APPENDIX Q

PROPOSED

LEV III GHG

TECHNICAL SUPPORT DOCUMENT

DEVELOPMENT LEV III GREENHOUSE GAS STANDARDS

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I. GHG Reduction Technology

This section summarizes the data on fundamental technology packages that were utilized to analyze compliance with the model year 2017-2025 standards. The technology packages apply technology CO_2 effectiveness and incremental prices, as discussed in Section III.A.4 of the Staff Report and utilized in the compliance assessment of Section III.A.5 of the Staff Report. Table Q1 shows characteristics of each of 19 vehicle classes, including the general vehicle type category, the baseline engine technology, and average model year 2008 attributes (e.g., CO_2, power, footprint, weight) for each class.

Table Q1. Vehicle classes and baseline model year 2008 attributes

Class	Category	Base	Test cycle gCO_2/mi	Power (kW)	Footprint (ft2)	Curb weight (lb)	2008 market share
1	Subcompact I4	1.5L 4V DOHC I4	235	92	41.1	2572	8%
2	Compact Car I4	2.4L 4V DOHC I4	230	104	43.7	2891	10%
3	Midsize Car/Small MPV (unibody) I4	2.4L 4V DOHC I4	274	126	46.3	3316	10%
4	Compact Car/Small MPV (unibody) V6	3.0L 4V DOHC V6	313	164	43.6	3399	7%
5	Midsize/Large Car V6	3.3L 4V DOHC V6	335	185	47.3	3728	13%
6	Midsize Car/Large Car V8	4.5L 4V DOHC V8	398	253	49.3	4104	3%
7	Mid-sized MPV (unibody)/Small Truck I4	2.6L 4V DOHC I4/I5	312	128	45.1	3529	10%
8	Midsize MPV (unibody)/ Small Truck V6/V8	3.7L 2V SOHC V6	394	156	45.3	3798	1%
9	Large MPV (unibody) V6	4.0L 2V SOHC V6	429	156	47.8	4447	1%
10	Large MPV (unibody) V8	4.7L 2V SOHC V8	448	205	55.9	4755	2%
11	Large Truck (+ Van) V6	4.2L 2V SOHC V6	423	155	57.6	4791	1%
12	Large Truck + Large MPV V6	3.8L 2V OHV V6	356	151	49.7	4100	6%
13	Large Truck (+ Van) V8	5.7L 2V OHV V8	447	241	61.2	5237	5%
14	Large Truck (+Van) V8	5.4L 3V SOHC V8	480	223	57.4	5059	2%
15	Midsize MPV (unibody) /Small Truck V6/V8	5.7L 2V OHV V8	392	278	49.6	3667	1%
16	Large MPV (unibody) V6	3.5L 4V DOHC V6	374	192	50.7	4354	15%
17	Large MPV (unibody) V8	4.6L 4V DOHC V8	468	243	53.2	5327	2%
18	Large Truck (+ Van) V6	4.0L 4V DOHC V6	401	182	56.5	4190	2%
19	Large Truck (+ Van) V8	5.6L 4V DOHC V8	477	262	66.2	5270	2%

Tables Q2 through Q5 show the CO_2-reduction effectiveness and incremental technology prices for each of the 19 vehicle classes. The tables show for each of the technology packages in the vehicle classes, the incremental price over the model year 2008 baseline (in 2012, 2020, and 2025 incorporating time and volume learning effects), as well as the estimated lifetime consumer savings, benefit/cost ratio, and the consumer payback for a 2025 consumer. Assumptions are consistent with the technology section above for median vehicle lifetime, on-road fuel economy adjustment, discount rate, fuel prices, etc.

Table Q2. Technology packages for vehicle classes 1-4

Class	Technology package	CO2 reduction from baseline	Incremental price in 2012	Incremental price in 2020	Incremental price in 2025	Lifetime consumer savings	Benefit / cost	Consumer payback period (years)
1	Base: 1.5L 4V DOHC I4, 4sp AT	0.0%	$0	$0	$0	$0	-	0
1	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, 6sp DCT	22.9%	$651	$557	$518	$4,421	8.5	1
1	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, 6sp DCT	25.4%	$755	$640	$594	$4,899	8.2	1
1	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, 8sp DCT	27.7%	$880	$752	$688	$5,355	7.8	1
1	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, 8sp DCT	31.8%	$1,186	$1,009	$902	$6,131	6.8	2
1	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT	37.3%	$1,918	$1,574	$1,432	$7,190	5.0	2
1	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp DCT	37.6%	$2,026	$1,662	$1,512	$7,255	4.8	2
1	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp DCT	38.0%	$2,204	$1,803	$1,643	$7,329	4.5	2
1	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT	41.2%	$2,543	$2,152	$1,891	$7,945	4.2	2
1	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp DCT	41.5%	$2,651	$2,240	$1,972	$8,005	4.1	2
1	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp DCT	41.9%	$3,224	$2,580	$2,274	$8,093	3.6	3
1	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp DCT	42.4%	$3,802	$3,078	$2,699	$8,182	3.0	3
1	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, 8sp DCT, 5% mass	53.4%	$5,883	$4,417	$3,894	$10,310	2.6	4
1	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, 8sp DCT, 5% mass	53.7%	$5,991	$4,505	$3,974	$10,362	2.6	4
1	EV75 mile, IACC2, Aero2, LRRT2, EPS	95.5%	$24,702	$13,610	$10,356	$13,819	1.3	9
1	EV100 mile, IACC2, Aero2, LRRT2, EPS, 6% mass	95.5%	$28,454	$15,544	$11,780	$13,819	1.2	11
1	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV20, 8sp DCT, 7% mass	71.7%	$17,779	$11,200	$9,399	$12,008	1.3	10
1	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV40, 8sp DCT, 13% mass	81.5%	$22,521	$13,649	$11,210	$12,859	1.1	11
1	EV150 mile, IACC2, Aero2, LRRT2, EPS, 18% mass	95.5%	$36,406	$19,715	$14,866	$13,819	0.9	16
1	FCV, IACC2, Aero2, LRRT2, EPS	80.8%	$37,845	$10,762	$8,464	$9,665	1.1	12
2	Base: 2.4L 4V DOHC I4, 4sp AT	0.0%	$0	$0	$0	$0	-	0
2	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, 6sp DCT, 2% mass	26.7%	$655	$560	$521	$5,031	9.7	1
2	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, 6sp DCT, 2% mass	29.5%	$759	$643	$597	$5,572	9.3	1
2	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, 8sp DCT, 2% mass	32.1%	$884	$755	$690	$6,049	8.8	1
2	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, 8sp DCT, 2% mass	36.0%	$1,190	$1,012	$904	$6,795	7.5	1
2	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, 8sp DCT, 2% mass	37.3%	$1,368	$1,154	$1,035	$7,046	6.8	2
2	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 2% mass	41.7%	$2,019	$1,666	$1,513	$7,871	5.2	2
2	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, 8sp DCT, 2% mass	43.6%	$2,211	$1,866	$1,647	$8,224	5.0	2
2	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 2% mass	45.6%	$2,547	$2,155	$1,894	$8,603	4.5	2
2	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp DCT, 2% mass	45.9%	$2,655	$2,243	$1,974	$8,667	4.4	2
2	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp DCT, 2% mass	46.4%	$3,228	$2,583	$2,277	$8,764	3.8	3
2	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp DCT, 2% mass	46.9%	$3,806	$3,081	$2,702	$8,857	3.3	3
2	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, 8sp DCT, 7% mass	56.2%	$6,104	$4,577	$4,033	$10,607	2.6	4
2	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, 8sp DCT, 7% mass	56.5%	$6,212	$4,665	$4,113	$10,665	2.6	4
2	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, 8sp DCT, 7% mass	56.5%	$6,212	$4,665	$4,113	$10,665	2.6	4
2	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp DCT, 2% mass	44.0%	$4,559	$3,687	$3,382	$8,296	2.5	4
2	EV75 mile, IACC2, Aero2, LRRT2, EPS	91.9%	$26,970	$14,978	$11,380	$12,497	1.1	12
2	EV100 mile, IACC2, Aero2, LRRT2, EPS, 7% mass	91.9%	$31,383	$17,254	$13,057	$12,497	1.0	16
2	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV20, 8sp DCT, 9% mass	71.4%	$18,732	$11,795	$9,902	$11,571	1.2	11
2	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV40, 8sp DCT, 14% mass	80.0%	$24,458	$14,748	$12,084	$12,096	1.0	14
2	EV150 mile, IACC2, Aero2, LRRT2, EPS, 19% mass	91.9%	$40,358	$21,963	$16,542	$12,497	0.8	16
2	FCV, IACC2, Aero2, LRRT2, EPS	81.2%	$46,286	$13,090	$10,285	$9,450	0.9	16
3	Base: 2.4L 4V DOHC I4, 4sp AT	0.0%	$0	$0	$0	$0	-	0
3	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, 8sp DCT, 5% mass	33.1%	$907	$773	$707	$7,253	10.3	1
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, 8sp DCT, 5% mass	37.0%	$1,213	$1,030	$921	$8,109	8.8	1
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, 8sp DCT, 10% mass	38.8%	$1,294	$1,093	$978	$8,489	8.7	1
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, 8sp DCT, 10% mass	40.0%	$1,472	$1,235	$1,109	$8,767	7.9	1
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 10% mass	44.2%	$2,123	$1,747	$1,587	$9,683	6.1	2
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 15% mass	45.8%	$2,283	$1,885	$1,698	$10,032	5.9	2
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp DCT, 15% mass	46.2%	$2,391	$1,972	$1,778	$10,106	5.7	2
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp DCT, 15% mass	46.6%	$2,569	$2,114	$1,909	$10,196	5.3	2
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 10% mass	47.9%	$2,748	$2,325	$2,046	$10,495	5.1	2
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 15% mass	49.4%	$2,908	$2,463	$2,157	$10,822	5.0	2
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp DCT, 15% mass	49.8%	$3,016	$2,551	$2,238	$10,891	4.9	2
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp DCT, 15% mass	50.2%	$3,589	$2,891	$2,541	$10,996	4.3	2
3	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp DCT, 15% mass	50.7%	$4,070	$3,301	$2,887	$11,096	3.8	3
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, 8sp DCT, 20% mass	58.9%	$6,407	$4,846	$4,256	$12,890	3.0	3
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, 8sp DCT, 20% mass	59.2%	$6,515	$4,934	$4,337	$12,952	3.0	3
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp DCT, 15% mass	47.9%	$4,823	$3,906	$3,567	$10,491	2.9	3
3	EV75 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	93.0%	$25,360	$14,084	$10,745	$15,520	1.4	8
3	EV100 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	93.0%	$29,888	$16,469	$12,502	$15,520	1.2	10
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV20, 8sp DCT, 20% mass	73.2%	$18,420	$11,703	$9,827	$14,105	1.4	8
3	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV40, 8sp DCT, 20% mass	81.1%	$24,098	$14,630	$11,994	$14,749	1.2	10
3	EV150 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	93.0%	$40,296	$21,950	$16,540	$15,520	0.9	16
3	FCV, IACC2, Aero2, LRRT2, EPS	79.0%	$46,286	$13,090	$10,285	$10,993	1.1	13
4	Base: 3.0L 4V DOHC V6, 4sp AT	0.0%	$0	$0	$0	$0	-	0
4	4V DOHC V6, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, 6sp DCT, 5% mass	26.3%	$779	$674	$625	$6,516	10.4	1
4	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, GDI, TDS18, 6sp DCT, 5% mass	36.2%	$1,362	$1,098	$1,037	$8,958	8.6	1
4	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, GDI, TDS18, 8sp DCT, 5% mass	38.1%	$1,516	$1,232	$1,151	$9,445	8.2	1
4	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, GDI, TDS18, 8sp DCT, 10% mass	39.8%	$1,598	$1,296	$1,209	$9,857	8.2	1
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 10% mass	43.0%	$1,904	$1,553	$1,423	$10,657	7.5	1
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 15% mass	44.7%	$2,066	$1,693	$1,536	$11,061	7.2	1
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp DCT, 15% mass	45.0%	$2,174	$1,780	$1,616	$11,143	6.9	2
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp DCT, 15% mass	45.4%	$2,352	$1,922	$1,747	$11,247	6.4	2
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 10% mass	46.8%	$2,529	$2,131	$1,882	$11,596	6.2	2
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 15% mass	48.4%	$2,691	$2,271	$1,995	$11,973	6.0	2
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp DCT, 15% mass	48.7%	$2,799	$2,359	$2,076	$12,050	5.8	2
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp DCT, 15% mass	49.2%	$3,449	$2,744	$2,419	$12,170	5.0	2
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp DCT, 15% mass	49.6%	$4,026	$3,242	$2,843	$12,285	4.3	2
4	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp DCT, 15% mass	46.9%	$4,905	$3,974	$3,627	$11,616	3.2	3
4	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, 8sp DCT, 20% mass	58.4%	$7,428	$5,632	$4,966	$14,456	2.9	3
4	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, 8sp DCT, 20% mass	58.7%	$7,536	$5,719	$5,046	$14,525	2.9	3
4	EV75 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	90.4%	$29,581	$16,302	$12,380	$17,230	1.4	9
4	EV100 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	90.4%	$35,758	$19,580	$14,797	$17,230	1.2	11
4	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV20, 8sp DCT, 20% mass	70.2%	$22,175	$14,078	$11,837	$15,261	1.3	9
4	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV40, 8sp DCT, 20% mass	77.2%	$30,117	$18,189	$14,889	$15,783	1.1	13
4	EV150 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	90.4%	$50,976	$27,606	$20,710	$17,230	0.8	16
4	FCV, IACC2, Aero2, LRRT2, EPS, 10% mass	79.1%	$55,291	$15,630	$12,282	$13,053	1.1	13

