Designing A New Fuel Economy Bill

Policymakers who are convinced new CAFE legislation is a desirable approach to improving fleet fuel economy must confront a number of key issues. The two overriding issues are, first, how the standards should be structured, and, second, how high the target fuel economy should be. Selecting a structure for the standards may be as important as selecting the numerical target.

ESTABLISHING THE STRUCTURE OF NEW CAFE STANDARDS

The current CAFE standard assigns a goal of 27.5 mpg to every automaker regardless of the vehicles they produce. Domestic automakers have severely criticized this regulatory structure because manufacturers producing larger vehicles or a variety of vehicle sizes must meet a more demanding technological standard than manufacturers who concentrate on smaller vehicles that normally are more fuel efficient.[1] This leaves automakers who focus on small cars far more flexibility than "full line" manufacturers to introduce features that are attractive to consumers but fuel inefficient-e. g., four-wheel drive, high-performance engines, etc. Further, the fuel economy standard selected under such a structure will tend to be heavily influenced by the (relatively low) fuel economy level that can be reached by the company with the most difficult task (i.e., the largest, most powerful mix of vehicles). Since such a standard would provide little challenge to companies manufacturing primarily small vehicles, the fleetwide fuel economy level achieved will be lower than could be achieved if ***all*** automakers were forced to improve fuel economy to the maxmum extent possible.

Another problem with the current approach involves the separation of domestic and import fleets according to the percentage of parts manufactured in the United States (the "local content"). Because the "import" fleets of the domestic automakers have high CAFE ratings (in 1990, 35.6 mpg for Ford, 37.6 mpg for General Motors'), the domestics have been able to manufacture more of some low-efficiency models' parts overseas and move those models to the import fleet-thus improving the CAFES of their domestic fleet while leaving the import fleet's CAFES safely within standards. Ford recently switched its Crown Victoria model to an "import" by increasing its foreign parts content to 25 percent —trading away U.S. jobs for an improvement in Ford's regulatory position vis-a-vis CAFE enforcement with no actual fuel economy improvement. On the other hand, earlier in the history of the legislation, CAFE rules forced automakers to build small cars as part of the U.S.-made fleet-with a positive effect on domestic job creation.

In spring, 1989, Senator Richard Bryan of the Consumer Subcommittee (Senate Committee on Commerce, Science, and Transportation) introduced legislation calling for all automakers to improve their companywide fuel economy levels 20 percent by 1995, and 40 percent by 2001, over levels achieved by model year 1988. This legislation sought to overcome criticism leveled at the current uniform standard by forcing all automakers to improve by the same amount. The structure called for in the legislation generally is referred to as a "uniform percentage increase." Senator Bryan has reintroduced this legislation for 1991, as S.279.

Another CAFE proposal would base each automaker's standard on the size mix of vehicles it manufactures, giving makers of small cars a higher mpg target to reflect the inherent fuel economy

[1] Obviously, some small cars that are high-power sports models obtain relatively low fuel economy levels. However, vehicle size is a critical factor in fuel economy, and manufacturers of small vehicles generally will have an easier task than manufacturers of large vehicles in meeting the same fuel economy standard.

advantage small cars have over large cars.[2] Ideally, to meet individual mpg standards, each company would have to install about the same level of fuel economy technology as every other company. In other words, a correctly set standard would not create any market advantage or disadvantage.

The standard would work as follows:

1. Each vehicle model would be assigned a fuel economy target determined by a formula ***relating required fuel economy to vehicle interior volume.*** (Alternatively, each vehicle size class could be given a fuel economy value, and each vehicle would then be given a target based simply on its size class.[3]) As discussed in box 9-A, interior volume must be defined carefully to allow a single standard to apply to a range of auto types, including station wagons.
2. Each company's fuel economy standard would then be calculated by taking the sales-weighted average of the various fuel economy targets assigned to all of its models. This company standard, or Volume Average Fuel Economy (VAFE) standard, could be computed at the beginning of the year, based on last year's sales mix, or at the end of the year based on actual sales.
3. It is worth noting that ***each model*** in an automaker's fleet would not have to meet its fuel economy target so long as the sales-weighted average of all of the maker's models achieved the assigned VAFE standard. This leaves each company the flexibility of deciding how to allocate fuel economy technology across its fleet, and further allows it to have a mix of family-oriented, commuter, and high-performance models so long as the average of their fuel economies satisfies the company standard.
4. **The** formula for assigning fuel economy targets can be established by the government

