expressed in 2006 dollars, Federal gasoline taxes are currently $0.172, while State and local gasoline taxes together average $0.262 per gallon, for a total tax burden of $0.434 per gallon.

Following the assumptions used by EIA in its National Energy Modeling System (NEMS), state and local gasoline taxes are assumed to keep pace with inflation in nominal terms, and thus to remain constant when expressed in constant 2006 dollars. In contrast, federal gasoline taxes are assumed to remain unchanged in nominal terms, and thus to decline throughout the forecast period when expressed in constant 2006 dollars. These differing assumptions about the likely future behavior of federal and state/local fuel taxes are consistent with recent historical experience, and reflect the fact that Federal motor fuel taxes and most State taxes are specified on a cents-per-gallon basis (some State taxes are levied as a percentage of the wholesale price of fuel), and typically require legislation to change.

Actual fuel economy levels achieved by light-duty vehicles in on-road driving fall somewhat short of their levels measured under the laboratory-like test conditions used by EPA to establish its published fuel economy ratings for different models. In analyzing the fuel savings from alternative CAFE standards, NHTSA has previously adjusted the actual fuel economy performance of each light truck model downward from its rated value to reflect the expected size of this on-road fuel economy "gap." On December 27, 2006, EPA adopted changes to its regulations on fuel economy labeling, which were intended to bring vehicles' rated fuel economy levels closer to their actual on-road fuel economy levels.[175]

In its Final Rule, EPA estimated that actual on-road fuel economy for light-duty vehicles averages 20 percent lower than published fuel economy levels. For example, if the overall EPA fuel economy rating of a light truck is 20 mpg, the on-road fuel economy actually achieved by a typical driver of that vehicle is expected to be 16 mpg (20*.80). NHTSA has employed EPA's revised estimate of this on-road fuel economy gap in this analysis of the fuel savings resulting from alternative CAFE standards proposed in this rulemaking.

Table VIII-3
Adjustment of Forecast Retail Gasoline Price to Reflect Social Value of Fuel Savings

Year	**AE0 2008 Forecast of Retail Gasoline Price (2006 $/gallon)**	**Estimated Federal and State Taxes (2006 $/gallon)**	**Forecast Gasoline Price Excluding Taxes (2006 $/gallon)**	**Forecast Gasoline Price Including Externalities (2006 $/gallon)**
2011	$2.553	$0.420	$2.133	$2.428
2012	$2.477	$0.416	$2.061	$2.356
2013	$2.405	$0.412	$1.993	$2.288
2014	$2.389	$0.409	$1.980	$2.275
2015	$2.316	$0.405	$1.911	$2.206
2016	$2.255	$0.402	$1.853	$2.148
2017	$2.267	$0.399	$1.868	$2.163
2018	$2.293	$0.395	$1.898	$2.193
2019	$2.362	$0.392	$1.970	$2.265
2020	$2.420	$0.388	$2.032	$2.327
2021	$2.386	$0.385	$2.001	$2.296
2022	$2.406	$0.381	$2.025	$2.320
2023	$2.414	$0.378	$2.036	$2.331
2024	$2.409	$0.374	$.2.035	$2.330
2025	$2.425	$0.371	$2.054	$2.349
2026	$2.438	$0.371	$2.067	$2.362
2027	$2.451	$0.371	$2.080	$2.375
2028	$2.474	$0.371	$2.103	$2.398
2029	$2.498	$0.371	$2.127	$2.422
2030-2052	$2.514	$0.371	$2.143	$2.438

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[175] 71 FR 77871 (Dec. 27, 2006).

Other Economic Benefits from Reducing Petroleum Use

The agency believes that assessing the economic case for increasing the stringency of fuel economy standards requires a comprehensive analysis of the resulting benefits and costs to the U.S economy, rather than simply comparing the direct costs associated with petroleum use and fuel production to current fuel taxes. The benefits of more stringent fuel economy standards include the market value of the savings in resources from producing less fuel, together with the resulting reductions in the costs of economic externalities associated with petroleum consumption, and of environmental externalities caused by fuel consumption and production. Environmental externalities include adverse health impacts associated with criteria pollutants and environmental damage associated with greenhouse gases. The costs imposed on the U.S. economy by more stringent fuel economy regulation include those costs for manufacturing more fuel-efficient vehicles, as well as the increased external costs of congestion, crashes, noise and pollution from added driving caused by the rebound effect.

Vehicle buyers value improved fuel economy using retail fuel prices and miles per gallon, but may consider fuel savings only over the time they expect to own a vehicle, while the value to the U.S. economy of saving fuel is measured by its pre-tax price, and includes fuel savings over the entire lifetime of vehicles. Thus, it cannot simply be assumed that the interaction of manufacturers' costs and vehicle buyers' demands in the private marketplace will determine optimal fuel economy levels, and that these levels should only be adjusted by Federal regulation if the external costs of fuel production and use exceed current fuel taxes.

The Agency's analysis estimates the value of each category of benefits and costs separately, and it compares the total benefits resulting from each alternative level to its total costs in order to assess its desirability. This more complete accounting of benefits and costs to the U.S. economy from reducing fuel use is necessary to assess the case for fuel economy regulation generally, and for increasing the stringency of the current passenger car and light truck fuel economy standards in particular.

U.S. consumption and imports of petroleum products also impose costs on the domestic economy that are not reflected in the market price for crude petroleum, or in the prices paid by consumers of petroleum products such as gasoline. These costs include (1) higher prices for petroleum products resulting from the effect of U.S. oil import demand on the world oil price; (2) the risk of disruptions to the U.S. economy caused by sudden reductions in the supply of imported oil to the U.S.; and (3) expenses for maintaining a U.S. military presence to secure imported oil supplies from unstable regions, and for maintaining the strategic petroleum reserve (SPR) to cushion against resulting price increases. Higher U.S. imports of crude oil or refined petroleum products raise the magnitude of these external economic costs, thus increasing the true economic cost of supplying transportation fuels above the resource costs of producing them. Conversely, reducing U.S. imports of crude petroleum or refined fuels or reducing fuel consumption can reduce these external costs. Any reduction in their total value that results from improved vehicle fuel economy represents an economic benefit of raising fuel economy standards in addition to the value of fuel savings and emissions reductions itself.

Demand Costs

Increased U.S. oil imports can impose higher costs on all purchasers of petroleum products, because the U.S. is a sufficiently large purchaser of foreign oil supplies that changes in U.S. demand can affect the world price. The effect of U.S. petroleum imports on world oil prices is determined by the degree of OPEC monopoly power over global oil supplies, and the degree of monopsony power over world oil demand exerted by the U.S. The combination of these two factors means that increases in domestic demand for petroleum products that are met through higher oil imports can cause the price of oil in the world market to rise, which imposes economic costs on all other purchasers in the global petroleum market in excess of the higher prices paid by U.S. consumers.[176] Conversely, reducing U.S. oil imports can lower the world petroleum price, and thus generate benefits to other oil purchasers by reducing these “monopsony costs.”

Although the degree of current OPEC monopoly power is subject to considerable debate, the consensus appears to be that OPEC remains able to exercise some degree of control over the response of world oil supplies to variation in world oil prices, so that the world oil market does not behave competitively.[177] The extent of U.S. monopsony power is determined by a complex set of factors including the relative importance of U.S. imports in the world oil market, and the sensitivity of petroleum supply and demand to its world price among other participants in the international oil market. Most evidence appears to suggest that variation in U.S. demand for imported petroleum continues to exert some influence on world oil prices, although this influence appears to be limited.[178]

In analyzing benefits from its recent actions to increase light truck CAFE standards for model years 2005-07 and 2008-11, NHTSA relied on a 1997 study by Oak Ridge National Laboratories (ORNL) to estimate the value of reduced economic externalities from petroleum consumption and imports.[179] More recently, ORNL updated its estimates of the value of these externalities, using the analytic framework developed in its original 1997 study in conjunction with recent estimates of the variables and parameters that determine their value.[180] These include world oil prices, current and anticipated future levels of OPEC petroleum production, U.S. oil import

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[176] For example, if the U.S. imports 10 million barrels of petroleum per day at a world oil price of $80 per barrel, its total daily import bill is $800 million. If increasing imports to 11 million barrels per day causes the world oil price to rise to $81 per barrel, the daily U.S. import bill rises to $891 million. The resulting increase of $91 million per day ($891 minus $800 million) is attributable to increasing daily imports by only 1 million barrels. This means that the incremental cost of importing each additional barrel is $91, or $10 more than the newly-increased world price of $81 per barrel. This additional $10 per barrel represents a cost imposed on all other purchasers in the global petroleum market by U.S. buyers, in excess of the price they pay to obtain those additional imports.

[177] For a summary see Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997, at 17. *Available at* http://dmses.dot.gov/docimages/pdf93/343894_web.pdf (last accessed Dec. 2, 2007).

[178] *Id.*, at 18-19.

[179] Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997. *Available at* http://dmses.dot.gov/docimages/pdf93/343894_web.pdf (last accessed Dec. 2, 2007).

[180] Leiby, Paul N. "Estimating the Energy Security Benefits of Reduced U.S. Oil Imports," Oak Ridge National Laboratory, ORNL/TM-2007/028, Revised July 23, 2007. *Available at* http://pzl1.ed.ornl.gov/energysecurity.html (click on link below “Oil Imports Costs and Benefits”) (last accessed Sept. 10, 2007).

levels, the estimated responsiveness of oil supplies and demands to prices in different regions of the world, and the likelihood of oil supply disruptions. ORNL's prepared its updated estimates of oil import externalities were for use by EPA in evaluating the benefits of reductions in U.S. oil consumption and imports expected to result from its recently-issued Renewable Fuel Standard Rule of 2007 (RFS)[181].

The updated ORNL study was subjected to a detailed peer review and its estimates of the value of oil import externalities were subsequently revised to reflect their comments and recommendations.[182] Specifically, reviewers recommended that ORNL increase its estimates of the sensitivity of oil supply by non-OPEC producers and oil demand by nations other than the U.S. to changes in the world oil price, as well as reduce its estimate of the sensitivity of U.S. gross domestic product (GDP) to potential sudden increases in world oil prices. After making the revisions recommended by peer reviewers, ORNL's updated estimates of the monopsony cost associated with U.S. oil imports range from $5.22 to $9.68 per barrel, with a most likely estimate of $7.41 per barrel. These estimates imply that each gallon of fuel saved as a result of adopting higher CAFE standards will reduce the monopsony costs of U.S. oil imports by $0.124 to $0.230 per gallon, with the actual value most likely to be $0.176 per gallon saved. This represents an economic benefit in addition to the value of savings in fuel production costs that would result from improving fuel economy.

Disruption and Adjustment Costs

The second component of external economic costs imposed by U.S. petroleum imports arises partly because an increase in oil prices triggered by a disruption in the supply of imported oil reduces the level of output that the U.S. economy can produce. The reduction in potential U.S. economic output depends on the extent and duration of the increases in petroleum product prices that result from a disruption in the supply of imported oil, as well as on whether and how rapidly these prices return to pre-disruption levels. Even if prices for imported oil return completely to their original levels, however, economic output will be at least temporarily reduced from the level that would have been possible without a disruption in oil supplies.

Because supply disruptions and resulting price increases tend to occur suddenly rather than gradually, they can also impose costs on businesses and households for adjusting their use of petroleum products more rapidly than if the same price increase had occurred gradually over time. These adjustments impose costs because they temporarily reduce economic output even below the level that would ultimately be reached once the U.S. economy completely adapted to higher petroleum prices. The additional costs to businesses and households reflect their inability to adjust prices, output levels, and their use of energy and other resources quickly and smoothly in response to rapid changes in prices for petroleum products.

Since future disruptions in foreign oil supplies are an uncertain prospect, each of these disruption costs must be adjusted by the probability that the supply of imported oil to the U.S. will actually be disrupted. The "expected value" of these costs – the product of the probability that an oil import disruption will occur and the costs of reduced economic output and abrupt adjustment to

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[181] Federal Register Vol.72, #83, May 1, 2007 pp.23,900-24,014

[182] *Peer Review Report Summary: Estimating the Energy Security Benefits of Reduced U.S. Oil Imports*, ICF, Inc., September 2007.

sharply higher petroleum prices – is the appropriate measure of their magnitude. Any reduction in these expected disruption costs resulting from a measure that lowers U.S. oil imports represents an additional economic benefit beyond the direct value of savings from reduced purchases of petroleum products.

While the vulnerability of the U.S. economy to oil price shocks is widely thought to depend on total petroleum consumption rather than on the level of oil imports, variation in imports is still likely to have some effect on the magnitude of price increases resulting from a disruption of import supply. In addition, changing the quantity of petroleum imported into the U.S. may also affect the probability that such a disruption will occur. If either the size of the likely price increase or the probability that U.S. oil supplies will be disrupted is affected by oil imports, the expected value of the costs from a supply disruption will also depend on the level of imports.

Businesses and households use a variety of market mechanisms, including oil futures markets, energy conservation measures, and technologies that permit rapid fuel switching to "insure" against higher petroleum prices and reduce their costs for adjusting to sudden price increases. While the availability of these market mechanisms has likely reduced the potential costs of disruptions to the supply of imported oil, consumers of petroleum products are unlikely to take account of costs they impose on others, so these costs are probably not reflected in the price of imported oil. Thus changes in oil import levels probably continue to affect the expected cost to the U.S. economy from potential oil supply disruptions, although this component of oil import costs is likely to be significantly smaller than estimated by studies conducted in the wake of the oil supply disruptions during the 1970s.

ORNL's updated and revised estimates of the increase in the expected costs associated with oil supply disruptions to the U.S. and the resulting rapid increase in prices for petroleum products amount to $4.54 to $5.84 per barrel, although its most likely estimate of $4.59 per barrel is very close to the lower end of this range. According to these estimates, each gallon of fuel saved will reduce the expected costs disruptions to the U.S. economy by $0.108 to $0.139, with the actual value most likely to be $0.109 per gallon. Like the reduction in monopsony costs, the reduction in expected disruption costs represents an economic benefit in addition to the value of savings in fuel production costs that would result from improving fuel economy.

Military Security and Strategic Petroleum Reserve Costs

The third component of the external economic costs of importing oil into the U.S. includes government outlays for maintaining a military presence to secure the supply of oil imports from potentially unstable regions of the world and to protect against their interruption. Some analysts also include outlays for maintaining the U.S. Strategic Petroleum Reserve (SPR), which is intended to cushion the U.S. economy against the consequences of disruption in the supply of imported oil, as additional costs of protecting the U.S. economy from oil supply disruptions.

NHTSA believes that while costs for U.S. military security may vary over time in response to long-term changes in the actual level of oil imports into the U.S., these costs are unlikely to decline in response to any reduction in U.S. oil imports resulting from raising future CAFE standards for light-duty vehicles. U.S. military activities in regions that represent vital sources of oil imports also serve a broader range of security and foreign policy objectives than simply protecting oil supplies, and as a consequence are unlikely to vary significantly in response to changes in the level of oil imports prompted by higher standards.

Similarly, while the optimal size of the SPR from the standpoint of its potential influence on domestic oil prices during a supply disruption may be related to the level of U.S. oil consumption and imports, its actual size has not appeared to vary in response to recent changes in oil imports. Thus while the budgetary costs for maintaining the Reserve are similar to other external costs in that they are not likely to be reflected in the market price for imported oil, these costs do not appear to have varied in response to changes in oil import levels. As a result, the agencies' tentative analysis of benefits from alternative CAFE standards does not include cost savings from either reduced outlays for U.S. military operations or maintaining a smaller SPR among the external benefits of reducing gasoline consumption and petroleum imports by means of tightening future standards. This view concurs with that of the recent ORNL study of economic costs from U.S. oil imports, which concludes that savings in government outlays for these purposes are unlikely to result form modest reductions in consumption of petroleum products and oil imports.

Thus NHTSA has tentatively included only the likely reductions in monopsony and disruption costs from lower U.S. petroleum imports in its estimate of the savings in external economic costs from reducing fuel consumption. The updated and revised ORNL estimates suggest that the combined reduction in monopsony costs and expected costs to the U.S. economy from oil supply disruptions resulting from lower fuel consumption total $0.232 to $0.370 per gallon, with a most likely estimate of $0.286 per gallon. This represents the additional economic benefit likely to result from each gallon of fuel saved by higher CAFE standards, *beyond* the savings in resource costs for producing and distributing each gallon of fuel saved. NHTSA tentatively employs this midpoint estimate in its analysis of the benefits from fuel savings projected to result from alternative CAFE standards for model years 2011-15. It also analyzes the effect on these benefits estimates from variation in this value over the range from $0.232 to $0.370 per gallon of fuel saved.

The Effect of Fuel Savings on Fuel Supply

Based on a detailed analysis of differences in fuel consumption, petroleum imports, and imports of refined petroleum products among the Reference Case, High Economic Growth, and Low Economic Growth Scenarios presented in the Energy Information Administration's *Annual Energy Outlook 2007*, the agency estimates that approximately 50 percent of the reduction in fuel consumption resulting from adopting higher CAFE standards is likely to be reflected in reduced U.S. imports of refined fuel, while the remaining 50 percent would be expected to be reflected in reduced domestic fuel refining. Of this latter figure, 90 percent is anticipated to reduce U.S. imports of crude petroleum for use as a refinery feedstock, while the remaining 10 percent is expected to reduce U.S. domestic production of crude petroleum. Thus on balance, each gallon of fuel saved as a consequence of higher CAFE standards is anticipated to reduce total U.S. imports of crude petroleum or refined fuel by 0.95 gallons.[183]

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[183] This figure is calculated as $0.50 + 0.50*0.9 = 0.50 + 0.45 = 0.95$.

Emissions Reductions Resulting from Fuel Savings

NHTSA has estimated emissions reductions resulting from fuel savings for purposes of this PRIA. However, as indicated previously, NHTSA will consider the potential environmental impacts of the proposed standards and reasonable alternatives for purposes of NEPA through the NEPA process.

Criteria Pollutants

While reductions in domestic fuel refining and distribution that result from lower fuel consumption will reduce emissions of criteria pollutants, additional vehicle use associated with the rebound effect of higher fuel economy will increase emissions of these pollutants (see detailed discussion of the Rebound Effect earlier in this chapter). The net effect of stricter standards depends on the relative magnitudes of reduced emissions in fuel refining and distribution, and increased emissions from vehicle use. Because the relationship between emission rates (emissions per gallon refined of fuel or mile driven) from fuel refining and vehicle use differs for each specific criteria pollutant, the net effect of fuel savings from the proposed standards on total emissions of each pollutant is likely to differ. Predominant criteria pollutants emitted in fuel production and use include carbon monoxide (CO), hydrocarbon compounds (usually referred to as "volatile organic compounds," or VOC), nitrogen oxides (NOx), fine particulate matter (PM), and sulfur dioxide (SO2).

For purposes of NHTSA's PRIA, the increase in emissions of these pollutants from additional vehicle use due to the rebound effect is tentatively estimated by multiplying the increase in total miles driven by vehicles of each model year and age during future calendar years by age-specific emission rates per vehicle-mile for each pollutant. The agencies developed these emission rates using EPA's MOBILE6.2 motor vehicle emissions factor model, with updated vehicle emission factors for some pollutants.[184] Emissions of these pollutants also occur during crude oil extraction and transportation, gasoline refining, and gasoline storage and distribution. The reduction in total emissions from each of these sources thus depends on the extent to which fuel savings result in lower imports of refined gasoline, or in reduced domestic gasoline refining.[185]

Based on analysis of changes in U.S. gasoline imports and domestic gasoline consumption forecast in AEO 2007, NHTSA tentatively estimates that 50 percent of fuel savings resulting from higher CAFE standards will result in reduced imports of refined gasoline, while the remaining 50 percent will reduce domestic refining.[186] The reduction in domestic refining is assumed to leave its sources of crude petroleum unchanged from the mix of 90 percent imports and 10 percent domestic production projected by AEO 2007.

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[184] U.S. Environmental Protection Agency, MOBILE6 Vehicle Emission Modeling Software, *available at* http://www.epa.gov/otaq/m6.htm#m60 (last accessed Sept. 10, 2007).

[185] To a lesser extent, they also depend on whether any reduction in domestic gasoline refining is translated into reduced imports of crude oil or reduced domestic extraction of petroleum.

[186] Estimates of the response of gasoline imports and domestic refining to fuel savings from stricter standards are variable and highly uncertain, but our preliminary analysis indicates that under any reasonable assumption about these responses, the magnitude of the net change in criteria pollutant emissions (accounting for both the rebound effect and changes in refining emissions) is extremely low relative to their current total.

NHTSA proposes to estimate reductions in criteria pollutant emissions from gasoline refining and distribution using emission rates obtained from Argonne National Laboratories' Greenhouse Gases and Regulated Emissions in Transportation (GREET) model.[187] The GREET model provides separate estimates of air pollutant emissions that occur in four phases of fuel production and distribution: crude oil extraction, crude oil transportation and storage, fuel refining, and fuel distribution and storage.[188] We tentatively assume that reductions in imports of refined fuel would reduce criteria pollutant emissions during fuel storage and distribution only. Reductions in domestic fuel refining using imported crude oil as a feedstock are tentatively assumed to reduce emissions during crude oil transportation and storage, as well as during gasoline refining, distribution, and storage, simply because less of it would be occurring. Similarly, reduced domestic fuel refining using domestically-produced crude oil is tentatively assumed to reduce emissions during all phases of gasoline production and distribution.[189]

The net changes in emissions of each criteria pollutant are calculated by comparing the increases in their emissions that result from increased vehicle use to the reductions that result from lower domestic fuel refining and distribution. The net change in emissions of each criteria pollutant is converted to an economic value using estimates of the economic costs per ton emitted (which result primarily from damages to human health) developed by EPA and submitted to the federal Office of Management and Budget for review. For certain criteria pollutants, EPA estimates different per-ton costs for increases in emissions from vehicle use than for reductions in emissions from fuel refining, reflecting differences in their typical geographic distributions, contributions to ambient pollution levels, and resulting population exposure. The per unit costs for each criteria pollutant is summarized in Table VIII-B.