Table Q3. Technology packages for vehicle classes 5-8

Class	Technology package	CO2 reduction from baseline	Incremental price in 2012	Incremental price in 2020	Incremental price in 2025	Lifetime consumer savings	Benefit / cost	Consumer payback period (years)
5	Base: 3.3L 4V DOHC V6, 4sp AT	0.0%	$0	$0	$0	$0	-	0
5	4V DOHC V6, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, 6sp DCT, 5% mass	27.3%	$782	$676	$627	$7,263	11.6	1
5	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, GDI, TDS18, 6sp DCT, 5% mass	37.4%	$1,365	$1,101	$1,039	$9,953	9.6	1
5	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, GDI, TDS18, 8sp DCT, 5% mass	39.4%	$1,519	$1,234	$1,153	$10,479	9.1	1
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 5% mass	42.6%	$1,825	$1,491	$1,367	$11,341	8.3	1
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 10% mass	44.2%	$1,915	$1,562	$1,431	$11,761	8.2	1
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 15% mass	45.8%	$2,094	$1,717	$1,556	$12,187	7.8	1
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp DCT, 15% mass	46.1%	$2,202	$1,804	$1,636	$12,277	7.5	1
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp DCT, 15% mass	46.6%	$2,381	$1,946	$1,767	$12,393	7.0	2
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 10% mass	48.0%	$2,540	$2,140	$1,891	$12,770	6.8	2
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 15% mass	49.5%	$2,719	$2,295	$2,015	$13,166	6.5	2
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp DCT, 15% mass	49.8%	$2,827	$2,382	$2,096	$13,250	6.3	2
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp DCT, 15% mass	50.3%	$3,477	$2,768	$2,439	$13,383	5.5	2
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp DCT, 15% mass	50.8%	$4,055	$3,266	$2,863	$13,510	4.7	2
5	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, 8sp DCT, 20% mass	59.3%	$7,519	$5,702	$5,024	$15,773	3.1	3
5	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, 8sp DCT, 20% mass	59.6%	$7,627	$5,790	$5,104	$15,848	3.1	3
5	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp DCT, 15% mass	47.8%	$5,659	$4,573	$4,181	$12,731	3.0	3
5	EV75 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	91.7%	$29,835	$16,554	$12,579	$19,304	1.5	7
5	EV100 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	91.7%	$34,198	$18,903	$14,314	$19,304	1.3	9
5	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV20, 8sp DCT, 20% mass	71.8%	$22,671	$14,433	$12,156	$17,068	1.4	8
5	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV40, 8sp DCT, 20% mass	79.3%	$30,922	$18,714	$15,341	$17,894	1.2	11
5	EV150 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	91.7%	$48,556	$26,545	$19,951	$19,304	1.0	16
5	FCV, IACC2, Aero2, LRRT2, EPS, 10% mass	78.2%	$64,885	$18,282	$14,357	$14,029	1.0	16
6	Base: 4.5L 4V DOHC V8, 4sp AT	0.0%	$0	$0	$0	$0	-	0
6	4V DOHC V8, LUB, EFR1, LDB, ASL, IACC, EPS, Aero1, LRRT1, HEG, 6sp DCT, 5% mass	23.5%	$720	$609	$569	$7,274	12.8	1
6	4V DOHC V8, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, 6sp DCT, 5% mass	27.3%	$842	$736	$684	$8,444	12.3	1
6	4V DOHC V8, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, 8sp DCT, 5% mass	30.2%	$996	$870	$799	$9,347	11.7	1
6	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, 8sp DCT, 5% mass	34.6%	$1,302	$1,127	$1,013	$10,714	10.6	1
6	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, 8sp DCT, 10% mass	36.4%	$1,400	$1,203	$1,082	$11,271	10.4	1
6	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, 8sp DCT, 10% mass	38.6%	$1,624	$1,381	$1,246	$11,930	9.6	1
6	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS27, EGR, 8sp DCT, 10% mass	48.5%	$2,822	$2,417	$2,136	$15,006	7.0	2
6	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp DCT, 10% mass	48.8%	$2,929	$2,504	$2,216	$15,106	6.8	2
6	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp DCT, 10% mass	49.3%	$3,579	$2,890	$2,559	$15,259	6.0	2
6	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, 8sp DCT, 15% mass	58.3%	$7,650	$5,804	$5,131	$18,027	3.5	3
6	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, 8sp DCT, 15% mass	58.6%	$7,758	$5,891	$5,211	$18,116	3.5	3
6	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp DCT, 10% mass	46.3%	$5,667	$4,579	$4,207	$14,326	3.4	3
6	EV75 mile, IACC2, Aero2, LRRT2, EPS, 10% mass	92.8%	$31,426	$17,451	$13,228	$23,634	1.8	6
6	EV100 mile, IACC2, Aero2, LRRT2, EPS, 15% mass	92.8%	$35,092	$19,402	$14,672	$23,634	1.6	7
6	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV20, 8sp DCT, 17% mass	71.9%	$23,140	$14,753	$12,445	$20,210	1.6	7
6	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV40, 8sp DCT, 20% mass	80.1%	$31,226	$18,970	$15,576	$21,563	1.4	9
6	EV150 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	92.8%	$48,598	$26,580	$19,981	$23,634	1.2	11
6	FCV, IACC2, Aero2, LRRT2, EPS, 10% mass	76.5%	$64,895	$18,289	$14,364	$16,312	1.1	12
7	Base: 2.6L 4V DOHC I4 (I5), 4sp AT	0.0%	$0	$0	$0	$0	-	0
7	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, 8sp DCT, 5% mass	32.1%	$909	$775	$708	$8,960	12.7	1
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, 8sp DCT, 5% mass	36.0%	$1,215	$1,031	$922	$10,071	10.9	1
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, 8sp DCT, 10% mass	37.8%	$1,301	$1,099	$983	$10,563	10.7	1
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, 8sp DCT, 10% mass	39.1%	$1,479	$1,240	$1,114	$10,924	9.8	1
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 10% mass	43.3%	$2,130	$1,752	$1,592	$12,112	7.6	2
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 15% mass	45.0%	$2,301	$1,900	$1,710	$12,566	7.3	2
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp DCT, 15% mass	45.3%	$2,408	$1,987	$1,791	$12,654	7.1	2
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp DCT, 15% mass	45.7%	$2,587	$2,129	$1,922	$12,770	6.6	2
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 10% mass	47.1%	$2,755	$2,331	$2,051	$13,167	6.4	2
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 15% mass	48.6%	$2,925	$2,478	$2,170	$13,590	6.3	2
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp DCT, 15% mass	48.9%	$3,033	$2,565	$2,250	$13,672	6.1	2
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp DCT, 15% mass	49.4%	$3,683	$2,951	$2,593	$13,806	5.3	2
7	4V DOHC I3, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp DCT, 15% mass	49.9%	$4,164	$3,361	$2,939	$13,936	4.7	2
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp DCT, 15% mass	47.2%	$4,848	$3,926	$3,584	$13,186	3.7	3
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, 8sp DCT, 20% mass	58.6%	$6,969	$5,254	$4,614	$16,386	3.6	3
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, 8sp DCT, 20% mass	58.9%	$7,077	$5,342	$4,695	$16,459	3.5	3
7	EV75 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	90.4%	$29,606	$16,324	$12,397	$19,550	1.6	8
7	EV100 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	90.4%	$35,783	$19,601	$14,814	$19,550	1.3	10
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV20, 8sp DCT, 20% mass	70.4%	$21,716	$13,701	$11,486	$17,312	1.5	8
7	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV40, 8sp DCT, 20% mass	77.4%	$29,658	$17,811	$14,537	$17,909	1.2	11
7	EV150 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	90.4%	$51,002	$27,628	$20,728	$19,550	0.9	16
7	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	75.1%	$55,468	$15,781	$12,404	$13,259	1.1	14
8	Base: 3.7L 2V SOHC V6, 4sp AT	0.0%	$0	$0	$0	$0	-	0
8	2V SOHC V6, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, CCP, 6sp DCT, 5% mass	27.2%	$885	$760	$704	$9,407	13.4	1
8	2V SOHC V6, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, CCP, 8sp DCT, 5% mass	29.7%	$1,039	$894	$818	$10,265	12.5	1
8	2V SOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, 8sp DCT, 5% mass	33.7%	$1,345	$1,151	$1,032	$11,629	11.3	1
8	2V SOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, 8sp DCT, 10% mass	35.5%	$1,439	$1,224	$1,099	$12,260	11.2	1
8	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 10% mass	40.7%	$2,024	$1,656	$1,512	$14,046	9.3	1
8	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp DCT, 15% mass	42.4%	$2,209	$1,816	$1,641	$14,633	8.9	1
8	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp DCT, 15% mass	42.7%	$2,317	$1,904	$1,721	$14,759	8.6	1
8	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp DCT, 15% mass	43.1%	$2,496	$2,045	$1,852	$14,880	8.0	1
8	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 10% mass	44.4%	$2,649	$2,234	$1,971	$15,320	7.8	2
8	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp DCT, 15% mass	45.9%	$2,834	$2,394	$2,100	$15,871	7.6	2
8	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp DCT, 15% mass	46.3%	$2,942	$2,482	$2,181	$15,989	7.3	2
8	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp DCT, 15% mass	46.7%	$3,592	$2,867	$2,524	$16,138	6.4	2
8	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp DCT, 15% mass	47.1%	$4,170	$3,366	$2,949	$16,284	5.5	2
8	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, CCC, 8sp DCT, 20% mass	57.1%	$7,575	$5,762	$5,087	$19,733	3.9	3
8	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, CCC, 8sp DCT, 20% mass	57.4%	$7,683	$5,850	$5,168	$19,838	3.8	3
8	EV75 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	93.1%	$29,426	$16,461	$12,523	$26,527	2.1	5
8	EV100 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	93.1%	$35,203	$19,506	$14,766	$26,527	1.8	6
8	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV20, 8sp DCT, 20% mass	70.8%	$21,295	$13,560	$11,406	$22,171	1.9	6
8	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV40, 8sp DCT, 20% mass	79.0%	$28,553	$17,306	$14,181	$23,667	1.7	7
8	EV150 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	93.1%	$49,981	$27,302	$20,511	$26,527	1.3	10
8	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	81.2%	$52,329	$14,930	$11,739	$20,507	1.7	7

