Automakers' Corporate Carbon Burdens

UPDATE FOR 1990-2003

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finding the ways that work

Cover photo: PhotoEdit, Inc. GMC Sierra pickup truck displayed at a car dealership.

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Environmental Defense is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because thy are nonpartisan, cost-effective and fair.

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Executive summary

Global climate change is one of the gravest environmental threats the world faces. Caused mainly by human activities that release greenhouse gases, global warming poses serious risks to ecosystems, economies and human health. Responding to the threat requires a concerted effort by all parties whose policies shape and drive energy use. Automobiles (cars and light trucks) are of primary importance in efforts to reduce greenhouse gas emissions, since burning motor fuel releases carbon dioxide (CO_2), the main heat-trapping gas. Automobiles account for 20% of the nation's CO_2 emissions and 62% of CO_2 emitted by the U.S. transportation sector, itself the largest source of greenhouse gas emissions in the United States.

Because the United States is the world's largest emitter of greenhouse gases, our automobiles account for a significant portion of the world's heat-trapping pollution—about 5% of the global energy-use related CO_2 emissions. Automotive CO_2 emissions are also linked to the nation's oil dependence, with car and light truck CO_2 emissions corresponding to the single largest portion (40%) of the nation's petroleum consumption.

Updating our 2002 study, *Automakers' Corporate Carbon Burdens: Reframing Public Policy on Automobiles, Oil and Climate,* this report analyzes the automobile's global warming impact in terms of *carbon burden,* a way of measuring the annual average CO_2 emissions over the life of a group of vehicles. Automotive carbon burdens are influenced by many parties, including public officials who finance and shape the transportation system, oil companies that supply motor fuel, automakers and consumers themselves. This report focuses on automakers because their product strategies have a profound influence on CO_2 emissions.

The effectiveness of any corporate action or public policy for cutting CO_2 emissions is ultimately measured by tons of carbon reduced, rather than the type of technology or fuel used. Similarly, the effectiveness of measures to reduce petroleum dependence is measured in terms of barrels of oil consumption avoided. By focusing on these bottom-line metrics of "barrels and tons" (of oil and carbon, respectively), this report provides a framework for accessing strategies to reduce the substantial and growing portion of greenhouse gas emissions and oil demand created by automobiles in the United States.

The report highlights new vehicle CO_2 emissions by automaker for the period 1990–2003. It also reviews the historical trend of total U.S. light vehicle carbon emissions, analyzing the on-road stock of all vehicles, both new and used, during the period 1970–2003. We focus here on the CO_2 emitted when cars are driven. CO_2 and other greenhouse gases are also emitted during the manufacture of cars and components, accounting for about 11% of the total "cradle-to-grave" emissions associated with automobiles. The remaining 89% is essentially proportional to the amount of fuel cars burn, although about 30% of these emissions occur at petroleum refineries and elsewhere in the fuel supply chain.

National trends in automotive carbon emissions

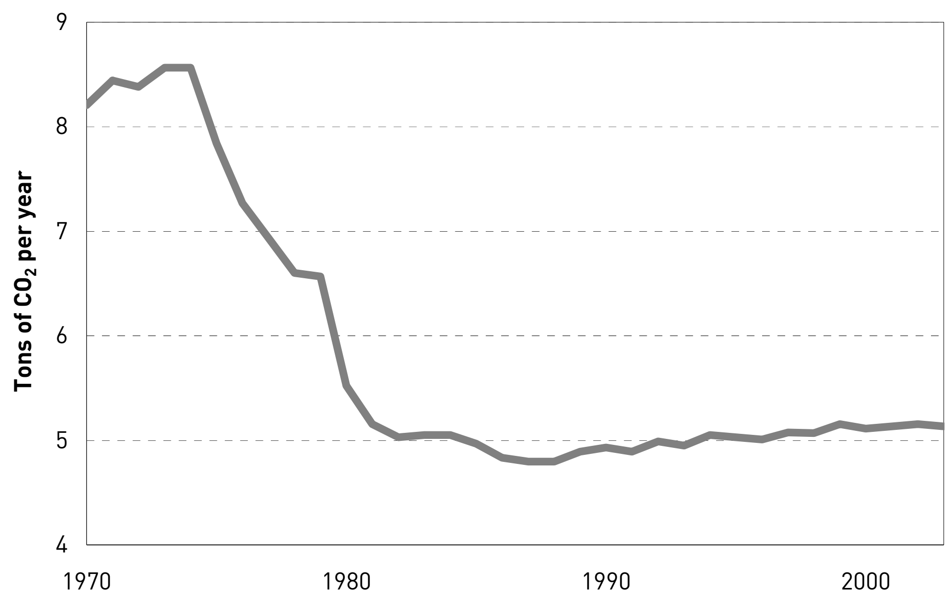
Automobiles are the largest source of U.S. greenhouse gas emissions where we are seeing no improvement. The total quantity of CO_2 emissions, as well as the average emissions rates of all automakers' fleets, continue to rise despite notable changes in factors thought to influence emissions. In particular, the past five years have seen much higher gasoline prices than 1990–98 as well as remarkable progress in automobile technology, highlighted by the introduction of hybrid-electric cars. However, as shown in Figure ES1, these trends have made little difference in new fleet CO_2 emissions rates. In fact, annual sales of even a million hybrids—which some analysts now foresee as soon as 2010—would not suffice to offset even half the increase in CO_2 emissions and oil dependence observed in the auto market between 1990 and 2003.

INCREASING TRAVEL AND STAGNATED CAFE STANDARDS

Total U.S. car and light truck carbon emissions—the sum of emissions for both new and used vehicles—topped 317 million metric tons of carbon (MMTc) in 2003. This CO_2 emissions level is equivalent to 8.6 million barrels of gasoline consumption per day, or 132 billion gallons per year. It represents net growth of 64% from 1970 and a 25% increase from the 1990 level, a common base for climate policies. Nevertheless, the 64% growth in carbon emissions is much less than the 160% jump in vehicle miles of travel from 1970 to 2003 because of the rapid improvement in new vehicle fuel economy between 1974 and 1981.

This effect is also illustrated in Figure ES1, which depicts the changes in

FIGURE ES1
Average new car and light truck CO_2 emissions rate



Source: Derived from Hellman and Heavenrich (2004).

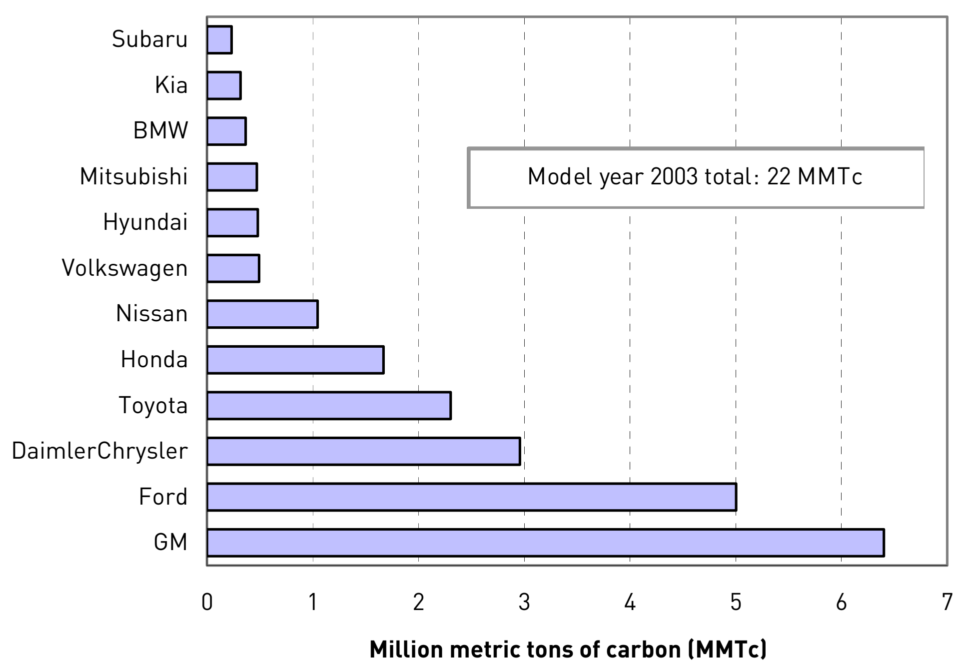
average new vehicle CO_2 emissions rate (an inverse of average fuel economy) from 1970 to 2003. The sharp decline in the average new vehicle emissions rate between 1974 and 1981 reflects the new vehicle fuel economy improvements that were driven by the oil shocks and Corporate Average Fuel Economy (CAFE) standards. From 1988 onwards, the emissions rate has climbed gradually as regulations stagnated while sales shifted from cars to light trucks.

Carbon burdens of major automakers

The six largest automakers in the U.S. market—GM, Ford, DaimlerChrysler (DCX), Toyota, Honda and Nissan—had an 87% market share and accounted for 88% of the new fleet carbon burden in 2003. The next six firms—Volkswagen, Hyundai, Mitsubishi, BMW, Kia, and Subaru—had a combined market share of 12% in 2003 and accounted for nearly all of the remaining new fleet carbon burden. The ranking of new vehicle carbon burdens of these 12 firms follows their market share, with GM accounting for the largest share, and Subaru claiming the smallest part as shown in Figure ES2.

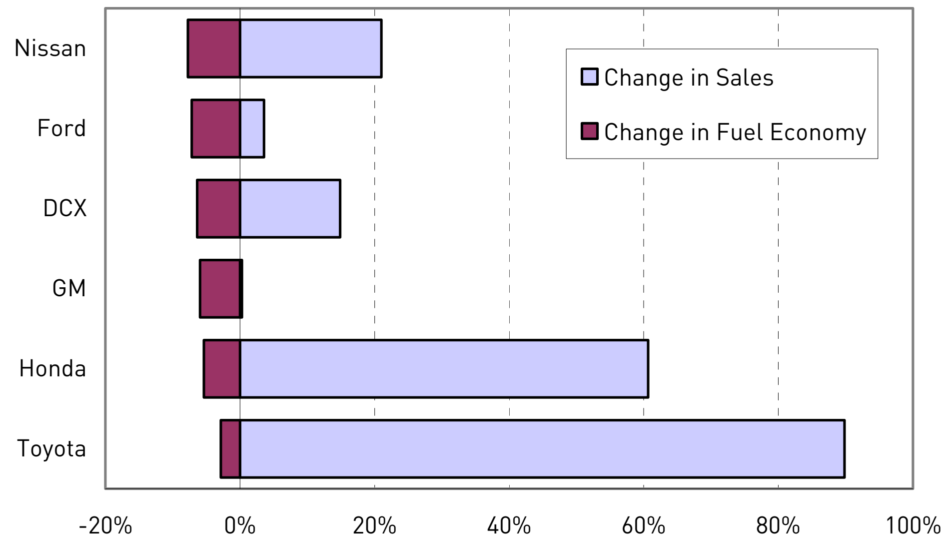
Focusing on the Big Six, Figure ES3 shows each firm's carbon burden growth from 1990 to 2003 broken into its two components, sales increase and fuel economy decrease. The average fuel economy for all Big Six automakers decreased from 1990 to 2003, largely due to each firm's rising truck fraction (proportion of trucks in its total sales), resulting in increased fleet-average CO_2 emissions rates. All automakers significantly expanded their light truck offerings, with the overall light truck fraction growing 21 points over this 14-year period.

FIGURE ES2
Carbon burdens of automakers' U.S. new vehicle sales in 2003



Source: Authors' analysis of NHTSA CAFE data and data from NHTSA (2004) and NHTSA (2005).

FIGURE ES3
Breakdown of growth in Big Six carbon burdens over 1990-2003



Source: Derived from NHTSA CAFE data, NHTSA (2004) and NHTSA (2005).

Nissan had the largest increase in its average CO_2 emissions rate due to the combined effect of rising truck fraction and declining truck fuel economy. Toyota's 95% increase in new vehicle carbon burdens was the greatest among the Big Six, but its fuel economy declined the least; its carbon burden increase was due predominately to its sales success.

Two other trends have been serving to increase oil dependence and CO_2 emissions by U.S. cars and light trucks. One is the Big Three's growing reliance on flex-fuel vehicle (FFV) credits. Federal law gives automakers extra fuel economy credit for selling flexible-fuel vehicles, regardless of whether alternative fuel is actually used. These credits then enable the companies to sell less fuel-efficient vehicles. The use of flex-fuel credits pushed GM's 2003 CO_2 emissions rate 2% higher, Ford's 3% higher, and DCX's 0.2% higher than if they had met CAFE standards without using the credits. None of the Asian or other automakers have exploited this dysfunctional aspect of federal policy.

The other adverse trend is an apparent increase in sales of heavier light trucks (those between 8,500 and 10,000 pounds gross vehicle weight). These vehicles are mainly three-quarter and one-ton pickups, but include a growing number of the largest SUVs, such as the Hummer H2, some models of the Chevy Suburban and Tahoe (and their GMC variants), and the Ford Excursion. Because these vehicles escape CAFE regulation and federal agencies fail to track them, we cannot quantify the additional carbon burdens associated with their sales. In any case, the actual carbon burdens of the Big Three are even larger than what is estimated here using data for only the CAFE-regulated (under 8,500 pound) fleet.

What follows is a summary of the key findings regarding new fleet CO_2 emissions trends for each of the Big Six and notable points for other automakers during the period of 1990–2003, derived from fuel economy and sales data for their CAFE-regulated fleets.

GENERAL MOTORS

CO_2 emissions rate up 6.3% while market share dropped 6.8 points; still the largest carbon burden overall.

- The 6.4 MMTc carbon burden of GM's model year 2003 fleet accounted for 29% of the total new light-duty fleet carbon burden.
- GM's new car fuel economy improved over each of the past four years, reaching a value 5% higher in 2003 than it was in 1990.
- Light trucks rose from 28% of GM's sales in 1990 to 56% as of 2003 while showing no trend toward fuel economy improvement.
- Increasing reliance on FFV credits pushed GM's 2003 CO_2 emissions rate nearly 2% higher than if the company had met CAFE standards without the credits.
- GM's new fleet-average CO_2 emissions rate was 6.3% higher in 2003 than it was in 1990, as rising light truck share and FFV credits more than offset the recent increase in GM's car fuel economy.

FORD

CO_2 emissions rate up 7.7% while market share dropped 4.4 points; heavy use of flexible fuel vehicle credits contributes a 3% increase in emissions.

- Ford's new fleet carbon burden of 5.0 MMTc accounted for 23% of the market total in 2003.
- Light trucks rose from 35% of Ford's sales to 59% as of 2003 while the average fuel economy of Ford's light trucks dropped by 2% compared to 1990.
- Ford's SUV fuel economy dropped in 2003 after having risen for two years following the company's now-abandoned July 2000 pledge to improve it.
- Ford makes extensive use of FFV credits, inflating its combined CAFE by an estimated 1.1 mpg as of 2003 and making its new fleet-average CO_2 emissions rate 3% higher than if it had met CAFE standards without credits.
- As result of these factors, Ford's new fleet-average CO_2 emissions rate was 7.7% higher in 2003 than it was in 1990.
- To compensate for its 7.7% increase in fleet-average CO_2 emissions rate, Ford would have to sell over 650,000 hybrids (20% of its 2003 sales) with the same average fuel savings as the Escape Hybrid.

DAIMLERCHRYSLER

CO_2 emissions rate up 6.8% while market share declined 1.1 points; greatest dependence on trucks, though revealing recent signs of fuel economy improvement.

- DCX's new fleet carbon burden of 3.0 MMTc accounted for 14% of the total new light-duty fleet carbon burden in 2003.
- DCX's truck share increased by 24 points to reach 74% in 2003, the highest among the Big Six automakers.
- While its car CAFE revealed no obvious trend, DCX's truck fleet fuel economy rose 6% over the past two years but as of 2003 remains down a net 2% from its 1990 level.

- More extensive use of FFV credits inflated DCX's 2003 combined CAFE by 1 mpg, pushing its average CO_2 emissions rate 4.4% higher than it otherwise might have been.
- As a result of higher truck share and lower fuel economy, DCX's new fleet-average CO_2 emissions rate was 6.8% higher in 2003 than it was in 1990.

TOYOTA

CO_2 emissions rate up 2.9% while market share gained 4 points; greatest growth in carbon burden but smallest increase in CO_2 emissions rate among the Big Six.

- Toyota's new fleet carbon burden saw net 95% growth from 1990, reaching 2.3 MMTc in 2003, 11% of the market total.
- The 15-point increase in Toyota's truck share drove its CO_2 emissions rate up by 2.9% over 1990–2003, despite a 4.9% improvement in its car CAFE.
- Toyota's average light truck fuel economy was the same in 2003 as it had been in 1990 despite an extensive expansion of the company's lineup into SUVs and larger and more powerful trucks generally.
- Toyota's sales success accounted for 92% of its 95% increase in carbon burden and its declining overall CAFE accounted for 3% of the increase.
- To compensate for its 2.9% increase in fleet-average CO_2 emissions rate, Toyota would have to sell 150,000 hybrids (8% of its sales) with the same average fuel savings as the Prius and Lexus RX400h.

HONDA

Rapidly growing truck fraction pushed CO_2 emissions rate up 5.7% while market share gained two points, but still the fuel economy leader.

- Honda's 2003 carbon burden reached 1.7 MMTc, attributing to 8% of the total new light-duty fleet carbon burden.
- Since entering the light truck market in 1997, Honda's truck share grew at an average 5.6 points per year, reaching 39% in 2003.
- The company's truck fleet CAFE dropped by 8% since 1997, while its car fleet CAFE rose by 7% over 1990–2003.
- Driven by its growing truck fraction, Honda's CO_2 emissions rate increased by 5.7% from 1990 to 2003, even though its emissions rate is still the lowest among the Big Six.
- To compensate for its 5.7% increase in fleet-average CO_2 emissions rate, Honda would have to sell over 300,000 hybrids (22% of its 2003 sales) with the same average fuel savings as the Civic and Accord Hybrids.

NISSAN

CO_2 emissions rate up 8.4% while market share lost 0.2 points; growing truck reliance and declining truck CAFE.

- The 1.0 MMTc carbon burden of Nissan's 2003 new fleet was responsible for 4.8% of the total new light-duty fleet carbon burden in 2003.
- Notwithstanding great fluctuations in sales over the period, Nissan's market share reached 5% in 2003, about the same as the 1990 level.
- The truck fraction of Nissan's sales grew from 25% to 36% over 1990–2003, while its light truck fuel economy was 13% lower in 2003 than in 1990.

- Falling truck fuel economy and growing truck share pushed Nissan's average CO_2 emissions rate up 8.4% in 2003, the largest increase among the Big Six.

OTHER FIRMS

The "Next Six" automakers, in order of 2003 market share, are Volkswagen, Hyundai, Mitsubishi, BMW, Kia, and Subaru. Their collective sales nearly tripled between 1990 and 2003, when their combined market share reached 12% and they accounted for 11% of the new fleet carbon burden.

- Volkswagen more than doubled its market share 1990–2003 while improving fuel economy and cutting its fleet-average CO_2 emissions rate by 3.3%. Volkswagen's 2003 new fleet average CO_2 emissions rate was the lowest among the 12 automakers examined here.
- Hyundai nearly tripled its market share over 1990–2003 but had the worst increase (16%) in new fleet-average CO_2 emissions rate among major automakers, shifting it from having the lowest new fleet CO_2 emissions rate in 1990 to the 3rd lowest in 2003.
- Mitsubishi's market share generally declined through 1998, but rebounded by 2003; following the truck trend, its CO_2 emissions rate increased 6% over the 1990–2003 period.
- BMW improved its average fuel economy by more than any other firm, reducing its new fleet CO_2 emissions rate by 12.7% over a period in which it achieved a nearly fivefold increase in U.S. sales.
- Kia has steadily gained sales since entering the U.S. market in late 1993, but its new fleet CO_2 emissions rate rose 27% as it increased its truck sales and converged toward the market average.
- Subaru's market share had little net change from 1990 to 2003 and its new fleet-average CO_2 emissions rate increased 3% over the period.

The steady rise of light trucks

As noted above for nearly all automakers, the dominant factor for CO_2 emissions in the new vehicle market has been the steady rise of the light truck fraction of each company's fleet. This phenomenon started in the 1980s and has progressed in several waves. First was the introduction of the minivan in 1984, followed by the modern sport-utility vehicle (SUV) beginning in 1989 and exploding in share throughout the 1990s. Most recently the trend has included a growing popularity of various "crossover" vehicles, with body styles that blend the traits of traditional vehicles. Examples include car-based SUVs—such as "sport wagons" that once simply would have been called station wagons—as well as minivan-SUV and pickup-SUV hybrids (*not* the "hybrid-electrics" of recent fame).

Automakers are classifying nearly all of these new and trendy designs as trucks in order to ease their compliance with CAFE standards. Because light trucks are held to a lower standard—20.7 mpg as of model year 2003, compared to 27.5 mpg for cars—this strategy helps in several ways. Simply moving a vehicle from a car fleet to a truck fleet subjects it to a lower standard. Then, because vehicles that were once cars or derived from cars are generally more fuel-efficient than trucks, the averaging approach on which CAFE is based enables an automaker to sell more of the large trucks on which profit margins have been so high. Finally, because vehicles shifted into the truck category are typically less efficient than the average car, the company's remaining cars can more easily meet the car standard. Since 1988, when new fleet fuel economy peaked, the market share of vehicles classified as light trucks has climbed from 30% to 51%. It is this car-truck shift that largely accounts for the 7% increase in new fleet-average CO_2 emissions rate over this period.

Given the regulations in effect through 2003, light trucks on average emit 39% more CO_2 per mile traveled than passenger cars. Therefore, light trucks accounted for 59% of the new fleet carbon burden in 2003, disproportionately more than their 51% sales share. If the light trucks that have substituted for passenger cars during the period of market shift had been required to meet the passenger car CAFE standard, U.S. automobiles would consume 536,000 fewer barrels per day of gasoline and would have emitted 20 MMTc per year less carbon in 2003. This would be equivalent to the annual carbon emissions from about thirty 300-megawatt coal-fired electric power plants.

A look at the recent market trends suggests that the car-to-truck classification shift shows no sign of slowing down. All of the Big Six have rising truck fractions. DaimlerChrysler's is the highest, reaching 74% in 2003 as noted above. Honda's has been growing most rapidly because it is playing catch-up in the truck market. The overall truck share has been growing in an essentially linear fashion since 1980, when it was only 17% (it had averaged around 20% through the 1970s). Extrapolating the average gain of 1.5 points per year would put the new light truck share at 60% before the end of the decade.

The National Highway Traffic Safety Administration (NHTSA), which oversees CAFE regulations, is investigating increases in the light truck standard as well as reforms in how vehicles are classified and how the standards are structured. Significantly higher light truck standards would be one important step for slowing the rise in auto sector CO_2 emissions.

Reducing automobile carbon burdens

Many actors are involved in the decisions that determine what kind of cars are built and sold, how much they are driven and how they are fueled. Thus, cutting the carbon burdens of cars is a shared responsibility, though the auto industry is a dominant player.

The past several years have seen shifts in automakers' public positions on global warming. Not long ago, many firms and particularly the Big Three denied the problem and carried out campaigns to undermine U.S. support for climate action. Now, all firms profess a desire to help solve the problem. In 1998, major automakers made voluntary agreements with the European Union to cut their fleet-average CO_2 emissions rates. The recent World Business Council for Sustainable Development's *Mobility 2030* report, endorsed by the Big Six of the U.S. market (plus Renault and Volkswagen), recommended a goal of limiting GHG emissions to sustainable levels. Automakers have started reporting emissions from their fleets and factory operations; they now regularly publicize new technologies and other activities promising emissions reductions.

