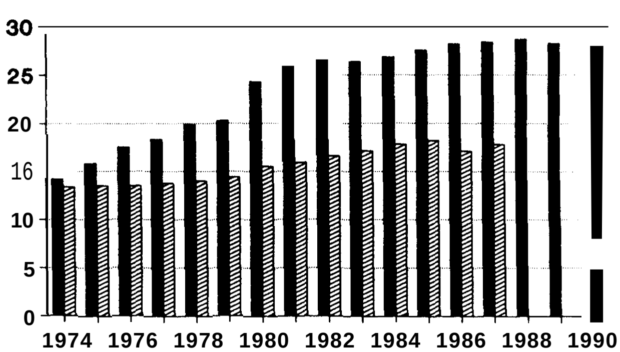
Chapter 4
Market-Driven Fuel Efficiency

There is widespread agreement among energy analysts that, without significant changes in market conditions or government policy, improvements in the efficiency of the U.S. automobile fleet will slow from the pace of the past decade and a half, with most improvements during the next decade coming from diffusion into the fleet of technologies already introduced into the new car fleet. In fact, as shown in figure 4-1, rapid improvements in new-car fuel economy that began in the 1970s essentially ended in 1982—the slowdown has already begun.

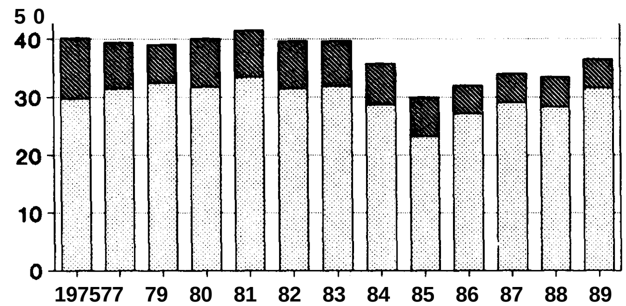
The primary factor reducing potential for rapid increases in fleet fuel efficiency is lack of strong market pressures for such increases. With lower gasoline prices (and lower expectations for price increases), relatively high ***non-fuel*** vehicle operating costs, and average fuel economy of most new vehicles already in the 20- to 35-mpg range, fuel costs have become a smaller fraction of total costs (figure 4-2) and fuel efficiency has

Figure 4-1 -Trends in U.S. Auto Fuel Economy
(miies per gaiion)



SOURCE. Motor Vehicle Manufacturer' s Association, Oak Ridge National Laboratory.

Figure 4-2-Auto Fuel Costs vs. Total Costs
(cents per mile-1986 doiiars)



SOURCE: Oak Ridge National Laboratory.

declined dramatically in importance as a factor in choosing a new vehicle. Presuming cost-effective efficiency improvements are available, the overall cost savings over vehicle lifetimes of any efficiency gain will be a small fraction of the total costs of ownership and operation.[1] Also, many technologies that improve fuel economy while maintaining performance and other vehicle attributes will cost more than the technologies they replace and thus will likely raise vehicle price. To the extent that automobile purchasers focus on purchase price rather than on "lifecycle" savings, high-efficiency vehicles may be less marketable than less efficient but lower priced vehicles.[2]

Available consumer surveys seem to confirm this. The firm of J.D. Power & Associates conducted an annual survey investigating factors consumers consider important in choosing their next car. In 1980, when most analysts and consumers anticipated rapidly escalating gasoline prices, about a third of the consumers surveyed listed fuel economy as the most important factor

[1] See, for example, J. Goldemberg, T.B. Johansson, A.K.N. Reddy, and R.H. Williams, *Energy for a Sustainable World* (Washington, World Resources Institute, September 1987).

[2] Assuming the vehicles are otherwise Comparable, which they often are not. NOTE: In today's market, high+ fficiency vehicles often are "bottom-of-the-line" models generally *less* expensive than alternative models.

they would consider in selecting their next car.[3] This placed fuel economy first among all factors (dependability was second with 24 percent listing it as most important). By 1987, only 3 percent of consumers considered fuel economy their primary selection factor; fuel economy had dropped from first to eighth place in 7 years.[4]