Table Q4. Technology packages for vehicle classes 9-13

Class	Technology package	CO2 reduction from baseline	Incremental price in 2012	Incremental price in 2020	Incremental price in 2025	Lifetime consumer savings	Benefit / cost	Consumer payback period (years)
9	Base: 4.0L 2V SOHC V6, 4sp AT	0.0%	$0	$0	$0	$0	-	0
9	2V SOHC V6, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, 8sp AT, 5% mass	27.4%	$990	$850	$781	$10,315	13.2	1
9	2V SOHC V6, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, CCP, 8sp AT, 5% mass	30.0%	$1,092	$933	$858	$11,292	13.2	1
9	2V SOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 5% mass	34.1%	$1,398	$1,190	$1,072	$12,834	12.0	1
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp AT, 5% mass	40.0%	$1,983	$1,622	$1,485	$15,044	10.1	1
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp AT, 10% mass	41.6%	$2,090	$1,705	$1,561	$15,666	10.0	1
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 10% mass	42.1%	$2,198	$1,793	$1,641	$15,834	9.6	1
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 15% mass	43.7%	$2,410	$1,976	$1,789	$16,459	9.2	1
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp AT, 15% mass	44.2%	$2,589	$2,118	$1,920	$16,621	8.7	1
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp AT, 10% mass	45.5%	$2,715	$2,284	$2,020	$17,129	8.5	1
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 10% mass	45.9%	$2,823	$2,371	$2,101	$17,286	8.2	1
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 15% mass	47.5%	$3,035	$2,555	$2,248	$17,869	7.9	1
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	48.0%	$3,685	$2,940	$2,591	$18,066	7.0	2
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	48.1%	$3,864	$3,082	$2,722	$18,088	6.6	2
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.5%	$4,263	$3,438	$3,016	$18,246	6.0	2
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, CCC, 8sp AT, 15% mass	45.7%	$5,274	$4,266	$3,896	$17,183	4.4	2
9	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	53.8%	$7,663	$5,772	$5,081	$20,237	4.0	3
9	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	71.8%	$55,538	$15,839	$12,453	$17,855	1.4	9
10	Base: 4.7L 2V SOHC V8, 4sp AT	0.0%	$0	$0	$0	$0	-	0
10	2V SOHC V8, LUB, EFR1, LDB, ASL, IACC, EPS, Aero1, LRRT1, HEG, CCP, 8sp AT, 5% mass	26.7%	$1,030	$865	$799	$10,432	13.1	1
10	2V SOHC V8, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, CCP, 8sp AT, 5% mass	30.0%	$1,152	$992	$914	$11,732	12.8	1
10	2V SOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 5% mass	34.1%	$1,458	$1,249	$1,128	$13,334	11.8	1
10	2V SOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 10% mass	35.9%	$1,568	$1,335	$1,207	$14,044	11.6	1
10	2V SOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, Deac, 8sp AT, 10% mass	37.5%	$1,809	$1,527	$1,384	$14,668	10.6	1
10	2V SOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, Deac, SAX, 8sp AT, 10% mass	38.0%	$1,917	$1,614	$1,464	$14,855	10.1	1
10	2V SOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, Deac, SAX, 8sp AT, 15% mass	39.8%	$2,136	$1,804	$1,617	$15,550	9.6	1
10	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS27, EGR, 8sp AT, 10% mass	46.0%	$3,039	$2,589	$2,287	$17,997	7.9	1
10	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 10% mass	46.4%	$3,146	$2,676	$2,368	$18,159	7.7	2
10	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 15% mass	48.0%	$3,366	$2,866	$2,520	$18,759	7.4	2
10	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 15% mass	43.7%	$3,340	$2,741	$2,486	$17,100	6.9	2
10	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.5%	$4,016	$3,251	$2,863	$18,957	6.6	2
10	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp AT, 15% mass	44.2%	$3,599	$2,946	$2,676	$17,268	6.5	2
10	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS18, 8sp AT, 15% mass	44.7%	$4,249	$3,332	$3,019	$17,498	5.8	2
10	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	48.1%	$5,072	$4,108	$3,625	$18,793	5.2	2
10	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, CCC, 8sp AT, 15% mass	45.7%	$5,500	$4,458	$4,075	$17,852	4.4	2
10	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	53.8%	$8,602	$6,544	$5,785	$21,026	3.6	3
10	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	71.5%	$55,550	$15,850	$12,462	$18,550	1.5	8
11	Base: 4.2L 2V SOHC V6, 4sp AT	0.0%	$0	$0	$0	$0	-	0
11	2V SOHC V6, EFR2, LDB, ASL2, IACC, EHPS, Aero1, LRRT1, HEG, 8sp AT, 5% mass	27.0%	$993	$852	$783	$10,151	13.0	1
11	2V SOHC V6, EFR2, LDB, ASL2, IACC, EHPS, Aero1, LRRT1, HEG, CCP, 8sp AT, 5% mass	29.5%	$1,095	$935	$860	$11,083	12.9	1
11	2V SOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 5% mass	33.6%	$1,402	$1,192	$1,074	$12,616	11.7	1
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp AT, 5% mass	39.3%	$1,986	$1,624	$1,487	$14,779	9.9	1
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp AT, 10% mass	41.0%	$2,103	$1,715	$1,570	$15,407	9.8	1
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 10% mass	41.6%	$2,210	$1,803	$1,650	$15,634	9.5	1
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 15% mass	43.3%	$2,441	$2,002	$1,810	$16,263	9.0	1
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp AT, 15% mass	43.7%	$2,620	$2,144	$1,941	$16,416	8.5	1
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp AT, 10% mass	44.9%	$2,728	$2,294	$2,029	$16,856	8.3	1
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 10% mass	45.4%	$2,835	$2,381	$2,109	$17,069	8.1	1
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 15% mass	47.0%	$3,066	$2,580	$2,270	$17,656	7.8	2
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS18, 8sp AT, 15% mass	44.3%	$3,333	$2,567	$2,318	$16,647	7.2	2
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	47.5%	$3,779	$3,003	$2,646	$17,862	6.8	2
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	47.6%	$3,958	$3,145	$2,777	$17,884	6.4	2
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.0%	$4,357	$3,501	$3,071	$18,036	5.9	2
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	52.6%	$7,874	$5,929	$5,214	$19,760	3.8	3
11	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, CCC, 8sp AT, 15% mass	45.1%	$6,606	$5,324	$4,874	$16,926	3.5	3
11	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	76.7%	$58,290	$16,616	$13,062	$20,346	1.6	8
12	Base: 3.8L 2V OHV V6, 4sp AT	0.0%	$0	$0	$0	$0	-	0
12	2V OHV V6, EFR2, LDB, ASL2, IACC, EHPS, Aero1, LRRT1, HEG, CCP, 8sp AT, 5% mass	29.5%	$1,039	$890	$818	$8,274	10.1	1
12	2V OHV V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 5% mass	33.6%	$1,345	$1,147	$1,032	$9,419	9.1	1
12	2V OHV V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 10% mass	35.4%	$1,446	$1,226	$1,104	$9,931	9.0	1
12	2V OHV V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, Deac, 8sp AT, 10% mass	36.9%	$1,660	$1,396	$1,261	$10,358	8.2	1
12	2V OHV V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, Deac, SAX, 8sp AT, 10% mass	37.6%	$1,768	$1,484	$1,342	$10,539	7.9	1
12	2V OHV V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, Deac, SAX, 8sp AT, 15% mass	39.4%	$1,969	$1,657	$1,481	$11,041	7.5	1
12	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 15% mass	43.3%	$3,067	$2,504	$2,259	$12,141	5.4	2
12	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp AT, 15% mass	43.7%	$3,245	$2,646	$2,390	$12,255	5.1	2
12	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 10% mass	45.4%	$3,491	$2,909	$2,579	$12,743	4.9	2
12	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 15% mass	47.0%	$3,692	$3,083	$2,719	$13,181	4.8	2
12	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	47.5%	$4,405	$3,506	$3,095	$13,335	4.3	2
12	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	47.6%	$4,583	$3,647	$3,226	$13,351	4.1	2
12	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.0%	$4,983	$4,004	$3,520	$13,465	3.8	3
12	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	52.6%	$8,461	$6,398	$5,636	$14,752	2.6	4
12	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, CCC, 8sp AT, 15% mass	45.1%	$7,079	$5,680	$5,197	$12,636	2.4	4
12	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	78.5%	$58,240	$16,574	$13,027	$15,150	1.2	11
13	Base: 5.7L 2V OHV V8, 4sp AT	0.0%	$0	$0	$0	$0	-	0
13	2V OHV V8, LUB, EFR1, LDB, ASL, IACC, EHPS, Aero1, LRRT1, HEG, CCP, 8sp AT, 5% mass	26.3%	$984	$828	$764	$10,471	13.7	1
13	2V OHV V8, EFR2, LDB, ASL2, IACC, EHPS, Aero1, LRRT1, HEG, CCP, 8sp AT, 5% mass	29.5%	$1,105	$954	$880	$11,726	13.3	1
13	2V OHV V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 5% mass	33.6%	$1,411	$1,211	$1,094	$13,349	12.2	1
13	2V OHV V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 10% mass	35.4%	$1,537	$1,310	$1,183	$14,075	11.9	1
13	2V OHV V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, Deac, 8sp AT, 10% mass	36.9%	$1,778	$1,501	$1,360	$14,679	10.8	1
13	2V OHV V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, Deac, SAX, 8sp AT, 10% mass	37.6%	$1,886	$1,588	$1,440	$14,937	10.4	1
13	2V OHV V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, Deac, SAX, 8sp AT, 15% mass	39.4%	$2,135	$1,804	$1,613	$15,648	9.7	1
13	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 10% mass	45.9%	$3,483	$2,949	$2,598	$18,256	7.0	2
13	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 15% mass	47.5%	$3,733	$3,164	$2,771	$18,872	6.8	2
13	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.0%	$4,446	$3,587	$3,147	$19,083	6.1	2
13	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	52.6%	$9,406	$7,164	$6,337	$20,907	3.3	3
13	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, CCC, 8sp AT, 15% mass	45.1%	$7,411	$5,956	$5,449	$17,908	3.3	3
13	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	76.1%	$58,321	$16,642	$13,084	$21,527	1.6	7