Box 9+4-Measuring Interior Volume for Application to a Volume-Based Standard

An examination of how fuel economy varies with vehicle interior volume shows that the simplest measure of volume (all available space within the automobile) is not the best measure for use with a fuel economy standard based on interior volume. Figure 9-A-1 shows how the average fuel consumption of different classes of automobiles varies with total interior volume. The figure demonstrates that the fuel consumption rates of subcompact through large sedans forma straight line on the graph; all station wagons fall on a different straight line. Minicompacts and two-seaters fall outside these lines, generally having high fuel consumption for their interior space compared to other classes—not surprising because most cars in these two categories are basically sports cars and have high power-to-weight ratios.

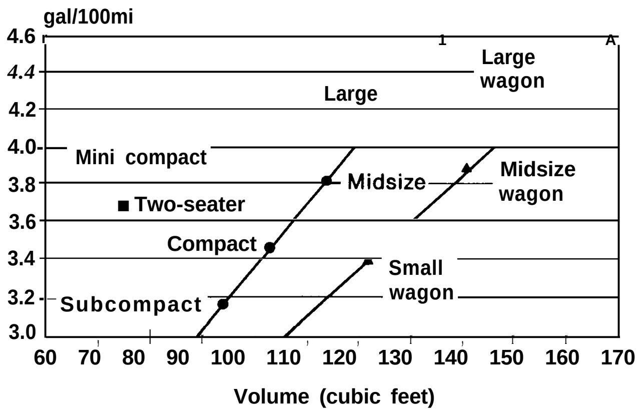
The fuel comsumption/interior volume relationships for sedans and wagons tend to converge toward a single line on the graph interior volume measurements for the wagon class do not give full "credit" to the added cargo volume in wagons. Using this more restricted definition of interior volume, it should be possible to design a single interior-volume-based fuel economy standard applicable to all sedans and wagons except sports cars that approaches the goal of creating a uniform technological challenge regardless of car size.

If Congress chooses this approach, it must decide how to deal with minicompacts and two-seaters, since these classes would tend to have great difficulty in attaining target fuel economy levels based on their (low) interior volumes. Companies focusing on these classes are likely to find it impossible to meet their company standards unless these classes are treated differently than the rest of the fleet. This would impose penalties on these classes, raising their purchase price and presumably lowering demand. Congress might be comfortable with such a result, but if not, it must allow separate treatment for these vehicles.

[2]OTA discussed this CAFE structure in its May 2,1990, testimony to the Consumer Subcommittee. Also, Barry McNutt of the Department of Energy discussed interior-volume-based standards and size-class standards in a May 1985 talk.

[3]This formulation has the disadvantage of providing an incentive for automakers to enlarge models at the upper limits of any size class to move them to the next higher class.

Figure 9-A-1 –Fuel Consumption and Volume, 1990 Sedans and Wagons



SOURCE U S Environmental Protection Agency, 1991

to aim for any fleetwide average desired. The VAFE formula would have to be based on extrapolating from the most recent data on fleetwide size distribution, so unexpected shifts in sales, for example, from larger to smaller cars, would result in the fleet attaining a fuel economy level slightly different than predicted. Differences would not be large unless large shifts in sales occurred.

Both Senator Bryan's "uniform percentage increase" and an "interior-volume-based-VAFE-standard" represent improvements over the current CAFE approach because they account for differences in fleet makeup among the various automakers. Simpler in concept, the Bryan approach is easier to understand and explain. However, it makes no allowance for differences in the degree to which automakers have applied fuel economy technology. To the extent that some automakers may have used a higher level of technology during the proposed base year, this approach penalizes them with a more difficult mpg target than other automakers with fleets similar in size mix but who used inferior efficiency technology (see box 9-B). In doing so, it rewards companies that have made less effort thus far, since these have the most technological "headroom" to improve their fuel economies. Furthermore, assigning standards based on company fuel economies achieved years earlier will make it difficult for automakers to shift sales strategies unless these shifts are toward a fleet with smaller vehicles. This will tend to discourage Japanese automakers from pursuing their current strategy of competing in the luxury and larger-car markets. In other words, the proposed legislation may be viewed as anticompetitive.