Nevertheless, as this report shows, automakers have made little progress in cutting CO_2 emissions in the United States, the world's largest auto market. With few exceptions, their product strategies have made emissions worse. What's missing is a constructive stance on public policy, which is essential for resolving the inherent tension between market forces and non-market concerns such as global warming and energy security. In short, automakers need to embrace balanced but meaningful regulation in order to be true to their promises to meet these challenges. There is no other way to break out of the competitive box that binds product strategies and design priorities to offering consumers almost everything imaginable but doing very little to address the huge, non-market problems of global warming and oil dependence.

Automakers rightly point out that lack of customer interest is a barrier to higher fuel economy, in contrast to when CAFE standards were established during the oil crisis. Indeed, an extensive public education effort to make fuel efficiency matter more to consumers is needed as part of a broader public strategy to realign market signals and establish U.S. leadership in addressing oil consumption and global warming. The auto industry's cooperation and expertise could help guide such endeavors, but effective steps seem unlikely until automakers take a more positive approach in the crucial area of regulation. A good-faith effort on the industry's part would open the door to developing more comprehensive policy solutions for the cars vs. climate challenge.

Introduction

Controlling greenhouse gas emissions from automobiles is one of the main challenges in the broader quest to protect Earth's climate from the hazards of global warming. A starting point for finding ways to cut this form of widespread greenhouse pollution is taking a close look at where it comes from.

The concept of *carbon burden* is a useful tool in this regard. The notion can apply to any activity that generates greenhouse gases. For automobiles, carbon burden is the amount of emissions from a given group of vehicles. We introduced the concept in our July 2002 report, *Automakers' Corporate Carbon Burdens: Reframing Public Policy on Automobiles, Oil and Climate.* This report is an update of that analysis. It focuses on the largest part of automotive greenhouse gas (GHG) emissions, namely, the carbon dioxide (CO_2) directly emitted when a vehicle is used.

The significance of CO_2 from U.S. automobiles

Carbon dioxide is the dominant greenhouse gas, accounting for over 80% of global warming pollution.[1] The United States is by far the world's largest global warmer, producing 23% of the world's total CO_2 emissions from fossil fuel use.[2] Other wealthy nations have started reducing their emissions under the Kyoto Protocol.[3] The United States, however, has taken no national action to cut its emissions. As a result, by 2002, U.S. GHG emissions had grown 13% since 1990, compared to the 2.5% cut achieved across the European Community.[4]

Automobiles—taken here to include cars, vans, sport-utility vehicles, pickups and other light-duty vehicles—are a large and rapidly growing source of greenhouse gases. The CO_2 emissions from America's automobiles represent 20% of total U.S. emissions,[5] but alone exceed the nationwide emissions of all but three other countries of the world.[6] As of 2000, the 301 million metric tons of carbon per year (MMTc) emitted by U.S. cars and light trucks amount to 46% of the estimated 649 MMTc from all light-duty vehicles worldwide.[7] This disproportionate contribution is due to two factors: American cars are driven more than those of other nations and their CO_2 emissions rates are higher.

Over 1990–2003, U.S. automobile CO_2 emissions grew by 25%, faster than emissions from the economy as a whole.[8] Furthermore, a key factor behind these emissions—namely, the average per-vehicle CO_2 emissions rate of new automobiles—has increased over this period (a situation we analyze in this report).

America's worsening new vehicle CO_2 emissions rates are a contrast to the situation in Europe. Even though they were lower to begin with, new automobile CO_2 emissions rates in Europe were cut by 11% as of 2002.[9] This progress is in line with the voluntary target of a 25% cut in automobile CO_2 emissions rates by 2008 that European automakers adopted in cooperation with the European Community's Kyoto commitment. Canada ratified the Kyoto Protocol in December 2002 and reached an agreement with the automobile industry to reduce annual greenhouse gas emissions from new vehicles in Canada by 5.3 megatons (1.4 MMTc) by 2010.[10]

In the United States, polling data consistently show strong public support for policies requiring more fuel-efficient cars. In July 2002, California passed a law (Assembly Bill 1493, sponsored by State Rep. Fran Pavley) for regulating greenhouse gas emissions from cars and light trucks. In September 2004, the state's Air Resources Board approved regulations that require a 30% cut in emissions to be phased in by 2016. States that have adopted California's low-emissions vehicle program for cutting smog will also be able to adopt these new regulations for cutting greenhouse gases. As of this writing, such states include Connecticut, Maine, Massachusetts, New Jersey, New York, Rhode Island, Vermont and Washington; along with California, they cover 27% of the U.S. car market.

This growing interest in addressing global warming increases the urgency of developing and implementing policies needed to guide the auto market toward higher efficiency and lower CO_2 emissions.

Autos, oil and carbon

In addition to being a major source of greenhouse gases, automobiles are also the single largest consumer of petroleum in the United States. There is an intimate link between America's oil dependence and the global warming impact of cars. Steps taken to cut automobile carbon burdens will also cut oil dependence.

Petroleum is the world's dominant fuel, accounting for 40% of global energy use and for the largest share of human-produced CO_2 emissions. But oil is also unique because of its geopolitical concentration. The Persian Gulf region provides 20% of the world's current oil production, yet it contains 65% of the world's proven reserves of conventional oil. There has been much publicity around the notion that oil production might soon peak and that alternatives are just around the corner. However, an objective look at petroleum resources, including unconventional sources such as shale oil and tar sands as well as advanced exploration and extraction technologies, means that any such peak may be far off in the future.[11] Moreover, the fundamentally low direct costs of oil production will undercut the economics of alternatives (such as hydrogen or biofuels) for the foreseeable future, even if oil's commodity price is propped up by the cartel.

As the dominant parties in the Organization of Petroleum Exporting Countries (OPEC), Saudi Arabia and other Gulf states wield substantial influence over the world oil market. Their cartel power, along with the region's vulnerability to disruptions, creates an all-too-real danger to the United States and the world. This danger will continue to grow as the United States wages war in the region and maintains a military presence to keep a measure of control over the oil fields, pipelines, and shipping lanes of the Persian Gulf and its surroundings.

The 317 MMTc of CO_2 emissions from U.S. cars and light trucks corresponds to 8.6 million barrels per day (Mbd) of oil consumption.[12] This level of demand is equivalent to being number two in terms of world oil supply. It is close to the 8.8 Mbd supplied by Saudi Arabia and is greater than the 8.1 Mbd supplied by Russia in 2003.[13] Thus, the United States has leverage on the demand side of the market. Reducing oil demand is economically superior to increasing supply from sources that are inevitably more expensive than oil from the Middle East.[14] Controlling petroleum demand rather than letting it rise unchecked will relieve price pressure and help lessen tensions resulting from the global competition for oil.

Steps America takes to cut the carbon burdens from automobiles, whether through higher fuel economy or through measures that improve efficiency throughout the transportation system (including more efficient use of all modes of transport and land use planning that minimizes car dependence), will result in reductions of oil demand. There is no better way to reduce U.S. oil dependence and the associated economic and security risks.

A shared responsibility

Ultimately, cutting greenhouse gas emissions and oil dependence from cars is a responsibility to be shared by all parties that affect how cars are designed, used, and fueled. Individual consumers and businesses that purchase and use cars, transportation and land-use planners, the fuels industry: all have roles to play.

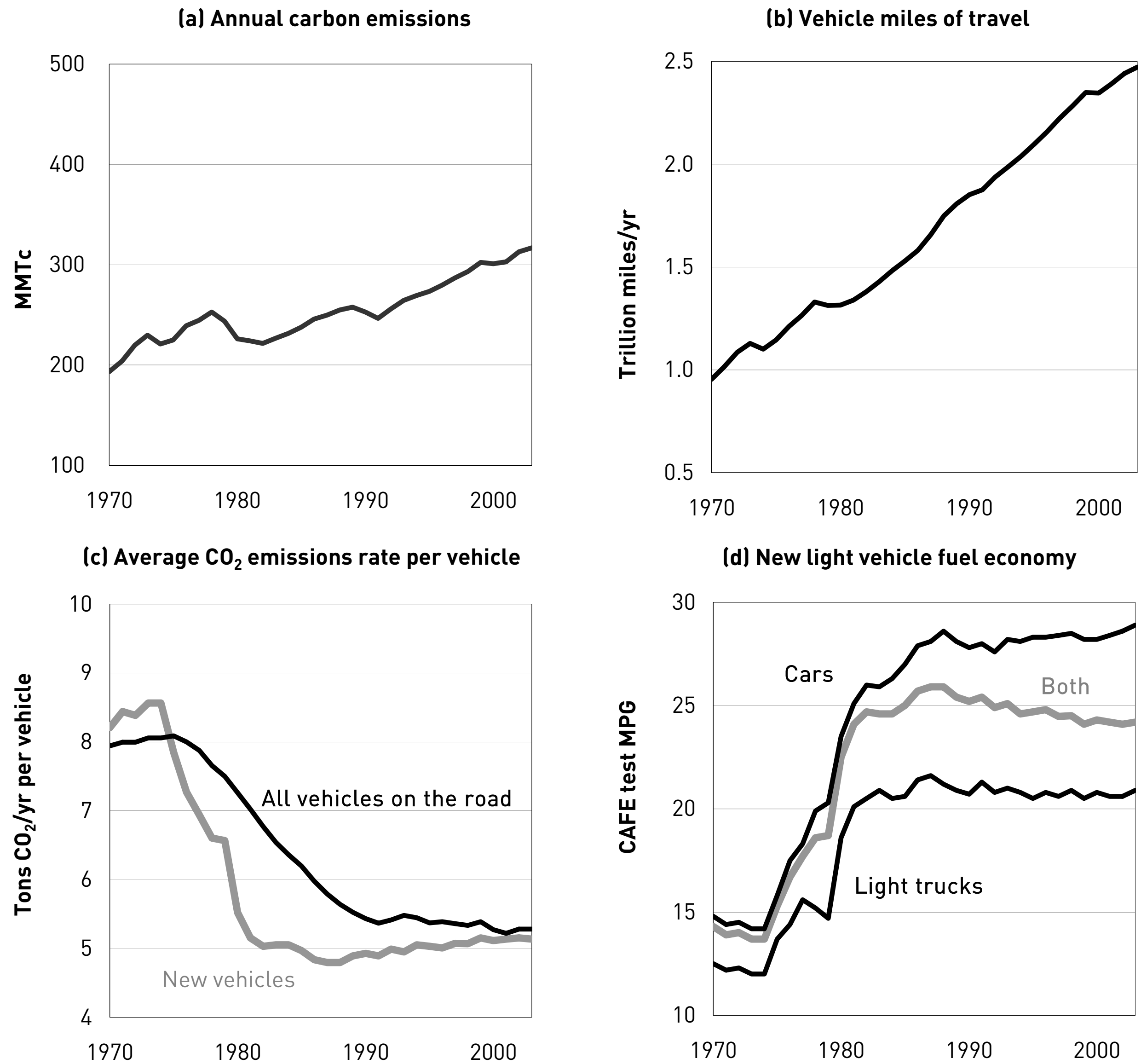
Nonetheless, the auto industry remains the dominant stakeholder and has enormous leverage in shaping the economic, cultural and political landscape surrounding the issue. The industry's access to capital, in addition to its design, engineering and marketing abilities, gives it great influence over the characteristics of cars available to consumers. A sincere effort on automakers' part to embrace a well-defined level of accountability for cutting car and light truck fuel use and CO_2 emissions rates will open the door to enlisting other parties' help in solving the problem.

In recent years, automakers have started offering vehicles with new technology—such as hybrid-electric and diesel engines—that promise to be more fuel efficient. But the benefits of such advances are yet to be seen in U.S. fuel use statistics. In fact, achieving real reductions in oil use and CO_2 emissions is unlikely without policies that address the fuel consumption rate of the entire fleet and motivate greater priority to fuel efficiency in all aspects of vehicle design, not just use of particular technologies. Applying the carbon burden concept to automakers' fleets—the new cars and trucks they sell each year—is a way to track the industry's contribution to oil dependency and global warming as well as measure its progress in addressing these problems.

U.S. light vehicle carbon emissions trends (1970–2003)

Figure 1 provides an overview of carbon emissions from U.S. light-duty vehicles between 1970 and 2003. Our analysis covers only cars and light trucks regulated by fuel economy standards, namely, those up to 8,500 pounds gross vehicle weight, because these are the only vehicles for which adequate data are available to accurately estimate CO_2 emissions. The set of graphs illustrates how various factors, such as the growth in the amount of driving and changes in fuel efficiency, have affected automotive carbon emissions. Data used in deriving these graphs are listed in Appendix A, Table A-1.

FIGURE 1
Historical overview of U.S. light vehicle carbon emissions



CO_2 emissions measured by metric tons. One metric ton equals to 1.102 short tons. Source: Table A-1, page 39

Annual light vehicle carbon emissions

Tracking fuel consumption, car and light truck carbon emissions generally followed a rising trend over the past three decades as shown in Figure 1(a). Major influences included the state of the economy and oil prices. U.S. auto sector emissions grew in the early 1970s, dropped in 1974 to 221 million metric tons of carbon (MMTc) during the first oil crisis and economic recession, then rose again before plunging to 226 MMTc in 1980 during the second oil shock. In fact, net growth was zero over the decade following the 1973 oil embargo, in contrast to both prior and subsequent decades. Thereafter, automotive carbon emissions increased at an average annual rate of 1.7% between 1983 and 2003. Emissions dropped during the 1990–91 recession and briefly leveled off in 2000–2001 coinciding with the economic slowdown and spike in fuel prices.

As of 2003, U.S. light-duty vehicles emitted 317 MMTc and consumed 8.6 million barrels of fuel per day (Mbd), representing a net growth of 64% from 1970 (see Table A-1). The 2003 level is 25% higher than the 253 MMTc emitted in 1990, a common base year for climate policies, reflecting an average 1.7%/yr growth rate over the 13 year period.

Figures 1(b) and (c) examine the two factors behind the auto carbon emissions trend: the increase in travel and changes in the average CO_2 emissions rate of vehicles. In contrast to the varying increase in vehicle carbon emissions over the past 33 years, the number of miles Americans drove increased steadily. From fewer than 1 trillion light-duty vehicle miles of travel (VMT) per year in 1970, it reached nearly 2.5 trillion VMT in 2003—a 160% increase, corresponding to an average compound growth rate of 2.9% per year.

As shown in Figure 1(b), the increase in vehicle miles traveled follows a linear rising trend, except during the recessions and oil shocks of 1974 and 1979. VMT growth slowed in 1990 and 2000, due to higher oil prices and economic recessions. A linear fit of the VMT data suggests that on average 47.3 billion new miles were added each year since 1970.[15] Since 1990, the compound rate of VMT growth has averaged 2.2% per year.

CO_2 emissions rate

Figure 1(c) shows the average CO_2 emissions rate of the new vehicle fleet and the vehicle stock assuming 12,000 miles of annual driving.[16] The gray curve depicts the average CO_2 emissions rate of the new fleet,[17] while the black curve shows the average CO_2 emissions rate of all vehicles on the road[18] (the vehicle stock) between 1970 and 2003.

Between 1974 and 1981, the new fleet's CO_2 emissions rate declined rapidly at an average of 7% per year, from its highest level of 8.6 tons of CO_2 per year in 1974 down to 5.2 tons of CO_2 per year in 1981. This seven-year period reflects rapid fuel efficiency improvements driven by fuel economy regulation and oil price shocks, as shown by the gray curve in Figure 1(d). Between 1981 and 1988, the new fleet's CO_2 emissions rate continued to fall, though at a much slower rate of 1% per year. From 1988 onwards, the trend in reduction has been reversed, and the new fleet CO_2 emissions rate has climbed by an average of 0.4% per year as a result of increased light truck market share (see Table A-1).[19]

Figure 1(c) also illustrates how the stock average CO_2 emissions rate lags behind the new fleet emissions rate trend. The stock average rate started to fall in 1976, two years after rapid new fleet fuel economy improvements were initiated. It declined at a slower rate than that of the new fleet CO_2 emissions rate, reflecting the gradual replacement of old vehicles by more fuel-efficient new fleet, and the lower usage rate of older vehicles. The stock CO_2 emissions rate continued to fall steadily until 1992, a lag of four years after the new fleet CO_2 emissions rate started to rise in 1988, and a decade after the last year of rapid decline in the new fleet CO_2 emissions rate in 1982. During its period of steady decline, the stock average CO_2 emissions rate fell by an average of 2.5% per year (1975–1991). Since then, it has declined slightly and unevenly, with the 2003 stock average CO_2 emissions rate being only 1.7% lower than the 1991 level (an average decline of only 0.14% per year 1991–2003).

The vertical axes of Figures 1(a) and 1(b), showing total light vehicle CO_2 emissions and VMT, respectively, have the same ratio (5:1) from the bottom of the axis to the top. The differing visual slopes of the two curves therefore show how automobile CO_2 emissions grew more slowly than the amount of driving, particularly during the 1980s, illustrating how auto sector carbon burdens can be offset at least partially by higher fuel economy.

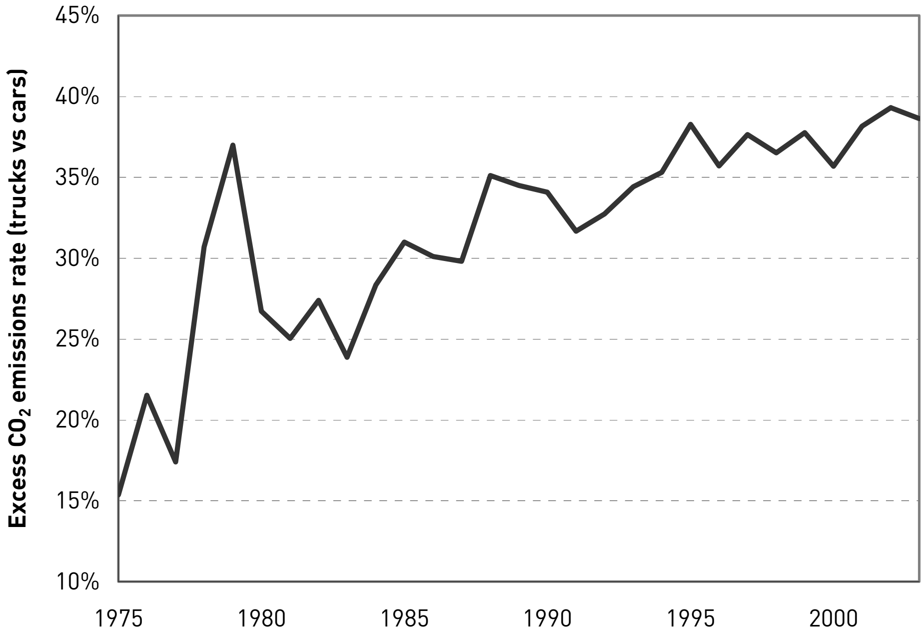
Impact of market shifts

Light trucks, designed for heavier loads, are larger than cars and have greater engine power. Light trucks therefore consume more fuel than cars and emit more CO_2 per mile traveled. However, the effects of this additional CO_2 emissions rate have been exacerbated, as light trucks have come to replace cars for many consumers.

Figure 2 tracks the percentage by which the average new light truck CO_2 emissions rate has exceeded that of new cars from 1975 to 2003. The CO_2 emissions rate of light trucks was roughly 18% higher than that of cars in the early 1970s. The ratio jumped briefly in 1978–79 but then returned to a gradually rising trend, recently approaching a level 40% higher than that of passenger cars.[20] During the 1990s and through 2004, the 20.5–20.7 mpg light truck CAFE standard permitted a CO_2 emissions rate roughly 33% higher than that implied by the 27.5 mpg car standard. Asian automakers have been less CAFE-constrained than domestic automakers and have a more significant share of the car fleet. Thus, the overall new fleet fuel economy for cars has exceeded the standard by a larger margin than has that for light trucks. This factor largely accounts for the fact that the excess light truck CO_2 emissions rate is greater than the 33% implied by the differences in the CAFE standards.

As shown in Table A-1, light trucks held a 17% market share in 1980, when mainly pickups were sold. Only a few models of sport-utility-like vehicles, such as the Jeep Wagoneer, Ford Bronco, and Chevrolet Suburban and Blazer, were sold at that time, and their share remained under 3% through 1983. With the introduction of minivans and the success of selected SUV models, such as the Jeep Cherokee, light truck sales doubled from 1.9 million in 1980 to 3.8 million in 1990. The 1990s saw dramatic growth in SUV sales after more broadly marketed models, such as the Jeep Grand Cherokee and Ford Explorer, were

FIGURE 2
Light truck CO_2 emissions rate excess compared to cars



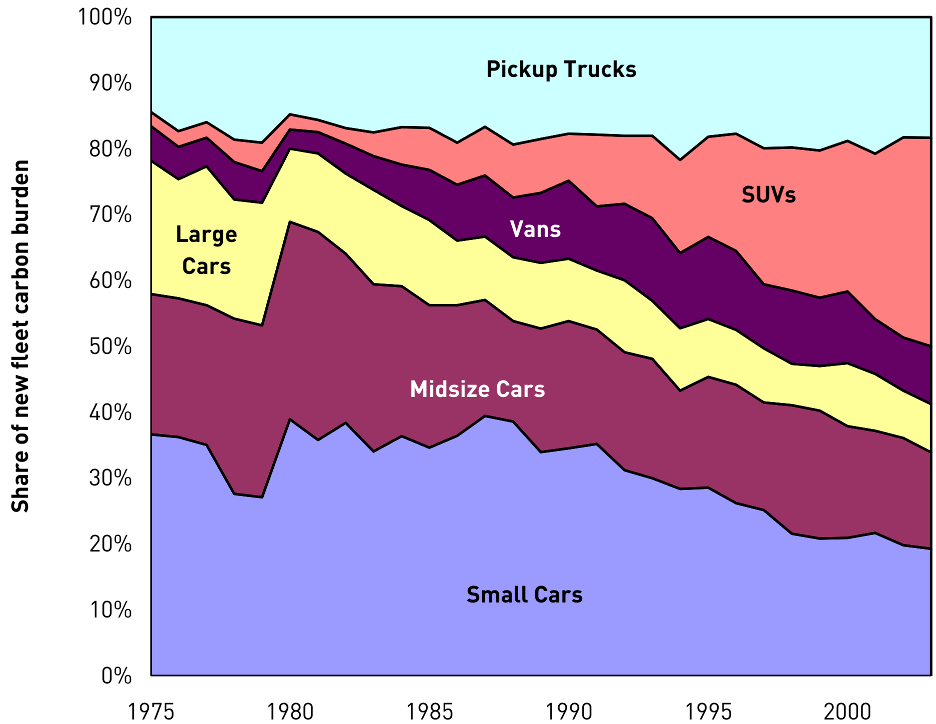
* Excess CO_2 emissions rate is defined as the percentage by which the average new light truck CO_2 emissions rate exceeds that of new cars.
Source: Derived from Hellman and Heavenrich (2004) and assumptions in Table A-5.

introduced. Led by the substantial growth of SUVs, sales of new light trucks reached 7.9 million units in 2003 (51% of the market using EPA statistics), well more than doubling the category's typical market share prior to the mid-1980s.

The sales share of the SUV segment alone went up 25 percentage points, rising from an average of 2% of new vehicle sales in 1975–83 to 27% in 2003.[21] From 1981 to 2003, the market share of vans grew by six points. In contrast, the market share of pickup trucks has been relatively stable, increasing by only about 1½ points from the late 1970s, and has been around 16% in recent years. The sales share of small cars has dwindled from 43% in 1981 to 25% in 2003. As of 2003, 3.8 million new small cars were sold, compared to 4.3 million SUVs, 2.4 million pickups, and 1.3 million vans (Table A-2). Thus, by 2003, light trucks (pickups, vans, SUVs and crossovers) outsold cars for the first time according to federal statistics,[22] exceeding 50% of new light-duty vehicle sales.