Table Q5. Technology packages for vehicle classes 14-19

Class	Technology package	CO2 reduction from baseline	Incremental price in 2012	Incremental price in 2020	Incremental price in 2025	Lifetime consumer savings	Benefit / cost	Consumer payback period (years)
14	Base: 5.4L 3V SOHC V8, 4sp AT	0.0%	$0	$0	$0	$0	-	0
14	3V SOHC V8, LUB, EFR1, LDB, ASL, IACC, EHPS, Aero1, LRRT1, HEG, CCP, 8sp AT, 5% mass	26.3%	$1,034	$868	$802	$11,197	14.0	1
14	3V SOHC V8, EFR2, LDB, ASL2, IACC, EHPS, Aero1, LRRT1, HEG, CCP, 8sp AT, 5% mass	29.5%	$1,155	$995	$917	$12,540	13.7	1
14	3V SOHC V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 5% mass	33.6%	$1,461	$1,252	$1,131	$14,274	12.6	1
14	3V SOHC V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, 8sp AT, 10% mass	35.4%	$1,583	$1,347	$1,218	$15,052	12.4	1
14	3V SOHC V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, Deac, 8sp AT, 10% mass	36.9%	$1,824	$1,539	$1,394	$15,697	11.3	1
14	3V SOHC V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, Deac, SAX, 8sp AT, 10% mass	37.6%	$1,932	$1,626	$1,475	$15,973	10.8	1
14	3V SOHC V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, CCP, Deac, SAX, 8sp AT, 15% mass	39.4%	$2,174	$1,835	$1,643	$16,733	10.2	1
14	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, TDS27, EGR, 8sp AT, 10% mass	45.4%	$2,997	$2,554	$2,259	$19,284	8.5	1
14	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 10% mass	45.9%	$3,105	$2,642	$2,340	$19,522	8.3	1
14	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 15% mass	47.5%	$3,347	$2,851	$2,508	$20,181	8.0	1
14	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.0%	$4,060	$3,274	$2,884	$20,407	7.1	2
14	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, CCC, 8sp AT, 15% mass	45.1%	$6,737	$5,441	$4,982	$19,150	3.8	3
14	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	52.6%	$8,780	$6,672	$5,894	$22,358	3.8	3
14	FCV, IACC2, Aero2, LRRT2, EPS, 10% mass	75.6%	$58,309	$16,632	$13,075	$23,020	1.8	7
15	Base: 5.7L 2V OHV V8, 4sp AT	0.0%	$0	$0	$0	$0	-	0
15	2V OHV V8, LUB, EFR1, LDB, ASL, IACC, EPS, Aero1, LRRT1, HEG, CCP, 6sp DCT, 5% mass	26.7%	$768	$648	$605	$8,257	13.7	1
15	2V OHV V8, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, CCP, 6sp DCT, 5% mass	30.3%	$890	$775	$720	$9,358	13.0	1
15	2V OHV V8, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, CCP, 8sp DCT, 5% mass	32.8%	$1,044	$909	$835	$10,145	12.2	1
15	2V OHV V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, 8sp DCT, 5% mass	36.8%	$1,350	$1,166	$1,049	$11,374	10.8	1
15	2V OHV V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, 8sp DCT, 10% mass	38.6%	$1,438	$1,234	$1,111	$11,911	10.7	1
15	2V OHV V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, Deac, 8sp DCT, 10% mass	40.2%	$1,678	$1,425	$1,287	$12,414	9.6	1
15	2V OHV V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, CCP, Deac, SAX, 8sp DCT, 10% mass	40.6%	$1,786	$1,513	$1,368	$12,529	9.2	1
15	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS27, EGR, 8sp DCT, 10% mass	48.5%	$3,276	$2,786	$2,445	$14,982	6.1	2
15	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp DCT, 10% mass	48.8%	$3,384	$2,874	$2,525	$15,082	6.0	2
15	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp DCT, 10% mass	49.3%	$4,034	$3,259	$2,868	$15,235	5.3	2
15	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, CCC, 8sp DCT, 15% mass	58.9%	$8,449	$6,417	$5,691	$18,189	3.2	3
15	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, HEV, SAX, CCC, 8sp DCT, 15% mass	59.2%	$8,557	$6,504	$5,771	$18,277	3.2	3
15	EV75 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	92.8%	$31,813	$17,779	$13,497	$23,586	1.7	6
15	EV100 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	92.8%	$35,285	$19,562	$14,807	$23,586	1.6	7
15	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV20, 8sp DCT, 20% mass	72.3%	$23,241	$14,837	$12,516	$20,290	1.6	7
15	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, ATKCS, REEV40, 8sp DCT, 20% mass	80.1%	$31,168	$18,921	$15,535	$21,522	1.4	9
15	EV150 mile, IACC2, Aero2, LRRT2, EPS, 20% mass	92.8%	$48,539	$26,532	$19,940	$23,586	1.2	11
15	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	76.6%	$64,882	$18,279	$14,355	$16,287	1.1	12
16	Base: 3.5L 4V DOHC V6, 4sp AT	0.0%	$0	$0	$0	$0	-	0
16	4V DOHC V6, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, 8sp AT, 5% mass	27.4%	$990	$850	$781	$9,108	11.7	1
16	4V DOHC I4, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, DCP, GDI, TDS18, 8sp AT, 5% mass	36.6%	$1,573	$1,274	$1,193	$12,165	10.2	1
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp AT, 5% mass	40.0%	$1,879	$1,531	$1,407	$13,283	9.4	1
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp AT, 10% mass	41.6%	$1,986	$1,615	$1,483	$13,833	9.3	1
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 10% mass	42.1%	$2,093	$1,702	$1,563	$13,981	8.9	1
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 15% mass	43.7%	$2,305	$1,885	$1,711	$14,533	8.5	1
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp AT, 15% mass	44.2%	$2,484	$2,027	$1,842	$14,675	8.0	1
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp AT, 10% mass	45.5%	$2,611	$2,193	$1,942	$15,124	7.8	2
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 10% mass	45.9%	$2,718	$2,281	$2,023	$15,263	7.5	2
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 15% mass	47.5%	$2,930	$2,463	$2,170	$15,778	7.3	2
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	48.0%	$3,580	$2,849	$2,513	$15,952	6.3	2
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	48.1%	$3,759	$2,990	$2,644	$15,971	6.0	2
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.5%	$4,158	$3,347	$2,938	$16,110	5.5	2
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp AT, 15% mass	45.7%	$5,037	$4,078	$3,722	$15,172	4.1	3
16	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	53.8%	$7,558	$5,680	$5,002	$17,869	3.6	3
16	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	73.1%	$55,537	$15,839	$12,452	$15,765	1.3	11
17	Base: 4.6L 4V DOHC V8, 4sp AT	0.0%	$0	$0	$0	$0	-	0
17	4V DOHC V8, LUB, EFR1, LDB, ASL, IACC, EPS, Aero1, LRRT1, HEG, 8sp AT, 5% mass	23.9%	$933	$787	$727	$9,906	13.6	1
17	4V DOHC V8, EFR2, LDB, ASL2, IACC, EPS, Aero1, LRRT1, HEG, 8sp AT, 5% mass	27.4%	$1,055	$913	$842	$11,350	13.5	1
17	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, 8sp AT, 5% mass	31.9%	$1,361	$1,170	$1,056	$13,224	12.5	1
17	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, 8sp AT, 5% mass	34.1%	$1,585	$1,348	$1,221	$14,121	11.6	1
17	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, 8sp AT, 10% mass	35.9%	$1,713	$1,449	$1,312	$14,873	11.3	1
17	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS27, EGR, 8sp AT, 5% mass	44.5%	$2,783	$2,384	$2,110	$18,427	8.7	1
17	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, TDS27, EGR, 8sp AT, 10% mass	46.0%	$2,911	$2,484	$2,201	$19,060	8.7	1
17	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 10% mass	46.4%	$3,019	$2,572	$2,281	$19,231	8.4	1
17	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 15% mass	48.0%	$3,273	$2,791	$2,458	$19,867	8.1	1
17	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.5%	$3,923	$3,177	$2,801	$20,076	7.2	2
17	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp AT, 15% mass	45.7%	$5,286	$4,291	$3,915	$18,906	4.8	2
17	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	53.8%	$8,586	$6,526	$5,768	$22,267	3.9	3
17	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	71.0%	$55,608	$15,898	$12,502	$19,645	1.6	8
18	Base: 4.0L 4V DOHC V6, 4sp AT	0.0%	$0	$0	$0	$0	-	0
18	4V DOHC V6, EFR2, LDB, ASL2, IACC, EHPS, Aero1, LRRT1, HEG, 8sp AT, 5% mass	27.0%	$989	$849	$780	$9,604	12.3	1
18	4V DOHC I4, EFR2, LDB, ASL2, IACC, EHPS, Aero1, LRRT1, HEG, DCP, GDI, TDS18, 8sp AT, 5% mass	36.0%	$1,572	$1,273	$1,192	$12,782	10.7	1
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp AT, 5% mass	39.3%	$1,878	$1,530	$1,406	$13,983	9.9	1
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, TDS18, 8sp AT, 10% mass	41.0%	$1,981	$1,611	$1,480	$14,577	9.9	1
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 10% mass	41.6%	$2,089	$1,699	$1,560	$14,792	9.5	1
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 15% mass	43.3%	$2,294	$1,876	$1,703	$15,387	9.0	1
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp AT, 15% mass	43.7%	$2,473	$2,017	$1,834	$15,532	8.5	1
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, TDS24, EGR, 8sp AT, 10% mass	44.9%	$2,606	$2,189	$1,939	$15,948	8.2	1
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 10% mass	45.4%	$2,714	$2,277	$2,020	$16,149	8.0	1
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS24, EGR, 8sp AT, 15% mass	47.0%	$2,919	$2,454	$2,162	$16,705	7.7	2
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	47.5%	$3,632	$2,877	$2,538	$16,900	6.7	2
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	47.6%	$3,811	$3,019	$2,669	$16,920	6.3	2
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.0%	$4,210	$3,375	$2,963	$17,065	5.8	2
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	52.6%	$7,694	$5,775	$5,083	$18,696	3.7	3
18	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp AT, 15% mass	45.1%	$6,327	$5,101	$4,670	$16,014	3.4	3
18	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	77.2%	$58,247	$16,580	$13,032	$19,250	1.5	9
19	Base: 5.6L 4V DOHC V8, 4sp AT	0.0%	$0	$0	$0	$0	-	0
19	4V DOHC V8, LUB, EFR1, LDB, ASL, IACC, EHPS, Aero1, LRRT1, HEG, 8sp AT, 5% mass	23.7%	$933	$787	$727	$10,025	13.8	1
19	4V DOHC V8, EFR2, LDB, ASL2, IACC, EHPS, Aero1, LRRT1, HEG, 8sp AT, 5% mass	27.0%	$1,055	$913	$842	$11,420	13.6	1
19	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, 8sp AT, 5% mass	31.5%	$1,361	$1,170	$1,056	$13,316	12.6	1
19	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, 8sp AT, 5% mass	33.6%	$1,585	$1,348	$1,221	$14,194	11.6	1
19	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, 8sp AT, 10% mass	35.4%	$1,713	$1,449	$1,311	$14,967	11.4	1
19	4V DOHC V8, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, SAX, 8sp AT, 10% mass	36.1%	$1,821	$1,536	$1,392	$15,247	11.0	1
19	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, TDS27, EGR, 8sp AT, 5% mass	43.8%	$2,783	$2,384	$2,110	$18,522	8.8	1
19	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, TDS27, EGR, 8sp AT, 10% mass	45.4%	$2,911	$2,484	$2,201	$19,175	8.7	1
19	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 10% mass	45.9%	$3,019	$2,572	$2,281	$19,412	8.5	1
19	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS27, EGR, 8sp AT, 15% mass	47.5%	$3,273	$2,791	$2,458	$20,067	8.2	1
19	4V DOHC I4, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SS, SAX, TDS27, EGR, 8sp AT, 15% mass	48.0%	$3,986	$3,214	$2,834	$20,292	7.2	2
19	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DSL-Adv, SAX, 8sp AT, 15% mass	45.1%	$6,587	$5,323	$4,872	$19,042	3.9	3
19	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, HEV, 8sp AT, 20% mass	52.6%	$8,741	$6,636	$5,863	$22,232	3.8	3
19	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 10% mass	41.6%	$3,023	$2,465	$2,261	$17,589	7.8	2
19	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, GDI, SAX, TDS18, 8sp AT, 15% mass	43.3%	$3,278	$2,684	$2,438	$18,296	7.5	2
19	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SAX, TDS18, 8sp AT, 15% mass	43.7%	$3,536	$2,890	$2,628	$18,469	7.0	2
19	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS18, 8sp AT, 15% mass	44.3%	$4,249	$3,313	$3,004	$18,729	6.2	2
19	4V DOHC V6, EFR2, LDB, ASL2, IACC2, EHPS, Aero2, LRRT2, HEG, DCP, DVVL, GDI, SS, SAX, TDS24, EGR, 8sp AT, 15% mass	47.6%	$5,073	$4,089	$3,609	$20,120	5.6	2
19	FCV, IACC2, Aero2, LRRT2, EPS, 15% mass	75.6%	$58,329	$16,648	$13,089	$22,890	1.7	7

