Changing Drivers

Appendix

Details on the Methodology, Assumptions and Results for the Value Exposure Assessment

1. Introduction

This appendix accompanies the report *Changing Drivers: The Impact of Climate Change on Competitivness and Value Creation in the Automotive Industry*, produced by SAM Research and the World Resources Institute (WRI). It is intended to be read in conjunction with the full report to provide further details on the methodology, assumptions and results from Chapter 4. Although *Changing Drivers* represents a collaboration between SAM and WRI, this document refers only to the Value Exposure Assessment performed by WRI.

2. Overview of the Methodology

The purpose of the Value Exposure Assessment is to identify the possible costs for Original Equipment Manufacturers (OEMs) to meet tighter CO_2 emissions (or fuel economy) standards by 2015. In the analysis, each OEM is characterized by its 2002 sales and corresponding fuel economy levels and has access to three main categories of lower carbon technologies – “incremental technologies”, hybrid and diesel. We then identify the lowest-cost combination of these technologies that an OEM must add to its existing vehicle fleet in order to meet specified new CO_2 emissions standards. Separate analyses are done for the US, EU and Japanese markets before being aggregated to produce an overall cost estimate for each OEM.

Because the future regulatory environment is uncertain, we assess both high and low scenarios for CO_2 emissions standards that may emerge between now and 2015 in the United States, European Union and Japan. The low scenarios represent CO_2 emissions standards (or fuel economy standards) already in place, while the high scenarios correspond to the possible future tightening of these regulations. The high and low scenarios are weighted equally in the analysis. In addition, because of the uncertainties of technological development and market acceptance of diesels and hybrids, we explore different limits to the market penetration rates of these technologies in each market.

Because OEMs’ vehicle sales and segment mix are assumed to remain fixed in the analysis, the results offer only a first-order indication of the magnitude of value loss facing each company. In practice, OEMs may be able to avoid some costs by shifting production into lower-carbon segments. However in the short and intermediate terms OEMs have limited flexibility to alter significantly the mix of vehicles they produce, and indeed, near-term production plans for some OEMs indicate that vehicles could on average become more carbon-intensive in the immediate future.

2.1 Scope of Analysis

We analyze ten leading OEMs: BMW, Daimler Chrysler (DC), Ford, GM, Honda, Nissan, PSA, Renault, Toyota and VW. We look at three major vehicle markets: the United States, European Union and Japan, which together account for nearly 70 percent of 2002 global vehicle sales. The analysis covers the period from 2003 to 2015 – a period in which major technological and policy changes are possible.

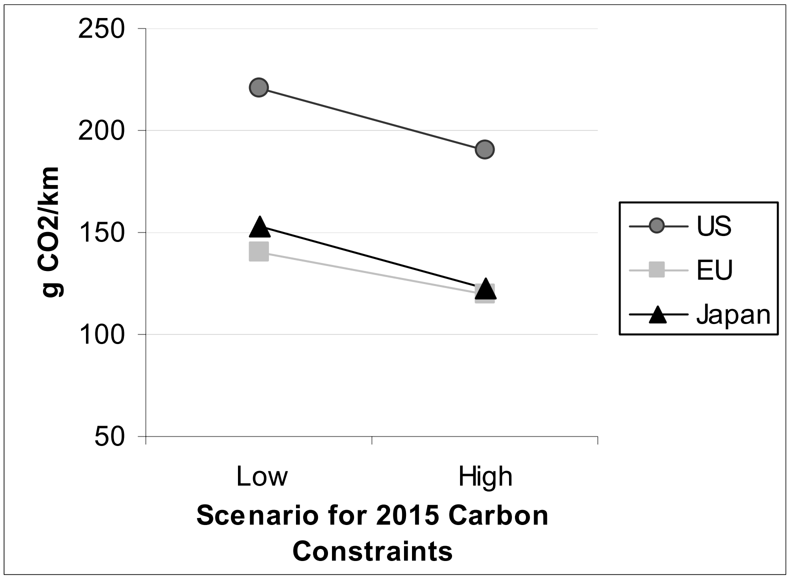
2.2 Scenarios for Carbon Constraints

The analysis is based on the assumption that the automotive industry will face progressively tighter CO_2 emissions (or fuel economy) standards over the next decade. To assess OEMs' risk from such developments, it is necessary to identify potential emissions standards in 2015 for the United States, European Union and Japan. For each market, we identified a "low" and a "high" level of emissions standards to explore uncertainties (see Table 1 and Figure 1).

Table 1: Details of Low and High Scenario Carbon Constraints in US, EU and Japan used in the Value Exposure Assessment

Market	**Low Scenario Carbon Constraints**		**High Scenario Carbon Constraints**	
United States	Cars	27.5 mpg (200 g/km)	Cars	33 mpg (167 g/km)
	Light trucks	22.2 mpg (249 g/km)	Light trucks	25 mpg (221 g/km)
European Union	Fleet average	140 g/km (39 mpg)	Fleet average	120 g/km (46 mpg)
Japan	Average for lightest four weight classes (i.e. cars):	158 g/km (35 mpg)	Average for lightest four weight classes (i.e. cars):	120 g/km (46 mpg)
	Average for heaviest two weight classes (essentially light trucks)	263 g/km (21 mpg)	Average for heaviest two weight classes (essentially light trucks)	194 g/km (28 mpg)

Figure 1: Comparison of Low and High Scenario Carbon Constraints in US, EU and Japan



The following describes the assumptions behind the two levels selected for each market:

United States

For the United States, scenarios reflect significant uncertainty about how and whether carbon constraints may develop. In April 2003, the United States tightened its CAFE standards for light trucks to 22.2 mpg (249 g CO_2/km) from 20.7 mpg (267g CO_2/km), representing the first change in standards in nearly ten years. However, fuel economy standards for passenger cars may not change before 2015. Bills proposing tighter standards for passenger cars have repeatedly been rejected by the US Congress, while both the Administration and Congress have shown little willingness to introduce specific policies to address climate change.