Greenhouse Gases

NHTSA has taken the economic benefits of reducing CO_2 emission into account in this rulemaking, both in developing proposed CAFE standards and in assessing the economic benefits of each alternative that was considered. As noted above, the 9th Circuit found in CBD that NHTSA had been arbitrary and capricious in deciding not to monetize the benefit of reducing CO_2 emissions, saying that the agency had not substantiated the conclusion in its April 2006 final rule that the appropriate course was not to monetize (i.e., quantify the value of) carbon emissions reduction at all.

To this end, NHTSA reviewed published estimates of the "social cost of carbon emissions" (SCC). The SCC refers to the marginal cost of additional damages caused by the increase in expected climate impacts resulting from the emission of each additional metric ton of carbon,

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[187] Argonne National Laboratories, *The Greenhouse Gas and Regulated Emissions from Transportation (GREET) Model*, Version 1.6, April 2005, *available at* http://www.transportation.anl.gov/software/GREET/index.html (last accessed Sept. 10, 2007).

[188] Emissions that occur during vehicle refueling at retail gasoline stations (primarily evaporative emissions of volatile organic compounds, or VOCs) are already accounted for in the "tailpipe" emission factors used to estimate the emissions generated by increased light truck use. GREET estimates emissions in each phase of gasoline production and distribution in mass per unit of gasoline energy content; these factors are then converted to mass per gallon of gasoline using the average energy content of gasoline.

[189] In effect, this assumes that the distances crude oil travels to U.S. refineries are approximately the same regardless of whether it travels from domestic oilfields or import terminals, and that the distances that gasoline travels from refineries to retail stations are approximately the same as those from import terminals to gasoline stations.

which is emitted in the form of CO_2.[190] It is typically estimated as the net present value of the impact over some time period (100 years or longer) of one additional ton of carbon emitted into the atmosphere. Because accumulated concentrations of greenhouse gases in the atmosphere and the projected impacts on global climate are increasing over time, the economic damages resulting from each additional ton of CO_2 emissions in future years are believed to be greater as a result. Thus estimates of the SCC are typically reported for a specific year, and these estimates are generally larger for emissions in more distant future years.

There is substantial variation among different authors' estimates of the SCC, much of which can be traced to differences in their underlying assumptions about several variables. These include the sensitivity of global temperatures and other climate attributes to increasing atmospheric concentrations of greenhouse gases, discount rates applied to future economic damages from climate change, whether damages sustained by developing regions of the globe should be weighted more heavily than damages to developed nations, how long climate changes persist once they occur, and the economic valuation of specific climate impacts.[191]

Taken as a whole, recent estimates of the SCC may underestimate the true damage costs of carbon emissions because they often exclude damages caused by extreme weather events or climate response scenarios with low probabilities but potentially extreme impacts, and may underestimate the climate impacts and damages that could result from multiple stresses on the global climatic system. At the same time, however, many studies fail to consider potentially beneficial impacts of climate change, and do not adequately account for how future development patterns and adaptations could reduce potential impacts from climate change or the economic damages they cause.

Given the uncertainty surrounding estimates of the SCC, the use of any single study may not be advisable since its estimate of the SCC will depend on many assumptions made by its authors. The Working Group II's contribution to the Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC)[192] notes that:

> The large ranges of SCC are due in the large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses, and discount rates.

Although the IPCC does not recommend a single estimate of the SCC, it does cite the Tol (2005) study on four separate occasions (pages 17, 65, 813, 822) as the only available survey of the peer-reviewed literature that has itself been subjected to peer review. Tol developed a

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[190] Carbon itself accounts for 12/44, or about 27%, of the mass of carbon dioxide (12/44 is the ratio of the molecular weight of carbon to that of carbon dioxide). Thus each ton of carbon emitted is associated with 44/12, or 3.67, tons of carbon dioxide emissions. Estimates of the SCC are typically reported in dollars per ton of carbon, and must be divided by 3.67 to determine their equivalent value per ton of carbon dioxide emissions.

[191] For a discussion of these factors, see Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos and R.T. Perez, 2007: Perspectives on climate change and sustainability. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, pp. 821-824.

[192] Climate Change 2007 – Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the IPCC, 17. Available at http://www.ipcc-wg2.org (last accessed <Feb. 4, 2008>).

probability function using the SCC estimates of the peer reviewed literature and found estimates ranging from less than zero to over $200 per metric ton of carbon. In an effort to resolve some of the uncertainty in reported estimates of climate damage costs from carbon emissions, Tol (2005) reviewed and summarized one hundred and three estimates of the SCC from 28 published studies. He concluded that when only peer-reviewed studies published in recognized journals are considered, "…climate change impacts may be very uncertain but is unlikely that the marginal damage costs of carbon dioxide emissions exceed $50 per [metric] ton carbon [about $14 per metric ton of CO2]." [193] He also concluded that the costs may be less than $14.

Because of the number of assumptions required by each study, the wide range of uncertainty surrounding these assumptions, and their critical influence on the resulting estimates of climate damage costs, some studies have undoubtedly produced estimates of the SCC that are unrealistically high, while others are likely to have estimated values that are improbably low. Using a value for the SCC that reflects the central tendency of estimates drawn from many studies reduces the chances of relying on a single estimate that subsequently proves to be biased.

It is important to note that estimates of the SCC almost invariably include the value of worldwide damages from potential climate impacts caused by carbon dioxide emissions, and are not confined to damages likely to be suffered within the U.S. In contrast, the other estimates of costs and benefits of increasing fuel economy included in this proposal include only the economic values of impacts that occur within the U.S. For example, the economic value of reducing criteria air pollutant emissions from overseas oil refineries is not counted as a benefit resulting from this rule, because any reduction in damages to health and property caused by overseas emissions are unlikely to be experienced within the U.S.

In contrast, the reduced value of transfer payments from U.S. oil purchasers to foreign oil suppliers that results when lower U.S. oil demand reduces the world price of petroleum (the reduced "monopsony effect") is counted as a benefit of reducing fuel use.[194] If the agency's analysis was conducted from a worldwide rather than a U.S. perspective, however, the benefit from reducing air pollution overseas would be included, while reduced payments from U.S. oil consumers to foreign suppliers would not.

In order to be consistent with NHTSA's use of exclusively domestic costs and benefits in prior CAFE rulemakings, the appropriate value to be placed on changes climate damages caused by carbon emissions should be one that reflects the change in damages to the United States alone. Accordingly, NHTSA notes that the value for the benefits of reducing CO_2 emissions might be restricted to the fraction of those benefits that are likely to be experienced within the United States.

Although no estimates of benefits to the U.S. itself that are likely to result from reducing CO_2 emissions are currently available, NHTSA expects that if such values were developed, the

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[193] Tol, Richard. The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties. Energy Policy 33 (2005) 2064–2074, 2072. The summary SCC estimates reported by Tol are assumed to be denominated in U.S. dollars of the year of publication, 2005.

[194] The reduction in payments from U.S. oil purchasers to domestic petroleum producers is not included as a benefit, since it represents a transfer that occurs entirely within the U.S. economy.

agency would employ those rather than global benefit estimates in its analysis. NHTSA also anticipates that if such values were developed, they would be lower than comparable global values, since the U.S. is likely to sustain only a fraction of total global damages resulting from climate change.

In the meantime, the agency has elected to use the IPCC estimate of $43 per metric ton of carbon as an upper bound on the benefits resulting from reducing each metric ton of U.S. emissions.[195] This corresponds to approximately $12 per metric ton of CO_2 when expressed in 2006 dollars. This estimate is based on the 2005 Tol study.[196] The Tol study is cited repeatedly as an authoritative survey in various IPCC reports, which are widely accepted as representing the general consensus in the scientific community on climate change science. Since the IPCC estimate includes the worldwide costs of potential damages from carbon dioxide emissions, NHTSA has elected to employ it as an upper bound on the estimated value of the reduction in U.S. domestic damage costs that is likely to result from lower CO_2 emissions.[197]

The IPCC Working Group II Fourth Assessment Report (2007, p. 822) further suggests that the SCC of carbon is growing at an annual 2.4 percent growth rate, based on estimated increases in damages from future emissions reported in published studies. NHTSA has also elected to apply this growth rate to Tol's original 2005 estimate. Thus by 2011, the agency estimates that the upper bound on the benefits of reducing CO_2 emissions will have reached about $14 per metric ton of CO_2, and will continue increase by 2.4 percent annually thereafter.

In setting a lower bound, the agency agrees with the IPCC Working Group II (2007) report that "significant warming across the globe and the locations of significant observed changes in many systems consistent with warming is very unlikely to be due solely to natural variability of temperatures or natural variability of the systems" (pp. 9). Although this finding suggests that the <u>global</u> value of economic benefits from reducing carbon dioxide emissions is unlikely to be zero, it does not necessarily rule out low or zero values for the benefit to the U.S. itself from reducing emissions.

For most of the analysis it performed to develop this proposal, NHTSA required a single estimate for the value of reducing CO_2 emissions. The agency thus elected to use the midpoint of the range from $0 to $14 (or $7.00) per metric ton of CO_2 as the initial value for the year 2011, and assumed that this value would grow at 2.4 percent annually thereafter. This estimate is employed for the analyses conducted using the Volpe CAFE model to support development of the proposed standards. The agency also conducted sensitivity analyses of the benefits from

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[195] The estimate of $43 per ton of carbon emissions is reported by Tol (p. 2070) as the mean of the "best" estimates reported in peer-reviewed studies (see fn. 4). It thus differs from the mean of all estimates reported in the peer-reviewed studies surveyed by Tol. The $43 per ton value is also attributed to Tol by IPCC Working Group II (2007), p. 822.

[196] Tol's more recent (2007) and inclusive survey has been published online with peer-review comments. The agency has elected not to rely on the estimates it reports, but will consider doing so in its analysis of the final rule if the survey has been published, and will also consider any other newly-published evidence.

[197] For purposes of comparison, we note that in the rulemaking to establish CAFE standards for MY 2008-11 light trucks, NRDC recommended a value of $10 to $25 per ton of CO2 emissions reduced by fuel savings and both Environmental Defense and Union of Concerned Scientists recommended a value of $50 per ton of carbon (equivalent to about $14 per ton of CO_2 emissions).

reducing CO_2 emissions using both the upper ($14 per metric ton) and lower ($0 per metric ton) bounds of this range.

NHTSA seeks comment on its tentative conclusions for the value of the SCC, the use of a domestic versus global value for the economic benefit of reducing CO_2 emissions, the rate at which the value of the SCC grows over time, the desirability of and procedures for incorporating benefits from reducing emissions of greenhouse gases other than CO_2, and any other aspects of developing a reliable SCC value for purposes of establishing CAFE standards.

Consumer Benefits from Additional Driving

The increase in travel associated with the rebound effect produces additional benefits to vehicle owners, which reflect the value to drivers and other vehicle occupants of the added (or more desirable) social and economic opportunities that become accessible with additional travel. As evidenced by the fact that they elect to make more frequent or longer trips when the cost of driving declines, the benefits from this added travel are at least as large as drivers' added costs for the fuel it consumes (measured at the improved level of fuel economy resulting from stricter CAFE standards).[198] The benefits from additional rebound effect travel also include the consumer surplus received by vehicle buyers who value the opportunities that increased travel makes available to them at more than the fuel cost of the additional driving. Because it depends on the improvement in fuel economy, the value of benefits from increased vehicle use changes by model year and alternative CAFE standard, and is shown in Tables VIII-5 through VIII-9.

Added Costs from Congestion, Crashes, and Noise

While it provides some benefits to drivers, increased vehicle use associated with the fuel economy rebound effect can also contribute to increased traffic congestion, motor vehicle crashes, and highway noise. Additional vehicle use can contribute to traffic congestion and delays by increasing recurring congestion on heavily-traveled roadways during peak travel periods, depending on how the additional travel is distributed over the day and on where it occurs. By increasing the number of crashes and disabled vehicles, added driving can also increase the delays that often result from these incidents, although the extent to which it actually does so again depends on when and where the added travel occurs. In either case, any added delays impose higher costs on drivers and other vehicle occupants in the form of increased travel time and operating expenses, and these should be considered as an additional economic cost associated with the rebound effect. Because drivers do not take these added costs into account in deciding when to make trips or where they travel, they must be accounted for separately as a cost of the added driving associated with the rebound effect.

Increased passenger car and light truck use due to the rebound effect may also increase the costs associated with traffic crashes. Drivers presumably take account of the potential costs they (and the other occupants of their vehicles) face from the possibility of being involved in a crash when they decide to make additional trips. However, they probably do not consider all of the potential costs they impose on occupants of other vehicles and on pedestrians when crashes occur, so any increase in these "external" crash costs must be considered as another cost of additional rebound-effect driving. Like increased delay costs, any increase in these external crash costs caused by

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[198] These benefits are included in the value of fuel savings reported in Tables VIII-5 through VIII-9.

added driving is likely to depend on the traffic conditions under which it takes place, since crashes are more frequent in heavier traffic, but their severity may be reduced by the slower speeds at which heavier traffic typically moves. Thus estimates of the increase in external crash costs from the rebound effect also need to account for when and where the added driving occurs.

Finally, added vehicle use from the rebound effect may also increase traffic noise. Noise generated by vehicles causes inconvenience, irritation, and potentially even discomfort to occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of surrounding property. Because none of these effects are likely to be taken into account by the drivers whose vehicles contribute to traffic noise, they represent additional externalities associated with motor vehicle use. Although there is considerable uncertainty in estimating its value, the added inconvenience and irritation caused by increased traffic noise imposes economic costs on those it affects, and these added costs are unlikely to be taken into account by drivers of the vehicles that cause it. Thus any increase in noise costs resulting from added vehicle use must be included together with other increased external costs from the rebound effect.

Our analysis uses estimates of the congestion costs, crash costs, and noise costs for pickup trucks and vans developed by the Federal Highway Administration to estimate the increased external costs caused by added light truck use from the rebound effect.[199] These estimates are intended to measure the increases in external costs – that is, the marginal external costs – from added congestion, property damages and injuries in traffic crashes, and noise levels caused by additional usage of light trucks that are borne by persons other than their drivers. FHWA's "Middle" estimates for congestion, crash, and noise costs imposed by passenger cars are 5.22 cents, 2.26 cents and 0.07 cents per vehicle mile when expressed in 2006 dollars.[200] For pickup trucks and vans these costs are 4.66 cents, 2.51 cents, and 0.07 cents per vehicle-mile. These costs are multiplied by the estimated increases in passenger car and light truck use from the rebound effect during each year of the affected model years' lifetimes in the fleet to yield the estimated increases in congestion, crash, and noise externality costs during that year. The resulting estimates are discounted to their present values as of the date each model year is sold and summed to obtain their total values.

The Federal Highway Administration's estimates of these costs agree closely with some other recent estimates. For example, recent published research conducted by Resources for the Future (RFF) estimates marginal congestion and external crash costs for increased light-duty vehicle use in the U.S. to be 3.9 and 3.4 cents per vehicle-mile when converted to 2006 dollars.[201] These estimates incorporate careful adjustments of congestion and crash costs that are intended to reflect the traffic conditions under which additional driving is likely to take place, as well as its likely effects on both the frequency and severity of motor vehicle crashes.

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[199] These estimates were developed by FHWA for use in its 1997 *Federal Highway Cost Allocation Study*.

[200] Federal Highway Administration, 1997 *Federal Highway Cost Allocation Study*, Tables V-22, V-23, and V-24, http://www.fhwa.dot.gov/policy/hcas/final/index.htm. The higher congestion cost for automobiles than for light trucks reflects the larger fraction of auto than of light truck use that occurs within congested urban areas.

[201] Ian W.H. Parry and Kenneth A. Small, "Does Britain or the U.S. Have the Right Gasoline Tax?" Discussion Paper 02-12, Resources for the Future, March 2002, pp. 19 and Table 1, http://www.rff.org/rff/Documents/RFF-DP-02-12.pdf.

Costs from Increased Air Pollutant Emissions

Finally, as noted previously under Emissions Reductions Resulting from Fuel Savings, additional passenger car and light truck use associated with the rebound effect will increase emissions of air pollutants that occur as motor vehicles are driven. Predominant air pollutants emitted by motor vehicles include hydrocarbon compounds (usually referred to as "volatile organic compounds," or VOC), nitrogen oxides (NOx), fine particulate matter (PM), and sulfur dioxide (SO_2). The increased use of passenger cars and light trucks that occurs through the rebound effect causes higher emissions of these "criteria" pollutants, since Federal standards limit their permissible emissions by motor vehicles on a per-mile basis. The increase in emissions of these pollutants from additional vehicle use is estimated by multiplying the increase in total miles driven by vehicles of each model year and age during a calendar year by age-specific emission rates per vehicle-mile developed using the U.S. Environmental Protection Agency's MOBILE6.2 motor vehicle emissions factor model[202]. The monetized value of changes in criteria pollutant emissions (fine PM, NOx, SO2, VOCs andCO) are derived from EPA estimates of the value of health and welfare-related damages (incurred or avoided). These estimates, expressed as dollars per ton, are based on the benefits associated with recently-adopted regulations that limit emissions of air pollutants from mobile sources, a category that includes passenger cars, light trucks, and other highway vehicles.[203]

The Value of Increased Driving Range

Improving the fuel economy of passenger cars and light-duty trucks may also increase their driving range before they require refueling. By reducing the frequency with which drivers typically refuel their vehicles, and by extending the upper limit of the range they can travel before requiring refueling, improving fuel economy thus provides some additional benefits to their owners. (Alternatively, if manufacturers respond to improved fuel economy by reducing the size of fuel tanks to maintain a constant driving range, the resulting cost saving will presumably be reflected in lower vehicle sales prices.)

No direct estimates of the value of extended vehicle range are readily available, so the agency's analysis calculates the reduction in the annual number of required refueling cycles that results from improved fuel economy, and applies DOT-recommended values of travel time savings to convert the resulting time savings to their economic value.[204] As an illustration of how the value of extended refueling range is estimated, a typical small light truck model has an average fuel tank size of approximately 20 gallons. Assuming that drivers typically refuel when their tanks are 20 percent full (i.e., 4 gallons in reserve), increasing this model's actual on-road fuel economy from 24 to 25 mpg would extend its driving range from 384 miles (= 16 gallons x 24 mpg) to 400 miles (= 16 gallons x 25 mpg). Assuming that it is driven 12,000 miles/year, this reduces the number of times it needs to be refueled each year from 31.3 (= 12,000 miles per year / 384 miles per refueling) to 30.0 (= 12,000 miles per year / 400 miles per refueling), or by 1.3 refuelings per year.

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[202] U.S. Environmental Protection Agency, MOBILE6 Vehicle Emission Modeling Software, http://www.epa.gov/otaq/m6.htm#m60

[203] EPA, "Mobile Source $ per Ton Estimates," document provided to NHTSA by EPA Office of Transportation and Air Quality staff, June 26, 2007.

[204] See http://ostpxweb.dot.gov/policy/Data/VOT97guid.pdf and http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf

Weighted by the nationwide mix of urban (about 2/3) and rural (about 1/3) driving and average vehicle occupancy for all driving trips (1.6 persons), the DOT-recommended value of travel time per vehicle-hour is $24.00 (in 2006 dollars).[205] Assuming that locating a station and filling up requires ten minutes, the annual value of time saved as a result of less frequent refueling amounts to $5.20 (calculated as 10/60 x 1.3 x $24.00). This calculation is repeated for each future calendar year that light trucks of each model year affected by the alternative CAFE standards considered in this rule would remain in service. Like fuel savings and other benefits, however, the value of this benefit declines over a model year's lifetime, because a smaller number of vehicles originally produced during that model year remain in service each year, and those remaining in service are driven fewer miles.

The following Table summarizes the values used to calculate the impacts of each scenario.

Table VIII-B

Economic Values for Benefits Computations (2006$)

Rebound Effect (VMT Elasticity)	-0.15
Discount Rate Applied to Future Benefits	7%
Payback Period (years)	5.0
"Gap" between Test and On-Road MPG	20%
Value of Travel Time per Vehicle ($/hour)	$24.00
Economic Costs of Oil Imports ($/gallon)	
"Monopsony" Component	$0.182
Price Shock Component	$0.113
Military Security Component	$ -
Total Economic Costs ($/gallon)	$0.295
Total Economic Costs ($/BBL)	$12.38
External Costs from Additional Automobile Use Due to "Rebound" Effect ($/vehicle-mile)	
Congestion	$0.052
Accidents	$0.023
Noise	$0.001
External Costs from Additional Light Truck Use Due to "Rebound" Effect ($/vehicle-mile)	
Congestion	$0.047
Accidents	$0.025
Noise	$0.001
Emission Damage Costs	
Carbon Monoxide ($/ton)	$ -
Volatile Organic Compounds ($/ton)	$1,700

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[205] The hourly wage rate during 2006 is estimated to be $24.00. Personal travel (94.4% of urban travel) is valued at 50 percent of the hourly wage rate. Business travel (5.6% or urban travel) is valued at 100 percent of the hourly wage rate. For intercity travel, personal travel (87%) is valued at 70 percent of the wage rate, while business travel (13%) is valued at 100 percent of the wage rate. The resulting values of travel time are $12.67 for urban travel and $17.66 for intercity travel, and must be multiplied by vehicle occupancy (1.6) to obtain the estimate value of time per vehicle hour.