II. Mass-reduction technology and cost

A. Overview

There are many diverse ways being employed by automakers to reduce the mass of vehicles with optimized design and advanced materials. Many engineering projects have assessed the costs and technical potential of various techniques to reduce vehicle mass over the years. This section summarizes the results of the studies that the agencies examined in their technical assessment and how they were utilized in the ultimate estimation of future vehicle mass-reduction costs.

Throughout the ongoing technical assessment, the agencies have found that there are many features that differentiate the different mass reduction studies under consideration. For example, the agencies have found that the various studies are not all equal in their rigor, transparency, and applicability to this regulatory assessment. To reflect the differences in the studies, the agencies have undertaken a thorough review of the particular merits of each of the available studies to better assess their applicability for the rulemaking analysis. As a result, the agencies have developed a number of criteria to help determine the relative applicability of studies in the 2017-2025 timeframe. The criteria, in turn, are used to develop ratings to be used as proportional weighting factors for estimating the mass reduction-cost relationship. CARB staff feels that the meta-analysis method employed, and described in this section, to assess mass reduction costs was the most suitable for the data at hand under the present situation.

B. Vehicle Mass-Reduction Context

For context within the overall technical analysis, critical details and assumptions from the joint-agency assessment of the deployment of mass-reduction technology are summarized here. As indicated in the joint-agency *TAR*, the agencies found that mass reduction technology is a core efficiency technology that is being increasingly investigated by every single automaker. Mass-reduction technology with new materials and designs in vehicles has always advanced historically. However, in times of relatively moderate regulatory or consumer pressure to reduce CO_2 emissions, mass reduction is used for increased vehicle performance; on the other hand, in times of greater demand for CO_2 reduction, mass-reduction is used for increased vehicle efficiency. In addition, staff has found that many automakers have already demonstrated many of the emerging technologies (at relatively small volume) that are expected to become mainstream by model year 2025 (see e.g., Lotus, 2010; Lutsey, 2010).

Due to a number of factors, staff is highly confident that the levels of mass-reduction that result from the proposed regulation are well within levels that automakers can design vehicles that are at least as safe as present vehicles. First, the use of size-based standards inherently reduces the motivation to downsize vehicles for compliance purposes, therefore eliminating a potential trend that has been associated with vehicle safety. Second, a number of mass-reduction technology-leading automakers have already proven the ability to reduce their vehicle models' mass by at least 10% below their competitors' models while still achieving the highest crash safety ratings. Third, many of the advanced materials and optimized designs investigated by the agencies are stronger than current materials and designs, offering the prospect for still safer vehicles.

Finally, a number of additional conservative assumptions have been employed to provide still further assurance that the levels of mass-reduction technology offer no potential compromise in vehicle safety. Despite abundant recent technical research on the ability to achieve mass-reduction at levels of 20% or greater across all vehicle classes (e.g., WorldAutoSteel, 2011; Lotus Engineering, 2011), staff used conservative constraints to artificially limit the amount of allowable mass-reduction, especially among smaller and lighter vehicle classes.

The artificial mass-reduction constraints used in this regulatory assessment on the feasibility and safety came from NHTSA's modeling of the fleet-wide societal safety effects of vehicles entering the fleet. The new 2011 NHTSA analysis does not finds a statistically significant relationship (at 95% confidence) between vehicle mass and safety for four or the five major vehicle classes. For those four classes that represent 82% of model year 2008 vehicle sales, the NHTSA analysis indicates that the mass-safety effect is not statistically different from zero. However, for the smallest vehicle class (i.e., cars of less than 3,106 pounds), NHTSA analysis suggests that mass reduction does statistically correlate with safety. The mixed statistical significance findings highlight that there are very safe (and less safe) vehicle designs within all vehicle classes, and that there are many other factors (e.g., driver behavior) that confound any clear-cut mass-safety relationship.

Despite the largely statistically insignificant results, the three agencies utilized the NHTSA supplied constraints for mass-reduction to ensure conservative analysis. NHTSA staff utilized results from their safety modeling to determine "safety-neutral" mass constraints, which allowed differing amounts of mass reduction in each vehicle class. The result of the NHTSA constraints was to limit the mass-reduction of subcompact cars to no mass reduction, limit the compact cars to 2% mass reduction, limit mid-size cars to 5% mass reduction, and limit large cars to 10% mass reduction. Other vehicle classes (i.e., light trucks) were permitted to utilize mass reduction by up to 20%. With these constraints, NHTSA indicated that the national fleet could see a safety-neutral 13% mass reduction. Ultimately, as indicated in this ARB regulatory assessment section above in Section 5.5, the final new vehicle fleet was projected to experience 8-10% mass reduction from 2008 to 2025. This reflects the above NHTSA-developed constraints, as well as all vehicle models not requiring the maximum allowable mass-reduction (due to use of engine, transmission, etc technologies) to comply with the GHG standards.

C. Description of Rationale for Mass Reduction Cost Relationship

To systematically base the rating system on technical engineering-based factors, the agencies developed and utilized a set of discrete criteria to evaluate the studies. The rating system establishes a quantitative assessment of the validity of different mass reduction studies and data from various technical and industry sources. In this meta-analysis framework, inclusion of all the data could be utilized in the agencies' overall relationship between mass reduction and its associated cost. Ultimately, the mass-reduction vehicle design studies are examined with respect to the following general formulation but allowing the flexibility for each agency to rate respective reports as they seem appropriate based on their expertise. The sections below summarize the studies that were examined, the development of the criteria and weighting factors, and the process to derive the agencies' mass reduction-cost relationship.

1. Mass Reduction Study Data Under Consideration

Table II-C-1-1 lists and summarizes basic details from the mass-reduction studies and the pages from which the data were found in the reports. The agencies catalogued each of the studies' basic details, including the baseline vehicle weight, the new designs' mass reduction (in lbs and percent), the associated cost, whether non-body components were considered directly or via compounding assumptions, and the dollar year of the study. Various technical studies employed different engineering approaches, investigated different mass-reduction concepts, and began with different baseline vehicles. The agencies view these differences as a strength of the research literature, to span vehicle platforms from compact cars to full-size trucks and to include mass-reduction concepts that range from component-scale near-term steel optimization to larger multi-material concepts.

Table II-C-1-1. Mass reduction studies included in development of mass-reduction-cost relationship

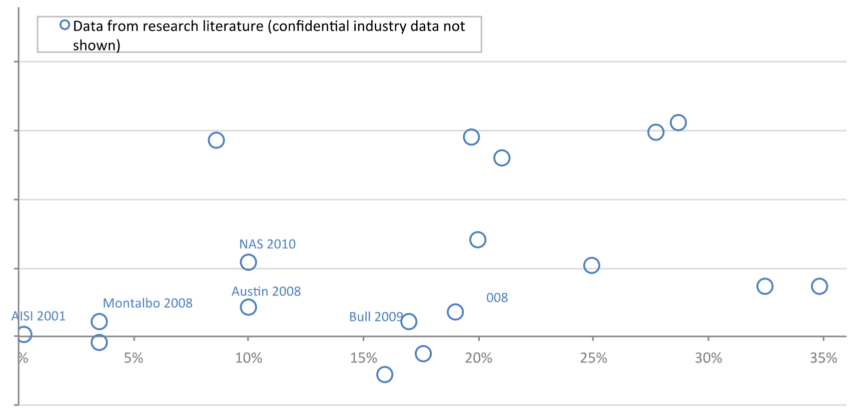
Study	Mass reduction (lb/vehicle)	Cost ($/vehicle)	Pages(s) from study
AISI, 1998 (ULSAB)	104	-32	1,53,60
AISI - ULSAC	6	15	6-9
Austin et al, 2008 (Sierra Research) Unibody -ULS	320	209	43,50,52
Austin et al, 2008 (Sierra Research) BoF -ULS	176	171	43,50,52
Austin et al, 2008 (Sierra Research) Unibody - AL	573	1805	43,50,52
Austin et al, 2008 (Sierra Research) BoF - AL	298	1411	43,50,52
Bull et al, 2007 (Alum Assoc.)	573	122	6,7
Cheah et al, 2007 (MIT)	712	646	6,28, 42
Das, 2008 (ORNL, AL)	637	180	8,13
Das, 2008 (ORNL, Glass-FRPMC)	536	-280	8,14
Das, 2009 (ORNL, Carbon-FRPMC)	931	1490	6,12
Das, 2010 (ORNL, Mg/Carbon-FRPMC)	1171	373	8,14,17
EEA, 2007 (Plus Mg) Mid-size vehicle	712	1508	6-3,6-10
EEA, 2007 (Plus Mg) Truck	657	1411	6-3,6-10
Geck et al, 2007 (Ford F150)	1310	500	10,11
Lotus, 2010 (Low Development)	660	-121	242,244,236
Lotus, 2010 (High Development)	1217	362	242,244,236
Montalbo et al, 2008 (GM/MIT) - AHSS	25	10	5,6
Montalbo et al, 2008 (GM/MIT) - AL	120	110	5,6
Montalbo et al, 2008 (GM/MIT) - Mg/Al	139	110	5,6
NAS, 2010	360	547	7-25,7-26
Plotkin et al 2009 (Argonne)	683	1300	41,204
Confidential OEM information (a)	*	*	
Confidential OEM information (b)	*	*	
Confidential OEM information (c)	*	*	