Because of rising sales compounded by their increasing excess CO_2 emissions rate (lower relative fuel economy), the carbon burden of light trucks has grown much more rapidly than that of cars since 1981. In the past two decades (1984–2003), carbon burden share of light trucks increased by 30%. CO_2 emissions from new SUVs jumped by over a factor of six, from 1.1 MMTc in 1984 to 6.93 MMTc in 2003. As can be seen in Figure 3, by 1998 SUVs became the vehicle class with the highest carbon burden and they have maintained this status ever since. Carbon emissions from small cars, in contrast, shrunk by 40% over these 20 years as their market share slipped to a historic low. The carbon burden share of

FIGURE 3
New fleet carbon burden share by major vehicle class, 1975-2003



Source: Derived from Hellman and Heavenrich (2004).

other vehicle classes (pickups, vans, large cars and midsize cars) has fluctuated but remained relatively stable since 1990 (Figure 3 and Table A-4), underscoring the impact of the SUV trend on the growth in vehicle carbon emissions.

If during the period of market shift, those light trucks that have primarily substituted for passenger cars (including minivans and SUVs) were required to comply with the CAFE standards for passenger cars, the overall average fuel economy for model year 2003 would have been 10% higher. U.S. automobiles would have emitted 20 MMTc less carbon and consumed 536,000 fewer barrels per day of gasoline in 2003[23]—the rough equivalent of carbon dioxide emissions from thirty 300-megawatt coal-fired electric power plants.[24]

Firm-level analysis

This section reports the new vehicle carbon burden trends of each major automaker in the U.S. market over the period of 1990 to 2003. It also examines the factors behind these trends, including market growth, company sales, market share trends and average new vehicle CO_2 emissions rates. Following the discussions of each firm, we address the general trend of rising light truck share seen for all of the Big Six automakers.

Sales and fuel economy data reported by government agencies are grouped according to fleet categories defined for regulatory purposes. However, these official classifications are not always a good basis for comparing CO_2 emissions trends. In this analysis, we combined the sales and fuel economy data for each automaker's car and light truck fleets to develop complete firm-level statistics. We also combined data for groups of manufacturers and product lines to reflect recent mergers and acquisitions. For instance, the trends of the separate Mercedes-Benz and Chrysler lines are combined to show a combined trend for DaimlerChrysler; the Ford trend comprises the traditional Ford brands plus Mazda, Volvo and Jaguar.

Overview

Table 1 summarizes the statistics on new fleet sales, fuel economy, and CO_2 emissions rate of the twelve largest automakers in the U.S. market in 1990 and 2003. As of model year 2003, these twelve firms accounted for 99% of new light vehicle sales. The largest of these firms—the "Big Six" of General Motors (GM), Ford, DaimlerChrysler (DCX), Toyota, Honda and Nissan—alone accounted for 87% of sales and 88% of the new fleet carbon burden. These companies are the focus of our firm-level analysis.

By 2003, the combined share of the Big Three—GM, Ford, and DCX— had fallen to 61%, down from 73% in 1990. GM lost 6.8 points of market share, Ford lost 4.4 points, and DCX lost 1.1 points. Toyota and Honda both saw a market share growth, with Toyota gaining 4 points and Honda gaining 2 points. Nissan's share reflected little net change over the 14-year analysis period in spite of some large fluctuations during the intervening years. Volkswagen, Hyundai and Mitsubishi followed with the seventh, eighth and ninth positions in the market, each accounting for more than 2% of U.S. market share in 2003.

Figure 4 shows the total market carbon burdens associated with new vehicle sales and the contributions from each major automaker from 1990 to 2003. The upper boundary of the plot shows the total new auto market carbon burden, which grew from 17 MMTc in 1990 to 22 MMTc in 2003. The trend was generally upward except for years when total new vehicle sales dipped, most notably in 1996. The 30% net growth in new vehicle carbon burdens between 1990 and 2003 was five points higher than the 25% growth in vehicle sales because of rising average CO_2 emissions rates. The Big Three collectively had little net growth in carbon burden; most came from Asian automakers. Figure 5 shows the new vehicle carbon burdens of the twelve major automakers.

TABLE 1

New fleet fuel economy, sales, oil and carbon burdens summary, 1990 and 2003

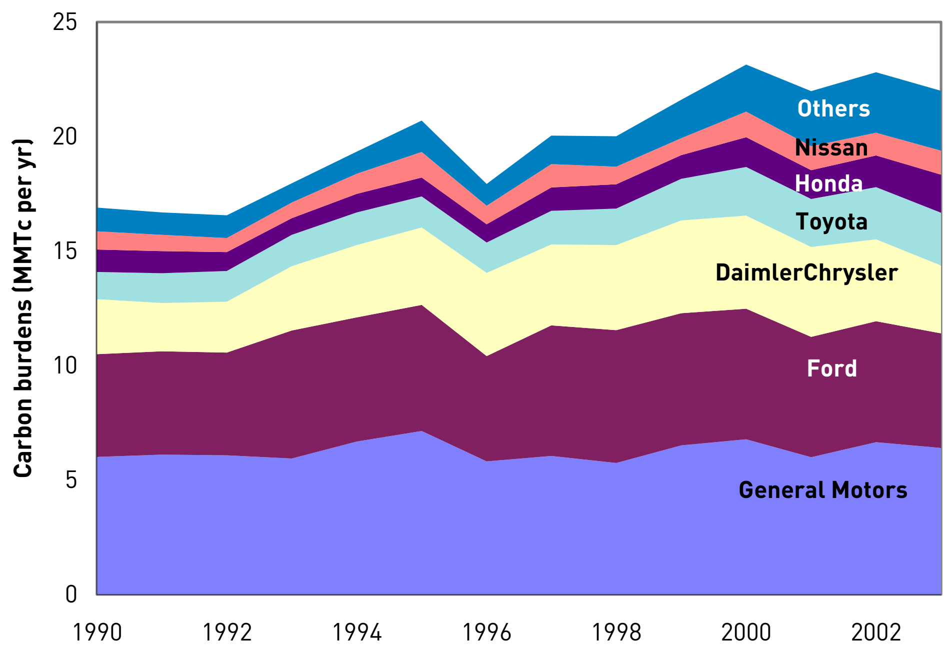
Combined new car and light truck fleet	Fuel Economy mpg 1990	Fuel Economy mpg 2003	Percent change	Sales Millions 1990	Sales Millions 2003	Market Share 1990	Market Share 2003	Cumulative Share in 2003
GM	24.6	23.1	-5.9%	4.358	4.372	34.5%	27.7%	27.7%
Ford	24.1	22.3	-7.2%	3.186	3.300	25.3%	20.9%	48.6%
DaimlerChrysler	24.0	22.4	-6.3%	1.706	1.960	13.5%	12.4%	61.0%
Toyota	28.0	27.2	-2.8%	0.975	1.852	7.7%	11.7%	72.7%
Honda	30.8	29.1	-5.4%	0.894	1.436	7.1%	9.1%	81.8%
Nissan	27.6	25.5	-7.7%	0.651	0.788	5.2%	5.0%	86.8%
VW	28.6	29.5	3.4%	0.154	0.430	1.2%	2.7%	89.5%
Hyundai	33.3	28.7	-13.8%	0.117	0.407	0.9%	2.6%	92.1%
Mitsubishi	28.4	26.8	-5.7%	0.221	0.373	1.8%	2.4%	94.5%
BMW	22.2	25.4	14.5%	0.056	0.274	0.4%	1.7%	96.2%
Kia *	N/A	24.9	N/A	0.000	0.233	0.0%	1.5%	97.7%
Subaru	28.3	27.5	-2.8%	0.131	0.189	1.0%	1.2%	98.9%
Overall	**25.3**	**24.3**	**-3.9%**	**12.617**	**15.792**			
Chrysler	24.0			1.649				
Ford Brand	23.8			2.713				
Mazda	27.9			0.371				
Mercedes	21.4			0.058				
Volvo	25.1			0.102				

Combined new car and light truck fleet	Average per-vehicle CO_2 emissions rate TCO_2/yr 1990	Average per-vehicle CO_2 emissions rate TCO_2/yr 2003	Percent change	Oil demand lifetime average 10^3bbl/day 1990	Oil demand lifetime average 10^3bbl/day 2003	Carbon Burden Lifetime average MMTc per year 1990	Carbon Burden Lifetime average MMTc per year 2003	Share in 2003
GM	5.05	5.37	6.3%	163.2	174.0	6.00	6.40	29.1%
Ford	5.16	5.56	7.7%	121.9	136.0	4.49	5.00	22.7%
DaimlerChrysler	5.18	5.54	6.8%	65.6	80.4	2.41	2.96	13.5%
Toyota	4.43	4.56	2.9%	32.0	62.6	1.18	2.30	10.5%
Honda	4.03	4.26	5.7%	26.7	45.4	0.98	1.67	7.6%
Nissan	4.49	4.87	8.4%	21.7	28.4	0.80	1.05	4.8%
VW	4.35	4.21	-3.3%	5.0	13.4	0.18	0.49	2.2%
Hyundai	3.73	4.33	16.1%	3.2	13.1	0.12	0.48	2.2%
Mitsubishi	4.38	4.64	6.0%	7.2	12.8	0.26	0.47	2.1%
BMW	5.60	4.89	-12.7%	2.3	9.9	0.09	0.36	1.7%
Kia *	N/A	4.99	N/A	N/A	8.6	NA	0.32	1.4%
Subaru	4.39	4.52	2.9%	4.3	6.3	0.16	0.23	1.1%
Overall	**4.91**	**5.11**	**4.0%**	**459.3**	**597.9**	**16.90**	**22.00**	

Source: Author's analysis of NHTSA CAFE data and data from NHTSA (2004) and NHTSA (2005) using assumptions given in Table A-5. Fuel economy is EPA composite test value in miles per gallon (mpg) with adjustment of 15% for all vehicle types; average per-vehicle CO_2 emissions are metric tons per year (TCO_2/yr); oil demand is thousands of barrels per day, and carbon burden is in millon tons of carbon (MMTc, direct vehicle emissions only, not full-fuel cycle).

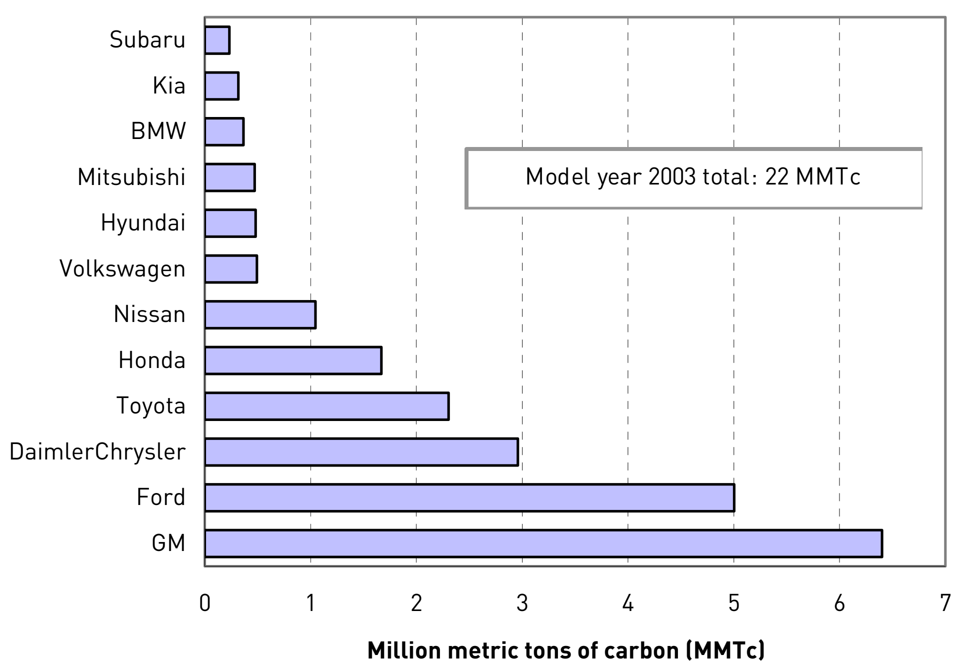
* Kia entered the U.S. market in 1993.

FIGURE 4
Automakers' carbon burdens from new automobiles sales, 1990-2003



Source: NHTSA (2004), NHTSA (2005), NHTSA database and authors' analysis results in million metric tons of carbon (MMTc) for sales under 8500 lb GVW.

FIGURE 5
Carbon burdens of automakers' U.S. new vehicle sales in 2003

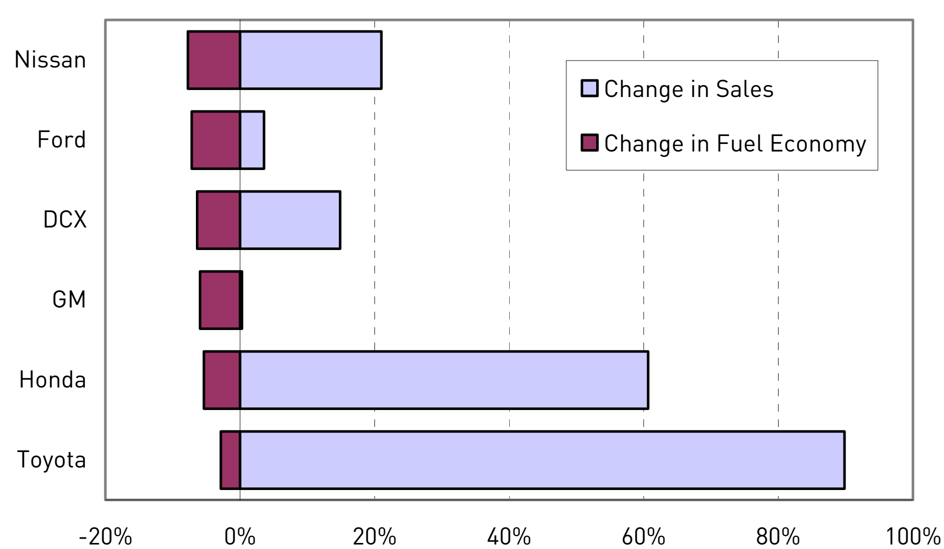


Source: Authors' analysis of NHTSA CAFE data and data from NHTSA (2004) and NHTSA (2005).

A given automaker's carbon burden increase is the combined result of rising sales and rising CO_2 emissions rates, the latter corresponding to falling fuel economy. Figure 6 breaks out the 1990–2003 changes in Big Six carbon burdens into two factors: fuel economy change, as shown by the darker portion to the left of the axis, and sales change, as shown by the lighter portion to the right.[25] Different ways of ranking the twelve largest automakers are shown in Table 2, with the Big Six highlighted in bold. Part (a) of the table lists firms by total new fleet carbon burden, which is largely determined by market share. Part (b) lists them by carbon burden increase and tabulates the factors behind the increase, as in Figure 6. Part (c) of Table 2 lists the twelve largest automakers by new vehicle average CO_2 emissions rate in 1990 and 2003. Part (d) lists them in terms of CO_2 emissions rate increases from 1990 to 2003.

Focusing on the Big Six, Toyota had the largest increase (95%) in terms of total new fleet carbon burden, putting it in the first position among the Big Six and the 4th among all twelve firms in Table 2b. On the other hand, Toyota had the least decline in fuel economy and so the least increase in its fleet-average CO_2 emissions rate (2.9%) among the Big Six, putting it at the bottom of the list in Figure 6. In terms of carbon burden growth, Honda (70%) was second, followed by Nissan (31%), DCX (23%), Ford (12%) and GM (7%), as shown in Table 2b and Figure 6. Over the period of 1990–2003, fuel economy dropped the most for Nissan (8%), followed by Ford, DaimlerChrysler and GM. Figure 6 makes it evident that the large carbon burden increases of Toyota, Honda, and Nissan were driven mainly by growth in sales, whereas the growths in carbon burden of GM and Ford were largely due to declining fuel economy (increasing fleet average CO_2 emissions rate).

FIGURE 6
Breakdown of growth in Big Six carbon burdens over 1990-2003



Source: Derived from NHTSA CAFE data, NHTSA (2004) and NHTSA (2005).

TABLE 2

CO_2 emissions-related rankings of the top twelve automakers (1990-2003)

(a) Ranked by carbon burden share in 2003

1. **General Motors**	**29.1%**
2. **Ford**	**22.7%**
3. **DaimlerChrysler**	**13.5%**
4. **Toyota**	**10.5%**
5. **Honda**	**7.6%**
6. **Nissan**	**4.8%**
7. Volkswagen	2.2%
8. Hyundai	2.2%
9. Mitsubishi	2.1%
10. BMW	1.7%
11. Kia	1.4%
12. Subaru	1.1%

(b) Ranked by increase in carbon burden 1990-2003, showing breakdown by changes in sales and fuel economy *

	Carbon Burden	Sales	Fuel Economy
1. BMW	326%	388%	15%
2. Hyundai	305%	249%	-14%
3. Volkswagen	170%	180%	3%
4. **Toyota**	**95%**	**90%**	**-3%**
5. Mitsubishi	79%	68%	-6%
6. **Honda**	**70%**	**61%**	**-5%**
7. Subaru	48%	44%	-3%
8. **Nissan**	**31%**	**21%**	**-8%**
9. **DaimlerChrysler**	**23%**	**15%**	**-6%**
10. **Ford**	**12%**	**4%**	**-7%**
11. **GM**	**7%**	**0.3%**	**-6%**

(c) Ranked by average per-vehicle CO_2 emissions rate (ton CO_2 per year) in 1990 and 2003 *

	1990 Emissions rate		2003 Emissions rate
1. BMW	5.60	1. **Ford**	**5.56**
2. **DaimlerChrysler**	**5.18**	2. **DaimlerChrysler**	**5.54**
3. **Ford**	**5.16**	3. **GM**	**5.37**
4. **GM**	**5.05**	4. Kia	4.99
5. **Nissan**	**4.49**	5. BMW	4.89
6. **Toyota**	**4.43**	6. **Nissan**	**4.87**
7. Subaru	4.39	7. Mitsubishi	4.64
8. Mitsubishi	4.38	8. **Toyota**	**4.56**
9. Volkswagen	4.35	9. Subaru	4.52
10. **Honda**	**4.03**	10. Hyundai	4.33
11. Hyundai	3.73	11. **Honda**	**4.26**
		12. Volkswagen	4.21

(d) Ranked by increase in average per-vehicle CO_2 emissions rate 1990-2003 *

1. Hyundai	16.1%
2. **Nissan**	**8.4%**
3. **Ford**	**7.7%**
4. **DaimlerChrysler**	**6.8%**
5. **GM**	**6.3%**
6. Mitsubishi	6.0%
7. **Honda**	**5.7%**
8. **Toyota**	**2.9%**
9. Subaru	2.9%
10. Volkswagen	-3.3%
11. BMW	-12.7%

* Kia entered the U.S. market in 1993, so is not included in the ranking of changes in carbon burdens and CO_2 emissions rate from 1990-2003 (Table 2b and 2d) and the ranking of 1990 CO_2 emissions rate (Table 2c).

Referring back to Table 1 for all twelve major automakers, we can see that two firms, BMW and VW, reduced their fleet-average CO_2 emissions rates between 1990 and 2003. BMW improved its average fuel economy by 15%, from 22.2 mpg to 25.4 mpg, implying a 13% reduction in CO_2 emissions rate, more than any other firm. The company achieved a nearly fivefold increase in sales, reaching 254,000 units (1.7% market share) in 2003, and had started selling one light truck (the X5, tallying about 15% of BMW's U.S. sales in 2003). Volkswagen also improved its fuel economy while greatly increasing its sales over the 1990–2003 period. Hyundai nearly tripled its market share but had the worst decline (14%) in fuel economy among the twelve automakers.

Results for the Big Six

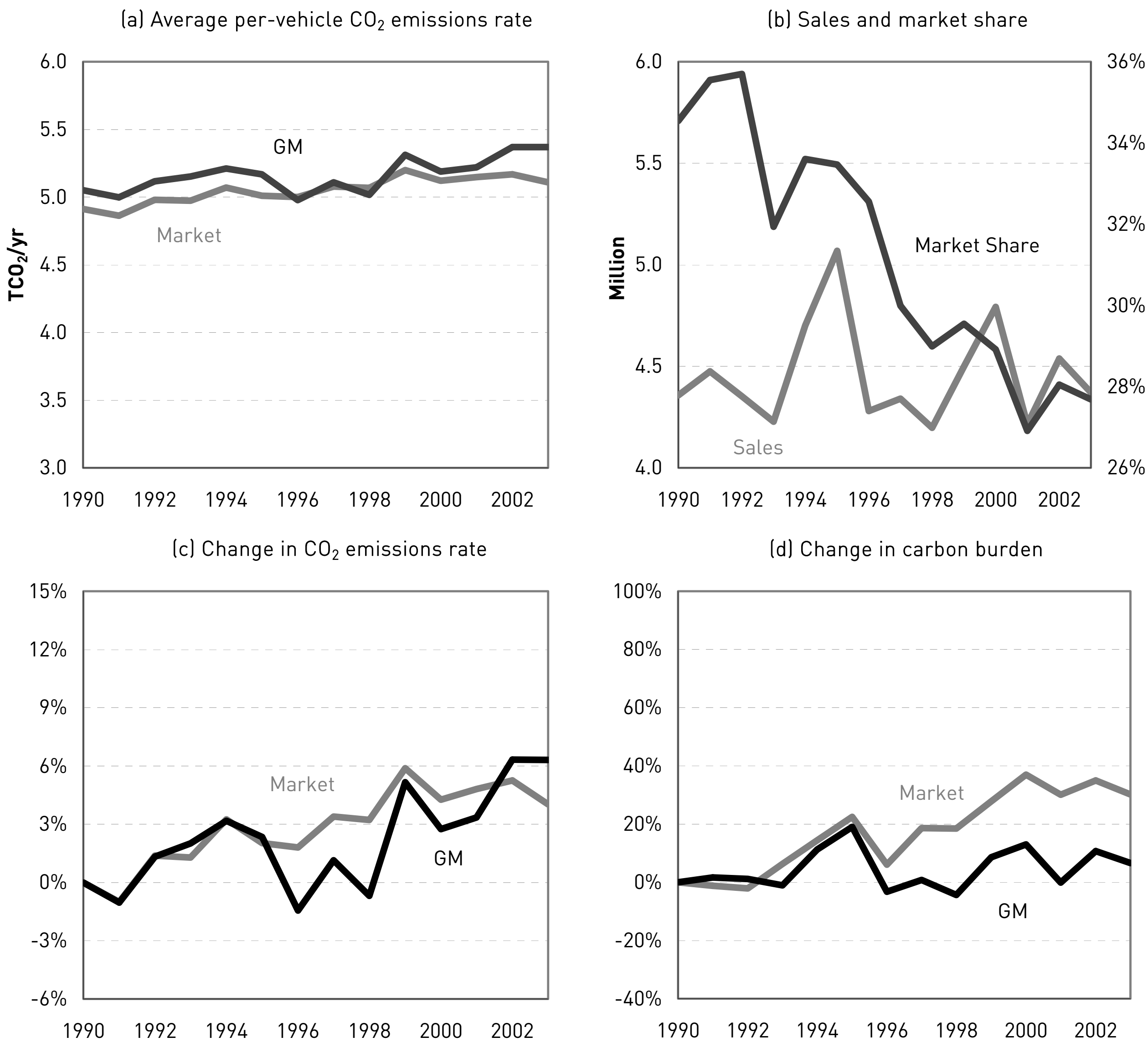
We now turn to a more detailed analysis of 1990–2003 carbon burdens trends for each of the Big Six, followed by a section elaborating briefly on trends for the remaining six of the twelve automakers analyzed. A final section of this chapter further discusses the shift from vehicles classified as cars to those classified as light trucks, an ongoing phenomenon that underpins the carbon burden trends for all automakers in the U.S. market.