Nitrogen Oxides ($/ton)	$3,900
Particulate Matter ($/ton)	$164,000
Sulfur Dioxide ($/ton)	$16,000
Carbon Dioxide ($/metric ton)	$ 7.00
Annual Increase in CO2 Damage Cost	2.4%

Summary of Benefits

Benefits were calculated separately for passenger cars and light trucks under each alternative CAFE requirement for each model year covered by this proposal. In Tables VIII-5 through VIII-9, the societal impacts for passenger car CAFE standards under the proposed Optimized Net Benefits alternative is shown over the 2011 through 2015 model years. Table VIII-10 summarizes the impacts for passenger cars across all 5 model years. In Tables VIII-11 through VIII-15 the societal impacts for light truck CAFE standards under the Optimized Net Benefits alternative is shown over the 2011 through 2015 model years. Table VIII-16 summarizes the impacts for light trucks across all 5 model years. Table VIII-17 summarizes the impacts across both the passenger car and light truck fleets for the 5 model years combined. These tables include undiscounted values as well as present value calculations at 3 percent and 7 percent. They also show changes in the physical units of measure that produced these values. Negative values in these tables reflect net reductions in fuel consumption or emissions and their resulting economic impacts, which represent benefits from the proposal, while positive values represent increasing emissions, congestion, noise or crash severity and their added costs. The net social benefit from these societal impacts is shown on the Total line in each table.

The proposed standards for passenger cars would save approximately 19 billion gallons of fuel and prevent 178 million metric tons of tailpipe CO_2 emissions over the lifetime of the passenger cars sold during those model years, compared to the fuel savings and emissions reductions that would occur if the standards remained at the adjusted baseline (i.e., the higher of manufacturer's plans or the manufacturer's required level of average fuel economy for MY 2010).

The total value of societal benefits of the proposed passenger car standards would be approximately $31 billion[206] over the lifetime of the 5 model years combined. This estimate of societal benefits includes direct impacts from lower fuel consumption as well as externalities, and also reflects offsetting societal costs resulting from the rebound effect. Direct benefits to consumers, including fuel savings, account for 85% ($29.5 billion) of the roughly $35 billion in gross consumer benefits[207] resulting from increased passenger car CAFE. Petroleum market externalities account for roughly 10% ($3.6 billion). Environmental externalities, i.e., reduction of air pollutants accounts for roughly 5% ($1.8 billion). Over half of this $1.8 billion is the result of greenhouse gas (primarily CO_2) reduction ($1.0 billion). Increased congestion, noise and accidents from increased driving will offset roughly $3.8 billion of the $35 billion in gross consumer benefits, leaving total consumer benefits of $31 billion.

The proposed standards for light trucks would save approximately 36 billion gallons of fuel and prevent 343 million metric tons of tailpipe CO_2 emissions over the lifetime of the light trucks sold during those model years, compared to the fuel savings and emissions reductions that would

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[206] The $31 billion estimate is based on a 7% discount rate for valuing future impacts. NHTSA estimated benefits using both 7% and 3% discount rates. Under a 3% rate, net consumer benefits for passenger car CAFE improvements total $36 billion.

[207] Gross consumer benefits are benefits measured prior to accounting for the negative impacts of the rebound effect. They include fuel savings, consumer surplus from additional driving, reduced refueling time, reduced criteria pollutants, and reduced greenhouse gas production. Negative impacts from the rebound effect include added congestion, noise, and crash costs due to additional driving.

occur if the standards remained at the adjusted baseline (i.e., the higher of manufacturer's plans or the manufacturer's required level of average fuel economy for MY 2010).

The total value of societal benefits of the proposed light truck standards would be approximately $57 billion[208] over the lifetime of the 5 model years combined. This estimate of societal benefits includes direct impacts from lower fuel consumption as well as externalities, and also reflects offsetting societal costs resulting from the rebound effect. Direct benefits to consumers, including fuel savings, account for 84% ($52.7 billion) of the roughly $63 billion in gross consumer benefits resulting from increased light truck CAFE. Petroleum market externalities account for roughly 10% ($6.5 billion). Environmental externalities, i.e., reduction of air pollutants accounts for roughly 6% ($3.5 billion). Over half of this $3.5 billion is the result of greenhouse gas (primarily CO_2) reduction ($1.9 billion). Increased congestion, noise and accidents from increased driving will offset roughly $5.4 billion of the $63 billion in gross consumer benefits, leaving total consumer benefits of $57 billion.

Tables VIII-18, 19, and 20 summarize the fuel savings from all alternatives over model years 2011-2015 for passenger cars and light trucks. Each table reports total fuel savings (in millions of gallons) over the lifetime of vehicles manufactured during each model year that are projected to occur under each scenario. As the tables indicate, there is a steady increase in fuel savings for both passenger cars and light trucks with each successive model year under all 7 scenarios. As would be expected, benefit levels parallel the increasing stringency of the various alternatives that were examined. The two Optimized scenarios pushes technology up to the point where is ceases to be cost effective, but the 3% based scenario produces more benefits than the 7% based scenario because it places a higher value on benefits experienced in the future. The TC=TB scenario produces benefits that exceed the Optimized scenario because it allows benefits that accrue from cost-beneficial technologies to offset costs that accrue from technologies that are not cost-beneficial. As might be expected, the High Technology scenario, which assumes the maximum use of all available technologies in all vehicles regardless of cost, produces higher savings than any of the 6 other scenarios in all model years. The 25% Below Optimized, 25% Above Optimized, and 50% Above Optimized scenarios were designed to produce results relative to the Optimized scenario, and their benefits accordingly reflect this.

Tables VIII-21, 22, 23, 24, 25 and 26 summarize the total social benefits from all alternatives over the 2011-2015 model years for passenger cars and light trucks at both 3 percent and 7 percent discount rates. These tables summarize the value of net consumer benefits over the lifetime of the vehicles manufactured during each model year and scenario. There is a steady increase in the social value of fuel savings and other benefits with each model year under all 7 scenarios, which mirrors the trends in fuel savings noted above. Likewise, the value of societal benefits mirrors the trends in stringency across alternative scenarios.

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[208] The $57 billion estimate is based on a 7% discount rate for valuing future impacts. NHTSA estimated benefits using both 7% and 3% discount rates. Under a 3% rate, net consumer benefits for light truck CAFE improvements total $72 billion.

Table VIII-5

Lifetime Monetized Societal Impacts, Optimized CAFE, MY 2011, Passenger Cars

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-1,563,348(kgal)	-3,082,877	-2,538,092	-2,074,331
Consumer Surplus from Additional Driving	6,154,197(kmiles)	-382,541	-320,292	-261,888
Refueling Time Value	-8,064,500 (hours)	-193,548	-161,963	-132,232
Petroleum Market Externalities	-1,563,348(kgal)	-437,683	-366,257	-299,025
Congestion Costs	6,154,197 (kmiles)	321,249	268,824	219,478
Noise Costs	6,154,197 (kmiles)	4,308	3,605	2,943
Crash Costs	6,154,197 (kmiles)	139,085	116,387	95,023
CO2	-15 (mmT)	-119,479	-98,360	-78,834
CO	281,949(tons)	0	0	0
VOC	-4,589 (tons)	-7,801	5,801	-4,102
NOX	-7,728 (tons)	-30,141	-23,583	-17,773
PM	-191 (tons)	-31,401	-25,396	-20,088
SOX	-2,261(tons)	-36,178	-30,274	-24,717
Total		-3,807,007	-3,181,201	-2,595,546

Table VIII-6

Lifetime Monetized Societal Impacts,
Optimized CAFE, MY 2012, Passenger Cars

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-2,967,962 (k gal)	-5,819,490	-4,859,768	-3,961,065
Consumer Surplus from Additional Driving	11,771,196(kmiles)	-721,598	-603,190	-492,159
Refueling Time Value	14,848,833 (hours)	-356,372	-298,216	-243,474
Petroleum Market Externalities	-2,967,962 (k gal)	-830,928	-695,329	-567,691
Congestion Costs	11,771,196 (kmiles)	614,456	514,183	419,797
Noise Costs	11,771,196 (kmiles)	8,240	6,895	5,629
Crash Costs	11,771,196 (kmiles)	266,029	222,616	181,751
CO2	-28 (mmT)	-238,466	-196,315	-157,343
CO	86,340(tons)	0	0	0
VOC	1,086 (tons)	1,851	1,300	840
NOX	-6,044 (tons)	-23,570	-20,210	-16,942
PM	-513(tons)	-84,176	-70,096	-56,968
SOX	-4,158 (tons)	-66,522	-55,667	-45,448
Total		-7,250,243	-6,053,796	-4,933,071

Table VIII-7

Lifetime Monetized Societal Impacts, Optimized CAFE, MY 2013, Passenger Cars

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-3,716,507 (k gal)	-7,272,841	-6,064,046	-4,932,346
Consumer Surplus from Additional Driving	14,947,099 (kmiles)	-902,219	-753,173	-613,455
Refueling Time Value	-18,783,958 (hours)	-450,815	-377,246	-307,997
Petroleum Market Externalities	-3,716,507 (k gal)	-1,040,492	-870,693	-710,865
Congestion Costs	14,947,099 (kmiles)	780,239	652,911	533,060
Noise Costs	14,947,099 (kmiles)	10,463	8,756	7,148
Crash Costs	14,947,099 (kmiles)	337,804	282,678	230,788
CO2	-36 (mmT)	-305,686	-251,653	-201,695
CO	104,544 (tons)	0	0	0
VOC	-1,946 (tons)	-3,308	-2,545	-1,882
NOX	-10,551 (tons)	-41,151	-33,835	-27,078
PM	-605 (tons)	-99,250	-81,737	-65,701
SOX	-5,271 (tons)	-84,335	-70,572	-57,618
Total		-9,071,590	-7,561,156	-6,147,651

Table VIII-8

Lifetime Monetized Societal Impacts,
Optimized CAFE, MY 2014, Passenger Cars

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-4,771,444(k gal)	-9,340,878	-7,780,728	-6,319,874
Consumer Surplus from Additional Driving	18,970,569 (miles)	-1,145,324	-955,266	-777,109
Refueling Time Value	24,182,292 (hours)	-580,375	-485,663	-396,513
Petroleum Market Externalities	-4,771,444(k gal)	-1,335,837	-1,117,841	-912,645
Congestion Costs	18,970,569 (miles)	990,264	828,662	676,549
Noise Costs	18,970,569 (miles)	13,279	11,112	9,072
Crash Costs	18,970,569 (miles)	428,735	358,769	292,912
CO2	-46 (mmT)	-401,009	-330,127	-264,593
CO	-147,821 (tons)	0	0	0
VOC	-2,690 (tons)	-4,573	-3,520	-2,603
NOX	-13,709 (tons)	-53,464	-43,909	-35,090
PM	-793 (tons)	-130,021	-106,690	-85,396
SOX	-6,764 (tons)	-108,229	-90,567	-73,942
Total		-11,667,432	-9,715,770	-7,889,231

Table VIII-9

Lifetime Monetized Societal Impacts,
Optimized CAFE, MY 2015, Passenger Cars

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-5,716,339(k gal)	-11,171,665	-9,298,183	-7,542,913
Consumer Surplus from Additional Driving	22,781,264 (kmiles)	-1,363,084	-1,135,944	-922,974
Refueling Time Value	28,938,083 (hours)	-694,514	-581,176	-474,492
Petroleum Market Externalities	-5,716,339 (k gal)	-1,600,375	-1,339,209	-1,093,378
Congestion Costs	22,781,264 (kmiles)	1,189,182	995,119	812,450
Noise Costs	22,781,264 (kmiles)	15,947	13,345	10,895
Crash Costs	22,781,264 (kmiles)	517,857	430,847	351,751
CO2	-54 (mmT)	-488,493	-402,147	-322,314
CO	-273,604 (tons)	0	0	0
VOC	-4,634 (tons)	-7,878	-6,026	-4,412
NOX	-17,657 (tons)	-68,864	-56,138	-44,462
PM	-958 (tons)	-157,158	-127,963	-101,508
SOX	-8,104 (tons)	-129,669	-108,508	-88,590
Total		-13,961,714	-11,615,995	-9,419,948

Table VIII-10

Lifetime Monetized Societal Impacts, Optimized CAFE, MY 2011- 2015, Passenger Cars

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-18,735,610 (kgal)	-36,637,752	-28,459,291	-24,830,539
Consumer Surplus from Additional Driving	74,624,325 (kmiles)	-4,514,765	-3,507,694	-3,067,584
Refueling Time Value	-94,817,655 (hours)	-2,275,624	-1,774,730	-1,554,709
Petroleum Market Externalities	-18,735,610 (kgal)	-5,245,315	-4,090,602	-3,583,605
Congestion Costs	74,624,325 (kmiles)	3,895,390	3,038,066	2,661,335
Noise Costs	74,624,325 (kmiles)	52,237	40,740	35,688
Crash Costs	74,624,325 (kmiles)	1,686,510	1,315,331	1,152,225
CO2	-178 (mmT)	-1,553,133	-1,190,956	-1,024,777
CO	-721,578 (tons)	0	0	0
VOC	-12,770 (tons)	-21,709	-15,625	-12,160
NOX	-55,689 (tons)	-217,189	-165,746	-141,345
PM	-3,061 (tons)	-502,006	-385,311	-329,661
SOX	-26,558 (tons)	-424,934	-331,395	-290,316
Total		-45,758,291	-35,527,213	-30,985,447

Table VIII-11

Lifetime Monetized Societal Impacts,
Optimized CAFE, MY 2011, Light Trucks

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-2,403,611 (kgal)	-4,811,383	-3,883,226	-3,087,364
Consumer Surplus from Additional Driving	7,666,300 (kmiles)	-595,411	-481,267	-383,161
Refueling Time Value	-9,383,882 (hours)	-225,213	-182,196	-144,998
Petroleum Market Externalities	-2,403,611 (kgal)	-672,927	-544,395	-433,248
Congestion Costs	7,666,300 (kmiles)	357,250	289,013	230,007
Noise Costs	7,666,300 (kmiles)	5,366	4,341	3,455
Crash Costs	7,666,300 (kmiles)	192,424	155,670	123,888
CO2	-23 (mmT)	-199,178	-156,241	-120,625
CO	84,710 (tons)	0	0	0
VOC	1,859 (tons)	3,161	2,062	1,256
NOX	-3,552 (tons)	-13,852	-12,277	-10,642
PM	-500 (tons)	-81,980	-66,292	-52,737
SOX	-3,382 (tons)	-54,105	-43,771	-34,834
Total		-6,095,848	-4,918,579	-3,909,004

Table VIII-12

Lifetime Monetized Societal Impacts, Optimized CAFE, MY 2012, Light Trucks

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-5,478,272 (kgal)	-10,868,471	-8,754,164	-6,941,594
Consumer Surplus from Additional Driving	17,399,527 (kmiles)	-1,327,696	-1,071,130	-850,722
Refueling Time Value	-20,525,226 (hours)	-492,605	-398,516	-317,152
Petroleum Market Externalities	-5,478,272 (kgal)	-1,533,724	-1,240,776	-987,452
Congestion Costs	17,399,527 (kmiles)	810,818	655,948	522,026
Noise Costs	17,399,527 (kmiles)	12,180	9,853	7,842
Crash Costs	17,399,527 (kmiles)	436,728	353,311	281,177
CO2	-53 (mmT)	-461,762	-362,219	-279,649
CO	761,706 (tons)	0	0	0
VOC	18,561 (tons)	31,554	21,119	13,250
NOX	17,083 (tons)	66,622	37,737	16,756
PM	-1,523 (tons)	-249,839	-201,709	-160,269
SOX	-8,040 (tons)	-128,642	-104,069	-82,820
Total		-13,704,838	-11,054,616	-8,778,608

Table VIII-13

Lifetime Monetized Societal Impacts, Optimized CAFE, MY 2013, Light Trucks

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-8,508,804 (kgal)	-16,796,650	-13,508,492	-10,688,849
Consumer Surplus from Additional Driving	27,188,329 (kmiles)	-2,054,826	-1,655,395	-1,312,269
Refueling Time Value	-32,253,023 (hours)	-774,073	-626,221	-498,368
Petroleum Market Externalities	-8,508,804 (kgal)	-2,382,167	-1,927,162	-1,533,702
Congestion Costs	27,188,329 (kmiles)	1,266,976	1,024,978	815,712
Noise Costs	27,188,329 (kmiles)	19,032	15,397	12,253
Crash Costs	27,188,329 (kmiles)	682,427	552,080	439,364
CO2	-82 (mmt)	-730,569	-573,079	-442,442
CO	734,617 (tons)	0	0	0
VOC	17,081 (tons)	29,037	19,409	12,103
NOX	9,106 (tons)	35,513	13,286	-2,256
PM	-2,232 (tons)	-366,080	-295,685	-235,000
SOX	-12,319 (tons)	-197,096	-159,448	-126,893
Total		-21,268,476	-17,120,333	-13,560,347

Table VIII-14

Lifetime Monetized Societal Impacts,
Optimized CAFE, MY 2014, Light Trucks

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-9,391,857 (kgal)	-18,376,166	-14,768,243	-11,671,696
Consumer Surplus from Additional Driving	30,130,353 (kmiles)	-2,265,105	-1,823,071	-1,443,287
Refueling Time Value	-35,503,043 (hours)	-852,073	-689,323	-548,587
Petroleum Market Externalities	-9,391,857 (kgal)	-2,629,391	-2,127,165	-1,692,871
Congestion Costs	30,130,353 (kmiles)	1,404,074	1,135,890	903,980
Noise Costs	30,130,353 (kmiles)	21,091	17,063	13,579
Crash Costs	30,130,353 (kmiles)	756,272	611,820	486,908
CO2	-89 (mmT)	-812,842	-637,617	-492,268
CO	-5,658 (tons)	0	0	0
VOC	-1,090 (tons)	-1,853	-2,068	-2,182
NOX	-9,088 (tons)	-35,445	-36,431	-35,546
PM	-2,786 tons)	-456,882	-367,050	-290,218
SOX	-13,876 (tons)	-222,024	-179,614	-142,941
Total		-23,470,345	-18,865,810	-14,915,129

Table VIII-15

Lifetime Monetized Societal Impacts, Optimized CAFE, MY 2015, Light Trucks

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-10,195,498 (kgal)	-19,973,909	-16,040,212	-12,660,941
Consumer Surplus from Additional Driving	32,977,172 (kmiles)	-2,454,647	-1,974,101	-1,560,979
Refueling Time Value	-38,972,327 (hours)	-935,336	-756,682	-602,194
Petroleum Market Externalities	-10,195,498 (kgal)	-2,854,383	-2,309,182	-1,837,726
Congestion Costs	32,977,172 (kmiles)	1,536,736	1,243,213	989,391
Noise Costs	32,977,172 (kmiles)	23,084	18,675	14,862
Crash Costs	32,977,172 (kmiles)	827,727	669,627	532,912
CO2	-96 (mmT)	-902,032	-707,580	-546,283
CO	-99,460 (tons)	0	0	0
VOC	-3,380 (tons)	-5,745	-4,895	-4,158
NOX	-13,408 (tons)	-52,290	-48,866	-44,507
PM	-3,048 (tons)	-499,947	-401,659	-317,517
SOX	-15,050 (tons)	-240,797	-194,802	-155,028
Total		-25,531,539	-20,506,465	-16,192,169

Table VIII-16

Lifetime Monetized Societal Impacts, Optimized CAFE, MY 2011-2015, Light Trucks

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-35,978,042 (kgal)	-70,826,579	-56,954,337	-45,050,444
Consumer Surplus from Additional Driving	115,361,681 (kmiles)	-8,697,686	-7,004,965	-5,550,419
Refueling Time Value	-136,637,500 (hours)	-3,279,300	-2,652,939	-2,111,299
Petroleum Market Externalities	-35,978,042 (kgal)	-10,072,593	-8,148,681	-6,485,000
Congestion Costs	115,361,681 (kmiles)	5,375,854	4,349,041	3,461,116
Noise Costs	115,361,681 (kmiles)	80,753	65,329	51,991
Crash Costs	115,361,681 (kmiles)	2,895,578	2,342,509	1,864,249
CO2	-343 (mmT)	-3,106,382	-2,436,737	-1,881,267
CO	1,475,915 (tons)	0	0	0
VOC	33,031 (tons)	56,154	35,627	20,269
NOX	141 (tons)	548	-46,551	-76,195
PM	-10,090 (tons)	-1,654,728	-1,332,395	-1,055,741
SOX	-52,667 (tons)	-842,664	-681,704	-542,517
Total		-90,071,046	-72,465,802	-57,355,257

Table VIII-17

Lifetime Monetized Societal Impacts,
Optimized CAFE, MY 2011-2015, Passenger Cars and Light Trucks