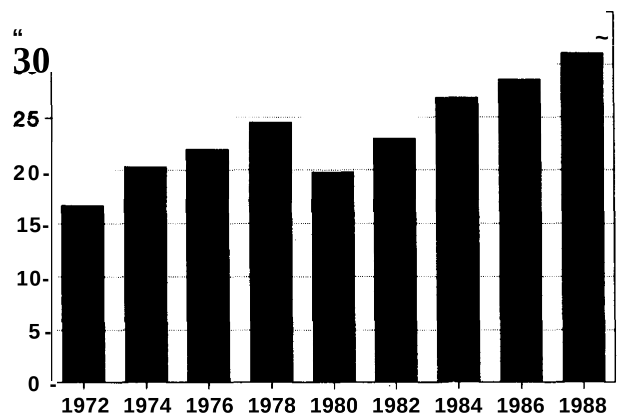
Other factors that may restrain increases in fleet fuel efficiency include:

- **Growth in the use of light trucks for passenger travel.** Although light-truck fuel efficiency has improved markedly since 1974, these vehicles remain substantially less fuel efficient than automobiles. Whereas the average 1990 EPA-rated fleet fuel economy for new automobiles was about 28 mpg, the fleet average for new light trucks was closer to 21 mpg.[5] This disparity inefficiency has a growing influence on overall efficiency of the "light-duty" fleet because sales of light trucks are rising relative to auto sales (figure 4-3) and passenger use of light trucks is growing far more rapidly than use of autos. Light-truck vehicle miles traveled (VMT) grew at a rate more than five times that for autos between 1970 and 1985; during this period, auto vmt increased 38 percent while light truck vmt tripled.[6] And according to 1985 census data, light trucks are used more as passenger vehicles than as freight haulers, making them legitimately part of a light-duty passenger fleet.

  The difference between light-truck and auto efficiency pulled the overall (nominal) new light-duty fleet average down to about **25.4** mpg in 1990,[7] and will likely continue to hold down fleet averages. The growing role of light trucks in passenger travel is a primary cause of recent stagnation in the fleetwide average fuel economy of new light-duty passenger vehicles, which has increased only 1.3 mpg from 1981 to 199@; greater numbers of light trucks in the fleet countered efficiency gains within each portion of the fleet.

- A **growing attraction among purchasers of new automobiles to more powerful (and thus less fuel-efficient) automobiles.** For example, as shown in figure **4-4,** average O-to-60 acceleration time for new vehicles has decreased in every year since 1982. Part of this trend is simply a recapture of performance levels lost earlier to emission con-

Figure 4-3–Sales of Light Trucks As a Percent of All Light:Duty Sales



SOURCE. Oak Ridge National Laboratory

[3] J.D. Power & Associates, The *Power Newsletter*, Westlake, California, as reported in P.D. Patterson, *Periodic Transportation Energy Report No. 4*, Sept. 8, 1988, and personal communication.

[4] Unfortunately, the survey has not been continued. P.D. Patterson, U.S. Department of Energy, personal communication, Mar. 8, 1991; and John Rettie, J.D. Power & Associates, personal communication, Mar. 8, 1991.

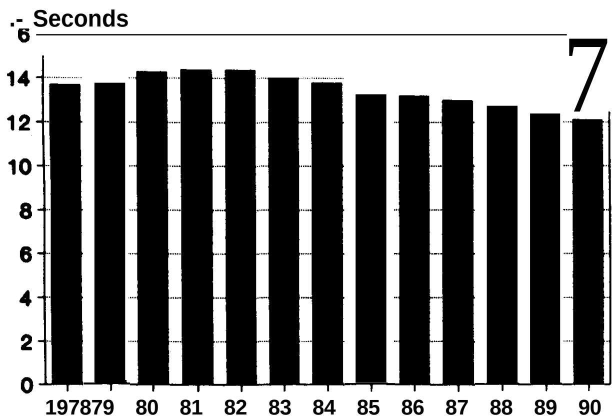
[5] R.M. Heavenrich and J.D. Murrell, U.S. Environmental Protection Agency, "Light-Duty Automotive Technology and Fuel Economy Trends Through 1990," U.S. Environmental Protection Agency, Ann Arbor, Michigan, EPA-AA-CTAB-9003, June 1990, p. 6 (cited hereafter as Heavenrich 1990). The light-truck average is up from about 12 mpg in 1974.

[6] P.D. Patterson, "Analysis of Future Transportation Petroleum Demand and Efficiency Improvements," paper presented at International Energy Agency, Energy Demand Analysis Symposium, Paris, France, Oct. 12-14, 1987.

[7] Heavenrich 1990, op. cit., p. 7.

[8] Heavenrich 1990, op. cit., p. 7.