On the other hand, some recent developments argue for the possibility of significantly tighter carbon constraints for passenger cars by 2015. California has passed a law that will regulate CO_2 emissions from vehicles by 2009, and other states have shown interest in emulating this approach. In addition, continued energy security concerns may advance CAFE standards by 2015. Finally, a recent National Academy of Science (NAS) review of the CAFE program identified a CAFE standard of 33 mpg (167 g/km) for cars and 25 mpg (221 g/km) as a level which would create significant economic benefits to the United States in terms of fuel savings exceeding additional manufacturing costs. [1]

Consequently, the US "low" scenario reflects the possibility that CAFE standards will continue to face significant opposition and that there will be no further increases in fuel economy before 2015 beyond the recent incremental change for light trucks. In this scenario, the fuel economy standard for cars remains at 27.5 mpg, while the standard for light trucks rises to the 22.2 mpg level mandated for 2007 but remains steady thereafter.

For the US "high" scenario, we based the fuel economy standards on the levels identified by the NAS that would lead to the greatest overall economic benefit for the nation. The standards for 2015 are 33 and 25 mpg (167 and 221 g CO_2/km) for cars and trucks respectively. These higher standards are also in line with the levels that would be achieved in 2015 if the trajectory of the current CAFE increase of 1.5 mpg for light trucks was continued beyond 2007 and applied to cars as well. For perspective, even the "high" scenario is considerably more lax than the *current* standards in the EU and Japan.

Finally, the distinction between imported and domestic vehicles was assumed to be removed by 2015 for both scenarios. Furthermore, the current vehicle weight cut-off for CAFE of 8,000 lbs was assumed to be removed so that all passenger vehicles are regulated under the fuel economy standards.[2]

European Union

The European Union is committed to reducing its CO_2 emissions to meet the requirements of the Kyoto Protocol and intends to introduce an EU-wide cap and trade system for GHGs by 2005. To address vehicle emissions (which will not be covered by the cap and trade system), the EU encouraged the European auto industry (represented by the Association des Constructeurs Européens d'Automobiles (ACEA)) to establish a voluntary target for overall vehicle emissions.

The resulting "ACEA agreement" initially calls for an industry-wide fleet average of 140 g/km (39 mpg) by 2008. Depending on progress towards this target, the industry hopes to transition to a second target of 120 g/km (46 mpg) by 2012. These two goals are used in our analysis as the EU "low" and EU "high" scenarios respectively.

To date, the industry has not disclosed the working structure of the ACEA agreement, creating marked uncertainty for investors about its financial implications. For this analysis, we assumed in both scenarios that the target would eventually be binding on each OEM's fleet. A binding target reflects the strong interest of EU regulators in seeing the agreement succeed and their likely willingness to step in if it does not. If so, it is plausible to imagine a system that places equal responsibilities on individual OEMs, whether it requires each to meet the standard through emissions reductions in its own fleet or whether the standard can be met through some form of trading among OEMs of CO_2 reduction credits. Thus, until the structure of the agreement is fully disclosed, investors will remain uncertain about the financial consequences for OEMs: while a CAFE-like structure of a single target for all OEMs would reward companies currently producing vehicles that are the least carbon-intensive, a structure based on proportionate reductions from current starting points would have the opposite effect.

Japan

Japan has committed to reducing its GHG emissions to 6 percent from the 1990 index level for the 2008-2012 implementation period. To honor its commitment to the Kyoto Protocol, the Japanese government has mandated that the transportation sector reduce its CO_2 emissions by 17 percent below the projected rate for 2010. Automobile related emissions currently account for 20 percent of Japan's total GHG emissions.

In 1998, the Japanese government increased fuel economy standards by approximately 23 percent relative to 1995 levels for 2010. The specific levels are determined by six weight classes. This regulation forms the basis of the Japan "low" scenario, where we aggregate the weight classes into vehicle types for modeling purposes. Specifically, the lightest four weight classes are classified as "cars" while the heaviest two classes are considered "trucks".

For Japan, we evaluated the Japan "high" scenario in which the fuel economy improvements currently in place for 2010 were renewed for 2015. This would essentially mean a 46 percent increase in fuel economy from 1995 for 2015. Although this level appears quite stringent, it is actually below what would be required to achieve the Japanese government's long term goal of having an average fleet fuel economy of 48 g CO_2/km (115 mpg) by 2025. Furthermore, many of the Japanese OEM's vehicle sales were already in compliance with the 2010 standards by 2002, giving scope for more stringent fuel economy standards in the next twelve years.

2.3 Characterization of OEMs

Each OEM was characterized in terms of vehicle sales in seven separate segments for each of the three main markets. OEMs have different initial fuel economy (or carbon intensity levels) for each segment (see Table 2).