GENERAL MOTORS (GM)

GM's average per-vehicle CO_2 emissions rate rose from 5.1 TCO_2/yr in 1990 to 5.4 TCO_2/yr in 2003, for a net increase of 6% as shown in Figures 7a and 7c. The trend largely mirrors that of the overall market.

GM's market share slipped to an historic low of 27% in 2001, as shown in Figure 7b. Boosted by heavy incentives,[26] it bounced back in 2002–2003 to the vicinity of 28%. Nevertheless, the picture is one of a declining trend, with GM's 2003 sales up only 0.3% since 1990 while the overall U.S. market saw a 25% growth. The 6.8-point share drop over the 13-year period was in line with GM's

FIGURE 7
General Motors new fleet carbon burden and related trends



average 0.5 point/year rate of share loss over the previous two decades.

Incentives attracted customers to more expensive models such as pickups and SUVs,[27] driving the truck fraction of GM's sales past the 50% mark in 2002 and to 56% in 2003. As shown in Table 3, GM's light truck fuel economy reveals no obvious trend. GM's car fuel economy shows a notable increase since 1999, with a net rise of 5.5% from 1990 to 2003.[28] The increase in GM's fleet-average CO_2 emissions rate, therefore, was a direct consequence of a shift from passenger cars to light trucks. Had the car and truck mix of GM's sales stayed the same as in 1990, the company's average CO_2 emissions rate in 2003 would have been 9.4% lower.

GM began using FFV credits in 1999 with a dual-fuel version of the Chevrolet S-10 pickup and sold similar versions of the GMC Sonoma in 2000 and 2001. However, GM's claimed FFV credits were small (less than 1% CAFE impact) through 2001. Subsequently, the company has introduced dual-fuel versions of nine additional models,[29] inflating GM's combined CAFE values by 0.8 mpg and 0.9 mpg respectively in 2002 and 2003.[30] Using FFV credits to help meet CAFE standards made GM's average CO_2 emissions rate 1.8% higher in 2003 than it would have been otherwise.

Driven by the rise and fall of GM's new vehicle sales, its new fleet carbon burden fluctuated in the last 13 years. In spite of GM's falling market share, its carbon burden showed net 7% growth, reaching 6.4 MMTc in 2003, due to the company's rising average CO_2 emissions rate. GM's carbon burden share fell from 36% in 1990 to less than 30% since 2001.

TABLE 3

General Motors light vehicle sales and carbon-burden related statistics

Model	Sales	Market	Truck	Fuel Economy (mpg)			Emissions Rate		Oil	Carbon Burden	
Year	million	Share	share	Cars	Trucks	Fleet	TCO_2/yr	change	kbd	MMTc/yr	share
1990	4.358	34.5%	28%	27.3	19.7	24.6	5.05	0.0%	163	6.00	35.5%
1991	4.474	35.5%	33%	27.1	21.3	24.9	5.00	-1.0%	166	6.10	36.5%
1992	4.352	35.7%	31%	26.7	20.2	24.3	5.12	1.3%	165	6.07	36.7%
1993	4.228	31.9%	34%	27.2	19.8	24.1	5.15	2.0%	161	5.94	33.1%
1994	4.701	33.6%	38%	27.1	19.9	23.8	5.21	3.2%	182	6.68	34.5%
1995	5.069	33.5%	38%	27.3	20.1	24.0	5.17	2.3%	194	7.15	34.5%
1996	4.279	32.6%	36%	28.3	20.7	25.0	4.98	-1.5%	158	5.81	32.4%
1997	4.341	30.0%	40%	28.1	20.2	24.3	5.11	1.1%	164	6.05	30.2%
1998	4.197	29.0%	41%	28.1	21.1	24.8	5.02	-0.7%	156	5.74	28.7%
1999	4.500	29.5%	42%	27.1	19.7	23.4	5.31	5.2%	177	6.52	30.2%
2000	4.793	28.9%	45%	27.6	20.6	23.9	5.19	2.7%	184	6.78	29.3%
2001	4.214	26.9%	45%	27.9	20.2	23.8	5.22	3.3%	163	6.00	27.3%
2002	4.539	28.0%	52%	28.2	19.9	23.1	5.37	6.3%	181	6.65	29.1%
2003	4.372	27.7%	56%	28.6	20.1	23.1	5.37	6.3%	174	6.40	29.1%

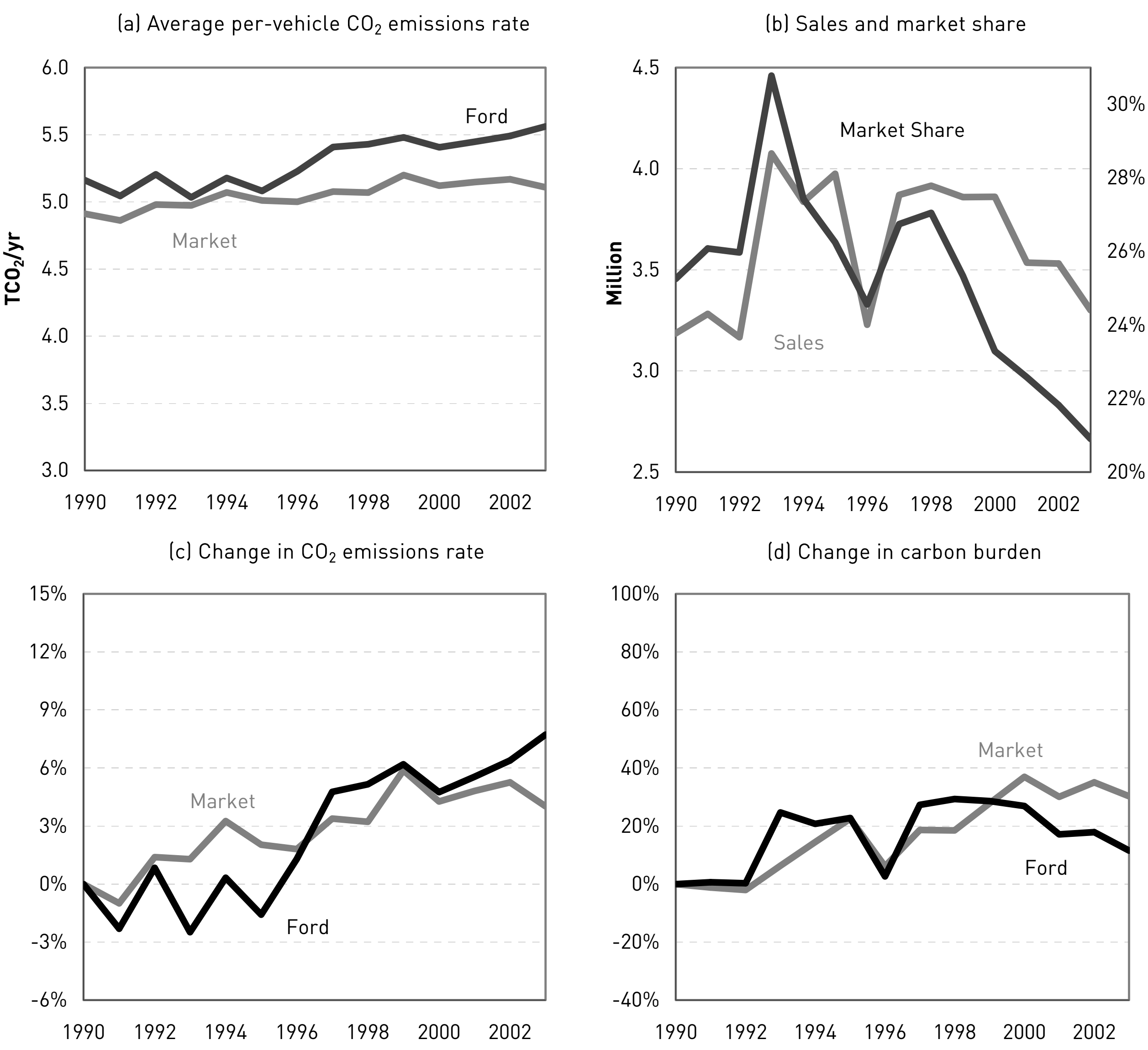
Note: Units are metric tons of CO_2 per year (TCO_2/yr) for average per-vehicle emissions rate, thousands of barrels per day (kbd) for oil demand, and million metric tons (MMTc) per year for carbon burden. Changes are given relative to 1990 levels.

FORD

As shown in Figure 8a, Ford's average per-vehicle CO_2 emissions rate generally trended upward from 1996, somewhat faster than the market average. It reached 5.6 TCO_2/yr in 2003, 8% higher than it was in 1990 and the highest level since 1980.[31] Ford's passenger car fuel economy showed little net trend and its light truck fuel economy moderately declined (Table 4). Thus, the rising CO_2 emissions rate was primarily due to the increasing truck fraction of Ford's new fleet, which saw an increase of 24 points from 1990 to 2003.

In July 2000, Ford pledged to improve the fuel economy of its SUVs 25% by

FIGURE 8
Ford new fleet carbon burden and related trends



2005. Even though Ford abandoned its pledge in 2003,[32] its average SUV fuel economy improved in 2000–2002 to a level nearly 10% higher than it was in 1999.[33] Ford's SUV fuel economy, however, declined slightly in 2003, as did the company's average light truck fuel economy.

As the first automaker to avail itself of FFV credits with a flex-fuel version of Taurus in 1993, Ford has used the credits for more than a decade. The credits claimed were minuscule until Ford started using them more extensively for its light truck fleet in 1999. FFV credits raised Ford's CAFE by 0.5 and 0.8 mpg in 1999 and 2000, respectively, but only 0.2 mpg in 2001. Credit use rose to 0.5 mpg in 2002 and 1.1 mpg in 2003 as Ford introduced dual-fuel versions of its top-selling Explorer SUV and F-150 pickup.[34] Ford's average CO_2 emissions rate in 2003 was 3% higher than if its cars and trucks had met CAFE requirements without FFV credits.

Ford's recently introduced Escape Hybrid demonstrates an average 60% fuel economy improvement over conventional versions of the SUV, and uses an average of 229 fewer gallons of fuel per year.[35] Ford would need to sell hybrids with this level of fuel savings across 20% of its lineup (over 650,000 units relative to its 2003 sales) in order to offset the 7.7% increase in its fleet-average CO_2 emissions rate from 1990 to 2003.

As shown in Figure 8b, Ford's sales have generally declined since their peak in 1993, ending the 1990–2003 period up 4% in a market that grew 25% overall. Ford's market share slid to 21% in 2003, down 4.4 points from its 1990 level.

Figure 8d shows that Ford's carbon burden largely followed the market trend from 1990 to 1996. In spite of Ford's rising CO_2 emissions rate, its carbon burden growth fell behind the market average since 1999 due to declining sales. In 2003, it was 5.0 MMTc, up 12% from its 1990 level. Ford's 23% carbon burden share in 2003 still ranked second among the Big Six.

TABLE 4
Ford light vehicle sales and carbon-burden related statistics

Model Year	Sales million	Market share	Truck share	Fuel Economy (mpg) Cars	Trucks	Fleet	Emissions Rate TCO_2/yr	change	Oil Kbd	Carbon Burden MMTc/yr	share
1990	3.186	25.3%	35%	26.6	20.4	24.1	5.16	0.0%	122	4.49	26.5%
1991	3.283	26.1%	38%	27.8	20.7	24.6	5.04	-2.3%	123	4.51	27.0%
1992	3.167	26.0%	41%	27.1	20.4	23.9	5.20	0.8%	122	4.50	27.2%
1993	4.075	30.8%	39%	28.0	20.8	24.7	5.03	-2.5%	152	5.59	31.1%
1994	3.836	27.4%	45%	27.4	20.8	24.0	5.18	0.3%	147	5.42	28.0%
1995	3.975	26.2%	41%	27.9	20.8	24.5	5.08	-1.6%	150	5.51	26.6%
1996	3.229	24.6%	46%	27.1	20.8	23.8	5.23	1.3%	125	4.60	25.7%
1997	3.870	26.7%	52%	27.3	20.0	23.0	5.41	4.8%	155	5.71	28.5%
1998	3.916	27.0%	54%	27.3	20.1	22.9	5.43	5.2%	158	5.80	29.0%
1999	3.859	25.3%	52%	27.0	19.7	22.7	5.48	6.2%	157	5.77	26.7%
2000	3.861	23.3%	51%	27.0	20.1	23.0	5.41	4.8%	155	5.69	24.6%
2001	3.535	22.6%	56%	27.0	20.3	22.8	5.45	5.5%	143	5.25	23.9%
2002	3.531	21.8%	58%	26.9	20.3	22.6	5.49	6.4%	144	5.29	23.2%
2003	3.300	20.9%	59%	26.9	20.0	22.3	5.56	7.7%	136	5.00	22.7%

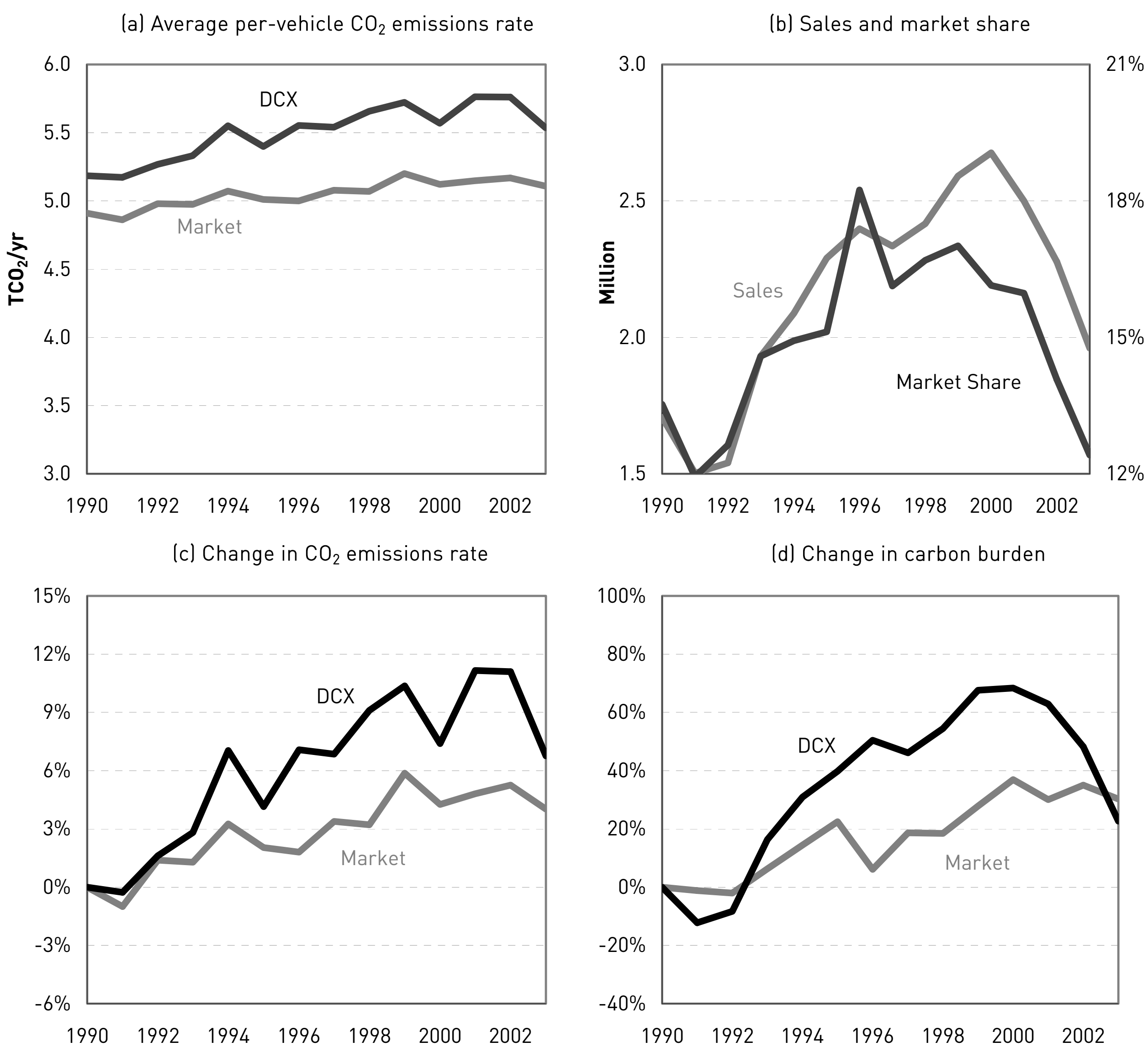
Note: Units are metric tons of CO_2 per year (TCO_2/yr) for average per-vehicle emissions rate, thousands of barrels per day (kbd) for oil demand, and million metric tons (MMTc) per year for carbon burden. Changes are given relative to 1990 levels.

DAIMLERCHRYSLER (DCX)

Our discussion combines the separate Chrysler and Mercedes-Benz fleets both before and after the 1998 merger to show the overall 1990–2003 performance of brands now owned by DaimlerChrysler. The average per-vehicle CO_2 emissions rate of DCX brands trended generally upward between 1990 and 1999, outpacing the trend of the overall market before declining gradually since 2000. As of 2003, DCX's average per vehicle CO_2 emissions rate reached 5.5 TCO_2/yr, a net increase of 7% from the 1990 level, but 4% lower than its 2001 peak.

Rising truck fraction and declining truck fuel economy were the main factors

FIGURE 9
DaimlerChrysler new fleet carbon burden and related trends



that pushed DCX's CO_2 emissions rate upward from 1990 through 2001. Over the 1990–2003 period, the truck fraction of DCX's fleet grew 24 points, topping 70% over the last three years. Meanwhile, its truck fuel economy fell by 2%. Although it has generally trended upward more than the overall market, DCX's CO_2 emissions rate did drop in 2003 as the company improved the fuel economy of several high-volume models.[36] For instance, the fuel economy of the 2002 PT Cruiser increased by 1.5 mpg, while the fuel economy of the 2003 Caravan 2WD, Dodge Durango, Jeep Grand Cherokee, and Jeep Liberty rose by 1.4, 1.6, 1.9 and 1.8 mpg respectively.[37]

Chrysler started to offer natural gas versions of several vehicles[38] in 1996, but volumes were very small and the credits claimed amounted to only 0.01 mpg. From 1998 onwards, Chrysler introduced dual-fuel ethanol versions of its minivans and natural gas versions of the Ram 2500 Van and Wagon. In 2003, DCX offered flex-fuel cars for the first time (Mercedes C320, Chrysler Sebring and Dodge Stratus), helping the company meet car CAFE standards. DCX's 2003 truck fleet met CAFE requirements even without FFV credits, as shown in Table 5. Between 1998 and 2003, FFV credits earned ranged from 0.5 to 1 mpg. As of 2003, DCX's fleet-average CO_2 emissions rate was 4.4% higher than it would have been had the company achieved the same fuel economy levels without FFV credits.[39]

DCX's sales climbed gradually since 1993, but started to plummet in 2001, falling to 2 million units in 2003 (Figure 9b). Following a similar trend, DCX's market share witnessed a net four-point growth between 1990 and 1999 but then slid five points, down to 12.4% by 2003.

As shown in Figure 9d, DCX's carbon burden growth exceeded the overall market from 1993, but the gap narrowed in 2002 and 2003, as a result of dwindling sales as well as the lower CO_2 emissions rate in 2003. DCX's carbon burden was 3.0 MMTc in 2003, a 13.5% share of the total.

TABLE 5
DaimlerChrysler light vehicle sales and carbon-burden related statistics

Model	Sales	Market	Truck	Fuel Economy (mpg)			Emissions Rate		Oil	Carbon Burden	
Year	million	Share	share	Cars	Trucks	Fleet	TCO_2/yr	change	kbd	MMTc/yr	share
1990	1.706	13.5%	50%	27.1	21.5	24.0	5.18	0.0%	66	2.41	14.3%
1991	1.502	11.9%	44%	27.1	21.0	24.0	5.17	-0.3%	58	2.12	12.7%
1992	1.540	12.6%	54%	27.1	21.2	23.6	5.27	1.6%	60	2.21	13.4%
1993	1.931	14.6%	57%	27.3	21.0	23.3	5.33	2.8%	76	2.81	15.6%
1994	2.088	14.9%	62%	26.3	20.5	22.4	5.55	7.0%	86	3.16	16.3%
1995	2.290	15.1%	54%	27.7	20.1	23.0	5.40	4.1%	92	3.37	16.3%
1996	2.398	18.2%	64%	27.3	20.3	22.4	5.55	7.1%	99	3.63	20.3%
1997	2.334	16.1%	62%	27.5	20.2	22.4	5.54	6.9%	96	3.53	17.6%
1998	2.417	16.7%	68%	28.0	19.9	22.0	5.66	9.1%	101	3.73	18.6%
1999	2.591	17.0%	68%	27.1	19.9	21.7	5.72	10.4%	110	4.04	18.7%
2000	2.676	16.1%	64%	26.9	20.4	22.3	5.57	7.4%	110	4.06	17.6%
2001	2.500	16.0%	70%	26.8	19.9	21.6	5.76	11.2%	107	3.93	17.9%
2002	2.277	14.1%	74%	26.5	20.2	21.6	5.76	11.1%	97	3.58	15.7%
2003	1.960	12.4%	74%	27.3	21.1	22.4	5.54	6.8%	80	2.96	13.5%

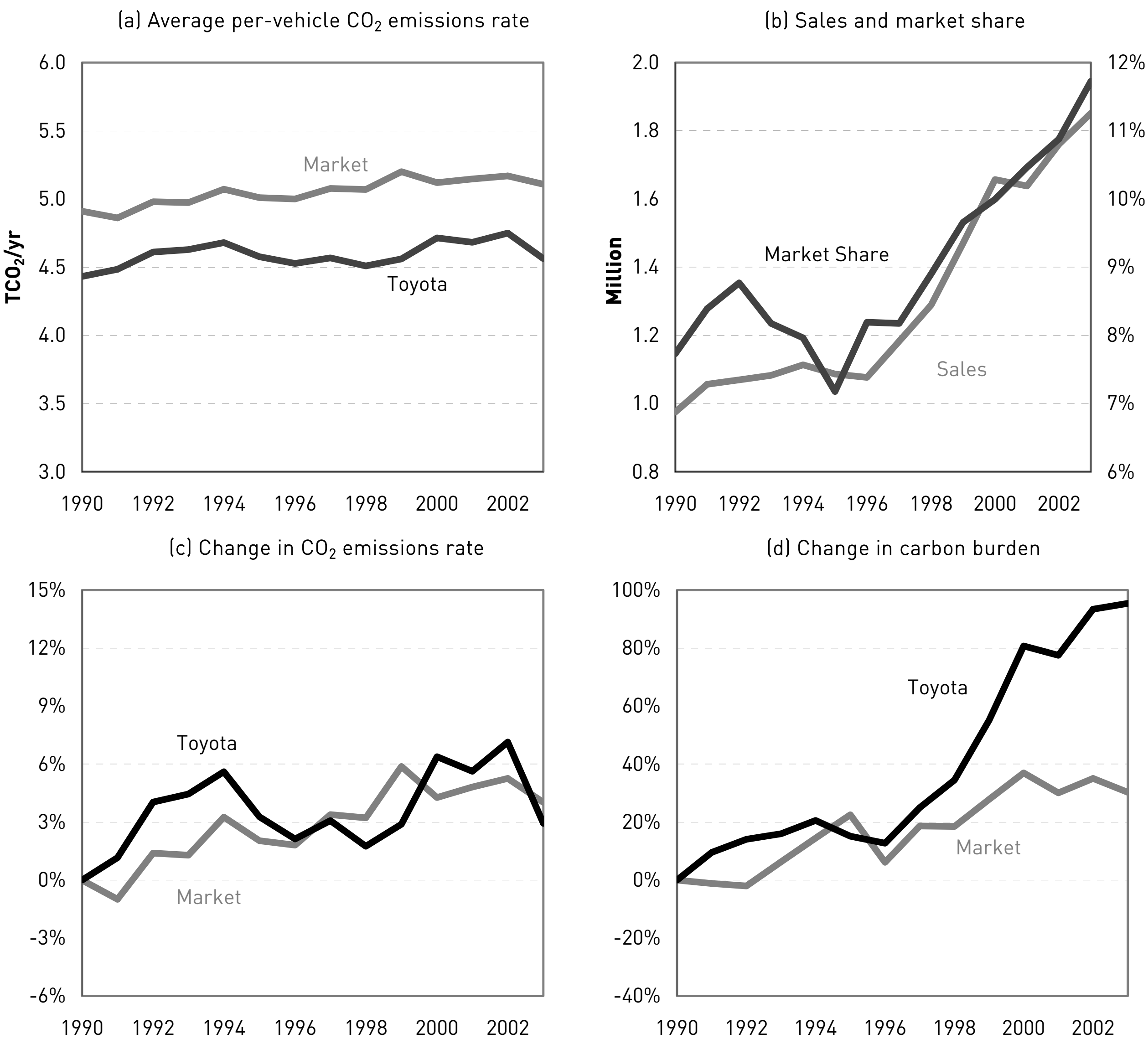
Note: Units are metric tons of CO_2 per year (TCO_2/yr) for average per-vehicle emissions rate, thousands of barrels per day (kbd) for oil demand, and million metric tons (MMTc) per year for carbon burden. Changes are given relative to 1990 levels.