Societal Effect	Physical Units	Undiscounted Value (2006$ k)	Present Discounted Value @ 3%	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-54,713,652 (kgal)	-107,464,331	-85,413,628	-69,880,983
Consumer Surplus from Additional Driving	189,986,006 (kmiles)	-13,212,451	-10,512,659	-8,618,003
Refueling Time Value	-231,455,155 (hours)	-5,554,924	-4,427,668	-3,666,008
Petroleum Market Externalities	-54,713,652 (kgal)	-15,317,908	-12,239,283	-10,068,605
Congestion Costs	189,986,006 (kmiles)	9,271,244	7,387,107	6,122,451
Noise Costs	189,986,006 (kmiles)	132,990	106,069	87,679
Crash Costs	189,986,006 (kmiles)	4,582,088	3,657,841	3,016,475
CO2	-521 (mmT)	-4,659,516	-3,627,693	-2,906,044
CO	754,337 (tons)	0	0	0
VOC	20,261 (tons)	34,444	20,001	8,109
NOX	-55,549 (tons)	-216,641	-212,298	-217,540
PM	-13,151 (tons)	-2,156,735	-1,717,706	-1,385,402
SOX	-79,225 (tons)	-1,267,599	-1,013,099	-832,832
Total		-135,829,336	-107,993,015	-88,340,704

Table VIII-18

Savings in Millions of Gallons of Fuel
Undiscounted, over the Lifetime of the Model Year Fleet
Passenger Cars

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	All 5 MYs
25% Below Optimized	708	1261	1946	3135	4151	11201
Optimized Net Impact -7%	1563	2968	3717	4771	5716	18735
25% Above Optimized	2313	4480	5221	6601	7476	26091
50% Above Optimized	2641	5523	6422	7913	9121	31620
Optimized Net Impact -3%	3463	6197	6905	8587	9784	34936
TC=TB	3599	6860	7676	9320	10461	37916
Technology Exhaustion	3677	7143	8261	10233	11562	40876

Table VIII-19
Savings in Millions of Gallons of Fuel
Undiscounted, over the Lifetime of the Model Year Fleet
Light Trucks

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	All 5 MYs
25% Below Optimized	2157	4933	7902	7799	7808	30599
Optimized Net Impact -7%	2404	5478	8509	9392	10195	35978
25% Above Optimized	2585	6339	9070	10592	12534	41120
50% Above Optimized	2909	6780	9697	11458	13584	44428
Optimized Net Impact -3%	2414	5488	8978	9959	11127	37966
TC = TB	3228	7471	10640	12778	14602	48719
Technology Exhaustion	3263	7506	12659	14448	16147	54023

Table VIII-20
Savings in Millions of Gallons of Fuel
Undiscounted, over the Lifetime of the Model Year Fleet
Passenger Cars and Light Trucks

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	All 5 MYs
25% Below Optimized	2865	6194	9848	10934	11959	41800
Optimized Net Impact -7%	3967	8446	12226	14163	15911	54713
25% Above Optimized	4898	10819	14291	17193	20010	67211
50% Above Optimized	5550	12303	16119	19371	22705	76048
Optimized Net Impact -3%	5877	11685	15883	18546	20911	72902
TC = TB	6827	14331	18316	22098	25063	86635
Technology Exhaustion	6940	14649	20920	24681	27709	94899

Table VIII-21
Present Value @3% Discount Rate of Lifetime Social Benefits
(Millions of 2006 Dollars), Passenger Cars

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	All 5 MYs
25% Below Optimized	1418	2581	3977	6399	8387	22762
Optimized Net Impact-7%	3181	6054	7561	9716	11616	38128
25% Above Optimized	4604	8939	10403	13109	14907	51962
50% Above Optimized	5241	10842	12571	15503	17893	62050
Optimized Net Impact -3%	6798	12188	13519	16833	19216	68554
TC = TB	7075	13366	14881	18059	20364	73745
Technology Exhaustion	7156	13865	15967	19654	22312	78954

Table VIII-22
Present Value @3% Discount Rate of Lifetime Social Benefits (Millions of 2006 Dollars), Light Trucks

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	All 5 MYs
25% Below Optimized	4414	9959	15910	15715	15745	61743
Optimized Net Impact -7%	4919	11055	17120	18866	20506	72466
25% Above Optimized	5286	12599	17972	20984	24662	81503
50% Above Optimized	5848	13249	18955	22375	26475	86902
Optimized Net Impact -3%	4939	11075	17976	19902	22246	76138
TC = TB	6343	14452	20631	24704	28352	94482
Technology Exhaustion	6420	14528	24517	27951	31387	104803

Table VIII-23
Present Value @3% Discount Rate of Lifetime Social Benefits (Millions of 2006 Dollars), Passenger Cars and Light Trucks

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	All 5 MYs
25% Below Optimized	5832	12540	19887	22114	24132	84505
Optimized Net Impact -7%	8100	17109	24681	28582	32122	110594
25% Above Optimized	9890	21538	28375	34093	39569	133465
50% Above Optimized	11089	24091	31526	37878	44368	148952
Optimized Net Impact -3%	11737	23263	31495	36735	41462	144692
TC = TB	13418	27818	35512	42763	48716	168227
Technology Exhaustion	13576	28393	40484	47605	53699	183757

Table VIII-24
Present Value @7% Discount Rate of Lifetime Social Benefits (Millions of 2006 Dollars), Passenger Cars

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	All 5 MYs
25% Below Optimized	1156	2104	3235	5197	6799	18491
Optimized Net Impact -7%	2596	4933	6148	7889	9420	30986
25% Above Optimized	3755	7280	8454	10638	12083	42210
50% Above Optimized	4274	8825	10213	12576	14495	50383
Optimized Net Impact -3%	5543	9922	10983	13654	15569	55671
TC=TB	5769	10878	12087	14644	16492	59870
Technology Exhaustion	5834	11282	12968	15930	18061	64075

Table VIII-25
Present Value @7% Discount Rate of Lifetime Social Benefits (Millions of 2006 Dollars), Light Trucks

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	All 5 MYs
25% Below Optimized	3508	7910	12603	12432	12441	48894
Optimized Net Impact - 7%	3909	8779	13560	14915	16192	57355
25% Above Optimized	4201	9990	14236	16587	19457	64471
50% Above Optimized	4642	10507	15011	17687	20892	68739
Optimized Net Impact -3%	3926	8794	14251	15752	17589	60312
TC = TB	5027	11453	16330	19515	22367	74692
Technology Exhaustion	5088	11513	19395	22074	24759	82829

Table VIII-26
Present Value @7% Discount Rate of Lifetime Social Benefits
(Millions of 2006 Dollars), Passenger Cars and Light Trucks

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	All 5 MYs
25% Below Optimized	4664	10014	15838	17629	19240	67385
Optimized Net Impact -7%	6505	13712	19708	22804	25612	88341
25% Above Optimized	7956	17270	22690	27225	31540	106681
50% Above Optimized	8916	19332	25224	30263	35387	119122
Optimized Net Impact -3%	9469	18716	25234	29406	33158	115983
TC = TB	10796	22331	28417	34159	38859	134562
Technology Exhaustion	10922	22795	32363	38004	42820	146904

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IX. NET BENEFITS AND SENSITIVITY ANALYSES

This chapter compares the costs of technologies needed to make improvements in fuel economy to meet the alternatives with the potential benefits, expressed in total costs (millions of dollars) for each model year. The costs do not include fines, since these are transfer payments. Thus, the total costs shown in this section do not match the total costs shown in Chapter VII. The following tables combine the estimated costs and benefits from a societal perspective. These are incremental costs and benefits compared to an adjusted baseline of manufacturers' production plans. Tables utilizing a 3 percent and 7 percent discount rate for benefits are presented. Sensitivity analyses are also performed on some of the assumptions made in this analysis. Finally, a payback period is calculated, from the consumer's perspective.

Table IX-1 provides the total incremental costs (in millions of dollars) from a societal perspective. Table IX-2a and Table IX-2b provide the total benefits at a 3 percent and 7 percent discount rate from a societal perspective for all vehicles produced during each model year to which the standard is applicable. Table IX-3a and Table IX-3b show the total net benefits in millions of dollars at a 3 percent and 7 percent discount rate for the projected fleet of sales for each model year.

Table IX-1
Incremental Total Cost (excludes fines)
(Millions of 2006 Dollars)

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
Passenger Cars						
25% Below Optimized	835	818	1,253	2,153	3,209	8,268
Optimized (7%)	1,884	2,373	2,879	3,798	4,862	15,796
25% Above Optimized	3,387	5,653	6,445	8,240	9,084	32,808
50% Above Optimized	4,010	7,885	8,986	11,207	12,981	45,070
Optimized (3%)	5,467	8,791	9,821	12,447	14,484	51,011
TC = TB	5,913	10,796	12,303	15,403	17,398	61,812
Technology Exhaustion	6,079	12,595	14,701	18,759	21,110	73,245
Light Trucks						
25% Below Optimized	1,349	4,296	6,329	6,212	6,326	24,512
Optimized (7%)	1,649	4,986	7,394	8,160	8,761	30,949
25% Above Optimized	2,072	7,034	9,815	11,903	14,781	45,606
50% Above Optimized	2,922	8,098	11,586	14,386	17,969	54,961
Optimized (3%)	1,662	4,974	8,190	9,058	10,253	34,136
TC = TB	3,788	10,525	15,196	18,762	21,364	69,635
Technology Exhaustion	3,933	10,670	18,275	21,051	23,479	77,408
Passenger Cars and Light Trucks Combined						
25% Below Optimized	2,184	5,114	7,582	8,365	9,534	32,780
Optimized (7%)	3,534	7,358	10,273	11,957	13,623	46,745
25% Above Optimized	5,459	12,687	16,261	20,143	23,865	78,414
50% Above Optimized	6,932	15,983	20,572	25,593	30,950	100,030
Optimized (3%)	7,128	13,765	18,011	21,505	24,737	85,147
TC = TB	9,702	21,321	27,499	34,164	38,761	131,447
Technology Exhaustion	10,013	23,266	32,976	39,810	44,589	150,653

Total costs follow a predictable pattern with costs rising to reflect the more expensive technologies that manufacturers must apply in order to achieve the CAFE levels that are required under the more aggressive alternatives, with the exception of the Optimized (3%) for light trucks. For the combined fleet, total compliance costs for the Total Cost = Total Benefit alternative is roughly 2.8 times those for the Optimized (7%) alternative over the 5 model years. Relative to the proposed Optimized (7%) alternative, Technology exhaustion produces costs that are 3.2 times the Optimized cost levels.

Table IX-2a
Present Value of Lifetime Societal Benefits by Alternative
(Millions of 2006 Dollars)
(Discounted 3%)

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
Passenger Cars						
25% Below Optimized	1,418	2,581	3,977	6,399	8,387	22,762
Optimized (7%)	3,181	6,054	7,561	9,716	11,616	38,128
25% Above Optimized	4,604	8,939	10,403	13,109	14,907	51,962
50% Above Optimized	5,241	10,842	12,571	15,503	17,893	62,050
Optimized (3%)	6,798	12,188	13,519	16,833	19,216	68,554
TC = TB	7,075	13,366	14,881	18,059	20,364	73,745
Technology Exhaustion	7,156	13,865	15,967	19,654	22,312	78,954
Light Trucks						
25% Below Optimized	4,414	9,959	15,910	15,715	15,745	61,743
Optimized (7%)	4,919	11,055	17,120	18,866	20,506	72,466
25% Above Optimized	5,286	12,599	17,972	20,984	24,662	81,503
50% Above Optimized	5,848	13,249	18,955	22,375	26,475	86,902
Optimized (3%)	4,939	11,075	17,976	19,902	22,246	76,138
TC = TB	6,343	14,452	20,631	24,704	28,352	94,482
Technology Exhaustion	6,420	14,528	24,517	27,951	31,387	104,803
Passenger Cars and Light Trucks Combined						
25% Below Optimized	5,832	12,540	19,887	22,114	24,132	84,505
Optimized (7%)	8,100	17,109	24,681	28,582	32,122	110,594
25% Above Optimized	9,890	21,538	28,375	34,093	39,569	133,465
50% Above Optimized	11,089	24,091	31,526	37,878	44,368	148,952
Optimized (3%)	11,737	23,263	31,495	36,735	41,462	144,692
TC = TB	13,418	27,818	35,512	42,763	48,716	168,227
Technology Exhaustion	13,576	28,393	40,484	47,605	53,699	183,757

From Table IX-2a, lifetime societal benefits follow a similar predictable pattern, with higher benefits associated with the more expensive technologies that are enabled under the more aggressive alternatives. For the combined fleet, the TC=TB alternative produces gross benefits roughly 1.5 times as high as the Optimized (7%) alternative, and the Technology exhaustion alternative produces gross benefits that are 1.7 times the Optimized (7%) alternative.

Similar results occur for benefits discounted at the 7% rate (Table IX-2b). However, while the pattern for benefits is directionally similar to the pattern for costs, the more aggressive technology scenarios do not increase benefits by as high a ratio as they do for costs. For example, the TC=TB alternative increases total benefits by $46 billion over the Optimized (7%) alternative, but it also increases total costs by $85 billion, a net loss to society of $39 billion. This is a function of the more aggressive alternatives relatively unrestrained functions. While the Optimized (7%) alternative adds technology until the marginal cost to society begins to exceed the marginal benefit, the TC=TB scenario and the Technology exhaustion scenario allow for continued investment in technology despite its negative net return. Thus, while both costs and benefits continue to rise with more aggressive technologies, the costs rapidly begin to exceed the benefits that society derives from the added investment.

Table IX-2b
Present Value of Lifetime Societal Benefits by Alternative
(Millions of 2006 Dollars)
(Discounted 7%)

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
Passenger Car						
25% Below Optimized	1,156	2,104	3,235	5,197	6,799	18,491
Optimized (7%)	2,596	4,933	6,148	7,889	9,420	30,986
25% Above Optimized	3,755	7,280	8,454	10,638	12,083	42,210
50% Above Optimized	4,274	8,825	10,213	12,576	14,495	50,383
Optimized (3%)	5,543	9,922	10,983	13,654	15,569	55,671
TC = TB	5,769	10,878	12,087	14,644	16,492	59,870
Technology Exhaustion	5,834	11,282	12,968	15,930	18,061	64,075
Light Trucks						
25% Below Optimized	3,508	7,910	12,603	12,432	12,441	48,894
Optimized (7%)	3,909	8,779	13,560	14,915	16,192	57,355
25% Above Optimized	4,201	9,990	14,236	16,587	19,457	64,471
50% Above Optimized	4,642	10,507	15,011	17,687	20,892	68,739
Optimized (3%)	3,926	8,794	14,251	15,752	17,589	60,312
TC = TB	5,027	11,453	16,330	19,515	22,367	74,692
Technology Exhaustion	5,088	11,513	19,395	22,074	24,759	82,829
Passenger Cars and Light Trucks Combined						
25% Below Optimized	4,664	10,014	15,838	17,629	19,240	67,385
Optimized (7%)	6,505	13,712	19,708	22,804	25,612	88,341
25% Above Optimized	7,956	17,270	22,690	27,225	31,540	106,681
50% Above Optimized	8,916	19,332	25,224	30,263	35,387	119,122
Optimized (3%)	9,469	18,716	25,234	29,406	33,158	115,983
TC = TB	10,796	22,331	28,417	34,159	38,859	134,562
Technology Exhaustion	10,922	22,795	32,363	38,004	42,820	146,904

Table IX-3a
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
(Millions of 2006 Dollars)*
(Discounted 3%)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
25% Below Optimized	583	1,763	2,724	4,246	5,178	14,494
Optimized (7%)	1,297	3,681	4,682	5,918	6,754	22,332
25% Above Optimized	1,217	3,286	3,958	4,869	5,823	19,154
50% Above Optimized	1,231	2,957	3,585	4,296	4,912	16,980
Optimized (3%)	1,331	3,397	3,698	4,386	4,732	17,543
TC = TB	1,162	2,570	2,578	2,656	2,966	11,933
Technology Exhaustion	1,077	1,270	1,266	895	1,202	5,709
Light Trucks						
25% Below Optimized	3,065	5,663	9,581	9,503	9,419	37,231
Optimized (7%)	3,270	6,069	9,726	10,706	11,745	41,517
25% Above Optimized	3,214	5,565	8,157	9,081	9,881	35,897
50% Above Optimized	2,926	5,151	7,369	7,989	8,506	31,941
Optimized (3%)	3,277	6,101	9,786	10,844	11,993	42,002
TC = TB	2,555	3,927	5,435	5,942	6,988	24,847
Technology Exhaustion	2,487	3,858	6,242	6,900	7,908	27,395
Passenger Cars and Light Trucks Combined						
25% Below Optimized	3,648	7,426	12,305	13,749	14,598	51,725
Optimized (7%)	4,566	9,751	14,408	16,625	18,499	63,849
25% Above Optimized	4,431	8,851	12,114	13,950	15,704	55,051
50% Above Optimized	4,157	8,108	10,954	12,285	13,418	48,922
Optimized (3%)	4,609	9,498	13,484	15,230	16,725	59,545
TC = TB	3,716	6,497	8,013	8,599	9,955	36,780
Technology Exhaustion	3,563	5,127	7,508	7,795	9,110	33,104

The impact of the relatively unrestricted technology application that is enabled by the more aggressive scenarios is apparent from Tables IX-3a and IX-3b, which show net total lifetime societal benefits under each alternative. Across all 5 model years the Optimized (7%) or the Optimized (3%) alternative produces the highest net total benefits to society, as would be expected. Under a 3% discount rate, net benefits produced by the Optimized (7%) alternative exceed those produced by the TC = TB alternative by an extra $27 billion, and exceed those produced under the Technology Exhaustion alternative by $30 billion. Under the 7% discount rate, the Technology exhaustion alternative produces a net <u>loss</u> to society of over $3.7 billion.

Table IX-3b
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
(Millions of 2006 Dollars)
(Discounted 7%)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	Total 5 years
25% Below Optimized	321	1,286	1,982	3,044	3,590	10,223
Optimized (7%)	712	2,560	3,269	4,091	4,558	15,190
25% Above Optimized	368	1,627	2,009	2,398	2,999	9,402
50% Above Optimized	264	940	1,227	1,369	1,514	5,313
Optimized (3%)	76	1,131	1,162	1,207	1,085	4,660
TC = TB	-144	82	-216	-759	-906	-1,942
Technology Exhaustion	-245	-1,313	-1,733	-2,829	-3,049	-9,170
Light Trucks						
25% Below Optimized	2,159	3,614	6,274	6,220	6,115	24,382
Optimized (7%)	2,260	3,793	6,166	6,755	7,431	26,406
25% Above Optimized	2,129	2,956	4,421	4,684	4,676	18,865
50% Above Optimized	1,720	2,409	3,425	3,301	2,923	13,778
Optimized (3%)	2,264	3,820	6,061	6,694	7,336	26,176
TC = TB	1,239	928	1,134	753	1,003	5,057
Technology Exhaustion	1,155	843	1,120	1,023	1,280	5,421
Passenger Cars and Light Trucks Combined						
25% Below Optimized	2,480	4,900	8,256	9,264	9,706	34,605
Optimized (7%)	2,971	6,354	9,435	10,847	11,989	41,596
25% Above Optimized	2,497	4,583	6,429	7,082	7,675	28,267
50% Above Optimized	1,984	3,349	4,652	4,670	4,437	19,092
Optimized (3%)	2,341	4,951	7,223	7,901	8,421	30,836
TC = TB	1,094	1,010	918	-5	98	3,115
Technology Exhaustion	909	-471	-613	-1,806	-1,769	-3,749

Sensitivity Analyses

The agency has performed several sensitivity analyses to examine important assumptions. The analyses include:

1) The value of CO_2. We examined a range from $0 per metric ton to $14 per metric ton, with the main analysis using a value of $7.50 per metric ton. These values can be translated into a value for carbon by multiplying by a factor of 3.66, or can be translated into cents per gallon by multiplying by 0.0089[209], as shown below:

   $7.50 per ton CO_2 = $7.50*3.667 = $27.50 per ton C = $7.50*0.0089 = $0.06675 per gallon
   $14.00 per ton CO_2 = $14.00*3.667 = $51.34 per ton C = $14.00*0.0089 = $0.1246 per gallon

2) The value of externalities. The main analysis uses $0.295 per gallon for externalities. The sensitivity analysis examines $0.120 and $0.504 per gallon.

3) The price of gasoline. The main analysis uses the AEO 2008 reference case estimate for the price of gasoline. The preliminary AEO 2008 estimate does not contain a high price or low price of gasoline case. We assumed for this analysis an estimate of the AEO 2008 high price and low price for gasoline (based on applying the percentage increase between the high price estimate and the reference case estimate in the AEO 2007 forecast to the AEO 2008 reference case estimate).

4) The rebound effect. The main analysis uses a rebound effect of 15 percent. The sensitivity analysis examines rebound effects of 10 percent and 20 percent.

Sensitivity analyses were performed on just the optimized (7%) alternative. Presented are information on the average mpg expected by model year, the price per vehicle increase for MY 2015, total benefits for MY 2015 vehicles, the total cost increase for MY 2015, the total fuel saved (all 5 model years combined) and the total CO_2 emissions reduction (all 5 model years combined).

The results of the sensitivity analyses indicate that the value of CO_2, the value of externalities, and the value of the rebound effect have almost no impact on the level of the standards. Assuming a higher price of gasoline has the largest impact of the sensitivity analyses examined (raising the MY 2015 passenger car standard level by 6.7 mpg and the light truck level by 0.8 mpg). It appears that the light truck levels are not as sensitive as the passenger car levels to changes in the estimated benefits. This can occur because the technologies that have not been used under the Optimized alternative, and are still available for light trucks, are not that close to being cost effective and it takes a larger increase in benefits to bring them over the cost-benefit threshold.