Table 2: Global Sales and Fuel Economy Levels in 2002, by OEM
(Sales in thousands of units; fuel economy in mpg)

		Sub	Compact	Midsized	Large	Minivan	SUV	Pickup
BMW	sales	130,207	466,151	21,957	179,692	0	81,456	0
	mpg	30.8	26.2	20.7	22.1	--	17.6	--
DC	sales	109,235	152,300	857,471	650,714	451,125	754,517	527,646
	mpg	46.9	34.2	23.1	22.0	19.3	17.9	16.9
Ford	sales	135,838	340,853	1,594,222	897,020	239,483	973,069	1,046,564
	mpg	35.9	40.1	27.0	21.4	20.8	16.6	16.2
GM	sales	93,518	329,394	1,741,626	1,030,751	283,694	1,381,850	985,163
	mpg	36.6	36.7	27.7	23.0	20.6	16.3	14.4
Honda	sales	195,152	293,029	1,016,680	1,189	349,203	315,937	0
	mpg	41.5	41.0	28.7	19.3	21.6	23.0	--
Nissan	sales	20,971	212,578	493,443	77,790	136,116	134,721	42,667
	mpg	40.0	41.9	26.6	23.2	37.2	20.2	18.9
PSA	sales	0	946,190	1,090,954	23,302	12,814	0	0
	mpg	--	35.6	31.5	26.3	26.2	--	--
Renault	sales	118,838	536,687	766,805	79,490	143,895	107,583	34,072
	mpg	40.0	42.9	30.0	23.8	34.2	20.2	18.9
Toyota	sales	27,039	546,889	909,433	875,564	527,473	578,423	264,610
	mpg	41.8	38.5	29.9	22.9	24.8	20.7	18.4
VW	sales	90,736	750,470	2,074,185	132,717	80,581	8,488	1,594
	mpg	37.5	36.4	28.4	23.3	23.4	18.6	32.1

Note: Sales includes sales in US, EU and Japanese markets only.

Sales data are from US and European editions of *Automotive News* and the Japan Automobile Dealers Association,[3] (which only includes domestic production in Japan). Data on fuel efficiency were obtained from the US Environmental Protection Agency and Department of Energy for US sales, from the German Federal Motor Transport Authority for EU sales, and from various company and industry data sources for Japanese sales.

OEM sales data include sales from subsidiaries in proportion to their ownership stakes. Hence, for example, a share of Mitsubishi's sales are included in DC's sales and similarly for Mazda and Ford. In addition, the figures reflect the current cross-ownership between Renault and Nissan. Renault owns 44 percent of Nissan while Nissan owns 15 percent of Renault. Hence, in some of the charts, Renault is shown as having sales in the United States and Japan, which essentially reflect Renault's share of Nissan's sales.

CO_2 emissions rates and fuel economy figures refer to "on road" levels as opposed to test levels. On road levels are considered to be a more accurate representation of the emissions rates and fuel economy realized in practice compared to official tests which tend to overestimate emissions and fuel economy performance.

2.4 Technology Costs

Between now and 2015, we assume that OEMs will have access to three core types of carbon-reducing technologies, including “incremental technologies”, hybrid and diesel technology:

- **Incremental technologies** refer to a wide range of technologies already or imminently available that can improve fuel economy through changes to the engine (e.g. valve timing, cylinder deactivation etc.), the transmission (e.g. 5-speed automatic, continuously variable transmissions etc.) and the vehicle (e.g. aero drag reduction, rolling resistance improvements etc.).
- **Hybrid** technology combines traditional combustion engines (potentially diesel or gasoline) with enhanced battery power to achieve significantly higher levels of fuel economy.
- **Diesel** engines, already widely used in heavy trucks worldwide and in European car and light truck markets, permit fuel combustion at efficiency rates 10 to 30 percent higher than their gasoline counterparts.

We ignore fuel cells as a technological option in the analysis because we think it unlikely that they will have sufficiently penetrated vehicle markets by 2015.

These technologies will have different costs in terms of dollars required to generate a specific CO_2 reduction. In addition, the costs of a same technology will vary across different vehicle segments (e.g. hybridization may be more expensive on pickups than smaller cars) and in some cases by OEM (e.g. Toyota and Honda should be able to add hybrid technology at lower cost than other OEMs given their head start in this technology).

Incremental Technology Costs
Cost information on incremental technologies forms the basis of the cost curves. We used cost data from the recent NAS study that reflects both *existing* technologies and *emerging* technologies that should be available by 2015.[4] These include engine technologies (e.g. variable valve timing and cylinder deactivation), transmission technologies (e.g. continuously variable transmissions) and vehicle technologies (e.g. drag reductions and integrated starter/generators) (see Table 3).

Table 3: Cost and Fuel Efficiency Improvement by Technology

Improvement as percentage decrease in fuel consumption

	Improvement %		Retail Price Equivalent	
	Low	High	Low	High
Engine Friction Reduction	1%	5%	$35	$140
Low Friction Lubricants	1%	1%	$8	$11
Multi-Valve, Overhead Camshaft	2%	5%	$105	$140
Variable Valve Timing	1%	2%	$35	$140
Variable Valve Lift & Timing	3%	8%	$70	$210
Cylinder Deactivation	3%	6%	$112	$252
Engine Accessory Improvement	1%	2%	$84	$112
Engine Supercharging & Downsizing	5%	7%	$350	$560
5-Speed Automatic Transmission	2%	3%	$70	$154
Continuously Variable Transmission	4%	8%	$140	$350
Automatic Transmission w/ Aggressive Shift Logic	1%	3%	$0	$70
6-Speeds Automatic Transmission	1%	2%	$140	$280
Aero Drag Reduction	1%	2%	$0	$140
Improve Rolling Resistance	1%	2%	$14	$56
5% Safety Weight Increase	0%	0%	$0	$0
Intake Valve Throttling	3%	6%	$210	$420
Camless Valve Actuation	5%	10%	$280	$560
Variable Compression Ratio	2%	6%	$210	$490
Automatic Shift Manual Transmission (AST/AMT)	3%	5%	$70	$280
Advanced CVT's	0%	2%	$350	$840
42 Volt Electrical Systems	1%	2%	$70	$280
Integrated Starter/Generator	4%	7%	$210	$350
Electric Power Steering	2%	3%	$105	$150
Vehicle Weight Reduction			$210	$350