TOYOTA

Toyota's average per-vehicle CO_2 emissions rate fluctuated but showed a generally rising trend over the past 13 years (Figure 10a). The CO_2 emissions rate went up gradually in the early 1990s, declined in the mid 1990s and then began rising more rapidly in 1999. The upward trend reversed in 2003 and Toyota ended the period with 3% net growth in its fleet-average CO_2 emissions rate, the least among the Big Six.

As for most automakers, Toyota's increased CO_2 emissions rate is attributed to rising truck fraction. The company entered the 1990s with two SUVs—the Land Cruiser and the 4Runner—and ended 2003 with eight SUVs plus its two

FIGURE 10
Toyota new fleet carbon burden and related trends



pickups and minivan.[40] Toyota's truck fraction gained 15 points from 1990 to 2003. Growing truck sales offset the small improvement in Toyota's car fuel economy over the past decade (see Table 6). The 2003 decline in CO_2 emissions rate coincided with a slight drop in truck fraction and a more than two-fold sales increase for the redesigned 38 mpg Toyota Corolla.[41]

Toyota has been the leader in commercialization of hybrid-electric vehicles. Introduced to the U.S. market in 2001, the first-generation Toyota Prius was rated at 58 mpg based on EPA CAFE (test) cycles and emitted 2.1 TCO_2/yr, roughly 30% less than a comparable compact car and 60% less than the 2003 market average.[42] Through our analysis period, Prius sales were still quite small; the 51,253 units sold in 2001–03 accounted for only 1% of Toyota's total sales over those three model years.

Toyota's redesigned 2004 Prius achieves an even higher fuel economy rating of 66 mpg, and demonstrates a 85% improvement in fuel economy over a comparable model.[43] The recently released Lexus Hybrid SUV RX400h reaches test fuel economy level of 34.5 mpg and is about 44% more fuel efficient than the comparable Lexus RX300.[44] The company has announced plans for more hybrid models, including the Highlander Hybrid SUV in 2005, a Lexus GS 450h Hybrid sedan and a Camry Hybrid. If the fuel economy of its non-hybrid vehicles is unchanged, Toyota could offset the 2.9% increase in its new fleet CO_2 emissions rate 1990–2003 if 8% of its sales (roughly 150,000 units) become hybrids with the same average fuel savings as the new Prius and Lexus RX400h.

Toyota's sales grew slowly through the mid 1990s, with its market share fluctuating around 8% through 1997 (Figure 10b). Toyota's sales[45] then climbed dramatically and the company's market share reached nearly 12% in 2003. With its burgeoning sales and rising average CO_2 emissions rate, Toyota's carbon burden escalated rapidly, ending the period with a net growth of 95%. However, most of this increase is accounted for by the company's 90% sales growth from 1990 to 2003. As noted earlier, Toyota's CO_2 emissions rate increase was the lowest among the Big Six.

TABLE 6
Toyota light vehicle sales and carbon-burden related statistics

Model Year	Sales million	Market share	Truck share	Fuel Economy (mpg) Cars	Trucks	Fleet	Emissions Rate TCO_2/yr	change	Oil kbd	Carbon Burden MMTc/yr	share
1990	0.975	7.7%	24%	30.8	21.8	28.0	4.43	0.0%	32	1.18	7.0%
1991	1.056	8.4%	30%	30.9	22.3	27.7	4.48	1.2%	35	1.29	7.7%
1992	1.069	8.8%	25%	29.1	22.0	26.9	4.61	4.0%	37	1.34	8.1%
1993	1.083	8.2%	28%	29.1	22.3	26.8	4.63	4.4%	37	1.37	7.6%
1994	1.114	8.0%	32%	29.2	22.2	26.5	4.68	5.6%	39	1.42	7.4%
1995	1.087	7.2%	27%	30.2	21.2	27.1	4.58	3.3%	37	1.36	6.6%
1996	1.077	8.2%	28%	29.7	23.1	27.4	4.53	2.1%	36	1.33	7.4%
1997	1.183	8.2%	31%	30.0	22.6	27.2	4.57	3.1%	40	1.47	7.4%
1998	1.289	8.9%	35%	30.4	23.5	27.5	4.51	1.7%	43	1.59	7.9%
1999	1.471	9.7%	31%	29.8	22.9	27.2	4.56	2.9%	50	1.83	8.5%
2000	1.657	10.0%	37%	30.0	21.8	26.3	4.72	6.4%	58	2.13	9.2%
2001	1.639	10.5%	40%	30.6	22.1	26.5	4.68	5.6%	57	2.09	9.5%
2002	1.760	10.9%	42%	30.3	22.1	26.2	4.75	7.1%	62	2.28	10.0%
2003	1.852	11.7%	39%	32.3	21.9	27.2	4.56	2.9%	63	2.30	10.5%

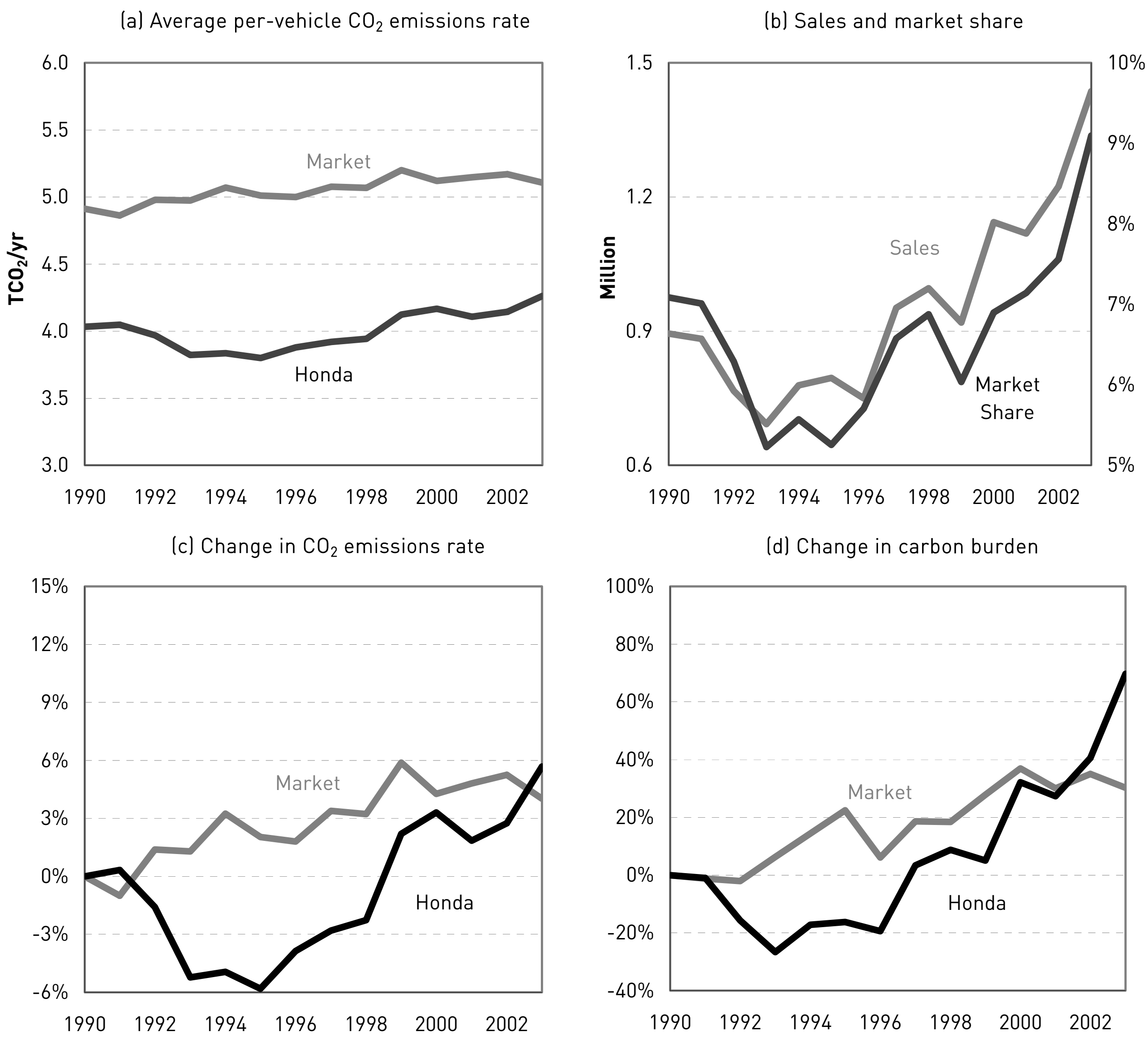
Note: Units are metric tons of CO_2 per year (TCO_2/yr) for average per-vehicle emissions rate, thousands of barrels per day (kbd) for oil demand, and million metric tons (MMTc) per year for carbon burden. Changes are given relative to 1990 levels.

HONDA

As seen in Figure 11a, Honda has maintained the lowest CO_2 emissions rate among the Big Six, averaging 20% below the market over the 1990–2003 period. The rate declined in the early 1990s but has climbed steadily since 1996, for net growth of 5.7% over the 1990 level by 2003.[46] The recent growth in Honda's CO_2 emissions rate has for the first time exceeded that of the overall market, as shown in Figure 11c.

These trends follow from Honda's late entry into the light truck segments that became so popular in the 1990s. Since the debut of its CR-V SUV in 1997,

FIGURE 11
Honda new fleet carbon burden and related trends



the truck fraction of Honda's mix grew by an average of 5.6 points per year, reaching 39% in 2003. The growth was particularly evident in 2003, when the new Element and Pilot SUVs boost Honda's truck fraction by 12 points in a single year. Honda's average light truck fuel economy dropped by 2.2 mpg from 1998 to 2003 (see Table 7) as its offerings moved up-market.[47]

Honda has always been a leader in fuel efficiency. Past examples include the 50 mpg CRX-HF through 1991, the 51 mpg Civic VX 1992–95, and the 40 mpg Civic HX since 1996.[48] Introduced in 2000, the Honda Insight was the first hybrid-electric vehicle on sale in North America; with ratings up to 75 mpg[49] it has been the most fuel-efficient vehicle on the market. The Honda Civic Hybrid went on sale in April 2002 as an early 2003 model. With a rating of 56 mpg, the Civic Hybrid is 30% more fuel efficient than a comparable model.[50]

Through 2003, cumulative sales of the Insight reached 17,311 units, while the first full year sales of the Civic Hybrid totaled 32,582 units (2.3% of overall 2003 Honda sales).[51] Honda introduced the Accord Hybrid in December 2004 with a rating of 38 mpg, providing 32% higher fuel economy[52] and better performance than a conventional V6 Accord. If the fuel economy of its other vehicles remains unchanged, Honda would have to sell roughly 22% of its vehicles[53] (over 300,000 units) as hybrids with the same average fuel savings as the Civic and Accord Hybrid to offset the 5.7% growth in its CO_2 emissions rate from 1990 to 2003.[54]

Honda's market share fell in the early 1990s, then bounced back in 1996 and reached a record high of 9.1% in 2003, as shown in Figure 11b. Honda's sales exceeded 1.4 million units in 2003, for a 61% net increase from the 1990 level. Thus, Honda's carbon burden went down in the early 1990s and escalated steadily from 1997 onwards. It reached 1.7 MMTc/yr in 2003, for a net growth of 70% from the 1990 level. Of course, the larger portion of this growth is due to the sales increase. Honda's carbon burden share reached 7.6% of the new vehicle market total in 2003.

TABLE 7
Honda light vehicle sales and carbon-burden related statistics

Model	Sales	Market	Truck	Fuel Economy (mpg)			Emissions Rate		Oil	Carbon Burden	
Year	million	share	share	Cars	Trucks	Fleet	TCO_2/yr	change	kbd	MMTc/yr	share
1990	0.894	7.1%	0%	30.8		30.8	4.03	0.0%	27	0.98	5.8%
1991	0.882	7.0%	0%	30.7		30.7	4.05	0.3%	26	0.97	5.8%
1992	0.767	6.3%	0%	31.3		31.3	3.97	-1.6%	23	0.83	5.0%
1993	0.692	5.2%	0%	32.5		32.5	3.82	-5.2%	20	0.72	4.0%
1994	0.779	5.6%	0%	32.4		32.4	3.83	-4.9%	22	0.81	4.2%
1995	0.796	5.3%	0%	32.7		32.7	3.80	-5.8%	22	0.82	4.0%
1996	0.750	5.7%	0%	32.0		32.0	3.88	-3.9%	22	0.79	4.4%
1997	0.952	6.6%	8%	32.2	26.9	31.7	3.92	-2.8%	28	1.02	5.1%
1998	0.996	6.9%	10%	32.1	26.9	31.5	3.94	-2.3%	29	1.07	5.3%
1999	0.919	6.0%	18%	31.2	26.1	30.1	4.12	2.2%	28	1.03	4.8%
2000	1.143	6.9%	21%	31.2	25.4	29.8	4.17	3.3%	35	1.30	5.6%
2001	1.118	7.1%	25%	32.5	25.0	30.2	4.11	1.8%	34	1.25	5.7%
2002	1.223	7.6%	27%	32.2	25.4	30.0	4.14	2.7%	38	1.38	6.1%
2003	1.436	9.1%	39%	32.9	24.7	29.1	4.26	5.7%	45	1.67	7.6%

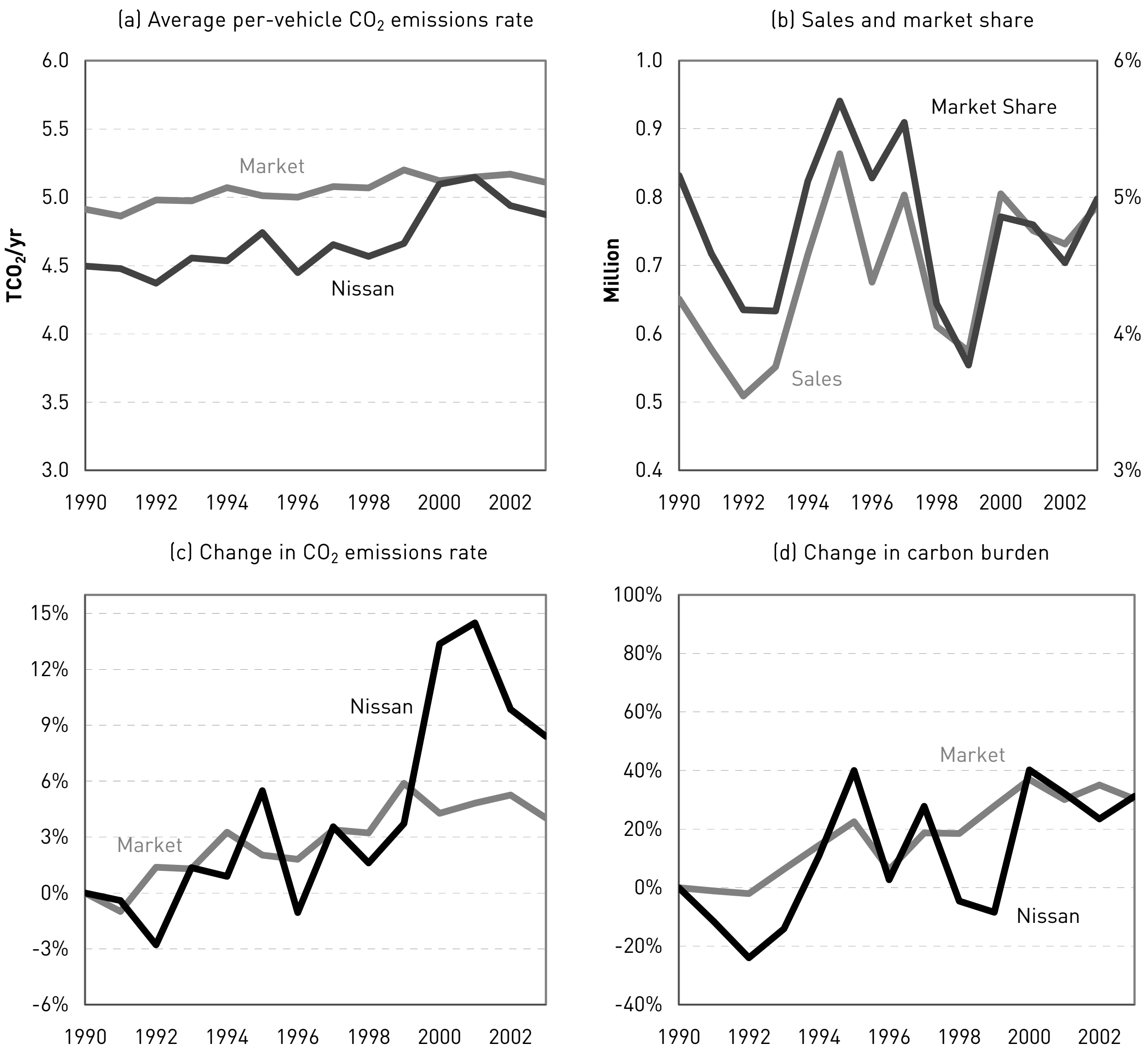
Note: Units are metric tons of CO_2 per year (TCO_2/yr) for average per-vehicle emissions rate, thousands of barrels per day (kbd) for oil demand, and million metric tons (MMTc) per year for carbon burden. Changes are given relative to 1990 levels.

NISSAN

From 1990 to 1999, Nissan's new fleet CO_2 emissions rate generally paralleled the rising market trend but averaged 9% lower, as seen in Figure 12a.[55] It then shot up in 2000 to 5.2 TCO_2/yr before declining a bit in 2002–2003 and ending the period at 4.9 TCO_2/yr. The result was net growth of 8% from its 1990 level, the worst increase in fleet-average CO_2 emissions rate among the Big Six.

Like other automakers, Nissan's rising CO_2 emissions rate resulted from a growing light truck fraction. Nissan's gained a net 11 points in the past 13 years (Table 8). It stood at 36% in 2003, down from the historic high of 47% in 2000

FIGURE 12
Nissan new fleet carbon burden and related trends



that coincided with the release of the Xterra SUV and the rising sales of the Frontier pickup. Its truck fraction dropped in 2002 and 2003 as Nissan introduced some new and redesigned car models, notably the Altima, 350Z, and Infiniti G35. The car-to-truck shift alone accounted for 2.8% of the 8.4% overall growth in Nissan's CO_2 emissions rate from 1990 to 2003.

Declining light truck CAFE was the other factor behind the increase in Nissan's overall new fleet CO_2 emissions rate. As shown in Table 8, Nissan's truck CAFE dropped by 13% over the 13 years, as the company's light trucks got larger and more powerful. It improved significantly in 2003, largely due to the release of the Murano sport wagon, and improved fuel economy of the Xterra SUV and the Frontier pickup.

Nissan's sales fluctuated considerably over the 1990–2003 period, increasing by 70% between 1992 and 1995 before plummeting again through 1999 (Figure 12b). Sales have since recovered, standing just below 800,000 units in 2003. This gave Nissan a market share of 5%, slightly lower than its 1990 level.

Recalling that an automaker's carbon burden is determined by its overall vehicles sales and the average per-vehicle CO_2 emissions rate, Nissan's carbon burden closely followed its sales fluctuations in the past 13 years (see Figures 12b and d). The net trend was similar to that of the overall market, rising due to higher truck sales and the corresponding rise in average CO_2 emissions rate. As of 2003, Nissan's carbon burden reached 1.0 MMTc/yr, for net 31% growth from the 1990 level. Like its market share, Nissan's carbon burden share remained the lowest among the Big Six, reaching 4.8% in 2003—a net 0.1-point increase from 1990.

TABLE 8
Nissan light vehicle sales and carbon-burden related statistics

Model	Sales	Market	Truck	Fuel Economy (mpg)			Emissions Rate		Oil	Carbon Burden	
Year	million	share	share	Cars	Trucks	Fleet	TCO_2/yr	change	kbd	MMTc/yr	share
1990	0.651	5.2%	25%	28.5	25.3	27.6	4.49	0.0%	22	0.80	4.7%
1991	0.577	4.6%	29%	29.2	24.8	27.8	4.48	-0.4%	19	0.70	4.2%
1992	0.509	4.2%	24%	30.2	23.9	28.4	4.37	-2.8%	16	0.61	3.7%
1993	0.552	4.2%	32%	29.4	23.7	27.3	4.56	1.4%	19	0.69	3.8%
1994	0.716	5.1%	31%	30.1	22.9	27.4	4.53	0.9%	24	0.89	4.6%
1995	0.864	5.7%	40%	29.5	22.4	26.2	4.74	5.5%	30	1.12	5.4%
1996	0.675	5.1%	28%	30.5	22.9	27.9	4.45	-1.1%	22	0.82	4.6%
1997	0.803	5.5%	35%	29.9	22.3	26.7	4.65	3.5%	28	1.02	5.1%
1998	0.611	4.2%	32%	30.4	22.3	27.2	4.57	1.6%	21	0.76	3.8%
1999	0.574	3.8%	30%	29.9	21.2	26.7	4.66	3.7%	20	0.73	3.4%
2000	0.805	4.9%	44%	28.2	20.8	24.4	5.10	13.4%	30	1.12	4.8%
2001	0.751	4.8%	47%	28.4	20.7	24.1	5.15	14.5%	29	1.05	4.8%
2002	0.731	4.5%	39%	29.2	20.7	25.2	4.94	9.9%	27	0.98	4.3%
2003	0.788	5.0%	36%	28.0	21.9	25.5	4.87	8.4%	28	1.05	4.8%

Note: Units are metric tons of CO_2 per year (TCO_2/yr) for average per-vehicle emissions rate, thousands of barrels per day (kbd) for oil demand, and million metric tons (MMTc) per year for carbon burden. Changes are given relative to 1990 levels.