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[209] The molecular weight of Carbon (C) is 12, the molecular weight of Oxygen (O) is 16, thus the molecular weight of CO_2 is 44. One ton of C = 44/12 tons CO_2 = 3.67 tons CO_2. 1 gallon of gas weighs 2,819 grams, of that 2,433 grams are carbon. $1.00 CO_2 = $3.67 C and
$3.67/ton * ton/1000kg * kg/1000g * 2433g/gallon = (3.67 * 2433) / 1000 * 1000 = $0.0089/gallon

Note that there are some slight inconsistencies in the relationships one would expect when comparing the required mpg levels for corresponding model years in the various sensitivity analyses to those under the proposed CAFE standards. For example, the level of the standard should increase when CO_2 is assigned a higher value, because this increases the benefit of each gallon of fuel saved, but the optimized standards for some model years are actually *lower* with the high CO_2 value than under the proposal. Problems such as this arise when making slight changes in parameter values used by the CAFE model, since the model derives a relationship between net benefits and the stringency level of standards for each model year, and minor changes in parameter values can affect the exact shapes and positions of those curves. In any case, the seemingly anomalous results are mostly small (0.1 mpg or less), and are sometimes the result of rounding. When larger variations are made to the model's parameters or other inputs, such as substituting EIA's High gasoline price forecast for the Reference Case forecast, the sensitivity analysis invariable produces the anticipated result.

Table IX-5a
Passenger Car Sensitivity Analyses
(mpg)

Optimized	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Proposal	31.2	32.8	34.0	34.8	35.7
Low CO_2	31.2	32.7	33.8	34.7	35.3
High CO_2	31.2	32.7	33.8	34.6	35.7
Low Externalities	31.2	32.8	33.9	34.7	35.4
High Externalities	31.1	32.7	34.1	34.9	36.0
Low Fuel Price	31.1	32.8	33.8	34.7	35.9
High Fuel Price	37.4	38.9	40.4	41.3	42.4
10% Rebound	31.1	32.7	33.9	34.6	36.0
20% Rebound	31.2	32.8	33.8	34.8	35.7

Optimized	MY 2015 Per Vehicle Cost ($)	MY 2015 Total Benefits ($ Mill.)	MY 2015 Total Cost ($ Mill.)	Total Fuel Saved (Bill. Gal.)	Total CO_2 Emissions Reduced (mmt)
Proposal	649	9,420	4,862	18.736	178
Low CO_2	571	8,583	4,263	18.129	173
High CO_2	633	9,655	4,731	18.351	174
Low Externalities	596	8,340	4,458	18.307	175
High Externalities	715	10,660	5,367	19.276	182
Low Fuel Price	675	8,273	5,014	18.446	171
High Fuel Price	2,081	24,622	15,477	36.686	319
10% Rebound	714	10,343	5,346	19.730	186
20% Rebound	644	8,833	4,811	17.738	169

Table IX-5b
Light Truck Sensitivity Analyses
(mpg)

Optimized	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Proposal	25.0	26.4	27.8	28.2	28.6
Low CO_2	25.0	26.4	27.7	28.2	28.6
High CO_2	25.0	26.4	27.7	28.1	28.6
Low Externalities	25.1	25.4	27.2	27.9	28.2
High Externalities	25.0	26.4	27.8	28.2	28.8
Low Fuel Price	25.1	25.2	26.9	27.6	28.2
High Fuel Price	25.1	26.7	28.1	28.6	29.4
10% Rebound	25.0	26.4	27.7	28.1	28.6
20% Rebound	25.0	26.4	27.8	28.2	28.7

Optimized	MY 2015 Per Vehicle Cost ($)	MY 2015 Total Benefits ($ Mill.)	MY 2015 Total Cost ($ Mill.)	Total Fuel Saved (Bill. Gal.)	Total CO_2 Emissions Reduced (mmt)
Proposal	979	16,192	8,761	35.978	343
Low CO_2	966	15,543	8,646	35.752	340
High CO_2	943	16,587	8,434	35.564	339
Low Externalities	775	13,874	6,927	31.927	304
High Externalities	1,025	18,001	9,172	36.331	346
Low Fuel Price	789	12,887	7,054	30.054	285
High Fuel Price	1,393	27,647	12,468	40.115	376
10% Rebound	943	16,839	8,434	37.262	355
20% Rebound	997	15,603	8,924	34.403	327

Payback Period

The "payback period" represents the length of time required for a vehicle buyer to recoup, through savings in fuel use, the higher cost of purchasing a more fuel-efficient vehicle. Thus, only these two factors are considered (purchase price and fuel savings). When a higher CAFE standard requires a manufacturer to improve the fuel economy of some of its vehicle models, the manufacturer's added costs for doing so are reflected in higher prices for these models. While buyers of these models pay higher prices to purchase these vehicles, their improved fuel economy lowers the consumer's costs for purchasing fuel to operate them. Over time, buyers may recoup the higher purchase prices they pay for these vehicles in the form of savings in outlays for fuel. The length of time required to repay the higher cost of buying a more fuel-efficient vehicle is referred to as the buyer's payback period.

The length of this payback period depends on the initial increase in a vehicle's purchase price, the improvement in its fuel economy, the number of miles it is driven each year, and the retail price of fuel. We calculated payback periods using the fuel economy improvement and average price increase estimated to result from the standard, the future retail gasoline prices, and estimates of the number of miles vehicles are driven each year as they age. These calculations are taken from a consumer's perspective, not a societal perspective. Thus, only gasoline savings are included on the benefits side of the equation. The price of gasoline includes fuel taxes and future savings are not discounted to present value, since consumers generally only consider and respond to what they pay at the pump. The payback periods was estimated for only MY 2015 vehicles and an average of all manufacturers for the different alternatives. The payback periods for MY 2015 are shown in Table IX-10.

Table IX-10
Payback Period for MY 2015 Average Vehicles
(in years)

	Passenger Cars	Light Trucks
25% Below Optimized	4.3	3.9
Optimized (7%)	4.7	4.2
25% Above Optimized	6.7	6.0
50% Above Optimized	8.3	7.0
Optimized (3%)	8.8	4.5
TC = TB	10.4	8.3
Technology Exhaustion	Never	8.3

X. PROBABILISTIC UNCERTAINTY ANALYSIS

OMB Circular A-4 requires formal probabilistic uncertainty analysis of complex rules where there are large, multiple uncertainties whose analysis raises technical challenges or where effects cascade and where the impacts of the rule exceed $1 billion. CAFE meets all of these criteria. This chapter identifies and quantifies the major uncertainties in the preliminary regulatory impact analysis and estimates the probability distribution of the benefits, costs, and net benefits of the compliance options selected for the proposed rule for MY 2011-2015 passenger car and light truck CAFE standards. Throughout the course of the main analysis, input values were selected from a variety of often conflicting sources. Best estimates were selected based on the preponderance of data and analyses available, but there is inevitably a level of uncertainty in these selections. Some of these inputs contributed less to the overall variations of the outcomes, and, thus, are less significant. Some inputs depend on others or are closely related (e.g. oil import externalities), and thus can be combined. With the vast number of uncertainties imbedded in this regulatory analysis, this uncertainty analysis identifies only the major independent uncertainty factors having appreciable variability and impact on the end results and quantifies them by their probability distributions. These newly defined values are then randomly selected and fed back into the model to determine the net benefits using the Monte Carlo statistical simulation technique.[210] The simulation technique induces the probabilistic outcomes accompanied with degrees of probability or plausibility. This facilitates a more informed decision-making process.

The analysis is based on the actual processes used to derive net benefits as described in the previous chapters. Each variable (e.g., cost of technology) in the mathematical model represents an uncertainty factor that would potentially alter the modeling outcomes if its value was changed. We assume that these variables are independent of each other. The confidence intervals around the costs and benefits of technologies reflect independent levels of uncertainty regarding costs and benefits, rather than linked probabilities dependent on higher or lower quality versions of a specific technology. By contrast, there is reason to believe that monopsony costs may be dependent on fuel prices. However, monopsony costs are only one of several oil import externalities, and the range of monopsony costs is quite narrow. The potential for significant error due to an assumption of independence for monopsony costs is thus quite low. Given this, the agency has elected to treat monopsony costs as an independent variable.

The uncertainties of these variables are described by appropriate probability distribution functions based on available data. If data are not sufficient or not available, professional judgments are used to estimate the probability distributions of these uncertainty factors. A complete description of the formulas and methods used in the CAFE model is available in the public docket.[211]

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[210] See, for example, Morgan, MG, Henrion, M, and Small M, "Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis", Cambridge University Press, 1990.

[211] CAFE Compliance and Effects Modeling System Documentation, Volpe Center, U.S. Dept. of Transportation, July 2005, pp. 27-46 and C-22 to C-35. Docket No. NHTSA 21974-2.

After defining and quantifying the major uncertainty factors, the next step is to simulate the model to obtain probabilistic results rather than single-value estimates. In the uncertainty analysis, CAFE levels were kept constant; in other words, we did not change the CAFE standards for each run based on net benefits. The simulation process was run repeatedly for 20,000 trials under each discount rate scenario. Each complete run is a trial. For each trial, the simulation first randomly selects a value for each of the uncertainty factors based on their probability distributions. The selected values are then fit into the models to forecast results. In addition to the simulation results, the program also estimates the degree of certainty (or confidence, credibility). The degree of certainty provides the decision-maker with an additional piece of important information with which to evaluate the forecast results.

Simulation Models and Uncertainty Factors

A Monte Carlo simulation was conducted using the CAFE modeling system that was developed to estimate the impacts of higher CAFE requirements described in previous chapters. The focus of the simulation model was variation around the chosen uncertainty parameters and their resulting impact on the key output parameters, fuel savings, and net benefits. Net benefits measure the difference between (1) the total dollar value that would be saved in fuel and other benefits and (2) the total costs of the rule.

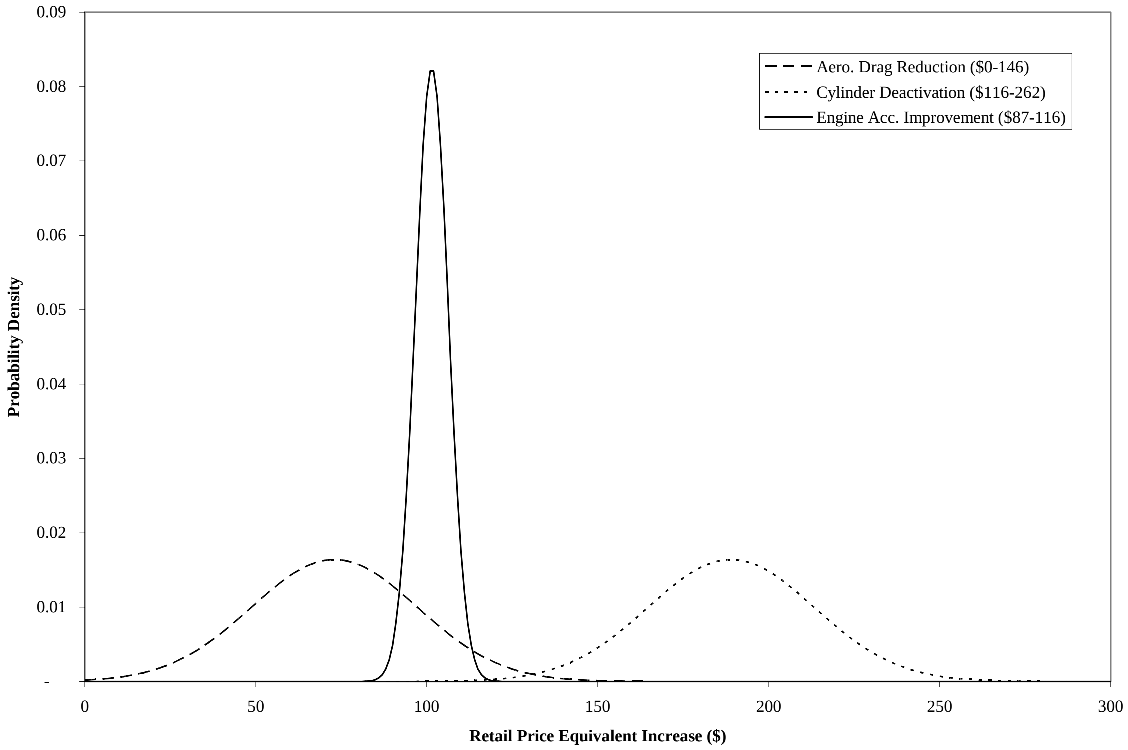
The agency reviewed the inputs and relationships that drive the CAFE model to determine the factors that are the major sources of uncertainty. Five factors were identified as contributing the most uncertainty to the estimated impacts of higher CAFE standards:
(1) Technology costs;
(2) Technology effectiveness;
(3) Fuel prices;
(4) The value of oil consumption externalities; and
(5) The rebound effect.

Technology Costs

The costs incurred by manufacturers to modify their vehicles to meet new CAFE levels are assumed to be passed on to consumers in the form of higher new car prices. These technology costs are the primary determinant of the overall cost of improving fuel economy.

Forty-one different technologies were examined as possible methods to comply with higher CAFE standards. These technologies were summarized in Chapter V earlier in this analysis. Chapter V also summarizes the estimated range of costs for these technologies. The expected values (mid-range values) were used in the main analysis. For the uncertainty analysis, the full range of NAS cost estimates is used. The uncertainty model assumes a normal distribution for these costs, with each end of the range being three standard deviations from the mean (or expected) value. Figure X-1 graphically demonstrates the distributions of a hypothetical sample of three of the technologies.

Figure X-1
Normal Distributions for 3 Different Technologies



Technology Effectiveness

The modifications adopted by manufacturers to enable their vehicles to meet new CAFE levels will improve fuel efficiency and reduce the cost of operating the more efficient vehicles. The effectiveness of each technology determines how large an impact it will have towards enabling manufacturers to meet the higher CAFE standards, and will thus determine how much additional improvement is needed and which additional technologies will be required to achieve full compliance. In selecting the likely path that manufacturers will choose to meet CAFE, the CAFE model tests the interaction of technology costs and effectiveness to achieve an optimal (cost-minimizing) technological solution. Technology effectiveness is thus a primary determinant of the overall cost and benefit of improving fuel economy.

As noted above, forty-one different technologies were examined as possible methods to comply with higher CAFE standards. These technologies were summarized in Chapter V earlier in this analysis. Chapter V also summarizes the estimated range of effectiveness for these technologies. The expected values (mid-range values) were used in the main analysis. For the uncertainty analysis, the full range of effectiveness estimates is used. The uncertainties model assumes a normal distribution for these values, with each end of the range being three standard deviations from the mean (or expected) value.

Fuel Prices

Higher CAFE standards will result in reduced gasoline consumption, which will translate into lower vehicle operating costs for consumers. The value of this reduced fuel consumption is a direct function of fuel prices. Fuel prices are thus a primary determinant of the overall social benefit that will result from improving fuel economy.

The analysis attempts to measure impacts that occur as much as 40 years in the future and estimating gasoline prices this far in advance is an uncertain process. In the main analysis, the agency utilized predicted fuel prices from the Energy Information Administration's (EIA) publication Annual Energy Outlook 2008 (AEO) Revised Early Release. The main analysis is based on the AEO Reference Case scenario, which represents EIA's best estimate of future fuel prices. For the uncertainty analysis, the Agency examined two other AEO scenarios, the Low Oil Price scenario (LOP) and the High Oil Price scenario (HOP). The AEO 2008 Early Release did not contain LOP and HOP estimates. The agency therefore estimated these levels by adjusting the 2008 Reference case proportionately to these cases in the AEO 2007 report. The LOP scenario was chosen to allow for the possibility that the EIA's Reference Case predictions could overestimate the price of gasoline in the future. However, recent escalation in the price of gasoline has resulted in prices that have at times exceeded those estimated by EIA for their reference case. It is unclear whether this just reflects a temporary spike in price levels or whether it is an indication of permanently higher price levels. To reflect the possibility of significantly higher prices, the Agency selected the HOP case, which among the AEO 2008 scenarios comes closest to matching the highest prices seen during the recent gasoline price surge, and which gives the highest gasoline price forecasts among all AEO 2008 scenarios

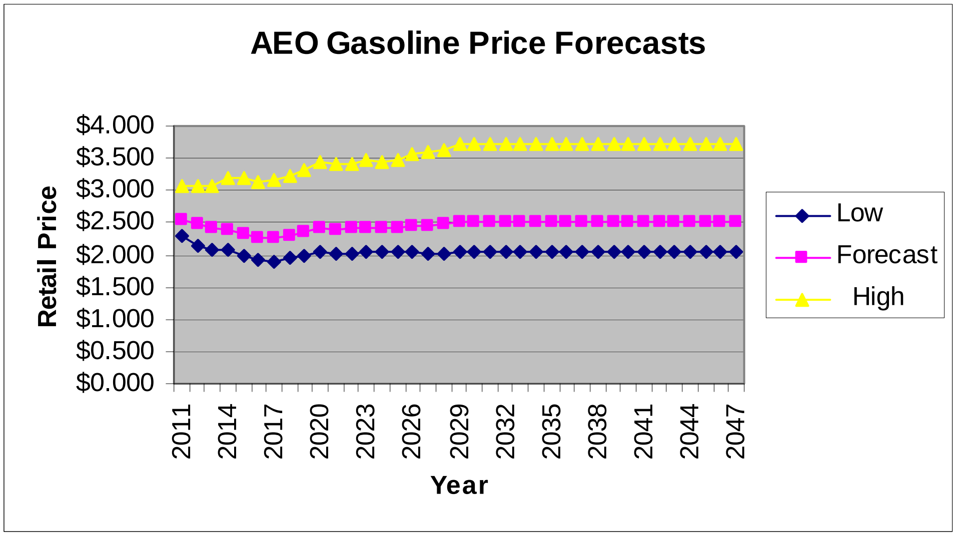
Each of these scenarios was applied as a discrete input (i.e., draws were not made from among the three scenarios separately for each future year). Rather, for each draw, one of the three scenarios was chosen and applied across the full vehicle life for each model year. The probability of selection for each of the three scenarios was modeled using discrete weights of 50 percent for the Reference Case, and 25 percent for both the LOP and HOP cases. Table X-1 lists the AEO gasoline price forecasts under each scenario. These same prices are demonstrated graphically (in 2006 economics) in Figure X-2. Note that these prices include Federal, State, and local fuel taxes. For the uncertainty analysis, taxes were removed because they are viewed as transfer payments (see discussion in Chapter VIII). Estimated retail prices are shown here because they are a better reference point for most readers.

Table X-1

AEO 2008 Gasoline Price Scenarios

	Low	Forecast	High
2011	$2.302	$2.553	$3.056
2012	$2.151	$2.477	$3.068
2013	$2.069	$2.405	$3.082
2014	$2.076	$2.389	$3.189
2015	$1.986	$2.316	$3.194
2016	$1.931	$2.255	$3.139
2017	$1.892	$2.267	$3.162
2018	$1.940	$2.293	$3.237
2019	$1.991	$2.362	$3.320
2020	$2.047	$2.420	$3.430
2021	$2.027	$2.386	$3.410
2022	$2.021	$2.406	$3.418
2023	$2.057	$2.414	$3.467
2024	$2.039	$2.409	$3.452
2025	$2.040	$2.425	$3.486
2026	$2.057	$2.438	$3.577
2027	$2.031	$2.451	$3.609
2028	$2.029	$2.474	$3.641
2029	$2.040	$2.498	$3.712
2030	$2.052	$2.514	$3.736
2031	$2.052	$2.514	$3.736
2032	$2.052	$2.514	$3.736
2033	$2.052	$2.514	$3.736
2034	$2.052	$2.514	$3.736
2035	$2.052	$2.514	$3.736
2036	$2.052	$2.514	$3.736
2037	$2.052	$2.514	$3.736
2038	$2.052	$2.514	$3.736
2039	$2.052	$2.514	$3.736
2040	$2.052	$2.514	$3.736
2041	$2.052	$2.514	$3.736
2042	$2.052	$2.514	$3.736
2043	$2.052	$2.514	$3.736
2044	$2.052	$2.514	$3.736
2045	$2.052	$2.514	$3.736
2046	$2.052	$2.514	$3.736
2047	$2.052	$2.514	$3.736

Figure X-2



Oil Consumption Externalities

Reduced fuel consumption can benefit society by lowering the world market price for oil, reducing the threat of petroleum supply disruptions, and reducing the cost of maintaining military security in oil producing regions and operating the strategic petroleum reserve. These benefits are called "externalities" because they are not reflected directly in the market price of fuel. A full description of these externalities is included in Chapter VIII under "Other Economic Benefits from Reducing Petroleum Use." These factors increase the net social benefits from reduced fuel consumption. Although they represent a relatively small portion of overall social benefits, there is a significant level of uncertainty as to their values. For this reason, they were examined in the uncertainty analysis.

Table X-3 lists the range of values that were examined for oil consumption externalities. The expected values were used in the main analysis. Both the value of reducing U.S. demand on the world market price for oil and the value of reduced threat of supply disruptions were derived from a study by Leiby (2008) (see Chapter VIII). For reasons noted in Chapter VIII, military security is not specifically valued in this analysis. A normal distribution was assumed for the range of values for oil consumption externalities with the low and high values assumed to be two standard deviations from the mean, based on the Leiby estimates.