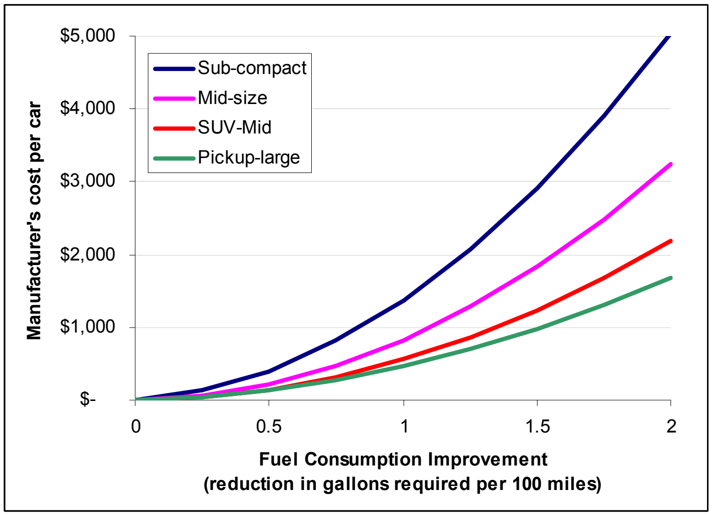
Source: NRC (2002).

For each technology, the NRC study documents the fuel consumption improvement and incremental increase in retail price equivalent (RPE) for ten separate vehicle classes. Following NRC, we used the average of the ranges expressed for both fuel consumption gains and incremental cost (the “NRC-mid” cost curves). Certain technologies, or technology combinations, were deemed unsuitable for particular vehicle segments, so each vehicle segment effectively has its own cost curve. We used the cost curves that corresponded to the 7 vehicle segments for which we had data on OEM sales (see Table 2 earlier).

The NRC cost curves were derived with input from automotive companies and industry experts. In addition, the NRC-mid cost curves fall approximately in the middle of a series of cost curves reviewed in a recent study prepared for the US Department of Energy.[5] The NRC-mid curve is marginally more pessimistic than the average curves from other studies for passenger vehicles, while the curve for light trucks is in the middle of the range.

Figure 2 shows illustrative cost curves for four of the seven vehicle segments that we assessed. An evident property of the cost curves is that the cost of a given fuel consumption gain is lower, the lower the initial fuel economy of the vehicle. Saving 1.5 gallons per 100 miles traveled can be achieved for roughly $1000 for pick-ups but $3000 for subcompact vehicles. Essentially, the latter vehicles are already fuel efficient, so further gains are harder to come by. (This property implies that less efficient OEMs may spend less per gallon saved in meeting new standards, even if they spend absolutely more than more efficient competitors to get to new targets).

Figure 2: Relative costs of fuel improvements across vehicle segments



The NRC study presents results in terms of RPE, which includes costs for systems integration, overhead, marketing, profit and warranty issues. To identify the manufacturing cost only that was required for our analysis, we applied a general discount factor of 0.71 to all of the NRC figures.[6] This assumes that all improvements have the same degree of cost overheads.

For incremental technologies, costs are assumed to be equal across all OEMs, reflecting the well understood and relatively well developed nature of those technologies. It is unlikely that there will be significant cost differences among OEMs in applying these technologies. Similarly, the technologies are not substantial enough to form the basis of new competitive advantage within the industry. In addition, though OEMs are at slightly different stages in introducing technologies such as continuously variable transmission and cylinder deactivation, we do not take account of these different starting points.

Diesel and Hybrid Costs

The underlying cost curves based on incremental technologies are modified in certain sub-scenarios by introducing diesel and hybrid powertrains as additional carbon-reducing technologies. These technology options were treated as cost points which were added to the incremental technology cost curves described above. The following outlines cost data for the diesel and hybrid scenarios:

Diesel Costs

Table 4 shows the costs and fuel economy improvements added to the cost curves for each segment. This data was derived from the data tables in the Energy Information Administration's (EIA) *Annual Energy Outlook 2003*. Specifically, the retail prices and fuel economy rates of diesel vehicles were compared with conventional gasoline-ICEs in the year 2015. The retail prices were reduced by 40 percent to derive the cost to manufacturer used in the cost curve.[7] We found these values to be consistent with Deutsche Bank estimates.