Trends for other automakers

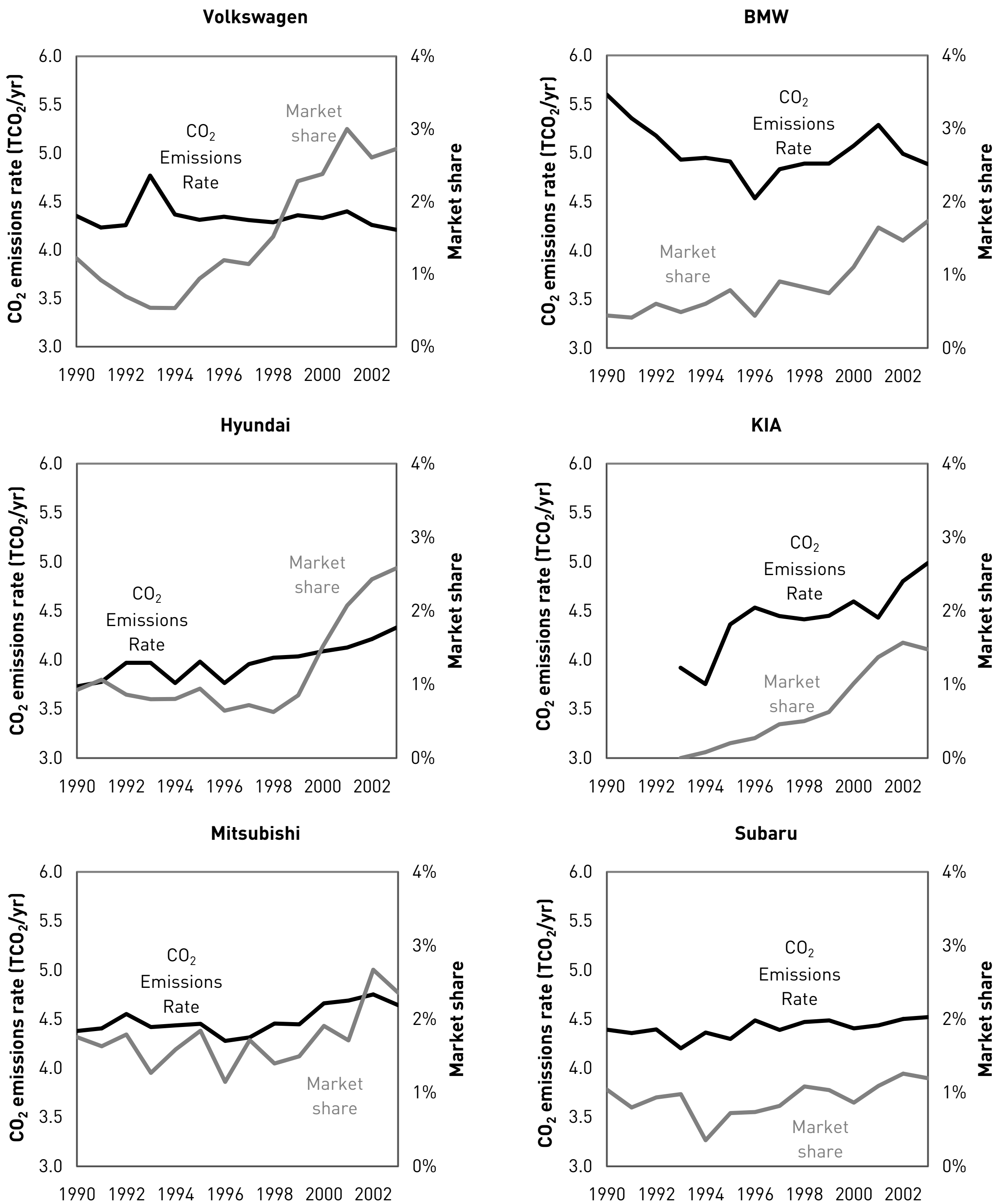
Referring back to the Table 1 summary results for 1990 and 2003, we can see some significant changes for the automakers ranking from the 7th to 12th in the U.S. light vehicle market. These "Next Six" automakers are Volkswagen, Hyundai, Mitsubishi, BMW, Kia, and Subaru. Collectively, their sales nearly tripled between 1990 and 2003. Their combined market share grew from 5% in 1990 to 12% in 2003 and by then, these six firms collectively accounted for 11% of the overall new fleet carbon burden.

Figure 13 traces changes in market share and average per-vehicle CO_2 emissions rate for each of the Next Six. Although each firm accounted for less than 3% of model year 2003 sales, all saw market share increases from 1990 to 2003. Kia was a new entrant, introducing its first U.S. model (the Sephia compact car) in late 1993. The company introduced the Sportage SUV in 1995 and by 2003 light trucks comprised 41% of Kia's U.S. sales. BMW and Hyundai did not sell any light trucks in 1990, but by 2003 their truck fractions reached 16% and 24%, respectively. Volkswagen and Subaru both had smaller truck fractions of their sales in 2003 than they did in 1990. Subaru's market share saw little net change over the period. Volkswagen's share rebounded in the late 1990s, with its 2003 market share of 2.7% being more than double what it was in 1990.

With the exception of BMW, the fleet-average CO_2 emissions rates of all these automakers remained below the market average from 1990 to 2003. This is largely because the five automakers—Volkswagen, Hyundai, Mitsubishi, Kia, and Subaru—focus on small and mid-size vehicles and traditionally rely less on truck sales. Volkswagen saw a net reduction in its average CO_2 emissions rate from 1990 to 2003; its CO_2 emissions rate was the lowest among major automakers in 2003. Hyundai's new fleet-average CO_2 emissions rate in 1990 was the lowest among the twelve automakers examined here, but increased the most during the period, rising 16% from 1990 to 2003. Kia's CO_2 emissions rate also increased rapidly since the company entered the U.S. market in 1993. By 2003, its emissions rate grew 27% to approach the market average, again as a result of growing truck fraction. Mitsubishi's CO_2 emissions rate also followed a rising trend as its sales of light trucks increased. Its market share generally fluctuated around 1.6% from 1990 to 2000, but then rebounded through 2003, so that its market share grew a net 0.6 point over the period, while its new fleet-average CO_2 emissions rate grew 6%. Subaru's 3% increase in 1990–2003 fleet-average CO_2 emissions rate was one of the smaller increases; the company's market share had little net change over the period.

With its product mix of upscale fast cars, BMW's CO_2 emissions rate was above the market average in the early 1990s even without trucks. Yet BMW's emissions rate saw the biggest reduction among all major automakers, reflecting notable fuel economy improvements across its lineup. The company cut its new fleet-average CO_2 emissions rate by 13% between 1990 and 2003, even with the X5 SUV (introduced in 2000) contributing to more than 15% of BMW's sales. Volkswagen also improved fuel economy over the period, posting a 3% decline in

FIGURE 13
New fleet CO_2 emissions rate and market share of Volkswagen, Hyundai, Mitsubishi, BMW, KIA, and Subaru



its 1990–2003 fleet-average CO_2 emissions rate and was the only major automaker besides BMW to do so.

Growth in light truck classes

Between 1990 and 2003, the U.S. auto market saw a 21-point growth in the market share of light trucks. As recounted in the individual firm discussions above, most companies expanded their truck lineups during this 14-year period. Some firms—Honda, Hyundai, BMW and Kia (and even Porsche)—launched their first light trucks in the U.S. market. As discussed previously, the climb in truck fraction was the key factor behind rising average new vehicle CO_2 emissions rates and falling fuel economy levels in recent years.

Among the twelve largest automakers, ten sold a higher fraction of trucks in 2003 than in 1990 (Table 9). The exceptions were Volkswagen and Subaru. VW, for example, still made its Vanagon in 1990, but by 2003 only its more exclusive Audi brand offered light trucks (the Allroad Quattro sport wagon and the Eurovan). Most firms had significant growth in truck fraction. Since light trucks now emit 39% more CO_2 per mile on average than cars, the growing truck fraction pushed the carbon burden share of trucks up from 37% in 1990 to 58% in 2003.

CAR-TO-TRUCK SHIFT APPEARS TO BE ONGOING

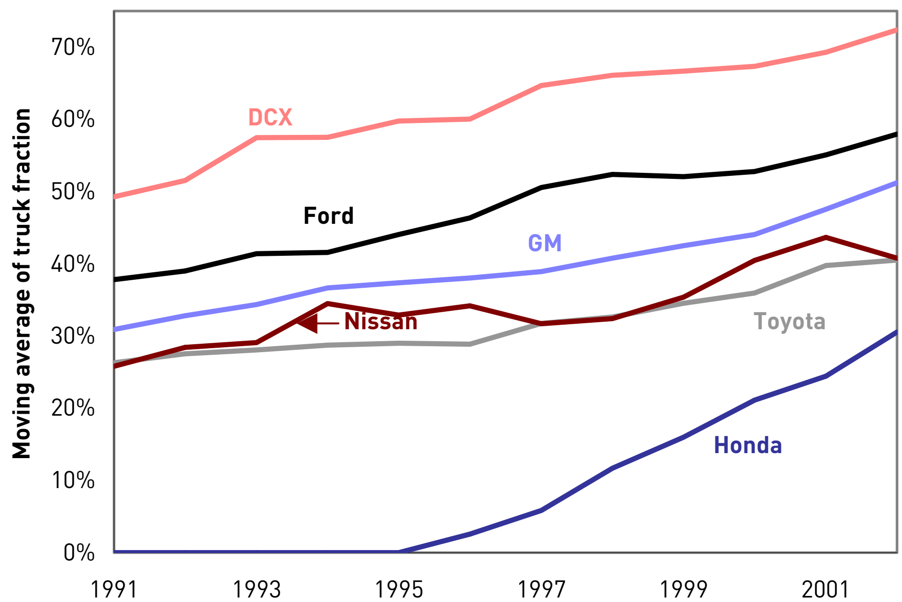
Figure 14 plots 3-year moving averages[56] of the Big Six automakers' light truck fractions from 1990 through 2003. All six firms' truck fractions follow a steady upward trend, even though each displays a different growth rate. Honda, the last of the Big Six to enter the truck market, showed the fastest growth in truck

TABLE 9
Truck fraction and carbon burden share of trucks for the twelve largest automakers (1990 vs. 2003)

	Truck Share		Carbon Burdens Share of Trucks	
	1990	2003	1990	2003
GM	28%	56%	36%	64%
Ford	35%	59%	41%	66%
DaimlerChrysler	50%	74%	56%	78%
Toyota	24%	39%	31%	49%
Honda	0%	39%	0%	46%
Nissan	25%	36%	27%	41%
VW	5%	2%	7%	3%
Hyundai	0%	24%	0%	28%
Mitsubishi	20%	26%	25%	30%
BMW	0%	16%	0%	20%
Kia	0%	40%	0%	51%
Subaru	12%	8%	11%	8%
Market	**30%**	**50%**	**37%**	**58%**

Source: Author's analysis results based on NHTSA (2004), NHTSA (2005) and NHTSA CAFE data.

FIGURE 14
Light truck fraction trends of the Big Six



Source: Author's analysis results based on NHTSA (2004), NHTSA (2005) and NHTSA CAFE data.

fraction, averaging 5.6 points per year from 1997 to 2003. Ford, GM and DCX averaged two points per year growth in their truck fraction; Nissan and Toyota gained an average of one point per year.

The truck fraction trends show little sign of leveling off. Automakers' product announcements continue to emphasize a growing variety of vehicles likely to be classified as light trucks, including new and modified designs that would have once been classified as cars. In early 2004, the Detroit automakers' media announcements heralded "The Year of the Car." This publicity campaign promised market success for slates of new car products, responding to criticisms that the Big Three had abandoned the car segments to foreign competitors. Several Big Three divisions revived classic sports car nameplates, hoping to recreate a nostalgic halo for their brands.

DCX succeeded with updated designs such as the Chrysler 300 that have enjoyed strong sales. However, a slowdown of the broader car-to-truck shift is yet to be seen in the fuel economy available to date. The most recent trade data indicate that trucks still dominate sales while Detroit's product plans continue to have a truck emphasis.[57] For example, GM has recently stated that updated full-size truck and SUV models will underpin its recovery strategy. Moreover, all automakers are announcing car-like products that they are classifying as light trucks for regulatory purposes.

THE TRUCK-VS.-CAR FUEL ECONOMY GAP

Compounding the adverse energy consumption and environmental impacts of car-to-truck shift over the past 25 years has been a growing gap between the average fuel economy of cars and light trucks. As shown earlier in Figure 2 (page 7), the resulting excess light truck CO_2 emissions rate compared to cars has essentially doubled since 1975, when detailed recordkeeping began.

The irony is that a generation ago, when light trucks were truly utilitarian in design and much of their use, their fuel economy gap relative to cars was much smaller than it is now, when their overwhelming use is as passenger car substitutes. In 1975 when 68% of light trucks were pickups and most of the rest were full-size vans, the average light truck consumed 15% more fuel per mile than the average car.[58] As of 2003, only 30% of new light trucks were pickups (SUVs accounted 54%) and the excess rate of fuel consumption had risen to 38%. That is to say, the average 2003 new light truck emits 38% more CO_2 per mile than the average new car (examining only light trucks up to 8,500 lb GVW).

Unlike the light truck sales fraction, which continues to rise, the light truck fuel economy deficit is constrained by the CAFE standards. The rise in the light truck standard announced so far, reaching 22.2 mpg by model year 2007, would trim the regulatory gap to 19%, corresponding to a nominal, regulatory CO_2 emissions rate excess of 24% higher than cars. The actual market gap will continue to vary from this nominal level mainly because several import automakers have both car and truck fleets still exceeding the CAFE standards.

Conclusions

U.S. cars and light trucks are one of the world's main sources of poorly controlled greenhouse gas emissions. They are also the single largest reason for America's petroleum dependence. The 25% growth in U.S. automobile fuel consumption over 1990–2003 alone burdens the atmosphere with an additional 64 MMTc of carbon emissions annually. That quantity of carbon is equivalent to burning over 1.7 million acres of forest, an area three times the size of the Great Smoky Mountains National Park. The emissions growth corresponds to an additional 1.7 million barrels per day of oil demand, bringing America's 8.6 million barrels per day total automobile fuel consumption up to a level that essentially matches Saudi Arabia's average oil production over the past 15 years.[59]

Reducing these oil and carbon burdens is a shared task, but the auto industry has a key responsibility for helping to develop the public policies needed to do the job. Examining how each automaker's products contribute to CO_2 emissions spotlights this responsibility. It also provides a benchmark for measuring whether or not car companies are making good on their word to be leaders in addressing the problems of oil dependence and climate disruption.

Counting carbon, not technology

Listening to automakers' public statements and seeing their advertisements regarding the environment, one can easily get the impression that the industry is making great strides on these issues.

Several firms (notably Toyota) have taken leadership positions on hybrid-electric vehicles; all automakers promise additional hybrid offerings in the years ahead. DaimlerChrysler and others are pointing to diesels as another promising solution. Detroit automakers also tout their flexible-fuel vehicles, capable of running on ethanol. Several companies are demonstrating hydrogen fuel cell cars, offered as concrete proof of their commitment. GM claims that this ultimate solution to the automobile's energy and environmental problems is right around the corner—and that pressure to improve fuel economy now will detract from their ability to make the needed technology breakthroughs.

Much of the public, news media, many environmentalists and a number of policymakers have embraced hybrids and other advanced and alternative technologies as a sign of hope that the industry is finally seeing the light. Politicians have endorsed automakers' efforts and invested tax dollar support, ranging from the Clinton-Gore and Bush-Cheney Administrations' research on zero-pollution "supercars" to California's pledge to build a "hydrogen highway." Many jurisdictions offer incentives and other forms of promotion for hybrid cars and alternative fuels. An observer might easily think that, by now, all of this activity adds up to a positive impact.

Sadly, the truth is just the opposite. The realities of U.S. auto sector oil consumption and carbon burdens can only be understood by asking the right questions and examining hard data. Our analysis of what each automaker has sold over the past 14 years (1990–2003) indicates that all firms, and notably all of the

Big Six (GM, Ford, DaimlerChrysler, Toyota, Honda, and Nissan) have increased their fleet-average oil dependency and CO_2 emissions rates.

A question of priorities

Results for the traditional Big Three suggest that their product priorities have been at odds with both market success and environmental progress. GM's market share dropped 6.8 points over our period of analysis while its fleet-average CO_2 emissions rate rose 6.3%. Ford's market share dropped 4.4 points while its CO_2 emissions rate rose 7.7%. DaimlerChrysler's market share (still dominated in the U.S. by Chrysler brands) declined 1.1 points as its CO_2 emissions rate increased 6.8%. These firms headed the charge in shifting from cars to trucks, through the SUV boom of the 1990s and, more recently, with larger, more luxurious and increasingly super-powered pickups. In short, the Big Three are losing in the market while leading a race to the bottom in terms of fuel economy and worsening carbon burdens.

In spite of the much-remarked upon American love of size and power in the car market, it seems ironic that the two firms having the greatest success in the 1990s tend to position their products on the more efficient end of segments in which they compete. Following the car-to-truck shift led by Big Three, Toyota and Honda both saw their new fleet-average CO_2 emissions rates rise—but not nearly as much as those of GM, Ford, and DaimlerChrysler—while posting large gains in market share.[60] Toyota's total new fleet carbon burden grew the most, but almost entirely as a result of its outstanding sales growth; Toyota's CO_2 emissions rate increased the least among the Big Six. Honda had the second lowest increase in CO_2 emissions rate among the Big Six, even as it gained market share. Thus, it can be said that, in terms of fuel economy, Honda and Toyota stayed on top in what has been, overall, a race to the bottom.

Nissan's sales performance was uneven from 1990 to 2003 and sales shifted to trucks, following the market trend. The company's sales rebounded in 2000 and 2001 as its truck fraction topped 40%. Redesigned cars further boosted Nissan's market share to 5% in 2003, so that the firm closed the 1990–2003 period down by only 0.2 point. Nissan's new fleet-average CO_2 emissions rate was up 8.4% in 2003 relative to 1990, but not nearly as much as it had been in 2001.

Other automakers showed mixed results on how new fleet-average CO_2 emissions rates related to market success. VW more than doubled its market share even while improving fuel economy and cutting its new fleet-average CO_2 emissions rate by 3.3% from 1990 to 2003. Hyundai nearly tripled its market share, shifting heavily into trucks and increasing its new fleet-average CO_2 emissions rate by 16%, the worst among the twelve automakers we analyzed. BMW, on the other hand, quadrupled its market share over the period while reducing its new fleet-average CO_2 emissions rate by 13%, more than any other firm.

Policy progress is essential

These results suggest that it is not just car-truck mix *per se* that determines either sales success or environmental progress. Many factors shape the auto market, but because global warming and energy security are societal concerns, they can only be addressed by public policy. The continued rise in light truck share, as well as increasingly powerful engines and many other amenities that degrade fuel economy, are symptoms of a lack of effective policies to restrain fuel use.

Thus, as U.S. auto sector carbon burdens continue to rise, most automakers still obstruct any significant effort to counterbalance these market trends through significantly higher fuel economy standards or other regulatory policies. Among major firms, only Honda has taken a truly constructive approach on public policy.[61] Other companies that have cultivated a progressive, green image—including GM, Ford and Toyota—continue to block policy progress. Examples include the public relations and lobbying efforts of the Alliance of Automobile Manufacturers,[62] whose members include all of the Big Six except Honda.

Although automakers have modified their public positions on global warming, most have not yet used their influence to help develop policy solutions in spite of the fact that they profess a desire to be part of the solution. It is true that insufficient consumer interest in higher fuel economy is a barrier to progress. Automakers, however, still largely hide behind this barrier rather than helping find ways to overcome it. Promotion of promising technologies (such as hybrids or diesels) that automakers have come to embrace fails to consider the deeper issues of increasing petroleum dependency and global warming.

By analyzing the U.S. auto market in terms of "barrels and tons" (of oil demand and CO_2 emissions respectively), this report highlights what must become the focal point for both cultivating consumer interest and constructing public policy. While solving transportation energy and climate problems is ultimately a shared responsibility, the auto industry's leadership and expertise are essential for crafting policies that address market barriers and yield measurable progress in reducing automobile fuel use and its associated oil and carbon burdens.

Appendix: Assumptions and data issues

This appendix summarizes data sources and assumptions in our analysis of CO_2 emissions trends in the U.S. new car and light truck market. This appendix also discusses new data issues that arose in the course of the analysis. It includes tables providing the numbers behind key graphs in the main text. Table A-1 lists the historical overview values that were plotted in Figure 1, while tables A-2 through A-4 summarize data and CO_2 emissions statistics by vehicle class, as used, for example, in Figure 3.

Data and assumptions

The data used in this analysis come primarily from the following U.S. government data sets and statistical reports covering motor vehicles, energy use, and greenhouse gas emissions.

Data sets:

- National Highway Traffic Safety Administration (NHTSA) data on new vehicle sales and fuel economy ratings (1990–2003)
- Highway Statistics from the Federal Highway Administration (FHWA)

Reports:

- NHTSA Summary of Fuel Economy Performance (2004) and (2005)
- Environmental Protection Agency (EPA) Light Duty Automotive Technology and Fuel Economy Trends: 1975 through 2004 (Hellman and Heavenrich 2004)
- The Transportation Energy Data Book (Edition 23) from the Oak Ridge National Laboratory (Davis and Diegel 2003)

From these data sets, a 34-year series (1970–2003) was built that allows us to examine the long-term trends of the U.S. light vehicle stock, including in-use fuel economy and vehicle miles traveled (VMT) before and after the oil shocks and the promulgation of the Corporate Average Fuel Economy (CAFE) standards. Firm-level fuel economy and sales data were not available until 1978, the first year when CAFE first took effect for cars.

The overall trend of carbon emissions from the vehicle stock is derived from the nationwide statistics on fuel consumption and VMT reported by FHWA,[63] supplemented by Davis and Diegel (2003, Table 2.6). Detail analysis for each automaker is primarily based on NHTSA's *Summary of Fuel Economy Performance* report (NHTSA 2004, NHTSA 2005). The fuel economy performance of the Big Three were estimated based on NHTSA CAFE data sets (see the Flexible-fuel Vehicle Credits section, below).

Table A-5 summarizes the key assumptions and parameters used in our analysis. These assumptions are the same as those used in our July 2002 *Automakers' Corporate Carbon Burdens* report. Additional details on the approaches used for analysis, simplifying assumptions, emissions factors, interpretation of the source data, and issues that came up in developing and verifying our data set are provided in Appendix A of our 2002 report.

Data issues

The 2002 *Automakers' Corporate Carbon Burdens* report summarizes three key data issues that arose when analyzing firm-level carbon burdens. These issues include limited data on light-duty vehicles of more than 8,500 lbs gross vehicle weight, discrepancies of fuel economy ratings recorded for CAFE purposes and the actual fuel economy of flex-fuel vehicles, and the differences between the EPA/NHTSA sales data and those reported by the trade press. Since the primary data utilized here are the latest versions of those used in our earlier analysis, we encounter similar data issues here.

Below is a more detailed account on how we adjust for the differences of regulatory and actual fuel economy for flex-fuel vehicles. Following this are discussions on new data issues that came up in the course of this analysis.

FLEXIBLE-FUEL VEHICLE CREDITS

CAFE law was modified in 1988 by the Alternative Motor Fuel Act (AMFA) to provide incentives for use of alternative fuels. One of the provisions of AMFA allows automakers who sell dual-fuel vehicles to earn credits that can be used to help meet fuel economy standards. Dual-fuel vehicles, also known as flexible-fuel vehicles (FFVs), are designed to run on either gasoline or an alternative fuel comprised largely of a non-petroleum-derived substance, such as ethanol or methanol.

For the purpose of CAFE calculation, an FFV's fuel economy when running on alternative fuel is defined as the test fuel economy as measured on the alternative fuel divided by 0.15 (with the expectation that the alternative fuel would be a blend of 15% gasoline with ethanol or methanol). The regulation also assumes that FFVs operate on the alternative fuel 50% of the time and on gasoline 50% of the time.

The fuel economy ratings reported in the NHTSA's Summary of Fuel Economy Performance Report 2004 and 2005 (NHTSA 2004 and NHTSA 2005) include the AMFA credits, as well as other regulatory credits. Because very few FFVs actually run on alternative fuel,[64] fleetwide CO_2 emissions estimates derived directly from NHTSA's report for automakers using AMFA credits (so far only the Big Three) would be underestimated. We therefore adjusted the model-level CAFE data for FFVs back to an estimated gasoline-equivalent fuel economy. These adjusted ratings were then used to calculate the average fuel economy performance and CO_2 emissions rates of the Big Three. For other automakers, the fuel economy results reported in NHTSA (2004) and (2005) were used directly for each manufacturer's fleet average.