Table X-3
Uncertainty Ranges for Oil Consumption Externalities ($/gallon)

	Low	Expected	High
For reducing U.S. demand on world market price	$0.028	$0.182	$0.336
For reducing the threat of supply disruptions	$0.035	$0.113	$0.191

The Rebound Effect

By reducing the amount of gasoline used and, thus, the cost of operating a vehicle, higher CAFE standards are expected to result in a slight increase in annual miles driven per vehicle. This “rebound effect” impacts net societal benefits because the increase in miles driven offsets a portion of the gasoline savings that results from more fuel-efficient vehicles. Although consumers derive some value from this extra driving, it also leads to increases in crash, congestion, noise, and pollution costs associated with driving. Most recent estimates of the magnitude of the rebound effect for light duty vehicles fall in the range of 10-20 percent (i.e., increasing vehicle use will offset 10-20 percent of the fuel savings resulting from an improvement in fuel economy). A more complete discussion of the rebound effect is included in Chapter VIII. The agency employed a rebound effect of 15 percent in the main analysis. For the uncertainty analysis, a range of 10 to 20 percent is used and employed in a skewed Beta distribution which produced a mean of approximately 14 percent. The skewed distribution reflects the agency’s belief that the more credible studies that differ from the 15 percent value chosen for the main analysis fall below this value and differ by more substantial margins than the upper range of credible values. Table X-3 Summarizes the economic parameters used in the uncertainty analysis.

Table X-3

Monte-Carlo Specific Parameters

Alternative Discount Rates (%)	0.03
Rebound Randomization Parameters	
Rebound Alpha Shape	6.0
Rebound Beta Shape	2.7
Rebound Scale	-0.20
Rebound Base	-0.05
Monopsony Randomization Parameters	
Monopsony Mean	$0.182
Monopsony Standard Deviation	$0.077
Price Shock Randomization Parameters	
Price Shock Mean	$0.113
Price Shock Standard Deviation	$0.039
Military Security Randomization Parameters	
Military Security Mean	$0.000
Military Security Standard Deviation	$0.000
Total Economic Costs of Petroleum Randomization Parameters (Specified in $/gallon)	
Total Economic Costs Alpha Shape	4
Total Economic Costs Beta Shape	2.4118
Total Economic Costs Scale	0.46
Total Economic Costs Base	0.05
Carbon Dioxide Randomization Parameters	
CO-2 Mean	$7.00
CO-2 Standard Deviation	$3.25
Default Cost and FC Variations	
Cost Variation %	0.37
FC Variation %	0.31

Modeling Results – Trial Draws

Because of the complexity of the CAFE model, the computer time required to perform the uncertainty analysis was significant. The uncertainty analysis conducted a total of 40,000 trials (20,000 for each discount rate) Figures X- 3 through X-14 graphically illustrate the draw results for a sample of the 85 variables (41 technology effectiveness rates, 41 technology costs, the fuel price scenario, oil import externalities, the rebound effect, and CO2.) that were examined. Tables X-3 through X-7 list the draw results for each economic input, technology cost, and technology effectiveness.

Figure X-3
Monte Carlo Draw Profile, Passenger Car Costs

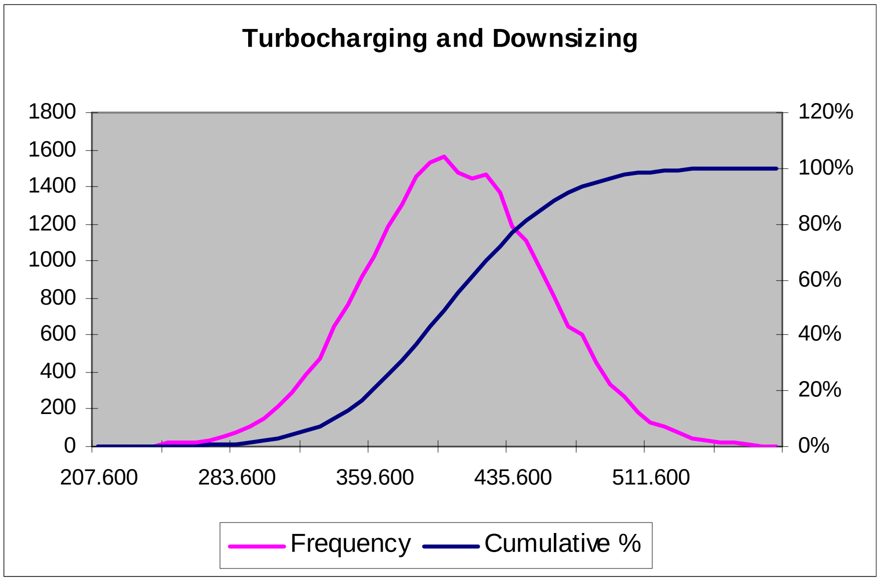


Figure X-4
Monte Carlo Draw Profile, Passenger Car Effectiveness

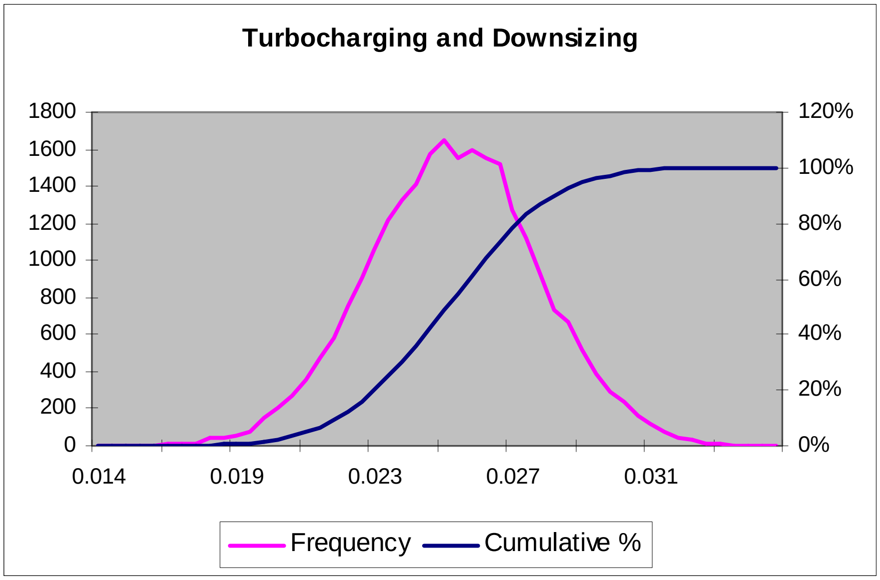


Figure X-5
Monte Carlo Draw Profile, Passenger Cars, Costs

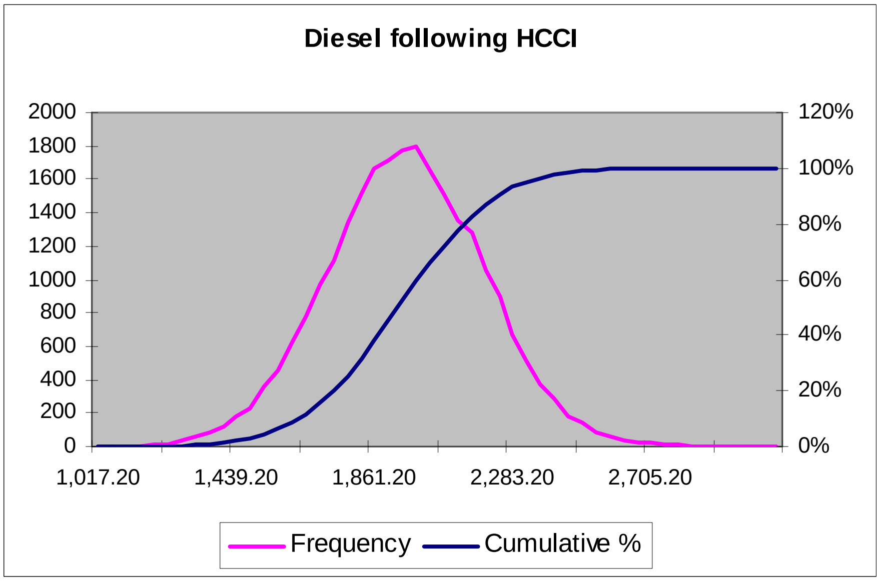


Figure X-6
Monte Carlo Draw Profile, Passenger Cars, Effectiveness

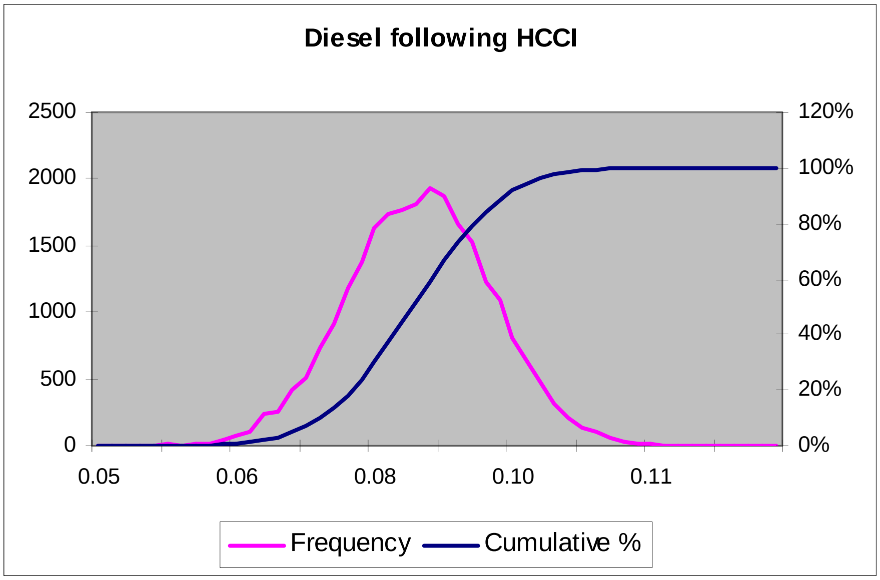


Figure X-7
Monte Carlo Draw Profile, Passenger Cars, Costs

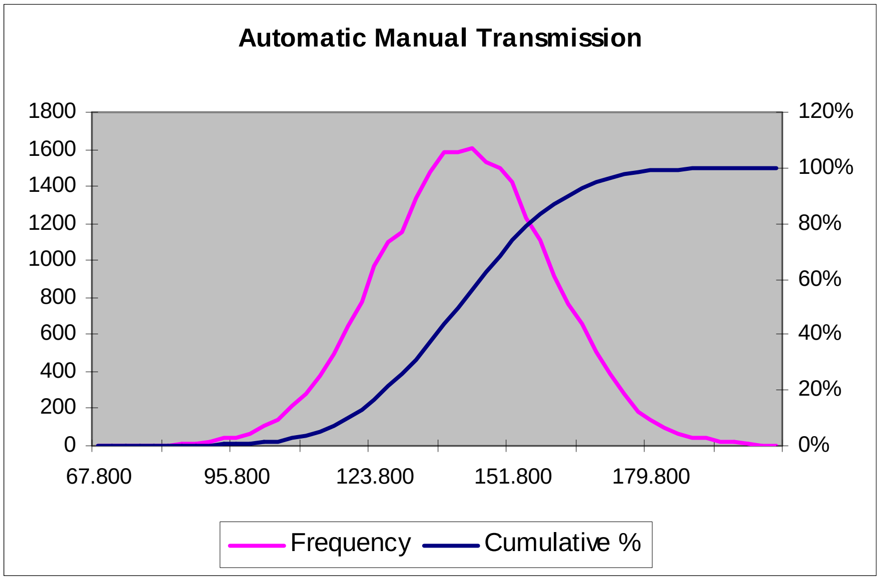


Figure X-8
Monte Carlo Draw Profile, Passenger Cars, Effectiveness

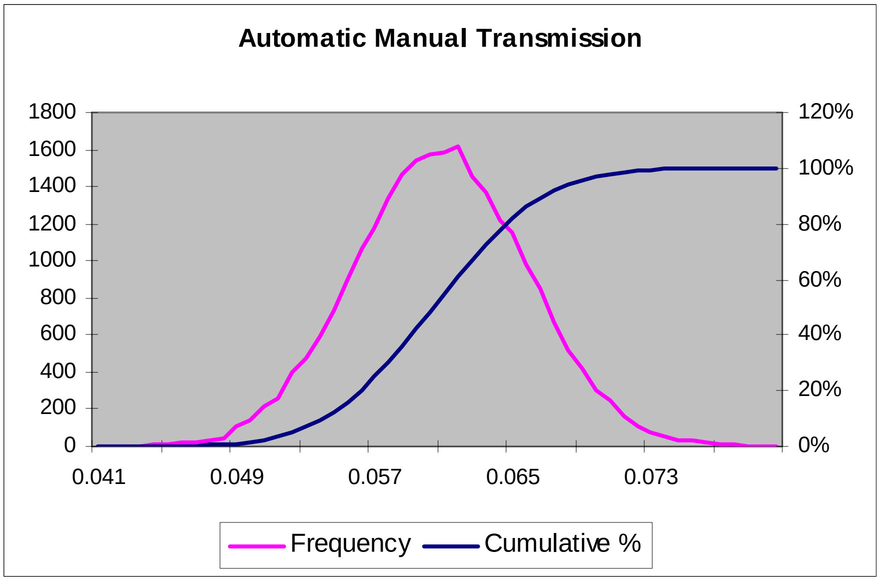


Figure X-9
Monte Carlo Draw Profile
Pretax Fuel Price Path

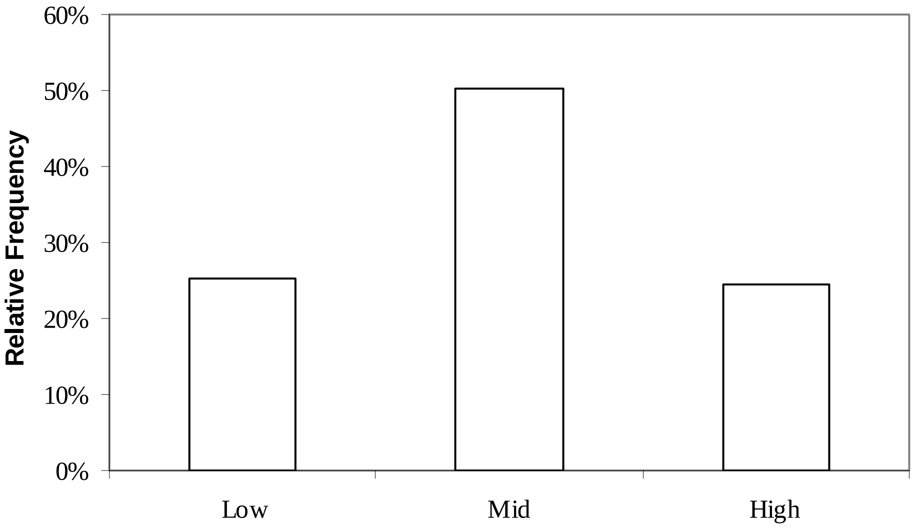


Figure X-10
Monte Carlo Draw Profile

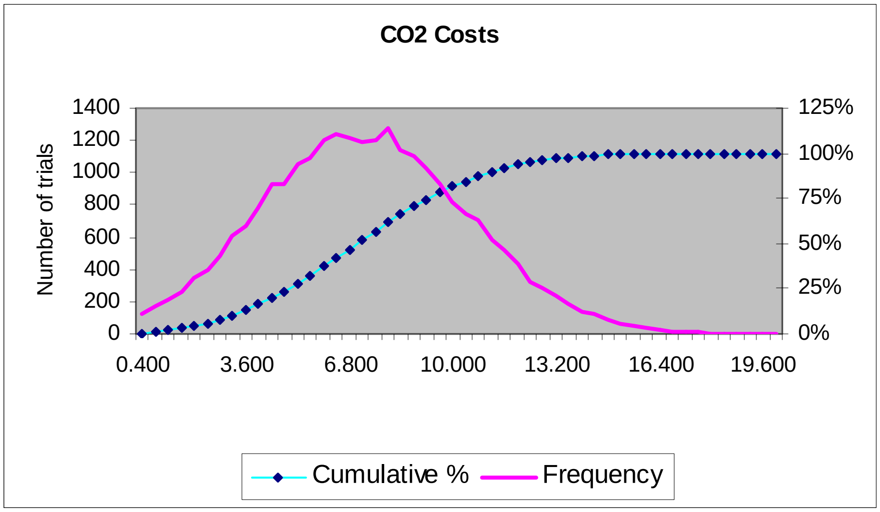


Figure X-11
Monte Carlo Draw Profile

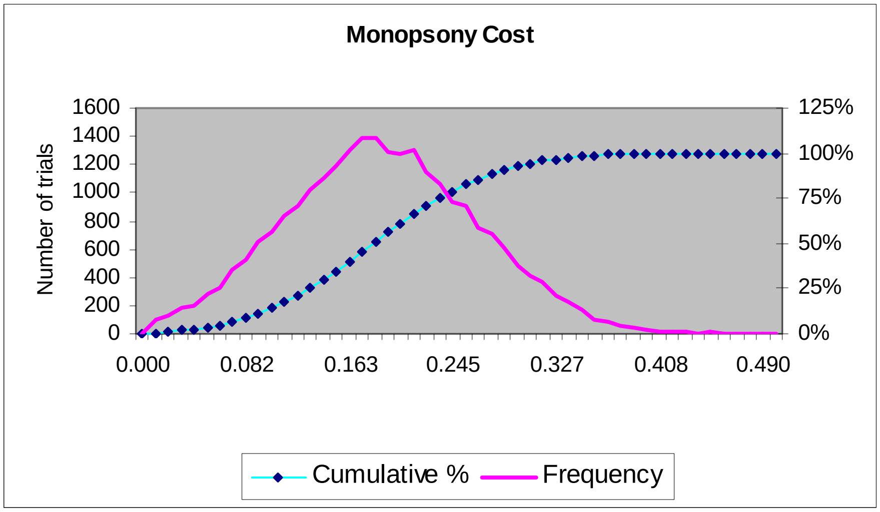


Figure X-12
Monte Carlo Draw Profile

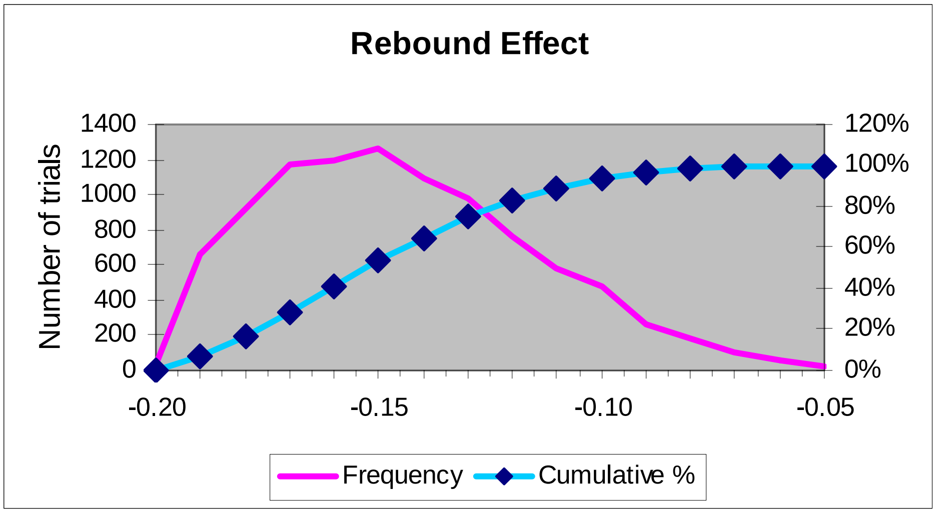


Figure X-13
Monte Carlo Draw Profile

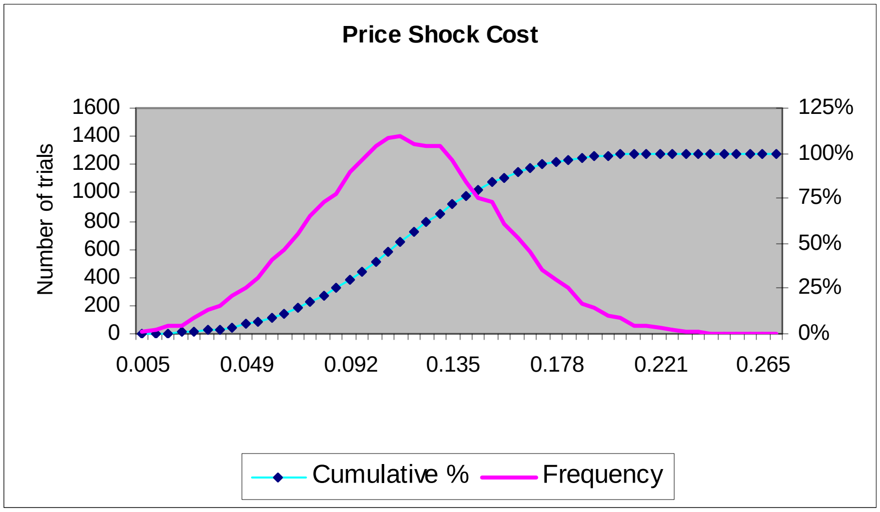


Figure X-14
Monte Carlo Draw Profile

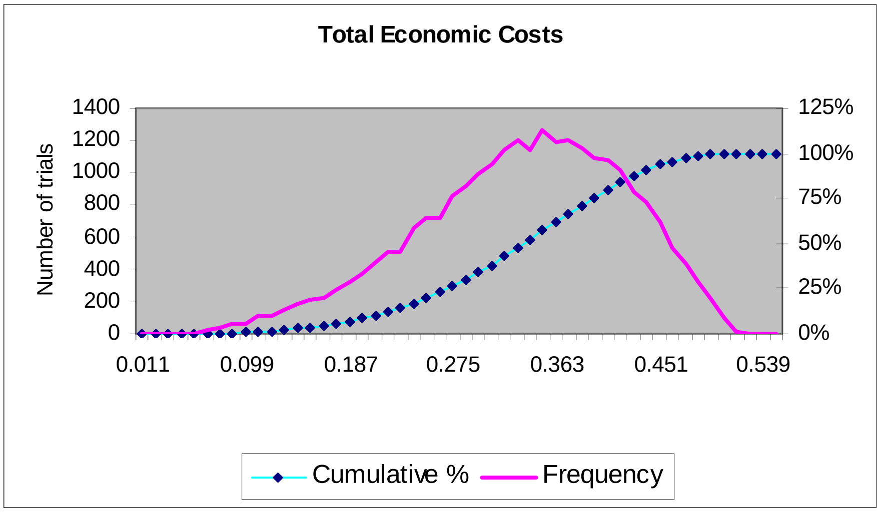


Table X-3
Monte Carlo Draw Results, Economic Inputs

Economic Inputs	**Minimum**	**Maximum**	**Mean**	**StdDev**
Rebound Effect	-0.200	-0.050	-0.139	0.031
Monopsony Cost	2.08E-05	0.4758454	0.184348	0.075127
Price Cost Shock	0.000587	0.2694044	0.112852	0.038933
Total Economic Costs	0.051902	0.508969	0.328306	0.087728
CO2 Costs	0.003939	19.552248	7.150228	3.110129