Table 4: Diesel Fuel Economy Improvements and Costs by Segment

	Subcompact	Compact	Medium	Large	SUV	Minivan	Pickup
Fuel Economy Improvement (%)	31	30	32	33	31	31	31
Cost ($)	870	840	1,260	1,350	1,170	1,260	1,170

Hybrid Costs

Table 5 contains the cost and fuel economy values for the hybrid technology cost points. These values were informed by a recent study from the Union of Concerned Scientists and reflect a "moderate" hybrid technology pathway.[8]

Table 5: Hybrid Fuel Economy Improvements and Costs by Segment

	Subcompact	Compact	Medium	Large	SUV	Minivan	Pickup
Fuel Economy Improvement (%)	58	58	58	71	68	72	58
Cost ($)	1,862	1,862	1,862	1,916	1,170	2,194	2,626

For hybrid and diesel scenarios, we assume that manufacturing costs vary among OEMs in accordance with different expertise and experience with these technologies to date, and the current technological focus. In essence, OEMs' differing abilities to develop and apply these new technologies could be a source of competitive advantage. Using results from SAM Research's Management Quality assessment in Chapter 5 of the main report, we ranked OEMs in terms of their expertise with diesel and hybrid technologies. Leaders in each group were assumed to be able to implement the new technology at a five percent cost reduction, while "laggards" were assumed to incur a five percent cost penalty. Table 6 shows how each OEM was ranked based on diesel and hybrid technology leadership.

Table 6: Ranking of OEMs by technological leadership

Technology	**Leaders**	**Neutral**	**Laggards**
Diesel	PSA VW	BMW DC Renault (Nissan) Toyota	Ford GM Honda
Hybrid	Honda Nissan (Renault) Toyota	DC Ford GM	BMW PSA VW

Source: Based on Management Quality Assessment in Chapter 5 of Changing Drivers report.

Whether diesel and hybrid technologies become widely implemented depends on a number of factors. Diesel for example must overcome adverse consumer perceptions in the US market even though it has been widely embraced in Europe. Moreover, there are questions regarding diesel's ability to meet tightening standards for nitrogen oxides and particulate matter in all 3 main markets. Similarly, while hybrid technologies do not face environmental trade-offs, they must win consumer acceptance before they can become mainstream.

To capture uncertainty about penetration rates of diesel and hybrids, we made two assumptions. First, ceilings are placed on the adoption rate of diesel and hybrid technologies reflecting likely production and market constraints on their penetration over a 12 year period (see Table 7).

Table 7: Maximum Diesel and Hybrid Penetration Rates by 2015, by Market

Market	Diesel penetration rate	Hybrid penetration rate
United States	20%	15%
European Union	65%	15%
Japan	n.a.	30%

Second, to reflect the possibility that diesel or hybrid technologies simply may not catch on in certain markets, we ran sub-scenarios for each main scenario restricting carbon reduction options to different technology combinations. For example, for the United States, we ran three sub-scenarios for incremental technologies only; incremental technologies plus diesel; and incremental technologies plus hybrid. Diesel appeared in all sub-scenarios for Europe but does not appear at all in sub-scenarios for Japan. We then averaged each OEM's cost results across the sub-scenarios for each market to attain the final result for the OEM in that market.

Though we included diesel and hybrid technologies in the analysis, it is worth noting that in all scenarios the use of incremental technologies to improve existing gasoline-ICE engines was capable of achieving virtually all of the required carbon reductions at lower cost than the use of diesel and hybrid technologies. This confirms what many have already shown, namely that piecemeal technologies that have already been developed could generate significant fuel economy and carbon emissions improvements.

2.5 Modeling and Cost Allocation

The least cost combination of relevant technologies across the seven vehicle segments was identified for each company for a single end-year, 2015. The technology costs and other parameters were selected to represent that year. We created the model in Microsoft Excel and used the Solver function to perform the optimization.

The initial result is the additional cost that an OEM would incur in producing today's vehicle mix to new carbon emissions standards in 2015. This is the main result reported for our scenarios below. However, to put these costs in the context of overall costs of goods sold and EBIT (earnings before interest and taxes), it was then necessary to make assumptions about what level of fuel economy might be achieved in intervening years and how costs would be spread over the years given that they reflect a mixture of one-off fixed costs and ongoing variable costs.

First, we assumed that fuel economy would improve in the years between 2003 and 2015 along a straight-line trajectory towards the identified final standard for each scenario. Consequently, OEMs would incur additional costs in making vehicles in the intervening years more efficient than they are today, even if those vehicles did not meet the standards assumed for the end year.

Second, we made assumptions about the mix of fixed capital and variable operating expenses. Though, the precise mix of fixed and variable costs will vary by technology option and by OEM, we assumed that fixed costs account for approximately a third of the total costs, in line with the industry's overall cost structure.[9] Consequently, a third of the total costs incurred in 2015 were assumed to be one-off capital costs that were evenly spread over the 2003-2015 time period. The remaining two-thirds of the costs were assumed to be operating costs incurred each year in proportion to the fuel economy standard achieved in each year. Adding the fixed and variable cost elements produced a stream of costs that would be incurred by OEMs in each year between 2003 and 2015.

2.6 Limitations of the Methodology

The main limitation of the current model is that vehicle sales by company and by segment are kept constant. This assumes that consumers will continue to buy the same types of vehicles from the same OEM. In practice, of course, as fuel economy levels (and potentially fuel prices) change over the decade, OEMs would be expected to gravitate towards more efficient vehicles and more efficient OEMs.

However, there are a number of reasons to expect that OEMs may be constrained in changing their segment mix. First, decisions about vehicle type are dominated by expectations regarding the use of the vehicle, such as passenger and load requirements, type of driving, etc. This limits substitution possibilities. Second, even where there is interest in fuel efficiency, survey results show that consumers would prefer to buy more fuel-efficient versions of their current vehicle rather than to switch to a more fuel-efficient vehicle type.[10] Third, the commitment to platforms and the time lags associated with production changes limit OEMs' ability to move rapidly in or out of segments.