Because model-level final CAFE data were not available from government sources in time for completion of this study, mid-model-year data were used for MY1990–2002. For MY2003, a new field of gasoline-equivalent fuel economy was added in NHTSA's data set, no adjustment for AMFA credits was needed.

The following presents the approach by which AMFA credited fuel economy ratings were adjusted back to gasoline-equivalent fuel economy levels.

The fuel economy of a FFV is the harmonic mean of its fuel economy values using gasoline and alternative fuels, with the latter evaluated using the 15% oil displacement assumption:

$$\frac{1}{FE_{Dual-fuel}} = \frac{0.5}{FE_G} + \frac{0.5}{FE_X / 0.15} = \frac{0.5}{FE_G} + \frac{0.5 \times 0.15}{FE_X}$$

$FE_{Dual-fuel}$ = *combined fuel economy of alternative fuel vehicles*

FE_G = *fuel economy as measured on gasoline*

FE_X = *fuel economy as measured on alternative fuel*

Assuming that the energy equivalence of alternative fuel to gasoline is *a,*

$$FE_X = a \times FE_G$$

Therefore,

$$\frac{1}{FE_{Dual-fuel}} = \frac{0.5}{FE_G} + \frac{0.5 \times 0.15}{a \times FE_G}$$

$$FE_{Dual-fuel} = 2FE_G \times \frac{a}{a + 0.15}$$

For instance, NHTSA assumes that the energy content of gasoline is 1.4 times that of ethanol (i.e., $a = 1/1.4 = 0.71$); therefore, the gasoline fuel economy of an ethanol FFV is equal to the AMFA credited fuel economy divided by a factor of about 1.65.[65] Table A-6 summarizes the FFVs produced by the Big Three from 1998 through 2003, their estimated base fuel economy, their credited fuel economy and their sales.

Because the NHTSA data set includes the base fuel economy of all 2002 GM vehicles rather than the AMFA credited ratings as for other model years, we were not able to identify which GM models offered flex-fuel versions. Inquiries with GM did not provide a full answer, so we compiled a list of GM FFVs for MY2002 based on EPA's Fuel Economy Guide and information on DOE's Alternative Fuels Data Center web site. To determine the amount of FFV CAFE credits earned by GM in 2002, the credited fuel economy ratings of GM's 2002 ethanol FFVs listed in Table A-2 were estimated by multiplying the base fuel economy rating of each FFV model in the NHTSA data by a multiplier of 1.65.

DISCREPANCIES IN SALES AND FUEL ECONOMY DATA

Gross discrepancies in aggregate sales volumes appear when comparing NHTSA/EPA data with those reported in trade press. For instance, NHTSA's sales volumes were about 2 million units lower in 1996, less than the Ward's data suggest. This issue is also discussed in Appendix A of our July 2002 report. Further clarifications with NHTSA did not provide explanations. The issue of discrepancies between sales data that automakers submit to NHTSA and data reported in the trade press calls for further examination.

TABLE A-1

U.S. light-duty vehicle fuel consumption and CO_2 emissions, 1970 to 2003

	Carbon MMTc	Fuel Mbd	VMT 10^{12}mi	NEW FLEET TEST FUEL ECONOMY (MPG) Cars	Light Trucks	Both	Truck Share	Stock (mpg)	EMISSION RATE (TCO_2/YR) New Fleet	Stock
1970	**193**	**5.25**	**0.954**	**14.8**	**12.5**	**14.3**	**20%**	**13.3**	**8.21**	**7.94**
1971	204	5.54	1.015	14.4	12.2	13.9	20%	13.2	8.44	7.99
1972	220	5.97	1.085	14.5	12.3	14.0	20%	13.2	8.38	7.99
1973	230	6.24	1.129	14.2	12.0	13.7	20%	13.1	8.56	8.05
1974	221	6.00	1.101	14.2	12.0	13.7	20%	13.1	8.56	8.05
1975	225	6.10	1.144	15.8	13.7	15.3	19%	13.1	7.84	8.09
1976	239	6.49	1.211	17.5	14.4	16.7	21%	13.2	7.27	8.00
1977	245	6.64	1.265	18.3	15.6	17.7	20%	13.4	6.94	7.87
1978	253	6.86	1.329	19.9	15.2	18.6	23%	13.8	6.60	7.65
1979	244	6.61	1.314	20.3	14.7	18.7	22%	14.1	6.57	7.50
1980	**226**	**6.14**	**1.315**	**23.5**	**18.6**	**22.5**	**17%**	**14.5**	**5.52**	**7.26**
1981	224	6.08	1.338	25.1	20.1	24.1	17%	15.0	5.15	7.02
1982	221	6.01	1.380	26.0	20.5	24.7	20%	15.6	5.03	6.77
1983	227	6.16	1.428	25.9	20.9	24.6	22%	16.2	5.05	6.54
1984	232	6.29	1.482	26.3	20.5	24.6	24%	16.6	5.05	6.36
1985	238	6.45	1.529	27.0	20.6	25.0	25%	17.0	4.97	6.20
1986	246	6.67	1.582	27.9	21.4	25.7	28%	17.7	4.83	5.97
1987	250	6.78	1.657	28.1	21.6	25.9	28%	18.2	4.80	5.79
1988	255	6.92	1.749	28.6	21.2	25.9	30%	18.7	4.80	5.64
1989	258	7.00	1.808	28.1	20.9	25.4	31%	19.1	4.89	5.52
1990	**253**	**6.87**	**1.852**	**27.8**	**20.7**	**25.2**	**30%**	**19.4**	**4.93**	**5.43**
1991	247	6.69	1.875	28.0	21.3	25.4	32%	19.7	4.89	5.37
1992	256	6.95	1.938	27.6	20.8	24.9	33%	19.5	4.99	5.42
1993	264	7.18	1.988	28.2	21.0	25.1	36%	19.3	4.95	5.48
1994	269	7.31	2.039	28.1	20.8	24.6	40%	19.4	5.05	5.44
1995	273	7.42	2.097	28.3	20.5	24.7	38%	19.7	5.03	5.37
1996	280	7.59	2.156	28.3	20.8	24.8	40%	19.6	5.01	5.39
1997	287	7.79	2.224	28.4	20.6	24.5	42%	19.7	5.08	5.36
1998	293	7.96	2.285	28.5	20.9	24.5	45%	19.8	5.07	5.33
1999	302	8.21	2.347	28.2	20.5	24.1	45%	19.6	5.15	5.39
2000	**301**	**8.17**	**2.346**	**28.2**	**20.8**	**24.3**	**45%**	**20.0**	**5.11**	**5.27**
2001	303	8.22	2.391	28.4	20.6	24.2	46%	20.2	5.13	5.22
2002	313	8.49	2.441	28.6	20.6	24.1	49%	20.0	5.15	5.28
2003	317	8.60	2.471	28.9	20.9	24.2	51%	20.0	5.13	5.28

Sources: Davis (2003); FHWA (2003); Hellman and Heavenrich (2004); and authors' derivations per assumptions in Table A-5.

TABLE A-2
New vehicle sales and market share by class, 1975-2003

Model	Small cars		Midsize cars		Large Cars		Pickups		Vans		SUVs		Total
Year	Sales	Share	Sales	Share	Sales	Share	Sales	Share	Sales	Share	Sales	Share	Sales
1975	4.565	44.7%	1.920	18.8%	1.752	17.1%	1.342	13.1%	0.457	4.5%	0.187	1.8%	10.223
1976	5.386	43.7%	2.449	19.9%	1.886	15.3%	1.866	15.1%	0.501	4.1%	0.244	2.0%	12.332
1977	5.865	41.5%	2.774	19.6%	2.659	18.8%	2.026	14.3%	0.514	3.6%	0.283	2.0%	14.121
1978	4.991	34.5%	3.842	26.6%	2.341	16.2%	2.267	15.7%	0.626	4.3%	0.380	2.6%	14.447
1979	4.715	34.0%	3.693	26.6%	2.386	17.2%	2.207	15.9%	0.480	3.5%	0.400	2.9%	13.881
1980	**5.135**	**45.4%**	**3.244**	**28.7%**	**1.065**	**9.4%**	**1.437**	**12.7%**	**0.242**	**2.1%**	**0.183**	**1.6%**	**11.306**
1981	4.495	42.6%	3.174	30.1%	1.064	10.1%	1.439	13.6%	0.245	2.3%	0.136	1.3%	10.553
1982	4.421	45.4%	2.420	24.9%	0.978	10.0%	1.441	14.8%	0.310	3.2%	0.162	1.7%	9.732
1983	4.249	41.2%	2.545	24.7%	1.209	11.7%	1.628	15.8%	0.382	3.7%	0.288	2.8%	10.301
1984	6.127	43.7%	3.135	22.4%	1.412	10.1%	2.043	14.6%	0.677	4.8%	0.625	4.5%	14.019
1985	6.015	41.6%	3.118	21.6%	1.657	11.5%	2.077	14.4%	0.855	5.9%	0.735	5.1%	14.457
1986	6.551	42.6%	3.075	20.0%	1.387	9.0%	2.532	16.5%	1.044	6.8%	0.773	5.0%	15.362
1987	6.814	45.8%	2.611	17.6%	1.306	8.8%	2.147	14.4%	1.114	7.5%	0.873	5.9%	14.865
1988	6.959	45.5%	2.398	15.7%	1.378	9.0%	2.459	16.1%	1.133	7.4%	0.967	6.3%	15.294
1989	5.836	40.4%	2.830	19.6%	1.352	9.4%	2.231	15.4%	1.277	8.8%	0.926	6.4%	14.452
1990	**5.159**	**40.9%**	**2.526**	**20.0%**	**1.123**	**8.9%**	**1.834**	**14.5%**	**1.261**	**10.0%**	**0.708**	**5.6%**	**12.611**
1991	5.241	41.7%	2.236	17.8%	1.046	8.3%	1.920	15.3%	1.034	8.2%	1.094	8.7%	12.571
1992	4.583	37.7%	2.257	18.5%	1.267	10.4%	1.840	15.1%	1.221	10.0%	1.003	8.2%	12.171
1993	4.838	36.6%	2.496	18.9%	1.122	8.5%	2.002	15.2%	1.441	10.9%	1.311	9.9%	13.210
1994	4.926	35.2%	2.195	15.7%	1.293	9.2%	2.591	18.5%	1.396	10.0%	1.584	11.3%	13.985
1995	5.388	35.6%	2.691	17.8%	1.316	8.7%	2.271	15.0%	1.662	11.0%	1.816	12.0%	15.144
1996	4.287	32.6%	2.528	19.2%	1.075	8.2%	1.955	14.9%	1.409	10.7%	1.889	14.4%	13.143
1997	4.598	31.8%	2.549	17.6%	1.195	8.3%	2.408	16.6%	1.265	8.7%	2.450	16.9%	14.465
1998	3.938	27.2%	3.121	21.6%	0.913	6.3%	2.415	16.7%	1.489	10.3%	2.581	17.9%	14.457
1999	3.997	26.2%	3.322	21.8%	1.059	7.0%	2.550	16.7%	1.465	9.6%	2.837	18.6%	15.230
2000	**4.334**	**26.1%**	**3.128**	**18.9%**	**1.665**	**10.0%**	**2.613**	**15.8%**	**1.692**	**10.2%**	**3.142**	**19.0%**	**16.574**
2001	4.277	27.4%	2.716	17.4%	1.416	9.1%	2.621	16.8%	1.237	7.9%	3.329	21.3%	15.596
2002	4.035	25.1%	3.015	18.7%	1.252	7.8%	2.380	14.8%	1.243	7.7%	4.179	26.0%	16.104
2003	3.820	24.5%	2.675	17.1%	1.210	7.7%	2.373	15.2%	1.291	8.3%	4.253	27.2%	15.622

Sales are in millions; market share is of overall sales under 8500 lb GVW. Station wagons are included with cars of corresponding size.

Source: Hellman and Heavenrich (2004).

TABLE A-3

Average fuel economy and average per-vehicle carbon emissions by class, 1975-2003

Model	Small cars		Midsize cars		Large Cars		Pickups		Vans		SUVs		Overall
Year	mpg	TCO_2/yr	mpg	TCO_2/yr	mpg	TCO_2/yr	mpg	TCO_2/yr	mpg	TCO_2/yr	mpg	TCO_2/yr	TCO_2/yr
1975	18.7	6.7	13.5	9.2	13.0	9.6	14.0	8.9	13.1	9.5	13.0	9.6	8.1
1976	20.1	6.2	15.8	7.9	14.1	8.8	14.6	8.5	13.8	9.0	13.8	9.0	7.4
1977	21.0	5.9	16.4	7.6	15.8	7.8	15.9	7.8	14.8	8.4	15.1	8.2	7.0
1978	23.3	5.3	18.6	6.7	16.7	7.4	15.7	7.9	14.2	8.7	14.4	8.6	6.7
1979	23.4	5.3	19.1	6.5	17.2	7.2	15.6	8.0	13.5	9.2	12.6	9.9	6.6
1980	**26.2**	**4.7**	**21.6**	**5.8**	**19.1**	**6.5**	**19.4**	**6.4**	**16.7**	**7.5**	**15.5**	**8.0**	**5.5**
1981	28.6	4.3	22.9	5.4	20.3	6.1	21.0	5.9	17.5	7.1	16.8	7.4	5.2
1982	29.2	4.3	24.0	5.2	20.5	6.1	21.7	5.7	17.3	7.2	17.6	7.1	5.0
1983	29.7	4.2	24.0	5.2	20.1	6.2	22.2	5.6	17.7	7.0	19.1	6.5	5.1
1984	29.6	4.2	24.2	5.1	20.4	6.1	21.5	5.8	18.9	6.6	19.3	6.4	5.0
1985	30.0	4.1	24.9	5.0	22.2	5.6	21.4	5.8	19.4	6.4	19.8	6.3	5.0
1986	30.1	4.1	25.9	4.8	23.7	5.2	22.2	5.6	20.6	6.0	20.2	6.2	4.8
1987	30.1	4.1	25.9	4.8	23.8	5.2	22.5	5.5	20.9	5.9	20.7	6.0	4.8
1988	30.5	4.1	26.6	4.7	24.1	5.2	21.5	5.8	21.2	5.9	20.4	6.1	4.8
1989	30.2	4.1	26.5	4.7	23.9	5.2	21.2	5.9	21.2	5.9	19.9	6.2	4.9
1990	**29.8**	**4.2**	**26.1**	**4.8**	**23.7**	**5.2**	**20.7**	**6.0**	**21.3**	**5.8**	**19.8**	**6.3**	**4.9**
1991	30.0	4.1	26.0	4.8	23.6	5.3	21.7	5.7	21.4	5.8	20.3	6.1	4.9
1992	30.0	4.1	25.8	4.8	23.8	5.2	20.9	5.9	21.5	5.8	19.9	6.2	5.0
1993	30.6	4.1	26.1	4.8	24.2	5.1	21.1	5.9	21.8	5.7	19.9	6.2	5.0
1994	30.5	4.1	25.9	4.8	24.1	5.2	21.0	5.9	21.5	5.8	19.7	6.3	5.1
1995	30.8	4.0	26.1	4.8	24.5	5.1	20.4	6.1	21.8	5.7	19.5	6.4	5.0
1996	30.8	4.0	26.5	4.7	24.3	5.1	20.8	6.0	22.2	5.6	20.0	6.2	5.0
1997	30.9	4.0	26.5	4.7	24.5	5.1	20.5	6.1	22.1	5.6	20.1	6.2	5.1
1998	30.9	4.0	27.1	4.6	24.6	5.1	20.7	6.0	22.7	5.5	20.1	6.2	5.1
1999	30.3	4.1	27.1	4.6	24.8	5.0	19.9	6.2	22.3	5.6	20.1	6.2	5.2
2000	**30.3**	**4.1**	**27.0**	**4.6**	**25.6**	**4.9**	**20.4**	**6.1**	**22.8**	**5.4**	**20.1**	**6.2**	**5.1**
2001	30.5	4.1	27.1	4.6	25.4	4.9	19.6	6.3	23.2	5.4	20.5	6.1	5.1
2002	30.4	4.1	27.7	4.5	26.0	4.8	19.4	6.4	23.0	5.4	20.6	6.0	5.2
2003	30.7	4.1	28.3	4.4	25.7	4.8	20.0	6.2	22.8	5.4	20.8	6.0	5.1

Fuel economy values are EPA composite test mpg (CAFE compliance) ratings; average per-vehicle emissions are in metric tons of CO_2 per year. Station wagons are included with cars of corresponding size.

Source: Hellman and Heavenrich (2004) and authors' assumptions as given in Table A-5.

TABLE A-4

New fleet carbon burdens and carbon burden share by major vehicle class, 1975-2003

	Small cars		**Midsize cars**		**Large cars**		**Pickups**		**Vans**		**SUVs**		**Total**
Year	Carbon	Share	Carbon	Share	Carbon	Share	Carbon	Share	Carbon	Share	Carbon	Share	Carbon
1975	8.29	36.7%	4.81	21.3%	4.58	20.3%	3.25	14.4%	1.18	5.2%	0.49	2.2%	22.60
1976	9.07	36.3%	5.27	21.0%	4.53	18.1%	4.33	17.3%	1.23	4.9%	0.60	2.4%	25.02
1977	9.48	35.1%	5.74	21.2%	5.68	21.0%	4.32	16.0%	1.18	4.4%	0.64	2.3%	27.04
1978	7.27	27.6%	7.00	26.6%	4.75	18.1%	4.89	18.6%	1.49	5.7%	0.89	3.4%	26.30
1979	6.81	27.1%	6.55	26.1%	4.69	18.7%	4.79	19.1%	1.20	4.8%	1.08	4.3%	25.13
1980	**6.63**	**39.0%**	**5.10**	**30.0%**	**1.89**	**11.1%**	**2.51**	**14.7%**	**0.49**	**2.9%**	**0.40**	**2.4%**	**17.02**
1981	5.32	35.8%	4.69	31.6%	1.77	11.9%	2.32	15.6%	0.47	3.2%	0.27	1.8%	14.85
1982	5.13	38.4%	3.42	25.7%	1.62	12.1%	2.25	16.9%	0.61	4.6%	0.31	2.3%	13.34
1983	4.84	34.1%	3.60	25.3%	2.03	14.3%	2.48	17.5%	0.73	5.1%	0.51	3.6%	14.20
1984	7.02	36.4%	4.39	22.8%	2.34	12.1%	3.22	16.7%	1.21	6.3%	1.10	5.7%	19.28
1985	6.79	34.7%	4.24	21.6%	2.53	12.9%	3.29	16.8%	1.49	7.6%	1.26	6.4%	19.60
1986	7.39	36.4%	4.02	19.8%	1.98	9.8%	3.86	19.1%	1.72	8.5%	1.30	6.4%	20.27
1987	7.66	39.5%	3.41	17.6%	1.86	9.6%	3.23	16.7%	1.81	9.3%	1.43	7.4%	19.40
1988	7.72	38.6%	3.05	15.2%	1.94	9.7%	3.88	19.4%	1.81	9.1%	1.61	8.0%	20.00
1989	6.54	34.0%	3.62	18.8%	1.91	9.9%	3.57	18.5%	2.04	10.6%	1.58	8.2%	19.26
1990	**5.87**	**34.6%**	**3.28**	**19.3%**	**1.61**	**9.5%**	**3.00**	**17.7%**	**2.01**	**11.8%**	**1.21**	**7.1%**	**16.97**
1991	5.91	35.2%	2.91	17.4%	1.50	9.0%	3.00	17.9%	1.64	9.7%	1.83	10.9%	16.79
1992	5.18	31.3%	2.96	17.9%	1.81	10.9%	2.98	18.0%	1.92	11.6%	1.71	10.3%	16.56
1993	5.35	30.0%	3.24	18.1%	1.57	8.8%	3.21	18.0%	2.24	12.5%	2.23	12.5%	17.85
1994	5.47	28.4%	2.87	14.9%	1.82	9.4%	4.18	21.7%	2.20	11.4%	2.72	14.1%	19.27
1995	5.93	28.6%	3.49	16.8%	1.82	8.8%	3.77	18.2%	2.58	12.4%	3.16	15.2%	20.75
1996	4.71	26.2%	3.23	18.0%	1.50	8.3%	3.18	17.7%	2.15	12.0%	3.20	17.8%	17.98
1997	5.03	25.2%	3.26	16.3%	1.65	8.3%	3.98	19.9%	1.94	9.7%	4.13	20.7%	20.00
1998	4.31	21.6%	3.91	19.5%	1.26	6.3%	3.95	19.8%	2.22	11.1%	4.35	21.7%	20.00
1999	4.47	20.8%	4.16	19.4%	1.45	6.8%	4.34	20.3%	2.23	10.4%	4.78	22.3%	21.42
2000	**4.85**	**21.0%**	**3.92**	**17.0%**	**2.20**	**9.5%**	**4.34**	**18.8%**	**2.51**	**10.9%**	**5.30**	**22.9%**	**23.13**
2001	4.75	21.7%	3.39	15.5%	1.89	8.6%	4.53	20.7%	1.81	8.3%	5.50	25.2%	21.87
2002	4.50	19.8%	3.69	16.3%	1.63	7.2%	4.15	18.3%	1.83	8.1%	6.88	30.3%	22.68
2003	4.22	19.3%	3.21	14.7%	1.60	7.3%	4.01	18.3%	1.92	8.8%	6.93	31.7%	21.88

Values in MMTc (million metric tons of carbon per year). Station wagons are included with cars of corresponding size.

Source: Derived from Tables A-2 and A-3.

TABLE A-5
Key assumptions for carbon burden analysis

Assumption or parameter Value	Value
Vehicles included. Main analyses and charts address only cars and light trucks covered by CAFE standards; heavier SUVs are selectively discussed in the text.	up to 8,500 pounds GVW (Gross Vehicle Weight)
Annual miles driven per vehicle. We assume a fixed value for all model years and vehicle types.	12,000 miles/year
Fuel Economy Shortfall. Relative to CAFE (test) values, with same value assumed for all vehicle types; actual shortfall might average closer to 20%[1], implying CO_2 emissions about 6% higher.	15%
CO_2 Emissions Factor. Direct emissions only, assuming full combustion; excluded are upstream emissions in the fuel supply chain (a 30% effect) and emissions from vehicle manufacturing (a 12% effect).	8,800 grams/gallon[2] (19.4 pounds/gallon)
Oil Consumption Factor. One barrel of crude oil demand per barrel of gasoline or diesel fuel consumption, assuming that oil demand is driven by these high-value fuels, rather than the ratio based on refinery yields.	1 : 1 oil : gasoline
Carbon Factor. Million metric tons of carbon (MMTc) per year corresponding to each million barrels per day of fuel consumption, corresponding to direct CO_2 emissions factor and oil consumption factor (i.e., not full-fuel cycle).	36.83 MMTc per Mbd

Notes:
1. From Mintz, et al. (1993).
2. An assumed standard nominal value for conventional gasoline; this value is between the CO_2 emissions factor in the GREET model developed by Argonne National Laboratory (8,750 grams/gallon) and the factor used by EPA (8,864 grams/gallon).