Figure 44-New-Car Performance O-to-60-mph Acceleration Time



SOURCE Environmental Protection Agency

trol and satisfaction of CAFE standards; automakers claim new-car owners raised strong objections to reduced power levels in the early 1980s. Although the preference for increased performance may disappear in the future, it is worrisome to those concerned with fuel conservation. An important consequence of this consumer preference has been that drivetrain improvements (such as engines with four valves per cylinder and turbochargers) with the potential to either increase fuel efficiency (at least in part by reducing engine displacement) or boost horsepower have been introduced in configurations emphasizing power increases rather than fuel savings.

The actual reduction in O-to-60 acceleration time from 1982 to 1990 is 2.3 seconds (from 14.4 to 12.1 seconds), a 16-percent decrease. Based on an EPA analysis of the sensitivity of fuel economy to changes in performance,[9] this decrease has caused more than an 8-percent decline in fuel economy—more than 2 mpg—from what it would have been at 1982-level performance.

- **Additional luxury and safety equipment on new cars.** Although airconditioning and power steering have penetrated more than 80 percent of the fleet, and further increases will be small, other equipment such as power seats, sunroofs, and power locks and windows may gain additional market share and can add significant weight to the vehicle. In addition, four-wheel drive, which can add 150 to 200 pounds to a vehicle and cut its fuel economy by 12 to 15 percent, is gaining popularity. Safety equipment such as airbags (30 to 45 lb) and anti-skid brakes (30 to 45 lb) will add further weight. The net effect of greater penetration of these technologies could be as large as a 3- to 5-percent decrease in fuel economy.[10]

- **More stringent emission standards, especially for nitrogen oxides.** To meet the new Tier I Federal standards on exhaust and evaporative hydrocarbons and nitrogen oxides, manufacturers will choose from alternative strategies that will have tradeoffs in cost, fuel efficiency, and emissions. There are approaches available to manufacturers —e.g., increasing the rhodium content of vehicle catalyst systems—that would meet a more stringent nitrogen oxide standard with a relatively small fuel economy penalty, but at an added cost over alternative approaches.[11] On the other hand, if manufacturers perceive that consumers do not value

[9] K. Hellman, Chief, Control Technology and Application Branch, U.S. Environmental Protection Agency, Ann Arbor, MI, personal communication.

[10] Energy & Environmental Analysis, Inc., "Developments in the Fuel Economy of Light-Duty Highway Vehicles," contractor report prepared for the Office of Technology Assessment, August 1988.

[11] Sierra Research, Inc., "The Feasibility and Costs of More Stringent Mobile Source Emission Controls," contractor report prepared for the Office of Technology Assessment, Jan. 20, 1988. The report estimates a cost per vehicle of $139 to achieve a 0.25 grams/mile standard for non-methane hydrocarbons and a 0.4 g/mi standard for NO_x with no fuel eeonomy penalty, and no *forgone* fuel economy improvements. The technology involved is an increase in rhodium loadings by 0.5 grams/vehicle in the exhaust catalyst and the addition of a bypassable start catalyst. Another OTA contractor-Energy & Environmental Analysis, Inc. –believes that satisfaction of the above standards would *at least* cause some future fuel economy improvement to be forgone, K.G. Duleep, Director of Engineering, Energy & Environmental Analysis, Inc., personal communication.

fuel economy highly, they may choose control strategies that add little or no cost but sacrifice more fuel economy. In addition, manufacturers could add technologies that have potential for both efficiency improvement and emission control—e.g., multipoint fuel injection—in ways that maximize emission reduction effects but sacrifice some efficiency potential. In these cases, the emission standards would have caused some potential improvement in fuel economy to be forgone. Historically, manufacturers have pursued a variety of strategies to achieve standards: to meet 1981 emission standards, many Japanese manufacturers used oxidation catalyst technology and accepted an efficiency loss of 4 to 6 percent; General Motors met the same standard with "closed loop" electronic fuel control systems with three-way catalysts that incurred no efficiency loss.[12] Energy and Environmental Analysis, Inc. has estimated the potential fuel economy penalty (or gain forgone) of the Tier I standard of 0.4 grams/mile for nitrogen oxides to be about 1 percent, ***with significant variation possible depending on how manufacture balance efficiency against costs.***[13]

- **Slower replacement of the automobile fleet, so that technological improvements introduced into the new car fleet will take longer to diffuse into the total fleet.** In 1%9, cars more than 10 years old accounted for only about 7 percent of vehicle miles traveled and fuel consumed; by 1977, such vehicles accounted for about 13 percent of vmt and fuel; and by 1983, they accounted for almost 20 percent of vmt and 23 percent of fuel.[14] In 1989, all light-duty vehicles (not just cars) more than 10 years old accounted for over 30 percent of vmt and roughly 31 percent of light-duty fuel consumption.[15] Note that the importance of turnover rates to total fleet fuel economy and, more significantly, to improved emissions performance indicates that policymakers must avoid strategies that would make new cars less attractive to potential purchasers, and thus slow new-car sales and vehicle turnover.