Table X-4
Monte Carlo Draw Results, Passenger Car Technology Costs

Passenger Car Technology Costs	Minimum	Maximum	Mean	StdDev
Low Friction Lubricants	$1.49	$4.74	$3.00	$0.37
Engine Friction Reduction	$0.33	$119.10	$52.78	$17.42
Variable Valve Timing (ICP)	$46.16	$142.36	$89.60	$11.00
Variable Valve Timing (CCP)	$0.00	$0.00	$0.00	$0.00
Variable Valve Timing (DCP)	$29.90	$93.84	$60.68	$7.50
Cylinder Deactivation	$53.49	$165.05	$103.36	$12.82
Variable Valve Lift & Timing (CVVL)	$180.04	$553.92	$361.94	$44.52
Variable Valve Lift & Timing (DVVL)	$103.16	$327.22	$208.04	$25.65
Cylinder Deactivation on OHV	$54.85	$152.41	$103.52	$12.78
Variable Valve Timing (CCP) on OHV	$29.20	$94.35	$59.33	$7.33
Multivalve Overhead Cam with CVVL	$469.56	$1,444.80	$936.29	$114.36
Variable Valve Lift & Timing (DVVL) on OHV	$103.30	$307.42	$208.46	$25.57
Camless Valve Actuation	$0.00	$0.00	$0.00	$0.00
Stoichiometric GDI	$123.72	$536.56	$318.20	$48.03
Diesel following GDI-S (SIDI)	$1,235.43	$3,339.62	$2,219.62	$275.52
Lean Burn GDI	$0.00	$0.00	$0.00	$0.00
Turbocharging and Downsizing	$204.72	$577.86	$399.36	$49.36
Diesel following Turbo D/S	$946.96	$2,877.83	$1,822.07	$224.84
HCCI	$145.97	$440.72	$289.76	$35.85
Diesel following HCCI	$991.05	$3,075.29	$1,932.76	$238.19
5 Speed Automatic Transmission	$59.29	$180.41	$121.75	$15.09
Aggressive Shift Logic	$18.76	$55.53	$38.05	$4.68
Early Torque Converter Lockup	$15.13	$47.27	$30.01	$3.68
6 Speed Automatic Transmission	$0.00	$0.00	$0.00	$0.00
Continuously Variable Transmission	$65.89	$187.47	$120.00	$14.91
6 Speed Manual	$54.50	$168.33	$106.43	$13.08
Improved Accessories	$116.76	$174.09	$145.25	$6.90
Electronic Power Steering	$103.77	$214.40	$157.73	$13.06
42-Volt Electrical System	$184.50	$267.97	$226.75	$10.75
Low Rolling Resistance Tires	$3.25	$8.69	$6.00	$0.74
Low Drag Brakes	$0.00	$0.00	$0.00	$0.00
Secondary Axle Disconnect - Unibody	$633.60	$721.41	$675.69	$11.88
Secondary Axle Disconnect - Ladder Frame	$0.00	$0.00	$0.00	$0.00
Aero Drag Reduction	$0.19	$84.64	$37.59	$12.40
Material Substitution (1%)	$0.00	$0.00	$0.00	$0.00
Material Substitution (2%)	$0.00	$0.00	$0.00	$0.00
Material Substitution (5%)	$0.00	$0.00	$0.00	$0.00
ISG with Idle-Off	$299.07	$858.05	$581.96	$71.76
IMA/ISAD/BSG Hybrid (includes engine downsizing	$967.35	$3,068.39	$1,958.43	$242.67
2-Mode Hybrid	$391.09	$1,163.87	$764.67	$94.39
Power Split Hybrid	$309.05	$960.34	$627.41	$76.93

Table X-5
Monte Carlo Draw Results, Passenger Car Fuel Economy Improvement Rates

Passenger Car Fuel Economy Improvement Rates	Minimum	Maximum	Mean	StdDev
Low Friction Lubricants	0.002908	0.0073035	0.004997	0.000518
Engine Friction Reduction	0.004595	0.0329195	0.01996	0.003341
Variable Valve Timing (ICP)	0.009356	0.0206904	0.014895	0.001545
Variable Valve Timing (CCP)	0.011859	0.0281932	0.020186	0.002083
Variable Valve Timing (DCP)	0.011895	0.0280668	0.02018	0.002085
Cylinder Deactivation	0.013563	0.0348619	0.022915	0.00237
Variable Valve Lift & Timing (CVVL)	0.023194	0.0522346	0.037476	0.003869
Variable Valve Lift & Timing (DVVL)	0.013216	0.0318864	0.022365	0.002324
Cylinder Deactivation on OHV	0.018306	0.044046	0.030546	0.003144
Variable Valve Timing (CCP) on OHV	0.017041	0.0407676	0.027473	0.00283
Multivalve Overhead Cam with CVVL	0.017591	0.0444581	0.030094	0.003111
Variable Valve Lift & Timing (DVVL) on OHV	0.008878	0.0223505	0.014976	0.001546
Camless Valve Actuation	0	0	0	0
Stoichiometric GDI	0.007243	0.0217997	0.014994	0.001682
Diesel following GDI-S (SIDI)	0.094756	0.2441063	0.160479	0.01659
Lean Burn GDI	0.023047	0.0549808	0.037155	0.003851
Turbocharging and Downsizing	0.014385	0.0345359	0.024998	0.002575
Diesel following Turbo D/S	0.078206	0.1893723	0.135461	0.013972
HCCI	0.044389	0.1117523	0.075102	0.007783
Diesel following HCCI	0.049223	0.1261183	0.085368	0.008877
5 Speed Automatic Transmission	0.015092	0.0344635	0.024962	0.002575
Aggressive Shift Logic	0.007926	0.0215958	0.015003	0.001683
Early Torque Converter Lockup	0.002939	0.0074048	0.004999	0.000518
6 Speed Automatic Transmission	0.000918	0.0281055	0.01499	0.003332
Continuously Variable Transmission	0.020615	0.0505527	0.034988	0.003622
6 Speed Manual	0.002992	0.0069901	0.005	0.000518
Improved Accessories	0.007504	0.0212326	0.015009	0.001664
Electronic Power Steering	0.015584	0.0168713	0.016271	0.000147
42-Volt Electrical System	0.008567	0.0217223	0.014992	0.001662
Low Rolling Resistance Tires	0.008928	0.0218487	0.014998	0.001664
Low Drag Brakes	0	0	0	0
Secondary Axle Disconnect - Unibody	0.005908	0.0144799	0.009997	0.001032
Secondary Axle Disconnect - Ladder Frame	0	0	0	0
Aero Drag Reduction	0.017873	0.041923	0.029955	0.003111
Material Substitution (1%)	0.005713	0.0071391	0.006498	0.000168
Material Substitution (2%)	0.00586	0.0071669	0.0065	0.000167
Material Substitution (5%)	0.016592	0.0214113	0.019248	0.000582
ISG with Idle-Off	0.044364	0.1094447	0.075005	0.0078
IMA/ISAD/BSG Hybrid (includes engine downsizing)	0.03486	0.083258	0.059502	0.006136
2-Mode Hybrid	0.010524	0.0267755	0.017813	0.001832
Power Split Hybrid	0.03312	0.0822965	0.057607	0.00598

Table X-6
Monte Carlo Draw Results, Light Truck Technology Costs

Light Truck Technology Costs	Minimum	Maximum	Mean	StdDev
Low Friction Lubricants	$1.49	$4.74	$3.00	$0.37
Engine Friction Reduction	$0.42	$155.39	$68.86	$22.73
Variable Valve Timing (ICP)	$61.18	$188.69	$118.76	$14.58
Variable Valve Timing (CCP)	$0.00	$0.00	$0.00	$0.00
Variable Valve Timing (DCP)	$44.25	$138.87	$89.81	$11.10
Cylinder Deactivation	$108.70	$335.40	$210.04	$26.04
Variable Valve Lift & Timing (CVVL)	$237.53	$730.81	$477.52	$58.74
Variable Valve Lift & Timing (DVVL)	$132.02	$418.79	$266.26	$32.82
Cylinder Deactivation on OHV	$111.47	$309.70	$210.37	$25.96
Variable Valve Timing (CCP) on OHV	$29.20	$94.35	$59.33	$7.33
Multivalve Overhead Cam with CVVL	$648.92	$1,996.67	$1,293.93	$158.04
Variable Valve Lift & Timing (DVVL) on OHV	$132.21	$393.45	$266.80	$32.73
Camless Valve Actuation	$0.00	$0.00	$0.00	$0.00
Stoichiometric GDI	$142.88	$619.65	$367.48	$55.47
Diesel following GDI-S (SIDI)	$1,470.51	$3,975.08	$2,641.97	$327.94
Lean Burn GDI	$0.00	$0.00	$0.00	$0.00
Turbocharging and Downsizing	$157.93	$445.79	$308.09	$38.08
Diesel following Turbo D/S	$1,214.16	$3,689.84	$2,336.19	$288.28
HCCI	$209.73	$633.21	$416.31	$51.51
Diesel following HCCI	$1,143.01	$3,546.83	$2,229.12	$274.71
5 Speed Automatic Transmission	$59.29	$180.41	$121.75	$15.09
Aggressive Shift Logic	$18.76	$55.53	$38.05	$4.68
Early Torque Converter Lockup	$15.13	$47.27	$30.01	$3.68
6 Speed Automatic Transmission	$0.00	$0.00	$0.00	$0.00
Continuously Variable Transmission	$8.78	$24.99	$16.00	$1.99
6 Speed Manual	$54.50	$168.33	$106.43	$13.08
Improved Accessories	$116.76	$174.09	$145.25	$6.90
Electronic Power Steering	$103.77	$214.40	$157.73	$13.06
42-Volt Electrical System	$184.50	$267.97	$226.75	$10.75
Low Rolling Resistance Tires	$2.36	$6.31	$4.36	$0.54
Low Drag Brakes	$38.97	$122.58	$77.27	$9.63
Secondary Axle Disconnect - Unibody	$580.10	$660.49	$618.63	$10.87
Secondary Axle Disconnect - Ladder Frame	$55.77	$159.17	$100.75	$12.41
Aero Drag Reduction	$0.19	$84.64	$37.59	$12.40
Material Substitution (1%)	$0.26	$0.73	$0.50	$0.06
Material Substitution (2%)	$0.37	$0.98	$0.67	$0.08
Material Substitution (5%)	$0.46	$1.23	$0.83	$0.10
ISG with Idle-Off	$308.54	$885.22	$600.39	$74.03
IMA/ISAD/BSG Hybrid (includes engine downsizing	$0.00	$0.00	$0.00	$0.00
2-Mode Hybrid	$2,121.66	$6,314.06	$4,148.37	$512.05
Power Split Hybrid	$0.00	$0.00	$0.00	$0.00

Table X-7
Monte Carlo Draw Results, Light Truck Fuel Economy Improvement Rates

Light Truck Technology Improvement Rates	**Minimum**	**Maximum**	**Mean**	**StdDev**
Low Friction Lubricants	0.002908	0.007303	0.004997	0.000518
Engine Friction Reduction	0.004595	0.03292	0.01996	0.003341
Variable Valve Timing (ICP)	0.007989	0.017667	0.012718	0.001319
Variable Valve Timing (CCP)	0.008747	0.020794	0.014888	0.001536
Variable Valve Timing (DCP)	0.007505	0.01771	0.012733	0.001315
Cylinder Deactivation	0.02665	0.068502	0.045026	0.004656
Variable Valve Lift & Timing (CVVL)	0.012312	0.027728	0.019894	0.002054
Variable Valve Lift & Timing (DVVL)	0.00584	0.014089	0.009882	0.001027
Cylinder Deactivation on OHV	0.03597	0.086549	0.060021	0.006178
Variable Valve Timing (CCP) on OHV	0.00783	0.018731	0.012623	0.001301
Multivalve Overhead Cam with CVVL	0.011624	0.029378	0.019886	0.002056
Variable Valve Lift & Timing (DVVL) on OHV	0.005849	0.014726	0.009867	0.001019
Camless Valve Actuation	0	0	0	0
Stoichiometric GDI	0.007243	0.0218	0.014994	0.001682
Diesel following GDI-S (SIDI)	0.106364	0.274009	0.180138	0.018622
Lean Burn GDI	0	0	0	0
Turbocharging and Downsizing	0.014385	0.034536	0.024998	0.002575
Diesel following Turbo D/S	0.089555	0.216855	0.155119	0.015999
HCCI	0.044389	0.111752	0.075102	0.007783
Diesel following HCCI	0.06055	0.155142	0.105014	0.01092
5 Speed Automatic Transmission	0.015092	0.034464	0.024962	0.002575
Aggressive Shift Logic	0.007926	0.021596	0.015003	0.001683
Early Torque Converter Lockup	0.002939	0.007405	0.004999	0.000518
6 Speed Automatic Transmission	0.000918	0.028105	0.01499	0.003332
Continuously Variable Transmission	0.010549	0.025869	0.017904	0.001853
6 Speed Manual	0.002992	0.00699	0.005	0.000518
Improved Accessories	0.007504	0.021233	0.015009	0.001664
Electronic Power Steering	0.019155	0.020736	0.019999	0.000181
42-Volt Electrical System	0.008567	0.021722	0.014992	0.001662
Low Rolling Resistance Tires	0.006489	0.015879	0.010901	0.00121
Low Drag Brakes	0.002886	0.00734	0.004883	0.000504
Secondary Axle Disconnect - Unibody	0.004294	0.010524	0.007266	0.00075
Secondary Axle Disconnect - Ladder Frame	0.004331	0.010856	0.007326	0.000759
Aero Drag Reduction	0.014964	0.0351	0.02508	0.002605
Material Substitution (1%)	0.005713	0.007139	0.006498	0.000168
Material Substitution (2%)	0.00586	0.007167	0.0065	0.000167
Material Substitution (5%)	0.016592	0.021411	0.019248	0.000582
ISG with Idle-Off	0.044364	0.109445	0.075005	0.0078
IMA/ISAD/BSG Hybrid (includes engine downsizing)	0	0	0	0
2-Mode Hybrid	0.035708	0.090851	0.06044	0.006215
Power Split Hybrid	0.027148	0.067457	0.047219	0.004901

Modeling Results – Output

Tables X-8 and X-9 summarize the modeling results for fuel saved, total costs, societal benefits, and net benefits for passenger cars and trucks respectively under a 7% discount rate. They also indicate the probability that net benefits exceed zero. Tables X-10 and X-11 summarize these same results under a 3% discount rate. These results are also illustrated in Figures X-15 through X-18 for passenger cars under Optimized CAFE at 7 percent for MY 2015. Although not shown here, the general shape of the resulting output distributions are similar for the light trucks, the 3 percent discount rate, and for other model years as well. The humped shape that occurs for both social benefits and net benefits reflects the three different gasoline price scenarios. About half of all draws were selected from the AEO Reference Case, while about one quarter were drawn from the Low Oil Price scenario and one quarter were drawn from the High Oil Price scenario. This produces three separate humps which reflect the increasing impact on benefits from the three progressively higher oil price scenarios. The Low Oil scenario is close enough to the Forecast scenario that the 2 humps visually begin to merge. However, the difference between the High Oil Price scenario and the Forecast is typically more than double the difference between the Forecast and the Low Oil price scenario, which results in a separate distribution further up the x axis. The following discussions summarize the range of results presented in these tables for the combined passenger car and light truck across both the 7 percent (typically the lower range) and 3 percent (typically upper range) discount rates[212].

Fuel Savings: The analysis indicates that MY 2011 vehicles (both passenger cars and light trucks) will experience between 3,370 million and 4,735 million gallons of fuel savings over their useful lifespan. MY 2012 vehicles will experience between 7,476 million and 9,639 million gallons of fuel savings over their useful lifespan. MY 2013 vehicles will experience between 10,863 million and 13,763 million gallons of fuel savings over their useful lifespan. MY 2014 vehicles will experience between 12,568 and 15,664 million gallons of fuel savings over their useful lifespan. MY 2015 vehicles will experience between 14,188 and 17,659 million gallons of fuel savings over their useful lifespan. Over the combined lifespan of the five model years, between 48.5 billion and 61.4 billion gallons of fuel will be saved.

Total Costs: The analysis indicates that owners of MY 2011 passenger cars and light trucks will pay between \$2,447 million and \$5,256 million in higher vehicle prices to purchase vehicles with improved fuel efficiency. MY 2012 owners will pay between \$5,817 million and \$10,427 million more. MY 2013 owners will pay between \$7,942 million and \$15,288 million more. MY 2014 owners will pay between \$9,338 million and \$17,189 million more. MY 2015 owners will pay between \$10,940 million and \$19,842 million more. Owners of all five model years vehicles combined will pay between \$36.5 billion and \$67.9 billion in higher vehicle prices to purchase vehicles with improved fuel efficiency.

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[212] In a few cases the upper range results were obtained from the 7% rate and the lower range results were obtained from the 3% rate. While this may seem counterintuitive, it results from the random selection process that is inherent in the Monte Carlo technique.

Societal Benefits: The analysis indicates that changes to MY 2011 passenger cars and light trucks to meet the proposed CAFE standards will produce overall societal benefits valued between $4,375 million and $13,041 million. MY 2012 vehicles will produce benefits valued between $9,363 million and $28,214 million. MY 2013 vehicles will produce benefits valued between $13,370 million and $41,027 million. MY 2014 vehicles will produce benefits valued between $15,586 million and $47,087 million. MY 2015 vehicles will produce benefits valued between $17,486 million and $53,708 million. Over the combined lifespan of the five model years, societal benefits valued between $60.1 billion and $183.1 billion will be produced.

Net Benefits: The uncertainty analysis indicates that the net impact of the higher CAFE requirements for MY 2011 passenger cars and light trucks will be a net benefit of between $937 million and $9,678 million. There is at least a 99.3 percent certainty that changes made to MY 2011 vehicles to achieve the higher CAFE standards will produce a net benefit. The net impact of the higher CAFE requirements for MY 2012 will be a net benefit of between $283 million and a net benefit of $21,139 million. There is at least a 99.6 percent certainty that changes made to MY 2012 vehicles to achieve the CAFE standards will produce a net benefit. The net impact of the higher CAFE requirements for MY 2013 will be a net benefit of between $494 million and a net benefit of $31,311 million. There is at least a 99.6 percent certainty that changes made to MY 2013 vehicles to achieve the higher CAFE standards will produce a net benefit. The net impact of the higher CAFE requirements for MY 2014 will be a net benefit of between $711 million and $35,746 million. There is 100 percent certainty that changes made to MY 2014 vehicles to achieve the CAFE standards will produce a net benefit. The net impact of the higher CAFE requirements for MY 2015 will be a net benefit of between $654 million and $40,703 million. There is 100 percent certainty that changes made to MY 2015 vehicles to achieve the CAFE standards will produce a net benefit. Over all five model years, the higher CAFE standards will produce net benefits ranging from $3.1 billion to $138.6 billion. There is at least a 99.3 percent certainty that higher CAFE standards will produce a net societal benefit in each of the model years covered by this final rule. In most years, this probability is 100%.