TABLE A-6

Alternative fuel vehicles produced by the Big Three (1998-2003)

Source: Author's analysis of NHTSA data and communications with automakers.

a. General Motors

2003

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
C1500 Sierra 2WD FFV	19.1	31.8	37
C1500 Silverado 2WD FFV	19.1	31.7	1,123
C1500 Suburban 2WD FFV	18.1	30.2	44,633
C1500 Tahoe 2WD FFV	18.9	31.5	52,983
C1500 Yukon 2WD FFV	18.9	31.5	17,611
C1500 Yukon XL 2WD FFV	18.1	30.2	17,461
K1500 Sierra 4WD FFV	17.9	29.9	260
K1500 Silverado 4WD FFV	17.9	29.9	1,431
K1500 Suburban 4WD FFV	18.2	30.4	70,487
K1500 Suburban AWD FFV	18.2	30.4	956
K1500 Tahoe 4WD FFV	18.2	30.4	93,235
K1500 Tahoe AWD FFV	18.2	30.4	883
K1500 Yukon 4WD FFV	18.2	30.4	23,015
K1500 Yukon AWD FFV	18.2	30.4	2,035
K1500 Yukon XL 4WD FFV	18.2	30.4	21,101
K1500 Yukon XL AWD FFV	18.2	30.4	1,777
Total			349,028

2002

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
S10 Pickup 2WD S5	28.4	45.4	20,170
S10 Pickup 2WD E4	24.8	41.2	29,638
Sonoma 2WD E4	28.4	45.4	4,641
Sonoma 2WD E4	24.8	41.2	6,582
K1500 Sierra 4WD	17.8	28.8	35
K1500 Silverado 4WD	17.8	28.8	612
K1500 Suburban 4WD	17.5	28.4	69,197
K1500 Tahoe 4WD	17.5	28.4	95,233
K1500 Yukon 4WD	17.7	28.7	26,324
K1500 Yukon XL 4WD	17.5	28.4	23,039
C1500 Sierra 2WD	19.5	31.6	55
C1500 Silverado 2WD	19.5	31.6	821
C1500 Suburban 2WD	18.6	30.1	48,759
C1500 Tahoe 2WD	19.3	31.3	61,083
C1500 Yukon 2WD	19.3	31.3	16,578
C1500 Yukon XL 2WD	19.3	31.3	15,626
Total			418,393

a. General Motors (cont'd)

2001

Nameplate	Base FE	Credit FE	Sales
Sonoma 2WD FFV E4	25.4	41.2	12,500
Sonoma 2WD FFV S5	28.0	45.4	6,100
S10 Pickup 2WD FFV E4	25.4	41.2	46,200
S10 Pickup 2WD FFV S5	28.0	45.4	26,800
Total			91,600

2000

Nameplate	Base FE	Credit FE	Sales
Sonoma 2WD FFV	23.8	38.6	12,500
Sonoma 2WD FFV	27.7	44.9	6,200
S10 Pickup 2WD FFV	23.8	38.6	54,300
S10 Pickup 2WD FFV	27.7	44.9	26,100
Total			99,100

b. Ford

2003

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Trucks			
Explorer 4X2 FFV	20.6	34.2	98,675
Explorer 4X4 FFV	19.7	32.7	149,659
F150 4X2 BI-FUEL	16.1	27.8	1,541
F150 4X4 BI-FUEL	15.4	26.7	451
Mazda B3000 4X2 FFV	22.2	37.0	4,107
Mountaineer 4X2 FFV	20.6	34.2	6,893
Mountaineer 4X4 FFV	19.3	32.1	17,490
Ranger 4X2 FFV	22.2	37.0	51,479
Total			330,295
Cars			
Crown Victoria NGV	17.4	115.8	463
Sable FFV	25.7	42.6	5,021
Taurus FFV	25.7	42.6	85,475
Taurus Wagon FFV	24.9	41.2	1,971
Total			92,930

b. Ford (cont'd)

2002

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Trucks			
F150 4X2 NGV	15.7	104.6	473
Explorer 4X2 FFV	20.6	34.3	27,417
Explorer 4X4 FFV	20.0	33.1	40,140
Mazda B3000 4X2 FFV	22.0	36.8	811
Mountaineer 4X2 FFV	20.6	34.3	1,823
Mountaineer 4X4 FFV	19.3	32.3	3,598
Ranger 4X2 FFV	22.2	37.1	21,895
Total			96,157
Cars			
Crown Victoria NGV	20.5	136.5	632
Taurus FFV	26.8	44.4	50,701
Taurus Wagon FFV	25.1	41.8	1,482
Total			52,815

2001

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Trucks			
E250 VAN NGV	14.9	99.2	10
F150 4X2 NGV	15.2	101.2	579
Mazda B3000 4X2 FFV	21.9	36.5	3,271
Ranger 4X2 EV		141.1	615
Ranger 4X2 FFV	21.8	36.2	30,029
Total			34,504
Cars			
Crown Victoria NGV	20.7	138.0	502
Sable FFV	25.0	41.7	5,333
Taurus FFV	25.0	41.7	51,033
Taurus Wagon FFV	24.1	40.3	4,499
Total			61,367

b. Ford (cont'd)

2000

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Trucks			
E250 VAN NGV	15.0	100.0	220
F150 4X2 NGV	16.0	106.5	653
Mazda 4X2 FFV E4	21.8	36.1	7,603
Mazda 4X2 FFV M5	23.2	38.5	4,134
Mazda 4X4 FFV E4	20.4	33.9	1,730
Mazda 4X4 FFV M5	22.2	36.9	1,041
Ranger 4X2 EV		197.3	508
Ranger 4X2 FFV E4	21.8	36.1	114,305
Ranger 4X2 FFV M5	23.2	38.5	26,160
Ranger 4X4 FFV E4	20.4	33.9	50,254
Ranger 4X4 FFV M5	22.1	36.8	12,989
Total			219,597
Cars			
Crown Victoria NGV	20.7	138.0	498
Taurus FFV	26.9	44.3	117,619
Taurus Wagon FFV	25.2	41.7	10,171
Total			128,288

1999

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Trucks			
Ranger 4X2 EV	15.7	101.9	500
Mazda 4X2 FFV E4	22.3	36.1	7,500
Mazda 4X2 FFV M5	23.8	38.5	4,000
Ranger 4X2 FFV E4	22.3	36.2	97,100
Ranger 4X2 FFV M5	23.8	38.5	24,700
E250 VAN NGV	14.9	99.5	100
F250 4X2 NGV	14.8	98.5	600
Mazda 4X4 FFV E4	21.3	34.5	3,200
Mazda 4X4 FFV M5	23.1	37.5	1,700
Ranger 4X4 FFV E4	21.4	34.6	47,300
Ranger 4X4 FFV M5	23.3	37.8	19,300
Total			206,000
Cars			
Taurus FFV	25.8	26.1	480
Crown Victoria NG	23.6	128.6	60
Total			540

b. Ford (cont'd)

1998

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Trucks			
Ranger 4X2 EV	25.9	42.0	200
E250 VAN NGV	16.7	111.4	200
F250 4X2 NGV	17.2	114.7	1,100
Total			1,500
Cars			
Taurus FFV	25.8	41.8	3,500
Crown Victoria NG	23.6	147.4	300
Total			3,800

c. DaimlerChrysler

2003

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Trucks			
Caravan 2WD FFV	25.4	41.5	158,527
Vogager/Town & Country 2WD FFV	24.4	40.1	49,937
Total			208,464
Cars			
Mercedes C320 FFV	25.8	42.9	7,095
Mercedes C320 Wagon FFV	25.8	42.9	412
Sebring 4-Dr. FFV	27.6	45.9	7,775
Sebring Convertible FFV	27.6	45.9	9,566
Stratus 4-Dr. FFV	27.6	45.9	6,498
Total			31,346

2002

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Ram Wagon 2500	16.0	105.6	57
Caravan 2WD FFV	24.7	38.2	178,437
Vogager/Town & Country 2WD FFV	24.5	38.2	79,292
Ram Van 2500	16.0	106.8	95
Total			257,881

2001

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Ram Wagon 2500	15.8	105.4	100
Caravan 2WD FFV	23.9	38.8	198,200
Ram Van 2500	16.0	106.5	100
Total			198,400

c. DaimlerChrysler (cont'd)

1999

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
B2500 Wagon NG	14.0	93.2	100
Caravan 2WD FFV	24.0	38.9	148,600
Town & Country 2WD FFV	24.1	39.0	5,900
B2500 Van NG	14.1	94.3	100
Vogager 2WD FFV	23.9	38.8	77,200
Caravan/Vogager 2WD	88.8	574.3	200
Total			232,100

1998

Nameplate	Base Fuel Economy	Credit Fuel Economy	Sales
Caravan/Voyager 2WD FFV	24.0	38.9	142,800
Town & Country 2WD FFV	23.8	38.5	4,400
Total			147,200

Notes

[1] This and several other GHG emissions statistics cited here are based on data through 2002 from the UNFCCC Greenhouse Gas Inventory Database (ghg.unfccc.int, accessed 22 December 2004).
[2] U.S. DOE/EIA, "World Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels, 1980-2002" (www.eia.doe.gov/pub/international/iealf/tableh1.xls, accessed 22 Dec 2004).
[3] The protocol is a treaty signed in Kyoto, Japan, in 1997, by which signatories agreed to cut their GHG emissions according to negotiated targets. With Russia's ratification on November 4, 2004, the treaty formally takes effect as of early 2005. The Kyoto Protocol has now been ratified by 127 nations, representing over 55% of the industrialized world's GHG emissions.
[4] National greenhouse gas inventory data from Annex I Parties, Table B-1 (op. cit. note 1).
[5] U.S. light-duty vehicle CO_2 emissions are listed here in Table A-1 and were derived from vehicle energy consumption statistics from Davis and Diegel (2003), Table 2.6. CO_2 emissions from light-duty vehicles worldwide are from the Transportation Model developed for the Sustainable Mobility project (http://www.wbcsd.org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=11467) by the World Business Council for Sustainable Development and International Energy Agency. In both cases, the estimates reflect CO_2 emissions during vehicle use, and not include emissions from production and distribution of motor fuel.
[6] *Automakers' Corporate Carbon Burdens* (July 2002), p. 7, Figure 12.
[7] The estimated total carbon emissions from light-duty vehicles worldwide were derived from the Mobility 2030 - IEA/SMP Transportation Model.
[8] Estimates derived from Table 2.6 of Davis and Diegel (2003), see Table A-1.
[9] See ACEA (2002), Figure 2.
[10] The 5.3 megaton value is expressed in terms of CO_2-equivalent (rather than carbon, as are the MMTc statistics used here); it includes all greenhouse gases and corresponds to 1.4 MMTc/yr, representing 6% of projected 2010 Canadian auto sector GHG emissions. See Natural Resources Canada, "Automobile Industry and Government Agree on Climate Change Action," (http://www.nrcan-rncan.gc.ca/media/newsreleases/2005/200522_e.htm)
[11] *Fossil Fuels, the Hydrogen Economy, and Energy Policy.* Report of the Aspen Institute 2004 Energy Policy Forum. Washington, DC: The Aspen Institute, December 2004. (www.aspeninstitute.org/eee)
[12] Estimates for 2003; see Table A-1.
[13] From U.S. DOE/EIA web site (http://www.eia.doe.gov/international/petroleu.html #IntlProduction, accessed 13 January 2004)
[14] Ross, Heather L. "Producing Oil or Reducing Oil: Which is Better for Energy Security?" *Resources,* Issue #148. Washington, DC: Resources for the Future, 2002.
[15] A linear regression of the VMT data suggests that the amount of driving increased by 47.3 (±0.9) billion miles per year from a 1970 intercept of 904 (±17) billion miles (adjusted $r^2 = 0.99$).
[16] See Appendix A for justifications of assumptions.
[17] The CO_2 emissions rate of new vehicles was derived from fuel economy values adjusted for estimated shortfall, starting with EPA lab values (55% city and 45% highway test cycle) from Hellman and Heavenrich (2004) and EPA (1980), as listed here as "New Fleet Test Fuel Economy" in Table A-1. We assumed a shortfall of 10% for 1970–75 (prior to start of official CAFE test data), interpolated up to 15% by 1980 (based on EPA 1980), and then held the shortfall adjustment fixed at 15% thereafter, a value close to that implied by adjusted mpg ratings on vehicle labels. We used the 15% adjustment consistently over our 1990–2003 analysis period when computing CO_2 emissions rates; we did not apply different shortfalls for different model years after 1980 or for different vehicle types. EPA is investigating the evidence that shortfall has worsened but new label adjustments are not yet available.
[18] The average CO_2 emissions rate of all vehicles on the road is derived from fuel economy estimates by the Federal Highway Administration (FHWA), developed from annual VMT and fuel sales data. The estimates therefore reflect the in-use fuel economy of the vehicle stock, subject to inherent uncertainties in highway fuel consumption data (see, e.g., Schipper et al. 1993).

[19] Between 1994 and 2003, fuel economy of new cars showed gradual improvements (a net increase of 2.8%), while the fuel economy of new trucks fluctuated around the level of 21 mpg, as shown in Figure 13(d). Therefore, the declining overall fuel efficiency of new cars and trucks (as depicted by the gray curve in Figure 13(d)), and the rising CO_2 emissions rate of the new fleet (as depicted by the gray curve in Figure 13(c)), are initially attributable to the falling fuel economy of both cars and trucks from 1988 to 1993, and subsequently to the rising share of trucks.
[20] The 1978–79 jump in the ratio of the light-truck-to-car CO_2 emissions rate was mainly due to the fact that car fuel economy began rising quickly in 1975 while light truck fuel economy rose more slowly until 1980, after light truck CAFE standards had come into effect.
[21] Note that the Federal SUV classification includes some crossover vehicles, such as the PT Cruiser (car-SUV blend) and Subaru Baja (pickup-SUV blend).
[22] Recall that the Federal statistics used here include only light trucks up to 8,500 lb GVW; trade statistics have reported that light trucks outsold cars for several years now, but those data include heavier light trucks and may also use different vehicle classifications.
[23] The impacts of having minivans and SUVs comply with the passenger car CAFE standard were estimated using two assumptions: (1) the average fuel economy of minivans and SUVs is 27.5 mpg; (2) light-duty vehicles have an average mileage-adjusted lifetime of 12 years, so that the vehicle mix of the 2003 on-road stock is approximated by the vehicle mix of the 1997 new fleet (i.e., half the vehicle lifetime, or 6 years, prior to 2003).
[24] According to DOE/EPA (2000), a coal-fired electric power plant on average releases 2.1 pounds of CO_2 per kilowatt-hour of operation in 1999. A power plant with a 300 megawatt name plate capacity would produce an equivalent of 2,628,000 megawatt hours annually at full operation, and emit 2.5 million metric tons of CO_2, or 0.68 million metric tons of carbon per year.
[25] The left and right portions of the bars in Figure 6 show percentage changes in fuel economy (Δe) and sales (Δs), respectively. The sum $\Delta e+\Delta s$ is slightly less than the change in carbon burden (Δc), but the total length of each bar is proportional to Δc by a factor of $\Delta c/(\Delta e+\Delta s)$. The ratio of Δe to Δs is the same as the ratio of the contribution of fuel economy to that of sales.
[26] GM's aggressive incentives efforts ramped up with the company's "Keep America Rolling" program in the wake of September 11, 2001, designed to lure customers with interest-free financing and cash incentives.
[27] Peter Brown, "Incentive Wars: GM 1, rest of industry 0", *Automotive News*, January 20, 2003. Accessed on September 10, 2004.
[28] A linear fit of GM's car CAFE values showed that GM's car CAFE increased by 0.1 (±0.03) mpg per year 1990–2004, at an observed significance level (p-value) of 0.004.
[29] The models introduced with dual-fuel versions in 2002 included Chevy Tahoe and Suburban, GMC Yukon and Yukon XL, Chevy Silverado pickup, GMC Sierra pickup, and Chevy Cavalier. GMC Savana and Chevy Express vans were added to GM's dual-fuel lineup in 2003. Data from NHTSA suggest that GM did not claim FFV credits for its car fleet in 2002 and 2003 even though GM introduced a bi-fuel compressed natural gas version of Chevy Cavalier in 2002. The NHTSA data also suggest that two models of dual-fuel vans, GMC Savana and Chevy Express, were not included in estimating the FFV credits.
[30] NHTSA's report *Automotive Fuel Economy Program Annual Update Calendar Year 2002* suggests that GM earned 0.9 mpg through FFV credits for its light truck fleet in 2002, which is slightly higher than our estimate of 0.8 mpg for GM's light truck fleet FFV credits. We were not able to resolve this small discrepancy with GM representatives, and so used our estimated value of 0.8 mpg for FFV credits in our analysis.
[31] Hellman and Heavenrich (2004), Table M-16.
[32] Ford backed away from its pledge in 2003, pointing out that declining sales of its compact SUV, the Ford Escape, and deteriorating fuel economy of its Land Rover division made it difficult for the company to meet the pledge (Hakim 2003).
[33] Our government-based statistics cover only SUVs up to 8500 lbs GVW, so we could not estimate fuel economy including Ford's largest SUV, the Excursion, which accounted for 2.5% of Ford's MY2003 SUV sales based on trade data (Ward's 2004). Ford (2004, p. 29) reported improvements in its average SUV fuel economy of 6% in 2003, down from 8.7% in 2002, over the 2000 level, with the company's own data covering the Excursion as well as other models.

[34] As of 2003, Ford offered flexible-fuel versions of 4 cars and 5 light trucks, including Taurus, Taurus Wagon, Sable and Crown Victoria; F-150 pickup, Ranger pickup, Mazda B3000 pickup, Ford Explorer and Mercury Mountaineer. In particular, Ford Explorer V6's were offered only with flex-fuel engines in 2003.
[35] The 60% estimate is the average improvement of 4-wheel drive versions of the Escape Hybrid over the averaged fuel economies of the corresponding 4- and 6-cylinder conventional versions of the Ford Escape, using 2005 data from www.fueleconomy.gov. The 229-gallon annual fuel savings per vehicle was derived based on the 60% fuel efficiency improvement, assuming each vehicle is driven 12,000 miles per year. The number of hybrids needed to offset the growth in Ford's new fleet CO_2 emissions rate was derived by dividing the 229 gallon savings into quantity of excess fleetwide fuel consumption implied by the decline in Ford's new fleet fuel economy.
[36] The notable dip in DCX's CO_2 emissions rate from 1999 to 2000 is mainly due to increased fuel economy of Dodge Durango SUV and Caravan, as well as a sales mix shift from pickups to minivans, notably a drop in sales of the Ram 1500 pickup (140,000 units in 2000 vs. 271,100 units in 1999) and a surge in sales of Caravan and Voyager minivans (517,200 units in 2000 vs. 389,500 in 1999). In 2001, sales shifted back to pickups; the minivan fraction of DCX's sales dropped from 35% to 25% while its pickup fraction grew from 19% to 29%. As a result, DCX's CO_2 emissions rate went back up again.
[37] Based on mid-model year estimate of MY2002 from NHTSA CAFE data.
[38] The compressed natural gas (CNG) option was offered on the Dodge B-series vans and wagons, Ram 1500 pickup, and Caravan/Voyager minivans.
[39] Because DCX's truck fleet exceeded the 20.7 mpg CAFE standard in 2003, if the company had not used FFV credits but then just met the standard rather than exceeding it, the excess CO_2 emissions rate would have been 0.2%.
[40] As of 2003, Toyota's light truck lineup included the Toyota Land Cruiser, 4Runner, RAV4, Highlander, Sequoia, Sienna, Tacoma and Tundra; plus the Lexus RX330, GX470 and LX470.
[41] The Corolla's MY2003 nameplate average laboratory fuel economy rating was 38.1 mpg, up 16% from its 2001-2002 levels near 33 mpg (as reported in Hellman and Heavenrich 2004, and previous editions).
[42] The 30% reduction estimate is a rounded value derived from the performance-adjusted 41% fuel economy increase for the first-generation Prius as estimated by An et al. (1999); the 60% reduction estimate is relative to the EPA MY2003 light-duty average of 24.2 mpg from Hellman and Heavenrich (2004, Table 1).
[43] The 85% fuel efficiency improvement is derived from comparing the fuel economy of the second generation Prius with the average fuel efficiency of Camry 4-cyl and Corolla. This translates to an annual fuel saving of 183 gallons per year.
[44] The laboratory fuel economy rating of 34.5 mpg of Lexus RX 400h is calculated based on the label value of 31 mpg and 27 mpg for highway and city driving respectively. The Lexus RX400h SUV is 44% more fuel efficient than the Lexus RX330 SUV, and consumes 181 fewer gallons of fuel each year.
[45] Sales include Toyota and Lexus brands; the vehicles under Toyota's Scion brand were introduced in late 2003 and 2004 and are not included in this analysis.
[46] The analysis in this section includes all vehicles from the Honda and Acura brands.
[47] The Honda Odyssey minivan was classified as midsize wagon rather than light truck until 1999 when the larger redesigned version came to the market. The Honda Passport, which was based on Isuzu's Rodeo and sold 1994–2002, was counted under Isuzu in the government statistics.
[48] Values are all 55/45 composite laboratory ratings from www.fueleconomy.gov.
[49] Composite lab rating for manual transmission version of Insight in MY2003.
[50] "Honda Civic Hybrid brings gas-electric technology to mass market," Press Release, Torrance, CA: American Honda Motor Co., 20 December 2001.
[51] Honda sold 2,200 units of the Insight in 2000. Insight sales went up to 6,100 units in 2001 and 8,000 units in 2002, but dropped to 1,011 units in 2003 when the Civic Hybrid came to market.
[52] The 38 mpg is the composite lab rating implied by the 29/37 city/highway mpg label values for the Accord Hybrid; the 32% improvement is in comparison to the 21/30 city/highway values for a V6 Accord, from www.honda.com.
[53] Based on Honda's total MY2003 sales of 1.436 million units.

[54] Assuming the same miles of travel, a Honda Civic Hybrid consumes 118 less gallons than a Honda Civic LX with a 1.7-liter engine while the Honda Accord Hybrid saves 120 gallons of fuel per year compared to a Honda Accord V6. The number of hybrids required to offset the 5.7% increase in fleet-average CO_2 emissions rate was calculated the same way as described in note 35.
[55] The analysis in this section includes all vehicles from the Nissan and Infiniti brands.
[56] The 3-year moving average is used here to smooth out year-to-year fluctuations.
[57] See, e.g., Teahen (2005), summarizing sales trends showing large increases in GM's SUV and other light truck nameplates while its car sales continued to lag.
[58] Based on comparing the car and light truck lab ratings of 15.8 mpg and 13.7 mpg, respectively, as reported by Hellman and Heavenrich (2004), Table 1 (also listed here in Table A-1).
[59] U.S. DOE/EIA, average Saudi Arabia oil production over 1988-2002 using data from http://www.eia.doe.gov/pub/international/iealf/tableg2.xls (accessed 24 January 2005).
[60] Even though Toyota and Honda offered more and larger trucks, neither company has used FFV credits for CAFE compliance.
[61] Alone among U.S. automakers, Honda explicitly has called for a comprehensive Federal program to reduce motor vehicle GHG emissions and called for more stringent fuel economy standards; see "Statement by American Honda Motor Co., Inc., on Greenhouse Gas Litigation," February 4, 2005 (Washington, DC: American Honda Motor Co.). This position builds on the company's longstanding endorsement of the value of regulation for addressing environment problems and its progressive stance during the development of Tier 2 and other emissions regulations.
[62] The positions on fuel economy, e.g., as posted on www.AutoAlliance.org (accessed May 31, 2005), constitute what we consider to be skewed and misleading information that is not conducive to progress on either CAFE or other regulatory policies for reducing automotive GHG emissions. In particular, the emphasis on technology rather than policies that directly address fuel consumption and GHG emissions runs directly counter to the main message of this report.
[63] The fuel consumption, VMT and fuel economy of the vehicle stock are based on Table VM-1 of Highway Statistics published by FHWA (www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.htm). Because Highway Statistics reports involve a time lag, we estimated the 2003 VMT level by extrapolating from the 2002 and 2003 moving 12-month VMT totals reported in the April 2004 edition of the Traffic Volume Trends monthly report (www.fhwa.dot.gov/ohim/tvtw/tvtpage.htm).
[64] DOT (2002), pg. iv.
[65] DOT (2002). p. 32.

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