- No **signs that U.S. drivers will shift to cars with less interior volume.** Although average ***exterior*** size and vehicle weight have been reduced substantially, with great positive effect on fuel efficiency, and though there have been substantial sales shifts among the different size classes, the average interior volume of new automobiles in the U.S. fleet has remained virtually constant for 13 years: 109 cubic feet in 1978 and 107 in 1990[16] (figure 4-5). On the other hand, the vehicles often cited as demonstrating potential for major fleet efficiency improvements—the very-high-efficiency vehicles in the current fleet and most ultrahigh-efficiency prototypes-are smaller than the average automobile. Although substantial efficiency gains can be made without a shift to smaller (lower interior volume) cars–less than one-tenth (0.5 mpg out of 6.6 mpg total increase) of 1978-1984-progress in new-car efficiency was due to shifts in size class[17]—the apparent difficulty in effecting such a shift limits prospects for future fuel economy gains from fleet downsizing.

[12]Energy & Environmental Analysis, Inc., 1988, op. cit.

[13]Duleep, op. cit.

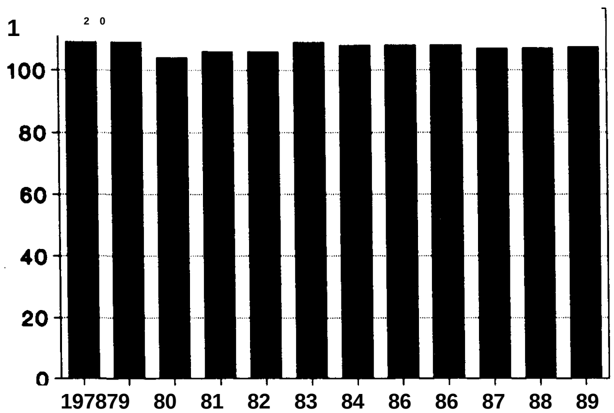
[14]U.S. Department of Energy, *Assessment of Costs and Benefits of Flexible and Alternative Fuel Use in* the *U.S. Transportation Sector. Progress Report One: Context and Analytical Framework, DOE-PE-0080,* January 1988.

[15]U.S. Department of Energy, Energy Information Administration, *Household Vehicles Energy Consumption 1988*, DOE/EIA-0464(88), February 1990, p. 29.

[16]Heavenrich 1990, op. cit., p. 17.

[17]P.D. Patterson, "Trends in Automobile Fuel Economy and Energy Use," paper presented at ORSA-TIMS Conference, Boston, MA, Apr. 30, 1985.

Figure 4-5–interior Volume of New Cars (cubic feet)



SOURCE: Oak Ridge National Laboratory.

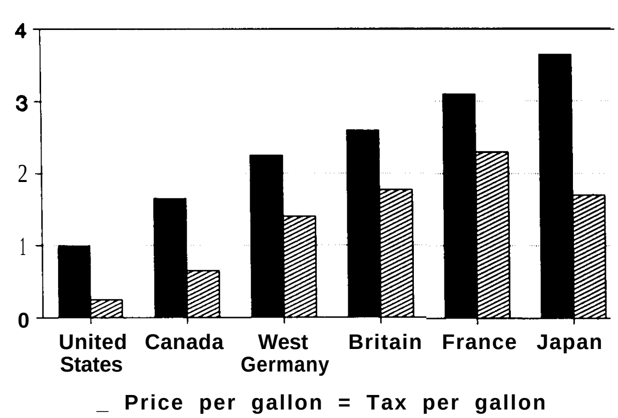
- **Continued consumer demand for "old--fashioned" car models.** U.S. manufacturers have found that a portion of new-car purchasers prefer large, heavy, rear-wheel-drive models even though newer, more fuel efficient designs appear functionally superior.[18] Because manufacturers can obtain high profit margins on these models, they have kept them in the fleet despite prior plans to phase them out.