Table X-8
Uncertainty Analysis Results, Passenger Cars
(7% Discount Rate)

MY 2011	Mean	Low	High
Fuel Saved (mill. gall.)	1487	1285	1813
Total Cost ($mill.)	1760	1291	2302
Societal Benefits ($mill.)	2605	1723	4201
Net Benefits ($mill.)	845	435	2574
% Certainty Net Ben. > 0	99.3%		
MY 2012			
Fuel Saved (mill. gall.)	2870	2618	3403
Total Cost ($mill.)	2271	1676	3237
Societal Benefits ($mill.)	5023	3296	8127
Net Benefits ($mill.)	2753	404	6009
% Certainty Net Ben. > 0	100%		
MY 2013			
Fuel Saved (mill. gall.)	3585	3237	4283
Total Cost ($mill.)	2769	2021	3970
Societal Benefits ($mill.)	6280	4071	10388
Net Benefits ($mill.)	3511	493	7666
% Certainty Net Ben. > 0	100%		
MY 2014			
Fuel Saved (mill. gall.)	4613	4200	5372
Total Cost ($mill.)	3707	2793	5109
Societal Benefits ($mill.)	8113	5262	12996
Net Benefits ($mill.)	4407	589	9669
% Certainty Net Ben. > 0	100%		
MY 2015			
Fuel Saved (mill. gall.)	5513	5025	6389
Total Cost ($mill.)	4713	3773	6339
Societal Benefits ($mill.)	9703	6296	15668
Net Benefits ($mill.)	4989	445	11413
% Certainty Net Ben. > 0	100%		

Table X-9
Uncertainty Analysis Results, Light Trucks
(7% Discount Rate)

MY 2011	Mean	Low	High
Fuel Saved (mill. gall.)	2312	2085	2922
Total Cost ($mill.)	1696	1156	2954
Societal Benefits ($mill.)	3968	2652	6131
Net Benefits ($mill.)	2272	502	4491
% Certainty Net Ben. > 0	100.0		
MY 2012			
Fuel Saved (mill. gall.)	5373	4858	6236
Total Cost ($mill.)	5213	4141	7190
Societal Benefits ($mill.)	9128	6067	14300
Net Benefits ($mill.)	3915	-121	9273
% Certainty Net Ben. > 0	99.6%		
MY 2013			
Fuel Saved (mill. gall.)	8270	7626	9453
Total Cost ($mill.)	7501	5921	11318
Societal Benefits ($mill.)	14053	9299	21967
Net Benefits ($mill.)	6552	-29	15031
% Certainty Net Ben. > 0	99.6		
MY 2014			
Fuel Saved (mill. gall.)	9071	8381	10258
Total Cost ($mill.)	8216	6545	12080
Societal Benefits ($mill.)	15489	10324	24311
Net Benefits ($mill.)	7273	122	16549
% Certainty Net Ben. > 0	100.0%		
MY 2015			
Fuel Saved (mill. gall.)	9942	9163	11270
Total Cost ($mill.)	8996	7167	13435
Societal Benefits ($mill.)	17013	11190	26862
Net Benefits ($mill.)	8018	209	18321
% Certainty Net Ben. > 0	100%		

Table X-10
Uncertainty Analysis Results, Passenger Cars
(3% Discount Rate)

MY 2011	Mean	Low	High
Fuel Saved (mill. gall.)	1503	1285	1798
Total Cost ($mill.)	1782	1309	2295
Societal Benefits ($mill.)	3235	2142	5087
Net Benefits ($mill.)	1454	-29	3544
% Certainty Net Ben. > 0	100%		
MY 2012			
Fuel Saved (mill. gall.)	2889	2621	3392
Total Cost ($mill.)	2299	1695	3286
Societal Benefits ($mill.)	6215	4050	10036
Net Benefits ($mill.)	3916	1180	7953
% Certainty Net Ben. > 0	100%		
MY 2013			
Fuel Saved (mill. gall.)	3611	3245	4284
Total Cost ($mill.)	2807	2086	3990
Societal Benefits ($mill.)	7789	5002	12868
Net Benefits ($mill.)	4982	1468	10164
% Certainty Net Ben. > 0	100%		
MY 2014			
Fuel Saved (mill. gall.)	4639	4220	5374
Total Cost ($mill.)	3754	2877	5050
Societal Benefits ($mill.)	10053	6475	16285
Net Benefits ($mill.)	6299	1847	12783
% Certainty Net Ben. > 0	100%		
MY 2015			
Fuel Saved (mill. gall.)	5538	5047	6389
Total Cost ($mill.)	4764	3730	6298
Societal Benefits ($mill.)	12025	7770	19419
Net Benefits ($mill.)	7262	1956	15167
% Certainty Net Ben. > 0	100%		

Table X-11

Uncertainty Analysis Results, Light Trucks
(3% Discount Rate)

MY 2011	Mean	Low	High
Fuel Saved (mill. gall.)	2324	2090	2836
Total Cost ($mill.)	1721	1190	2922
Societal Benefits ($mill.)	5031	3359	7954
Net Benefits ($mill.)	3311	1324	6134
% Certainty Net Ben. > 0	100%		
MY 2012			
Fuel Saved (mill. gall.)	5371	4855	6234
Total Cost ($mill.)	5212	4200	7046
Societal Benefits ($mill.)	11522	7622	18178
Net Benefits ($mill.)	6310	1853	13186
% Certainty Net Ben. > 0	100%		
MY 2013			
Fuel Saved (mill. gall.)	8278	7640	9479
Total Cost ($mill.)	7517	6049	11122
Societal Benefits ($mill.)	17791	11729	28159
Net Benefits ($mill.)	10274	2736	21147
% Certainty Net Ben. > 0	100%		
MY 2014			
Fuel Saved (mill. gall.)	9074	8348	1029
Total Cost ($mill.)	8227	6567	11945
Societal Benefits ($mill.)	19618	12966	30802
Net Benefits ($mill.)	11391	3169	22963
% Certainty Net Ben. > 0	100%		
MY 2015			
Fuel Saved (mill. gall.)	9942	9175	11264
Total Cost ($mill.)	9008	7297	13544
Societal Benefits ($mill.)	21567	14121	34289
Net Benefits ($mill.)	12559	3551	25536
% Certainty Net Ben. > 0	100%		

Figure X-13
Model Output Profile

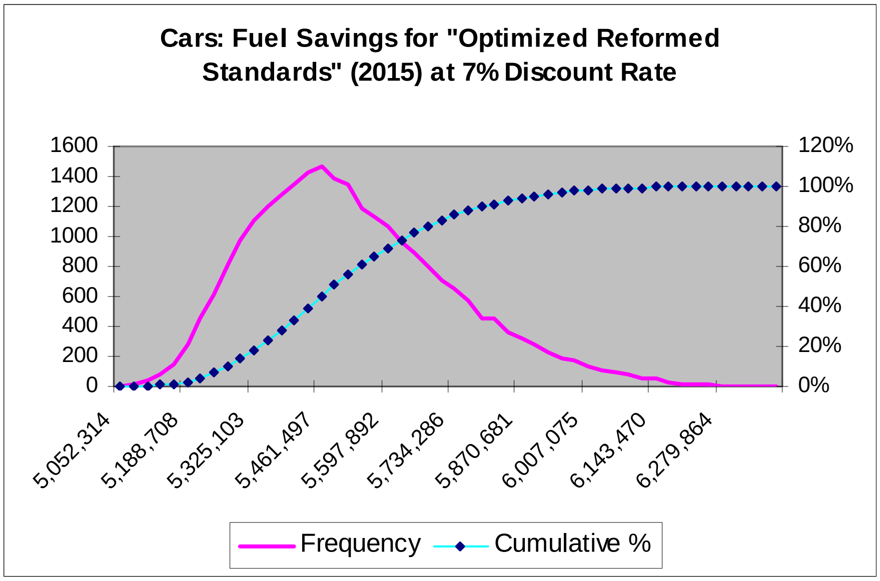


Figure X-14
Model Output Profile

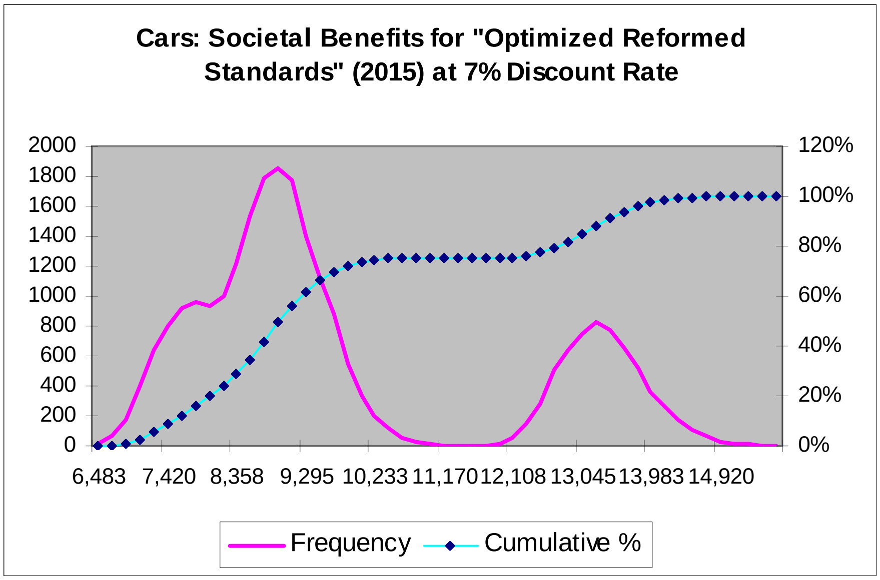


Figure X-15
Model Output Profile

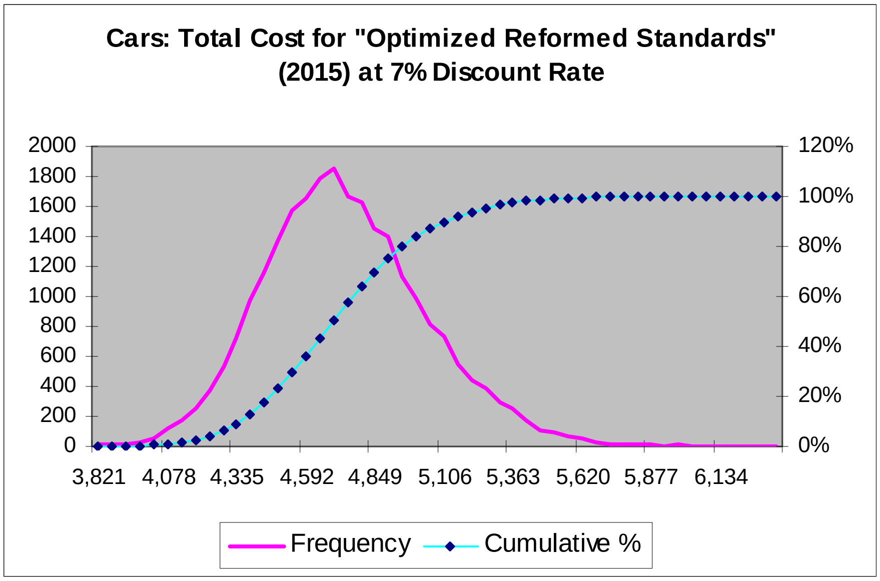
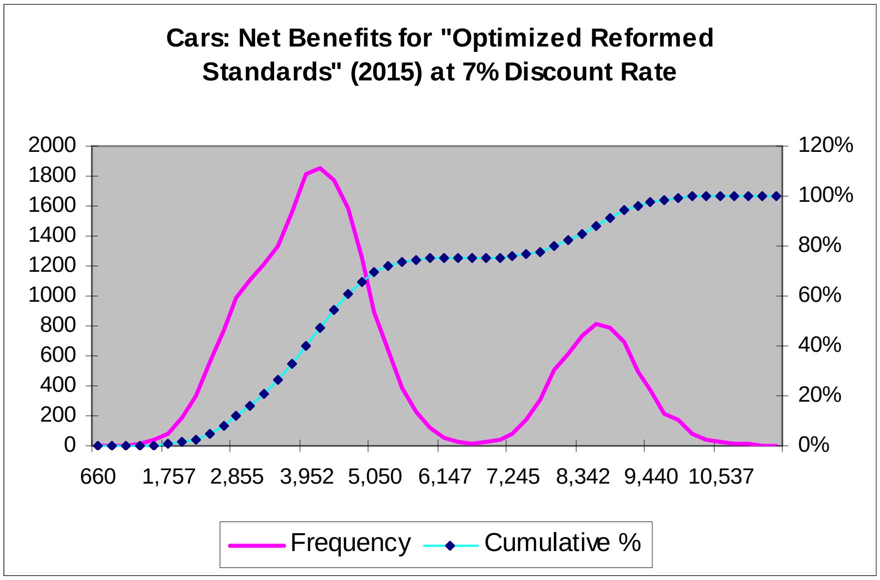


Figure X-16
Model Output Profile



XI. REGULATORY FLEXIBILITY ACT AND UNFUNDED MANDATES REFORM ACT ANALYSIS

A. REGULATORY FLEXIBILITY ACT

The Regulatory Flexibility Act of 1980 (5 U.S.C §601 et seq.) requires agencies to evaluate the potential effects of their proposed and final rules on small business, small organizations and small Government jurisdictions.

5 U.S.C §603 requires agencies to prepare and make available for public comments initial and final regulatory flexibility analysis (RFA) describing the impact of proposed and final rules on small entities. Section 603(b) of the Act specifies the content of a RFA. Each RFA must contain:

1. A description of the reasons why action by the agency is being considered;
2. A succinct statement of the objectives of, and legal basis for a final rule;
3. A description of and, where feasible, an estimate of the number of small entities to which the final rule will apply;
4. A description of the projected reporting, recording keeping and other compliance requirements of a final rule including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record;
5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap or conflict with the final rule;
6. Each final regulatory flexibility analysis shall also contain a description of any significant alternatives to the final rule which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the final rule on small entities.

1. Description of the reason why action by the agency is being considered

NHTSA is proposing this action to improve vehicle fuel economy.

2. Objectives of, and legal basis for, the final rule

The Energy Policy and Conservation Act requires the agency to set light truck fuel economy standards every year and allows the agency to update passenger car fuel economy standards. The Energy Independence and Security Act (EISA) mandates the setting of separate standards for passenger cars and for light trucks at levels sufficient to ensure that the average fuel economy of the combined fleet of all passenger cars and light trucks sold by all manufacturers in the U.S. in model year 2020 equals or exceeds 35 miles per gallon.

3. Description and estimate of the number of small entities to which the final rule will apply

The proposal will affect motor vehicle manufacturers. There are no light truck manufacturers that are small businesses. However, there are four domestically owned small passenger car manufacturers.

Business entities are defined as small business using the North American Industry Classification System (NAICS) code, for the purpose of receiving Small Business Administration assistance.

One of the criteria for determining size, as stated in 13 CFR 121.201, is the number of employees in the firm. For establishments primarily engaged in manufacturing or assembling automobiles, light and heavy duty trucks, buses, motor homes, or motor vehicle body manufacturing, the firm must have less than 1,000 employees to be classified as a small business.

We believe that the rulemaking would not have a significant economic impact on the small vehicle manufacturers because under Part 525, passenger car manufacturer making less than 10,000 vehicles per year can petition NHTSA to have alternative standards set for those manufacturers. These manufacturers currently don't meet the 27.5 mpg standard and must already petition the agency for relief. If the standard is raised, it has no meaningful impact on these manufacturers, they still must go through the same process and petition for relief.

Currently, there are four small passenger car motor vehicle manufacturers in the United States. Table X1-1 provides information about the 4 small domestic manufacturers in MY 2004. All are small manufacturers, having much less than 1,000 employees.

Table XI-1
Small Vehicle Manufacturers

Manufacturer	Employees	Estimated Sales	Sale Price Range	Est. Revenues*
Avanti	22	13	$25,000 to $63,000	$572,000
Panoz	50	150	$90,000 to $125,000	$16,125,000
Saleen	150	1,000	$39,000 to $59,000	$49,000,000
Shelby	44	60	$42,000 to $135,000	$5,310,000

* Assuming an average sales price from the sales price range.

The agency has not analyzed the impact of the proposal on these small manufacturers. However, assuming they would petition the agency, rather than meet the proposal, the cost is not expected to be substantial.

4. A description of the projected reporting, record keeping and other compliance requirements of a final rule including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record.
This proposal includes no new requirements for reporting, record keeping of other compliance requirements.

5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap, or conflict with the final rule
We know of no Federal rules which duplicate, overlap, or conflict with the final rule.

6. A description of any significant alternatives to the final rule which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the final rule on small entities.
There are no other alternatives that can achieve the stated objectives without installing fuel economy technologies into the vehicle.

B. Unfunded Mandates Reform Act

The Unfunded Mandates Reform Act of 1995 (Public Law 104-4) requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditures by States, local or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (adjusted annually for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for 2006 results in $126 million (116.043/92.106 = 1.26). The assessment may be included in conjunction with other assessments, as it is here.

C. Market Failure or Other Specific Problem

Executive Order 12866 requires that all new federal regulations specify the market failure or other specific problem that will be addressed by the rulemaking. A market failure occurs when the market fails to allocate scarce resources to their highest-valued uses. This can occur for several reasons, such as market power, externalities, or information problems. (OMB Circular A-4 describes each of these in detail. See http://www.whitehouse.gov/omb/circulars/a004/a-4.pdf). Normally in competitive markets, exchanges between self-interested buyers and sellers will allocate resources to their highest valued uses.

The Energy Policy and Conservation Act (EPCA) directs the Department to balance the technological and economic challenges related to fuel economy with the nation's need to conserve energy. Congress decided that the market would not balance these challenges in the best interest of the nation, and that the Department should regulate fuel economy.

APPENDIX A. Required MPG Levels

Table A-1 shows the required levels for the alternatives, along with the harmonically weighted average mpg. The Act requires that the agency set standards that achieve at least an average 35 mpg standard for MY 2020. These tables show the progress toward that requirement for each of the alternatives. The TC = TB and Technology Exhaustion alternatives already meet 35 mpg by MY 2015. The 2% increase alternative makes some progress toward the 35 mpg requirement, but you need an average annual increase of 4.5 percent to reach 35 mpg by MY 2020. The optimized alternative makes good progress toward the requirement and needs an average yearly increase of 2.3 percent to reach 35 mpg by MY 2020.

Table A-2 shows the incremental percentage increase in the required levels, each year compared to the previous year. The MY 2010 baseline for passenger cars is 27.5 mpg, and the MY 2010 baseline for light truck is the unreformed standard for MY 2010 of 23.5 mpg. The MY 2010 combined harmonically average baseline for passenger cars and light trucks is 25.34314 mpg, based on a 50/50 split for passenger car and light truck sales for MY 2010. The five year increase is the average yearly increase. In a formula it is (regulation mpg/baseline mpg)^(1/5). In simple terms, for the Optimized (7%) alternative, taking the MY 2010 passenger car baseline of 27.5 * 1.054 * 1.054* 1.054* 1.054* 1.054 = 35.77, the mpg needed to be achieved in MY 2015.

Table A-1
Required mpg Levels by Alternative

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
25% Below Optimized	29.6	30.3	31.7	32.7	33.9
Optimized (7%)	31.2	32.8	34	34.8	35.7
25% Above Optimized	32.8	35.3	36.1	36.8	37.5
50% Above Optimized	34.3	37.8	38.5	38.9	39.5
Optimized (3%)	37.1	39.1	39.3	40.7	40.9
TC = TB	37.5	42.7	43	43.1	43.3
Technology Exhaustion	38.6	45.4	48.9	50.1	52.6
Light Trucks					
25% Below Optimized	24.9	26	27.5	27.5	27.5
Optimized (7%)	25	26.4	27.8	28.2	28.6
25% Above Optimized	25.1	26.9	28	28.8	29.8
50% Above Optimized	25.3	27.3	28.3	29.5	30.9
Optimized (3%)	25	26.4	28	28.5	29
TC = TB	25.6	28.1	28.8	30.8	33.1
Technology Exhaustion	25.9	28.6	32.2	33.1	34.7
Harmonic Average mpg					
PC+LT	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
25% Below Optimized	27.1	28.0	29.4	29.8	30.2
Optimized (7%)	27.8	29.3	30.6	31.0	31.6
25% Above Optimized	28.5	30.6	31.5	32.2	33.0
50% Above Optimized	29.2	31.7	32.6	33.4	34.5
Optimized (3%)	30.0	31.5	32.6	33.3	33.7
TC = TB	30.6	33.9	34.4	35.7	37.3
Technology Exhaustion	31.1	35.1	38.7	39.6	41.4

Table A-2
Year by Year Percentage Increase
In Required mpg and 5 Year Annual Average[213]

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	5 years
25% Below Optimized	7.6%	2.4%	4.6%	3.2%	3.7%	4.3%
Optimized (7%)	13.5%	5.1%	3.7%	2.4%	2.6%	5.4%
25% Above Optimized	19.3%	7.6%	2.3%	1.9%	1.9%	6.4%
50% Above Optimized	24.7%	10.2%	1.9%	1.0%	1.5%	7.5%
Optimized (3%)	34.9%	5.4%	0.5%	3.6%	0.5%	8.3%
TC = TB	36.4%	13.9%	0.7%	0.2%	0.5%	9.5%
Technology Exhaustion	40.4%	17.6%	7.7%	2.5%	5.0%	13.8%
Light Trucks						
25% Below Optimized	6.0%	4.4%	5.8%	0.0%	0.0%	3.2%
Optimized (7%)	6.4%	5.6%	5.3%	1.4%	1.4%	4.0%
25% Above Optimized	6.8%	7.2%	4.1%	2.9%	3.5%	4.9%
50% Above Optimized	7.7%	7.9%	3.7%	4.2%	4.7%	5.6%
Optimized (3%)	6.4%	5.6%	6.1%	1.8%	1.8%	4.3%
TC = TB	8.9%	9.8%	2.5%	6.9%	7.5%	7.1%
Technology Exhaustion	10.2%	10.4%	12.6%	2.8%	4.8%	8.1%
PC+LT						
25% Below Optimized	6.9%	3.3%	5.1%	1.2%	1.5%	3.6%
Optimized (7%)	9.8%	5.2%	4.4%	1.6%	1.8%	4.5%
25% Above Optimized	12.5%	7.1%	3.1%	2.2%	2.7%	5.4%
50% Above Optimized	15.3%	8.6%	2.6%	2.5%	3.3%	6.4%
Optimized (3%)	18.4%	5.2%	3.5%	2.1%	1.1%	5.9%
TC = TB	20.6%	11.1%	1.5%	3.8%	4.4%	8.0%
Technology Exhaustion	22.8%	12.8%	10.3%	2.2%	4.7%	10.3%

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[213] The Baseline mpg levels for MY 2010 are assumed to be 27.5 mpg for passenger cars, 23.5 mpg for light trucks and a harmonic average of 25.34314 mpg for the combined fleet, assuming a 50/50 split in sales between passenger cars and light trucks for MY 2010.