In addition, a review of OEMs' near-term production plans reveals that some OEM fleets will become more carbon-intensive in the near future as they move to larger or more luxurious vehicles. Hence, holding segment mix constant at 2002 levels may *underestimate* cost impacts for some OEMs. Finally, some implications for sales and margins are reviewed in Section 5.

A second limitation is that the same cost curves were used for each OEM even though OEMs may already have adopted some of the technologies that make up the lower part of the NRC curve. With further research, it would be possible to create OEM-specific cost curves that would reflect the different starting points at which OEMs find themselves.

A third limitation is that the foundation of our cost curves are based on cost estimates derived for the US market. Though we were able to find similar information for the European market, this information was not disaggregated beyond cars and light trucks the way that the US information was. Consequently, we have applied the US-based estimates to the European and Japanese markets even though vehicles in those markets have higher current fuel economy levels (even after accounting for higher diesel usage in Europe). This may introduce error if the cost of adding carbon-reducing technologies to vehicles in Europe and Japan is markedly different than in the US.

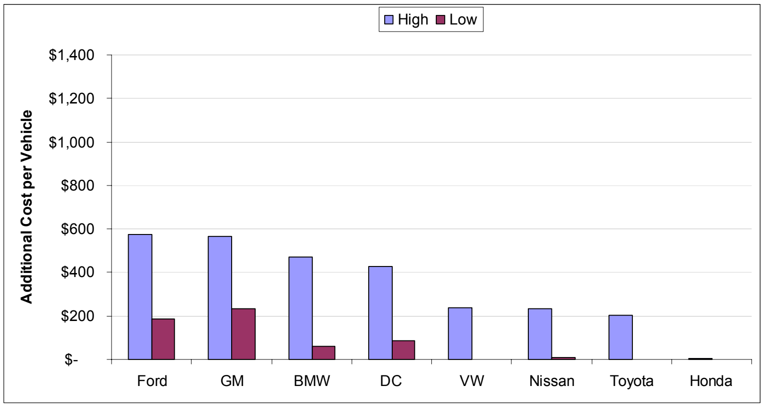
Finally, our analysis looks at initial costs only and does not attempt to quantify the magnitude of cost recovery that OEMs might achieve through price premiums and which would offset or outweigh the initial increase in costs. We discuss some of the implications for changes in margins in Section 5.

3. Market-specific results

3.1 United States

For the United States, we evaluated two scenarios as noted above. The costs of meeting a stricter CAFE standard vary widely between companies, because of the different vehicle mix and initial average fuel economy levels. (See Figure 3). Costs also differ depending on the assumed availability of hybrids and diesels. Costs are lower in scenarios where diesels and hybrids are available. The costs are presented in terms of additional cost per average vehicle to permit comparison between OEMs.

Figure 3: Cost per Vehicle of Meeting Higher CAFE Standards in the United States

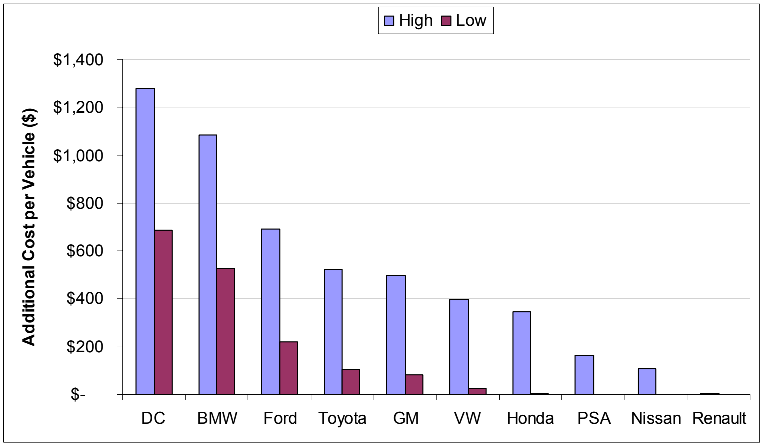


Note: OEMs not shown do not have sales in the U.S.

3.2. European Union

An important difference for the European market was the already high level of diesel vehicles in the market. In 2002, diesels accounted for 40 percent of sales and in the diesel scenario, we assumed that this level could increase to a maximum of 65 percent by 2015. This preference for diesel is due mainly to favorable tax regimes which establish lower prices for diesel fuel. Again, costs varied by OEM and depending on the technology that was available (See Figure 4).

Figure 4: Cost per Vehicle of Meeting Lower CO_2 Emissions Standards in the European Union



It is important to note that results in Figure 4 assume that the ACEA agreement will impose individual constraints on OEMs – either formally or informally. As such, costs are higher for OEMs whose vehicles currently have the highest carbon emissions rates.

However, reviewers pointed out that the precise structure of the ACEA agreement is unknown outside of the industry. While our interpretation of that structure was shared by a number of reviewers, at least one reviewer understood the commitment to require that each company make a uniform percentage improvement (UPI) in their carbon emissions rates such that the industry average emissions rate improves to the required 140 g CO_2/km. If ACEA intends to meet its commitment through a UPI approach, the relative implications for companies are quite different.