- **Growing road congestion and other factors affecting on-road fuel economy.** Current on-road efficiency of the fleet is estimated to be about 15 percent lower than estimates made with the EPA test procedure. As discussed in box 4-A, changing driving conditions may change the 15-percent adjustment, most likely increasing the gap between EPA and on-road values. In particular, growing congestion may play a major role in reducing fuel economy.

If low oil prices continue, relatively modest benefits to the individual automobile 'owner of improving fuel efficiency beyond about 30 mpg are unlikely to provide much incentive to manufacturers who must factor in both market risk and the risk of reliability problems into their design and marketing decisions. Manufacturers are likely to be reluctant to introduce major fuel-efficient technology unless it offers other important benefits as well, and they are likely to forgo some potential efficiency benefits to maximize other benefits. Possible side benefits include better emission control characteristics (e.g., from better combustion controls) and improved performance (e.g., from continuously variable transmissions). And despite the existence of some side benefits, improvement in new-car fuel economy is expected to be incremental and quite slow over the next decade or so, assuming the current market environment persists.

Thus, absent sharp increases in world oil prices, oil supply disruptions, or other events that might increase consumer demand for fuel economy, or policy intervention such as gasoline excise taxes (over $2/gallon in many industrial countries, see figure 4-6) and other market incentives (e.g., gas guzzler/sipper fees and rebates), or tightening of CAFE standards, fuel efficiency for the U.S. new vehicle fleet will likely have only modest increases over the next decade as engineering improvements well along in development are gradually introduced. Such technological and design

Figure 4-6-Gasoline Price With Tax
(dollars par gallon)



SOURCE: Business Week

[18] However, rear-wheel drive generally is more suitable than front-wheel drive for trailer towing.

Box 4-A-Potential for Reductions in On-Road Fuel Economy From Changing Driving Patterns

Recent analyses conducted for the Department of Energy[1] conclude that the 15 percent adjustment factor used to translate EPA fuel economy test results to estimated on-road fuel economy is too low for projectiorts of fuel use. First, the share of driving done on urban roads is now substantially higher than the assumed 55 percent; the 1987 share was 63 percent, and the projected sham for 2010 is 72 percent.[2] Taking these shifts in the urban/rural share into account would lead to a 1.3-percent decrease in estimated on-road fuel economy for 1987, and a 3.1-percent decrease by 2010. Second, rising urban congestion, caused by a rate of increase in vmt much greater than increases in road capacity in urban areas, will exert a downward pull on on-road efficiency; the estimated effect for 2010 is a 15-percent reduction in EPA city fuel economy, or a 9.1-percent reduction in estimated on-road fuel economy. Third, expected increases in highway speeds will further reduce highway fuel economies; an increase in average speeds from 55.8 mph in 1975 to 59.7 mph in 1987 cost an estimated 0.8-percent reduction from EPA values in on-road fuel economy, with an extrapolation to 66 mph for 2010 yielding an additional 1.6-percent reduction.[3]

The estimated overall effect in 2010 of the three factors depressing on-road fuel economy from EPA-estimated levels–expected increases in the urban share of driving, congestion, and highway speeds-is an additional 14.7-percent reduction from the EPA composite fuel economy on top of the current 15-percent adjustment factor, or a total adjustment factor of 29.7 percent.[4]

OTA judges that quantitative assessments of two of the three forces driving the expected change in adjustment factor are highly uncertain: rising urban congestion and increasing highway speeds. These forces account for nearly four-fifths of the expected adjustment factor increase. In particular, since much highway driving is on urban highways, we consider it unlikely that a simple extrapolation of past increases in highway speeds will yield a reliable projection of future highway speeds. We expect the projected M-percent reduction in fuel economy due to increased highway speeds to be an overestimate.

Additional factors that Will counterbalance forces adding to the gap between EPA and on-road mileage include:

- the large increase in fueI injection in new cars. The original 15-percent gap was calculated with a fIeet made up of carbureted vehicles; the gap is smaller with fuel injected vehicles;[5]
- regulations requiring on-board diagnostics will reduce the number of malfunctioning vehicles, with fIeetwide in-use fuel economy benefits;
- regulating evaporative and running losses will reduce fuel lost to evaporative emissions; and
- cold-temperature carbon monoxide emission regulation will reduce fuel enrichment during cold starts at temperatures below 65°F, with in-use fuel savings not recognized by the EPA test, which is conducted at higher temperatures.

We Conclude that the DOE estimate of a nearly 30-percent gap between measured and on-road fuel economy in 2010 probably is directionally correct but significantly overstated.