** confidential business information not shown*

Staff notes several very recent 2011 and ongoing studies that already could surpass technical rigor of those mentioned in the table and used in this scoring assessment. These studies are mentioned here. First, the updated version of the 2010 Lotus study is the on-going follow-on Lotus analysis that demonstrates enhanced safety-validated advanced mass-reduction technologies that reduce vehicle mass by 30%. This on-going Lotus study is being peer-reviewed and will be published in early 2012. Second, a new WorldAutoSteel (2011) study also offers a safety-validated vehicle design at no additional cost that offers an approximate 13-21% mass reduction. Due to the relatively late timing of these two new studies, they were not includes in the mass-cost assessment below.

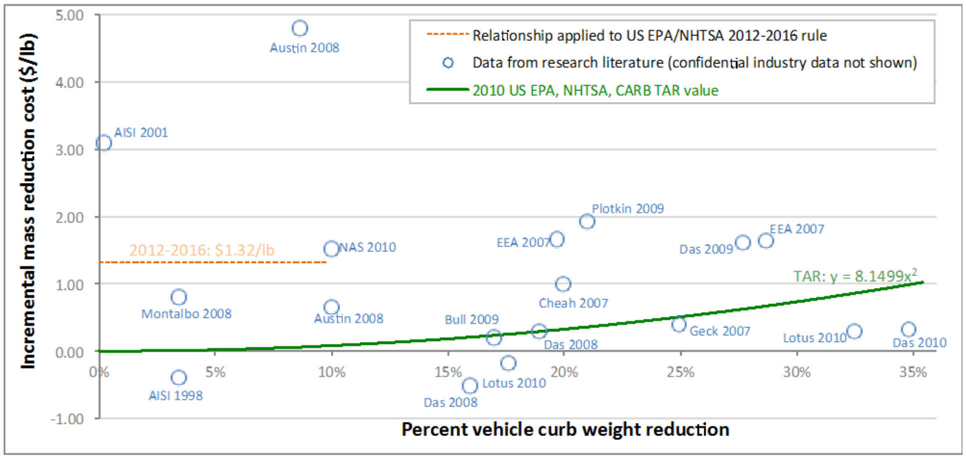
Several steps led to the processing of the data to make for comparable mass-reduction and cost estimations across the studies. When explicit baseline vehicle masses were not included, the assumed vehicle mass reduction of a car was 3600 lb and light truck 4000 lb. To arrive at the summarized data points, shown in Figure II-C-1-1, all the costs are converted into 2009 dollars, for consistency with all other costs in this assessment. Studies that did not include mass reduction compounding had it added, either according to each study's own assumption or with a 1.6 factor if the study did not suggest its own value. Each study was allowed up to two data points, but only under the condition that the study had two distinctly different vehicle mass-reduced redesign concepts (i.e., not minor deviations, approximations, or walk-ups from one common mass-reduced design concept). Note that confidential business information from auto manufacturing companies is not shown in the figure.

Figure II-C-1-1. Data on vehicle mass-reduction technology and associated direct incremental cost (industry data not shown)



The agencies had, in the past, used a cost-per-pound versus mass reduction percent relationship to assess the cost of future mass reduction. The relationship in the US EPA/NHTSA 2012-2016 rulemaking assumed a constant $1.32/lb for vehicle mass reduction up to 10%. Based on new information from various industry and literature sources since then, the joint-agency TAR in September 2010 modified the relationship to begin at the origin and have increasing cost with increasing mass reduction. The two past relationships, as well as the various data points from the literature, are shown in Figure II-C-1-2.

Figure II-C-1-2. Data on percent vehicle mass-reduction and cost-per-pound, and mass-cost relationship used in joint-agency TAR analysis (industry data not shown)



2. General Formulation

The agencies scoring framework involves evaluating each study according to a series of particular straightforward technical questions about validity and rigor, and appropriateness. The system of scoring involves three core areas that were determined to be critically important. Because the question of interest was to determine the future cost of deploying mass-reduction technologies, the first two factors involve assessing validity of the technical design and validity of the engineering cost estimation. A third area, a peer review, was added as a way to give additional weighting to studies that had gone through more extensive vetting through independent expert review. Subcomponents of the three areas are listed in Table II-C-2-1, and these are described in greater detail below. The three primary criteria are combined multiplicatively (i.e., not with simple addition) in order to more severely de-weight any particular technical work that was found to be deficient in any one of the areas. As a result, the final weighting of each study (W_{study}) is determined by the following equation.

$$W_{study} = W_{design} \times W_{cost} \times W_{Peer\ Review} = Final\ Score$$

Table II-C-2-1. Summary of three primary weighting criteria for mass-reduction study evaluation

Technology and design (W_{design})	Cost estimation (W_{cost})	Peer review ($W_{peer\ review}$)
• *Comprehensiveness of study (up to 20% of W_D)* • *Methodology technical rigor (10% of W_D)* • *Design validation (up to 30% of W_D)* • *Manufacture validation (up to 15% of W_D)* • *Appropriate timing of mass-reduction technologies (up to 25% of W_D)*	• *Complete cost analysis (65% of W_C)* • *Methodology cost rigor (35% of W_C)*	• *Complete peer review (100% of $W_{Peer\ Review}$)*

3. Technology and Design Considerations (W_{design})

As introduced above, the mass-reduction studies' technical design, encapsulated in the weighting factor W_{design}, is one of the three primary factors examined in the multiplicative scoring framework. Within this technical design area, the studies' mass-reduction designs are evaluated according to a series of five more detailed technical questions in order to better delineate more appropriate mass-reduction cost data from the overall body of research. The technology and design factors that the agencies considered as part of the technical design validity of the studies are (1) full-vehicle comprehensiveness, (2) methodology technical rigor, (3) design validation, (4) manufacture validation, and (5) appropriate technology timing. The logic behind including these design factors, and the system of scoring for each one, are described below.

The first component of the evaluation of the technical design refers to whether the study comprehensively examined the potential for mass-reduction in the entire vehicle. The inclusion of this factor is based on the fact that over the 2017-2025 timeframe, automakers would have the applicable lead-time to redesign all the major parts of the vehicle. In following with the 2010 NAS report, "Although material substitution for components can occur throughout the life cycle of a car in many cases, the mass saved in this way is relatively minor. . . . A reengineered vehicle allows for changing the design of major subassemblies (engine compartment, closure panels, body sides, etc.), thus allowing for entirely new approaches to reducing mass." As a result, studies that considered the reengineering of all of the physical systems of the vehicle would more aptly cover the full technology potential over the span of the rulemaking. This distinction was made on account of the various studies in some cases examining relatively small fractions of vehicles, some studies holistically modeling all major vehicle systems (e.g., including the body, chassis, suspension, powertrain, closures, interior), and many studies analyzing some partial amount of the total vehicle possibilities. Therefore, this criterion credits the extent to which studies address complexities of multiple-system mass-reduction design integration. The scoring for this criterion is out of 20% and is shown in Table II-C-3-1.

Table II-C-3-1. Design factor scoring for comprehensiveness of study

Question: *To what extent has an entire vehicle been studied for redesign to reduce mass?*	Score
A. Entire vehicle (Systems redesigned greater that 75 % of total vehicle mass resulting in mass reduction greater than 15%) or Major system (e.g., body-in-white) with engineering analysis and calculation of secondary mass compounding.	20%
B. Major system (e.g., body-in-white) or mass reduction of at least 5% of vehicle mass.	15%
C. Minor system (e.g. closures) or accounting for 3% to 5% vehicle mass reduction.	10%
D. Component mass reduction (e.g. wheel) or less than 3% vehicle mass reduction.	5%
E. Unknown or unclear	0%

The second component of the technical design evaluation relates to the level of methodological and technical rigor of each of the mass-reduction studies. This criterion helped to differentiate studies that employ greater technical rigor using best-available engineering approaches, versus studies that do not employ such rigor, use simpler analytical methods, and do not transparently elucidate their methods and assumptions. A number of studies are derivative upon other works and simply cite other existing primary technical work, whereas other studies show levels of detail that are comparable to that employed by automakers as they develop new models. Therefore the agencies determined that it was critical to emphasize fundamental technical engineering sources that demonstrate highly detailed mass-reduced vehicle designs and offered sufficient supporting engineering data to examine the vehicle design, materials chosen, packaging and joining techniques, and analytical methods. This criterion helps evaluate the relative feasibility of each studies' design and provides a higher relative score to studies that offer greater levels of detail on the precise materials, masses, geometries, and grades utilized across components. For the scoring of this criterion, it was decided that judgment may be exercised in determining the degree to which confidential business information submitted by an automaker should be considered as equivalent to a study that qualifies for given score. The scoring for this criterion is out of a maximum of 10% and is shown in Table II-C-3-2.