In particular, we found that assuming a UPI approach would change results in two ways:

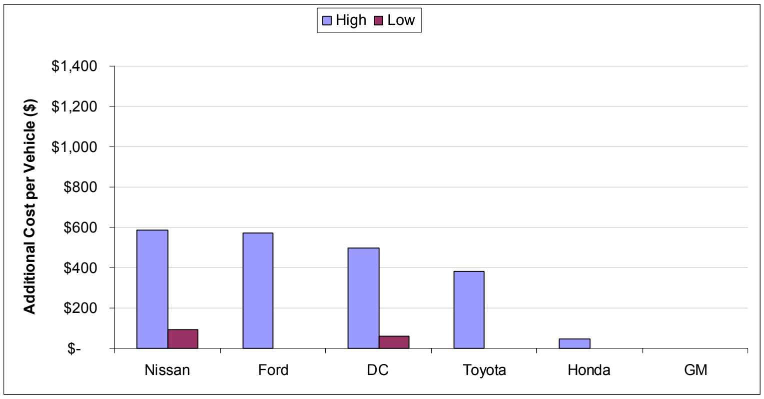
(i) It would reverse the relative ranking of OEMs. OEMs that are currently least efficient (or most carbon-intensive) would benefit by being able to adopt the lower cost carbon reduction technologies (or "low hanging fruit") that other OEMs have already introduced into their vehicles. In turn, the more efficient OEMs would have to turn to more advanced and more expensive carbon reduction technologies to achieve the same percentage improvement. Needless to say, a UPI structure has interesting implications as it essentially penalizes fuel economy leaders.

(ii) In general, the range of costs was much less varied across the industry. This reflects the relative lack of curvature in the cost curves.

3.3. Japan

The Japanese government has established a clear preference for hybrids over diesels. As a result, we look only at hybrids as an alternative technology for meeting the new standards (See Figure 5).

Figure 5: Cost per Vehicle of Meeting Lower CO_2 Emissions Standards in Japan



Note: OEMs not shown do not have sales in Japan.

4. Aggregate Results

The aggregate results of meeting new fuel economy standards are presented in different metrics:

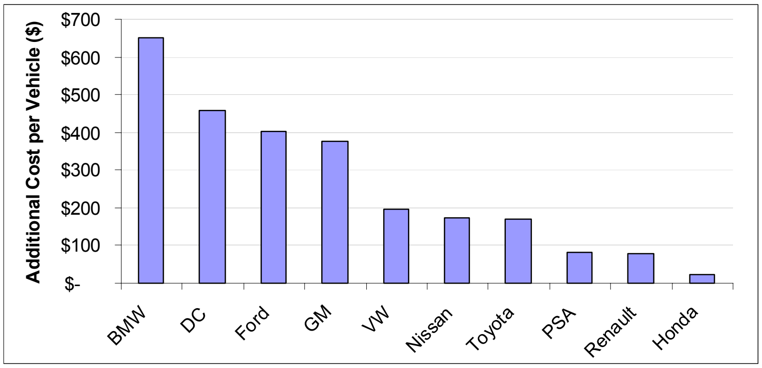
- Average cost per vehicle
- Total costs
- Impacts of cost on forecast EBIT (earnings before interest and taxes)

For some OEMs, their relative ranking against is influenced by which metric the results are presented in. This section explains how each result was derived and highlights some of the OEM-specific implications.

4.1. Average Additional Cost per Vehicle

Figures 3 to 5 above illustrate the average cost per vehicle impact in 2015 for each of the three main markets. We weighted the results for individual markets by OEMs' sales within each market to produce an average additional cost per vehicle for the three markets combined (See Figure 6). The average cost for the industry as a whole was $260 per vehicle. However, there was wide variation around that figure from $650 per vehicle for BMW to minimal costs of $24 per vehicle for Honda.

Figure 6: Aggregate Cost per Vehicle for Meeting Stricter Carbon Emission Standards in the United States, European Union and Japan ($)



4.2. Total Costs

In addition, we calculated the total costs in 2015 for each OEM. (See Table 8). Obviously total costs vary significantly, mainly because of the different size of OEMs.

Table 8: Total Cost of Meeting Stricter Carbon Emissions Standards in the United States, European Union and Japan ($millions)

BMW	571
DC	1,609
Ford	2,107
GM	2,205
Honda	53
Nissan	192
PSA	170
Renault	141
Toyota	634
VW	613

4.3 Implications of Costs on Earnings

In Chapter 6 of the main report, we converted our raw cost estimates for each OEM into estimated changes in (EBIT) earnings before interest and taxes – a key foundation of valuation in the industry. Setting our cost estimates in the context of existing and forecast business performance for each OEM adds confounding factors to our initial results. Nonetheless, one of the key insights for analysts to grasp is how carbon constraints may affect OEMs as they are currently configured and positioned.

We developed a simple model to forecast each company's discounted EBIT from the period 2003 to 2015. Information on recent years' cost and EBIT margins was combined with SAM forecasts for sales growth and changes in EBIT margins to derive a baseline EBIT forecast. ***It is important to recognize that this baseline reflects important business factors that go beyond the carbon constraints explicitly examined here***. For example, some OEMs, like GM and Ford, are expected to see slower than average sales growth in the coming years as others compete for their profitable light truck segment. Additionally, some OEMs such as BMW and Toyota are expected to command higher EBIT premiums in 2015 because of factors such as brand and quality.