Some of the tendency of the "uniform percentage increase" approach to reward companies that have low baseline fuel economies and penalize companies with high baselines can be mitigated by placing floors and caps on the company requirements—i.e., by demanding that companies achieve a minimum level of fuel economy regardless of baseline value, and placing an upper limit on the company standard, even if its baseline value is very high. S.279 places a floor of 27.5 mpg and a cap of 40 mpg for 1996, and a floor of 33 mpg and cap of 45 mpg for 2001. This means that for 1996, companies with baseline fuel economies below 22.9 mpg must attain a percentage increase higher than 20 percent to achieve their target fuel economy, and companies with baselines above 33.3 mpg will need increases less than 20 percent. For 2001, the baseline floor and cap breakpoints are 23.6 mpg and 32.1 mpg, respectively. This means companies such as Isuzu (34.9 mpg in 1988[4]), Suzuki (50.3 mpg) and Hyundai (35.0 mpg), as well as domestic import fleets (Ford obtained 35.6 mpg in 1988, General Motors, 37.6 mpg), will not be required to improve the full 20 and 40 percent by 1996 and 2001. However, neither Toyota (32.6 mpg) nor Honda (32.0 mpg), companies with superior fuel economy performances in 1988 even accounting for their size mix, really benefit from the cap.

A uniform percentage increase approach, because it is based on past relationships, must take special care in dealing with new market entrants with no "baseline" fuel economy values. If new entrants are treated more leniently than established automakers, the latter may form new com-

[4] Fleet fuel economy values from U.S. Department of Transportation, National Highway Traffic Safety Administration, "Summary of Fuel Economy Performance 1988," U.S. DOT/NHTSA NEF-31.

Box 9-B-What Accounts for the Difference in CAFE Among Different Automakers?

The fairness of a fuel economy standard demanding that each automaker attain a uniform percentage increase over its fleet fuel economy in a base year depends in part on the extent to which some automakers might have done very much more (or less) than the average in making their fleets efficient in that year. To the extent that an automaker may have installed more fuel efficiency technology, or used more fuel efficient design than the average, he would, in effect, be penalized by having a more stringent target to meet with less technological "headroom" than available to the average automaker. Similarly, a less-efficient-than-average automaker would be rewarded with a lower target and greater degree of technological headroom.

One way of measuring design and technology efficiency of different corporate fleets is to remove the effect of differing vehicle size mixes from each company's CAFE value. To do this, OTA devised a set of company-by-company size-class-mix-weighted standards to reach ***actual*** fleet new-car fuel economy in 1988-28.3 mpg—and compared these standards to the manufacturers' achieved fuel economies. Where achieved values were above, below, or the same as the standards, the manufacturers' cars were better than, worse than, or the same as the industry average fuel economy adjusted to account for the sales mix of the fleet.

Figure 9-B-1 compares the company-by-company targets with the actual fuel economy values achieved in 1988. The figure shows that two U.S. companies are within 1 percent of their targets; that is, their fleet fuel economies are near the industry average ***taking into account the size class mix of their fleets.*** Half of the Japanese companies are well over the industry average, with the other half at or near the average. The European company is considerably below the average.

This comparison shows that ***differences*** in ***the size class mix of domestic and import fleets account for much, though not all, of the differences in the fuel economies of these fleets.*** For example, of an 18-percent difference in the fuel economy levels between often-compared U.S. and Japanese manufacturers (General Motors and Toyota), approximately 12 percent–two-thirds-is explained by the size class mix. The remainder presumably is due to differences in technology, design, and vehicle performance.

The comparison indicates that a "uniform percentage increase" standard based on a 1988 baseline–as specified in the legislation sponsored by Senator Bryan-would penalize some Japanese manufacturers, though not nearly to the extent that might be presumed from examining only the large differences between their CAFES and those of U.S. companies. Because some Japanese companies--particularly Toyota and Nissan--have increased the size of their vehicles in the 1988-91 period relative to U.S. automakers, the disadvantage posed by this type of standard will be greater than implied by the above analysis.

panics to market their less efficient models, improving the CAFE position of the remaining models in their fleet at little cost and with no actual improvement in fuel economy.

If the volume-based or VAFE standard were determined from actual sales (i.e., standards would be computed at year-end based on that year's sales figures), automakers would have flexibility to change sales strategies without making their fuel economy targets impossibly difficult to attain. This also avoids penalizing automakers if market trends change unexpectedly, since standards would reflect changing sales figures. However, the VAFE standard's "size neutrality' '-giving small cars as difficult a standard as large cars—means there is no incentive for an automaker to boost sales of small cars, a feature of the current CAFE standard and, indeed, any standard based on a formula that does not change with shifts in fleet size mix. The more that Congress might want to encourage consumers to drive smaller cars, which tend to be more fuel efficient, the less a VAFE-type standard might be favored.