[1] F. Westbrook and P. Patterson, "C'hanging Driving Patterns and Their Effect on Fuel Economy," paper presented at the 1989 SAE Government/Industry Meeting, Washington, DC, May 2, 1989.

[2] Ibid.

[3] Ibid.

[4] Ibid.

[5] K.G. Duleep, Director of Engineering, Energy and Environmental Analysis, InC., personal communication.

Improvements and, above all, retirement of older, less efficient vehicles will allow fuel economy of the entire passenger vehicle fleet to rise during the remainder of this century, but at a rate notably below what is achievable.

Longer-term projections of new vehicle fleet fuel economy—to 2010 or beyond—are considerably more speculative because this timeframe allows sufficient lead time for new technologies to play a major role. By 2010, technologies such as two-stroke gasoline and diesel engines, direct injection diesels, even electric/fossil hybrid vehicles could attain significant market shares, with large impacts on fuel economy.

Projections ofboth new-car and light-duty fleet fuel economy beyond the next few years are at best educated guesses and should retreated as such. Some recent projections include:

- The Energy Information Administration's projection for the year 2000: for new automobiles, 32.6 mpg (EPA); for new light trucks, 24 mpg (EPA); for the entire light-duty fleet, 21 mpg (in use).[19]
- Data Resources, Inc.'s projection for the year 2000: for new automobiles, 30.8 mpg (EPA); for new light trucks, 23 mpg (EPA).[20]

Fuel efficiency could, of course, easily differ from these projections. For example, a combination of factors—additional safety equipment, increases in vehicle performance, more stringent emission standards that are met by least-first-cost (but fuel-inefficient) measures, trends in imports towards larger and more luxurious (and powerful) vehicles, and growing market share for vans and pickup trucks—could make it difficult for the new vehicle fleet to improve significantly beyond today's level. Yet a renewal in consumer and public policy interest in fuel economy could cause fleet efficiency to rise above the projected levels by shifts in market shares of alternative models, more rapid diffusion of existing technology into the fleet, and accelerated introduction of technologies.

Although 1995 fuel economy will be heavily influenced by existing industry plans, fuel economy in 2001 should be much less constrained by such influence, and consequently, especially difficult to predict. ***Assuming relatively stable gasoline prices and a general continuation of recent market trends in consumer preferences for vehicle perfomance, size, and other attributes, OTA's "best guess" for new car fleet fuel economy in 1995 is 29 mpg (EPA value).*** We are far less certain of the likely year-2001 value; but under relatively optimistic conditions for increasing fuel economy—oil prices rising by about $10/bbl, fuel economy technologies added to model lines achieving maximum fuel economy benefits consistent with manufacturer tradeoffs with size and performance, and trends to growing vehicle size, power, and luxury leveling out after 1995-we believe the fleet could achieve 33 mpg. Lower oil prices, continued "horsepower wars," less-than-optimal fuel economy performance from new technologies, and so forth, can lower this value significantly.

With the "optimistic" fuel economy scenarios, assuming the 15-percent EPA/in-use fuel economy adjustment will still hold in the future, the in-use values are about 25 mpg for the 1995 new car fleet and about 28 mpg for the 2001 fleet. If urban congestion increases significantly, however, these values will be too optimistic. The corresponding values for the ***total*** fleet of cars in service are: **27.4** mpg (EPA) and 23.3 mpg (in-use) for 1995; 29.6 mpg (EPA) and 25.1 mpg (in-use) for 2001. With a year-2001 fuel economy value of about 24 mpg (EPA) for new light trucks, the overall light-duty new vehicle fleet average for 2001 would be about 29 mpg (EPA), and the entire light-duty fleet would average about 22 to 23 mpg in-use.[21] If market trends or gasoline prices change significantly, obviously the projections will change, especially for the later years. As will be discussed later, increased consumer preference for the most efficient vehicles in each size class could raise average fleet fuel economy by several miles/gallon even without new technology or radical changes in the size mix of the fleet.

[19] U.S. Department of Energy, Energy Information Administration, *1991 Annual Energy Outlook*, DOE/EIA-0383(91), *March* 1991. In-use estimate assumes degradation of efficiency from increasing congestion.

[20] Based on Data Resources, Inc., *Energy* Review, winter 1990-91, table 18, using 0.844 as the ratio of in-use to EPA-rated fuel economy.

[21] Assuming a 15-percent adjustment between fuel economy measured on the EPA test cycle and actual on-road fuel economy.