To this baseline we then subtracted the expected stream of costs from baseline EBIT to derive a new value for the discounted EBIT between 2003 and 2015. The new value was compared with the baseline value and expressed as a percentage decline. Most significantly, this analysis lowers Ford and GM in the overall rankings because their weaker than average near-term financial prospects exacerbated by the additional costs of meeting carbon constraints. BMW improves further as the analysis takes account of its ability to command high margins for its vehicle, giving the company greater scope to tolerate additional costs. The results are shown in Table 9 below.

The EBIT discounted cash-flow model can be downloaded from either http://capmarkets.wri.org or http://www.sam-group.com/changingdrivers. This file allows the user to test sensitivities to our scenarios and/or to the underlying financial metrics we used for this report.

Table 9: Change in Estimated EBIT for Meeting Stricter Carbon Emission Standards in the United States, European Union and Japan (percentage change relative to baseline EBIT)

BMW	-3
DC	1
Ford	-10
GM	-7
Honda	3
Nissan	3
PSA	-2
Renault	4
Toyota	8
VW	-1

5. Further Implications for Sales and Market Share

It is uncertain how much cost increases could be passed on to customers. In the current atmosphere of highly competitive pricing among OEMs, the scope to pass on costs may be significantly limited. Consequently, cost increases could translate directly into lower EBIT margins. This is the simplest interpretation of these results and the one that is used for aggregating results in Chapter 6 of the main report.

While production cost increases are the most immediate manifestation of new carbon constraints, it may not be all bad news for OEMs. Efforts to lower carbon intensity could also create an upside opportunity for OEMs to enhance profits. Some OEMs may see vehicle sales increase, while all OEMs have an opportunity to increase margins if the benefits of fuel economy can be effectively marketed to the public.

5.1 Implications for Sales

Though vehicle pricing is currently very competitive, if the industry as a whole is facing pressure to lower carbon intensity, it is likely that average vehicle prices will rise as OEMs try to recoup costs. Moreover, over a 10 year period, there is ample scope for OEMs to raise vehicle prices - since 1970, the average amount that US consumers have been willing to spend on a new vehicle has increased by $229 each year.[11]

However, the combined efforts of OEMs to recover costs through higher prices may create new incentives for customers to switch vehicle segments and/or manufacturers. For example, if the full costs are passed on to consumers, we found that efforts to improve fuel economy in the US might lead to a nearly $540 increase in the average SUV price, but only a $280 increase in the average compact vehicle price. Though customers purchase different vehicle types for many reasons, the change in relative price could alter relative sales growth in segments over time.

Similar effects are true for OEMs. The price of an average vehicle sold in the United States by Ford (which has the lowest fleet average fuel economy in 2002) would rise by $800 in the high scenario to meet new standards while the price of an average vehicle sold by Honda (which has the highest average fuel economy) would rise by a mere $5. To recoup costs Ford will have to raise the price of its vehicles by more than the average OEM, while Honda will have to raise its price by only a negligible amount, and by considerably less than the average OEM. Consequently, one would expect Ford's sales to suffer, while Honda's might increase.

5.2 Fuel Economy Improvements and Scope for Higher Margins

Though fuel economy improvements initially entail higher production costs, the fuel savings generated more than offset those costs. Consequently, the value proposition of a new vehicle increases for the customer and could be a source of higher profits for all OEMs.

For example, for the US industry as a whole, the requirement to meet higher fuel standards in the high US Scenario leads to an average sales price increase of $587 per vehicle. However, the fuel savings that result in the first 5 years – the typical ownership period for new vehicle buyers – amount to $913, which more than offsets the cost increase.[12] Theoretically, if OEMs could induce consumers to recognize the value of fuel savings, then the consumers would perceive more efficient vehicles as more valuable than their current models. In turn, this might offer OEMs an opportunity to capture some of the fuel savings value created in the form of higher prices, thereby increasing margins.

Moreover, if the fuel economy gains in this example are achieved through hybridization, the consumer may see the final vehicle as having additional value because of the new features associated with a hybrid vehicle. This would create additional opportunities for the manufacturer to derive further profit through price premiums.

Contact Details:
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Endnotes

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[1] National Research Council , *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Washington D.C.: National Academy Press, 2002 p.42).

[2] Currently there are a small number of passenger vehicle models that exceed the weight limit and are not regulated under CAFE.

[3] Japan Automobile Dealers Association, *New Car Sales Statistics 2002* (Tokyo, Japan: December 2002).

[4] These are the "Path 3" costs in National Research Council (2002).

[5] Plotkin, Steven et. al., "Examining the Potential for Voluntary Fuel Economy Standards in the United States and Canada," Center for Transportation Research, Argonne National Laboratory (2002), p. 110.

[6] National Research Council (2002).

[7] This assumes that the retail price includes the 40 percent markup by OEMs.

[8] Friedman, David, *A New Road: The Technology and Potential of Hybrid Vehicles* (Cambridge MA: Union of Concerned Scientists, 2003).

[9] Deutsche Bank, *The Drivers: How to Navigate the Auto Industry* (Global Equity Research, July 31, 2002).

[10] JD Power and Associates, Interest in Hybrid Technology is High, Especially Among Women (Agora Hills, CA: March 6, 2002).

[11] DeCicco, John et al., "Technical Options for Improving the Fuel Economy of U.S. Cars and Light Trucks by 2010-2015" American Council for an Energy Efficient Economy, (2001) p. 49. Real $2000.

[12] This is for an assumed gas price of $1.45 per gallon over the next 5 years.