Table II-C-3-2. Design factor scoring for methodology technical rigor

Question: *Does the study analyze the mass- reduction technologies (e.g., materials, designs, joining techniques) in a technically rigorous matter and present its methods and results transparently? **	Score
A. Completely transparent with technical design and engineering specification with use of best available analytical methods	10%
B. Nearly complete transparency with technical design detail, sound methods	8%
C. Some technical design detail/rigor, unclear methods	6%
D. Based on other verifiable technical data or studies	4%
E. Design relies mainly on other studies, rules-of-thumb, and simple scaling methods	2%
F. No technical rigor or methodology is unclear or insufficient	0%

* *Judgment may be exercised in determining the degree to which CBI submitted by an OEM or supplier should be considered as equivalent to a study that qualifies for this score*

The third component of the technical design evaluation is the level of validation of the mass-reduction studies' design. Generally this criterion is established to score the studies on the depth of their studies' validation of new mass-reduction technology on all of the customary engineering performance characteristics of modern vehicles. Within this component are several critical considerations. It is important that the studies' mass-reduction concepts have been proven in actual automotive applications and/or through associated engineering analytical tools for simulation and design. The extent to which mass-reduction materials and designs have already been implemented in emerging, low-volume designs offers evidence that the proposed mass reduction solutions have been validated for major vehicle-level functional objectives and potential manufacturing concerns. Complete engineering validation would include satisfactory consideration of design, validation for crashworthiness, NVH, vehicle utility attributes (e.g., towing and acceleration), ergonomics, durability, and serviceability. The level of meeting this criterion ranges from real-world validation on production vehicle models, to demonstration and prototype testing, to pre-production analytical simulation via computer-aided engineering tools, to more simple conceptual design. If the mass-reduction studies' materials and design technology are well understood to meet all the validation factors, the study achieves the maximum possible score. Studies for which there is the greatest concern or uncertainty about the validation of its design would get the lowest score. Because this criterion about validation applied differently to different vehicle components or systems (e.g., closures need not be separately validated for acceleration performance), this criterion was scored according to the relative amount of applicable metrics. For the scoring of this criterion, it was decided that judgment may be exercised in determining the degree to which confidential business information submitted by an automaker should be considered as equivalent to a study that qualifies for a given score. The scoring of this criterion is out of a maximum of 30% and is shown in Table II-C-3-3.

Table II-C-3-3. Design factor scoring for design validation

Question: *To what extent have the results of the study been validated and how many vehicle functional objectives (below) were considered?*	Score
• For comprehensive vehicle studies, the following metrics will be used: (1) design concept, (2) safety, (3) noise, vibration, harshness; (4) durability; (5) dynamics; (6) powertrain performance; (7) towing, if applicable; (8) aesthetics (fit and finish) and ergonomics; and (9) serviceability. • For system or component studies, identify the metrics applicable for the system or component(s), assess only those metrics • Compute the score as follows: Score = (# completed)/(# applicable) x (30%)	Up to 30%

The fourth critical technical design component is the manufacture validation. On account of the rulemaking's focus on technologies for widespread applicability in the 2017-2025 timeframe, this criterion was established to score studies on the feasibility of their engineering designs to be mass-produced in high volumes for future vehicles. For example, technologies that have already demonstrated that they can be produced at very high volumes (i.e., at 200,000 units annually) with known manufacturing process would demonstrate the highest level of manufacturing readiness and therefore receive the highest score. Technologies that have only demonstrated low-volume production or prototype testing, or those with unproven manufacturability would get progressively lower scores for this criterion. For the scoring of this criterion, it was decided that judgment may be exercised in determining the degree to which confidential business information submitted by an automaker should be considered as equivalent to a study that qualifies for a given score. The scoring of this criterion is out of a maximum of 15% and is shown in Table II-C-3-4.

Table II-C-3-4. Design factor scoring for manufacture validation

Question: *To what extent are the technologies validated for manufacturability?*	Score
A. Mass reduction solution(s) are in high volume (>200k/year) production today or uses a demonstrated high volume manufacturing process.	15%
B. Mass reduction solution(s) are low volume (<50k/year) production today or uses a demonstrated low volume manufacturing process.	13%
C. Mass reduction technologies have been prototyped and tested.	10%
D. Concepts presented without validation of manufacturability.	5%
E. Mass reduction technologies deemed not valid for production.	0%

The fifth and final technical design component is appropriateness of the study technologies' timing. The focus of the regulatory analysis is to examine technologies' applicability to be implemented by 2025. Because the analytical reference point of the agencies' mass-reduction analysis is the model year 2008 fleet, any technologies that have the potential to go from no use in model year 2008 to 100% deployment in model year 2025 would achieve the highest score. Studies with technologies that had less applicability, either because they were already partially adopted by 2008 or were only partially applicable in 2025, receive lower scores. For the scoring of this criterion, it was decided that judgment may be exercised in determining the degree to which confidential business information submitted by an automaker should be considered as equivalent to a study that qualifies for given score. The scoring of this criterion is out of a maximum of 25% and is shown in Table II-C-3-5.

Table II-C-3-5. Design factor scoring for appropriateness of technology timing

Question: *To what extent are the mass reduction technologies applicable for reducing the mass of vehicles from the baseline 2008 model year vehicles for the rulemaking period (model years 2017-2025)?*	Score
A. All technology of vehicle/system/component is applicable for the rulemaking period.	25%
B. Majority of technology (90% - 70%) in the study deemed feasible for the rulemaking period.	20%
C. Most of technology (70% - 50%) in the study deemed feasible for the rulemaking period.	15%
D. Some of technology (50% - 20%) in the study deemed feasible for the rulemaking period.	10%
E. Little of technology (<20%) in the study deemed feasible for the rulemaking period.	5%
F. Technologies have no relevance in 2008 to 2025 timeframe.	0%

4. Cost Considerations (W_{cost})

After technical design, the second core evaluation area is the quality of the mass-reduction studies' cost assessment. Each studies' ability to properly assess the true future cost of its mass-reduction technology related to the rigor of the analytical work as well as the comprehensiveness of the study to include all applicable costs of mass-producing the technologies in vehicles in the 2017-2025 timeframe. As such, the cost assessment had two components: (1) complete cost and (2) methodology cost rigor.

Through the agencies' examination of the studies, it became clear that many different studies included various stages of supplier and automaker costs in their ultimate findings on the cost of given material substitution and design optimization techniques. Ideally studies would evaluate the new incremental costs of materials, manufacturing, tooling, assembly, and direct labor with a completeness that is comparable to the full industry costs that would be impacted by the regulation. The various studies offered varying levels of cost completeness across these cost aspects, and were, as a result, scored according to their satisfactorily inclusion of each component. For the scoring of this criterion, it was decided that judgment may be exercised in determining the degree to which confidential business information submitted by an automaker should be considered as equivalent to a study that qualifies for given score. The scoring of this criterion is out of a maximum of 65% and is shown in Table II-C-4-1.

Table II-C-4-1. Design factor scoring for complete cost analysis

Question: *To what extent does the study consider all of the incremental direct manufacturing costs for the mass reduction technologies including material cost, piece cost, tooling, manufacture equipment, assembly, direct labor, etc?*	Score
A. Complete cost including material cost, piece cost, manufacturing equipment, tooling, assembly and direct labor	65%
B. Cost including material cost plus 4 out of 5 of the following categories: Piece cost, manufacturing equipment, tooling, assembly and direct labor	50%
C. Cost including material cost plus 3 out of 5 of the following categories: Piece cost, manufacturing equipment, tooling, assembly and direct labor	40%
D. Cost including material cost plus 2 out of 5 of the following categories: Piece cost, manufacturing equipment, tooling, assembly and direct labor	30%
E. Piece cost	20%
F. Material cost only	10%

Along with the studies' varying inclusion of full incremental costs, a separate cost components of methodological cost rigor was evaluated. Whereas some studies fundamentally based their analytical work on a completely torn down reference vehicle and known physical hardware for mass-reduced vehicle components, other studies relied more heavily on simpler analytical methods, rules-of-thumb, and other less-clear primary data. As a result this scoring criterion was established to differentiate studies that exemplified highest levels of rigor, detail, and transparency in their cost assessment from those that did not. For the scoring of this criterion, it was decided that judgment may be exercised in determining the degree to which confidential business information submitted by an automaker should be considered as equivalent to a study that qualifies for given score. The scoring of this criterion is out of a maximum of 35% and is shown in Table II-C-4-2.

Table II-C-4-2. Design factor scoring for methodology cost rigor

Question: *Is the mass reduction study transparent in its description of the methodology applied to determine the costs associated with the proposed mass reduction technologies?*	Score
A. Complete transparency with rigorous detailed cost modeling based on detailed teardown engineering data of both baseline and redesigned vehicle/system or component(s).	35%
B. Study relies on cost modeling with partial tear down engineering data of baseline vehicle	25%
C. Study relies on cost modeling with limited (another vehicle) or partial tear down engineering	20%
D. Cost is based mainly on other studies, rules-of-thumb, and simple scaling methods.	15%
E. Information on cost methodology is insufficient to be assessed	0%

5. Peer Review ($W_{peer\ review}$)

After evaluating the technical and cost areas of the studies, the final area that is separately assessed is the strength of the study's external review. This final evaluation provides relative weighting for studies that have offered up their study to greater scrutiny and satisfactorily responded to critiques from an external critical peer review process. This category was specifically utilized to ensure expert reviewers outside the government agencies had reviewed the studies and the studies assumptions, analytical methods, and conclusions. The agencies used the Office of Management and Budget (OMB) peer review guidelines to help establish the scoring. For this scoring criterion, lower levels of review included anonymous review in technical journals and academic reviews for which the agencies did not have access to the review results and the authors' response to the critiques. Higher levels of review included peer-reviewed technical journal articles and reports that went through OMB-type reviews. For the scoring of this criterion, it was decided that judgment may be exercised in determining the degree to which confidential business information submitted by an automaker should be considered as equivalent to a study that qualifies for given score. The scoring of this criterion is out of a maximum of 35% and is shown in Table II-C-5-1.

Table II-C-5-1. Design factor scoring for peer review

Question: *To what extent have the results of the study been peer reviewed and has the study effectively addressed critical technical, methodological, and cost issues related to the mass reduction technologies considered?*	Score
A. The study has been peer reviewed in a scientific journal (e.g. SAE) or in accordance with OMB Peer Review guidelines and the results of the review are fully reflected in the final report. The peer review report is publicly accessible or available to the agencies	100%
B. After review, it was determined that the study has been thoroughly peer reviewed (e.g. Scientific journal, SAE) or in accordance with OMB Peer Review guidelines and the results of the review are partially reflected in the final report. The peer review report is not publicly accessible.	80%
C. After review, it was determined that the study has been reviewed by technical experts, but review results are not publically available and it is unclear to what extent the review comments have been sufficiently addressed in the final report	70%
D. After review, it was determined that it is unclear whether the study was reviewed by any external experts, and whether the study has addressed any critical concerns	60%
E. The study has been peer reviewed and identified with fundamental deficiencies. The study was not revised or commented to reflect these concerns	50%

Putting all the components of the three core evaluation areas together, the overall scoring framework is shown in Table II-C-5-2.

Table II-C-5-2. Overall mass-reduction study evaluation scoring system

W_{design} Technology and Design Considerations					X	W_{cost} Cost factors		X	$W_{Peer Review}$
Comprehensiveness of Study	**Methodology Technical Rigor***	**Design Validation****	**Manufacture Validation ***	**Appropriate Technology for 2017***		**Complete Cost Analysis***	**Methodology Cost Rigor**		**Peer Review***
To what extent has an entire vehicle been studied for redesign to reduce mass? A. Entire vehicle (Systems redesigned greater that 75 % of total vehicle mass resulting in mass reduction greater than 15%) or Major system (e.g. BIW) with engineering analysis and calculation of secondary mass compounding. 20% B. Major system (e.g. BIW) or MR>5%. 15% C. Minor system (e.g. Closures) or accounting for 3%-5% of vehicle mass reduction. 10% D. Component mass reduction (e.g. wheel) or less than 3% vehicle mass reduction. 5% E. Unknown or unclear 0%	Does the study analyze the mass- reduction technologies (e.g., materials, designs, joining techniques) in a technically rigorous matter and present its methods and results transparently? A. Completely transparent with technical design and engineering specification with use of best available analytical methods. 10% B. Nearly complete transparency with technical design detail, sound methods. 8% C. Some technical design detail/rigor, unclear methods. 6% D. Based on other verifiable technical data or studies. 4% E. Design relies mainly on other studies, rules-of-thumb, and simple scaling methods. 2% F. No technical rigor or methodology is unclear or insufficient 0%	To what extent have the results of the study been validated and how many vehicle functional objectives (below) were considered? For comprehensive vehicle studies, the following metrics will be used. - Design concept -Safety -NVH -Durability -Dynamics -P/T performance -Towing (if app) -Aesthetics (fit-and-finish) and ergonomics -Serviceability For system or component studies Identify the metrics applicable for the system or component(s). Assess only those metrics Compute the score as follows: Score = (# completed)/(# applicable) x (30%)	To what extent are the technologies validated for manufacturability? A. Mass reduction solution(s) are in high volume (>200k/year) production today or uses a demonstrated high volume manufacturing process. 15% B. Mass reduction solution(s) are low volume (<50k/year) production today or uses a demonstrated low volume manufacturing process. 13% C. Mass reduction technologies have been prototyped and tested. 10% D. Concepts presented without validation of manufacturability. 5% E. Mass reduction technologies deemed not valid for production. 0%	To what extent are the mass reduction technologies applicable for reducing the mass of vehicles from the baseline 2008 model year vehicles for the rulemaking period (2017-2025MY)? If the technology in the study is in widespread use by 2008 or fundamentally infeasible by 2025, it will receive a reduced score. A. All technology of vehicle/system/component is applicable for the rulemaking period. 25% B. Majority of technology (90% - 70%) in the study deemed feasible for the rulemaking period. 20% C. Most of technology (70% - 50%) in the study deemed feasible for the rulemaking period. 15% D. Some of technology (50% - 20%) in the study deemed feasible for the rulemaking period. 10% E. Little of technology (<20%) in the study deemed feasible for the rulemaking period. 5% F. Technologies have no relevance in 2008 to 2025 timeframe. 0%		To what extent does the study consider all of the incremental direct manufacturing costs for the mass reduction technologies including material cost, piece cost, tooling, manufacture equipment, assembly, direct labor, etc? A. Complete cost including material cost, piece cost, manufacturing equipment, tooling, assembly and direct labor. 65% B. Cost including material cost plus 4 out of 5 of the following categories: Piece cost, manufacturing equipment, tooling, assembly and direct labor. 50% C. Cost including material cost plus 3 out of 5 of the following categories: piece cost, manufacturing equipment, tooling, assembly and direct labor. 40% D. Cost including material cost plus 2 out of 5 of the following categories: piece cost, manufacturing equipment, tooling, assembly and direct labor. 30% E. Piece cost 20% F. Material cost only. 10%	Is the mass reduction study transparent in its description of the methodology applied to determine the costs associated with the proposed mass reduction technologies? A. Complete transparency with rigorous detailed cost modeling based on detailed teardown engineering data of both baseline and redesigned vehicle/system or component(s). 35% B. Study relies on cost modeling with partial tear down engineering data of baseline vehicle. 25% C. Study relies on cost modeling with limited (another vehicle) or partial tear down engineering. 20% D. Cost is based mainly on other studies, rules-of-thumb, and simple scaling methods. 15% E. Information on cost methodology is insufficient to be assessed 0%		To what extent have the results of the study been peer reviewed and has the study effectively addressed critical technical, methodological, and cost issues related to the mass reduction technologies considered? A. The study has been peer reviewed in a scientific journal (e.g. SAE) or in accordance with OMB Peer Review guidelines and the results of the review are fully reflected in the final report. The peer review report is publicly accessible or available to the agencies. 100% B. After review, it was determined that the study has been thoroughly peer reviewed (e.g. Scientific journal, SAE) or in accordance with OMB Peer Review guidelines and the results of the review are partially reflected in the final report. The peer review report is not publicly accessible. 80% C. After review, it was determined that the study has been reviewed by technical experts, but review results are not publically available and it is unclear to what extent the review comments have been sufficiently addressed in the final report. 70% D. After review, it was determined that it is unclear whether the study was reviewed by any external experts, and whether the study has addressed any critical concerns. 60% E. The study has been peer reviewed and identified with fundamental deficiencies. The study was not revised or commented to reflect these concerns. 50%
20%	**10%**	**30%**	**15%**	**25%**		**65%**	**35%**		**100%**

** Judgment may be exercised in determining the degree to which confidential business information submitted by an automaker should be considered as equivalent to a study that qualifies for given score*

D. Weighting of the Studies

The scoring system described above was used to evaluate the studies. The agencies each independently evaluated the technical studies on mass-reduction. The result was that each study (and in some cases, two data points from several studies that had distinctly different vehicle redesign concepts) received different scores between 0% and 100%. For example, a study with a 40% score would effectively receive twice the weight of a study with a 20% overall score. Table II-D-1-1 shows the final overall scores from ARB staff (the other two agencies' evaluations are not shown).

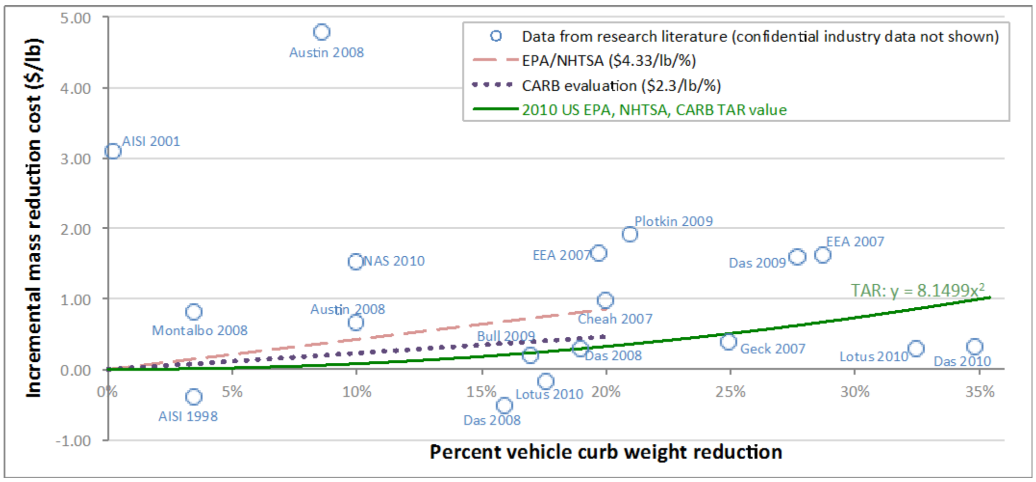
Table II-D-1-1. Mass reduction studies and final overall weighting of the study data

Study	Mass reduction	Cost ($/vehicle)	Cost ($/lb)	CARB overall weighting of data points
AISI, 1998 (ULSAB)	3%	-41	-0.40	27%
AISI, 2001 (ULSAC)	0%	19	3.08	12%
Austin et al, 2008 (Sierra) Unibody - Al	10%	211	0.66	12%
Austin et al, 2008 (Sierra) BoF	9%	1427	4.79	12%
Bull et al, 2007 (Alum Assoc.)	17%	114	0.20	19%
Cheah et al, 2007 (MIT)	20%	703	0.99	12%
Das, 2008 (ORNL, AL)	19%	182	0.29	29%
Das, 2008 (ORNL, glass)	16%	-283	-0.53	29%
Das, 2009 (ORNL, carbon)	28%	1490	1.60	27%
Das, 2010 (ORNL, Mg)	35%	371	0.32	29%
EEA, 2007 (car)	29%	1558	1.62	12%
EEA, 2007 (truck)	20%	1458	1.64	13%
Geck et al, 2007 (Ford F150)	25%	517	0.39	38%
Lotus, 2010 (Low)	18%	-120	-0.18	72%
Lotus, 2010 (High)	32%	360	0.30	35%
Montalbo et al, 2008 (GM/MIT) - Mg/Al	3%	111	0.80	17%
NAS, 2010	10%	545	1.51	4%
Plotkin et al 2009 (Argonne)	21%	1300	1.90	3%
Confidential OEM information (a)	*	*	*	5%
Confidential OEM information (b)	*	*	*	1%
Confidential OEM information (c)	*	*	*	3%

** confidential business information not shown*

These different scores were, in turn, used to proportionally weight the various data points for mass reduction percent versus mass reduction per pound ($/lb). As a result of the process, the three agencies generated three sets of scores for the mass-reduction technology data points. There was not consensus among the agencies about the mass-cost relationship. Based on the ARB evaluation of the studies, the mass-cost relationship was found to be $2.3/lb/%. The two federal agencies applied the same evaluation framework and had final mass-cost relationships that differed from one another by a factor of three. As a result of this assessment, it was decided that the federal agencies would use the average of the EPA and NHTSA results, or $4.33/lb/% to estimate the direct manufacturing costs of mass-reduction technology in the regulatory analysis. When it was understood that the federal agencies would not equally incorporate ARB scoring in their mass reduction cost estimation, ARB staff opted to apply its own evaluation of $2.3 per pound of mass reduction, per percent vehicle mass reduction. Figure II-D-1-1 illustrates the resulting constrained linear curve fits from the agencies.

Figure II-D-1-1. Agencies' weighted mass-reduction-cost relationships based on evaluation of the research data



As a result of the differing mass reduction cost relationships of the agencies, the overall incremental costs in the technology packages and the relative cost-effectiveness of ranking of the various technologies (aerodynamics, engine, transmission, mass reduction, etc) were impacted slightly. However the ARB analysis ultimately found mass reduction technology of about 9% would likely be applied toward compliance with the 2025 standards. Because the ultimate utilization of these relatively low amounts of mass reduction, the difference in the particular $/lb/% relationships is quite small. Table II-D-1-2 shows the impact of a 9% mass reduction on a vehicle with a 3800-lb curb weight (i.e., the approximate baseline average) with the ARB and federal mass-cost relationships. As shown, the difference between the ARB and federal cost in incremental price for this average amount of mass reduction for the average vehicle mass is only $77/vehicle. (i.e., $165 vs $88). However, at the higher levels of mass-reduction technology that a number of studies found technically feasible (e.g., 20-30% mass reduction), the price difference is more substantial. For example, for a 20% mass reduction, the ARB estimated incremental price in 2017 would be $486/vehicle, versus $915/vehicle based on the federal mass-cost relationship.

Table II-D-1-2. Incremental price of 9% and 20% mass-reduction from 3800-lb vehicle

Level of mass reduction	Mass-cost relationship	Mass reduction cost ($/lb/%)	Mass reduction (lb)	Indirect cost multiplier	Incremental price in 2017 ($/vehicle)
9%	ARB	2.3	342	1.24	88
	EPA/NHTSA	4.33	342	1.24	165
20%	ARB	2.3	760	1.39	486
	EPA/NHTSA	4.33	760	1.39	915

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