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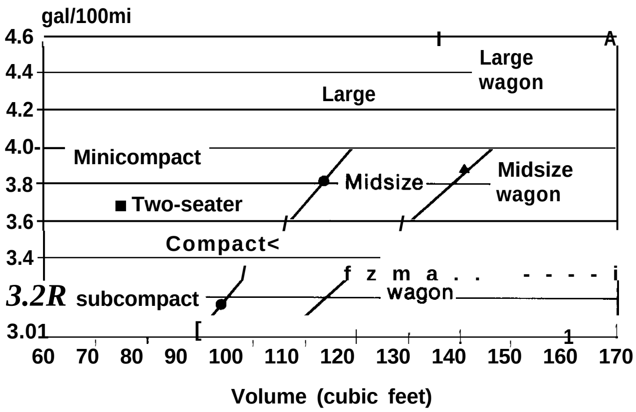

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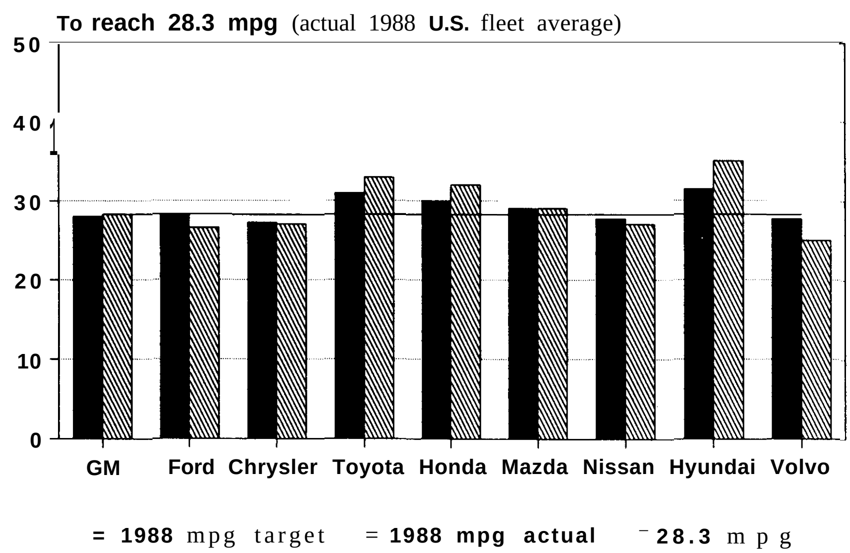
Figure 9-B-1 -Size-Class-Weighted Fuel Economy for 1988



SOURCE: Office of Technology Assessment, based on Oak Ridge data 1989.

target established by VAFE standards would shift as well. If more small cars are sold, the fleet target will increase; if more large cars are sold, it will decrease. In contrast, the current uniform CAFE guarantees a fleet minimum fuel economy, assuming all automakers are in compliance.

It has been presumed that the uniform percentage increase approach to fuel economy standards will not have this problem because required increases are based on previously established company fuel economy levels, and thus each company's target fuel economy cannot change. However, the ***fleet*** target will change with any shifts in the market shares of the companies. If a company with a high target gains market share, the fleet target will increase, and if a company with a low target gains market share, the fleet target will decrease. Consequently, ***neither*** currently proposed approach to new fuel economy standards can guarantee a minimum fleet fuel economy other than the minimum for any one component of the standard-for the uniform percentage increase, the target for the least efficient company; and for the VAFE approach, the target for the largest vehicle.

Recently, Mercedes-Benz, BMW, and Porsche proposed an alternative structure for fuel economy standards that relies on several factors—the vehicle curb weight, the ratio of curb weight to interior volume, and the ration of curb weight to torque—to define allowable fuel economy levels. The proposal establishes a fuel economy baseline for each model using a formula for fuel consumption derived from a regression analysis of all EPA certified 1990 models, with the above variables as regression variables. In other words, the proposal starts with a formula of the form:

$$\text{Fuel consumption} = A \times \text{curb weight} + B \times \frac{\text{Curb weight}}{\text{interior volume}} + C \times \frac{\text{curb weight}}{\text{torque}}$$

where A, B, and C are constants,

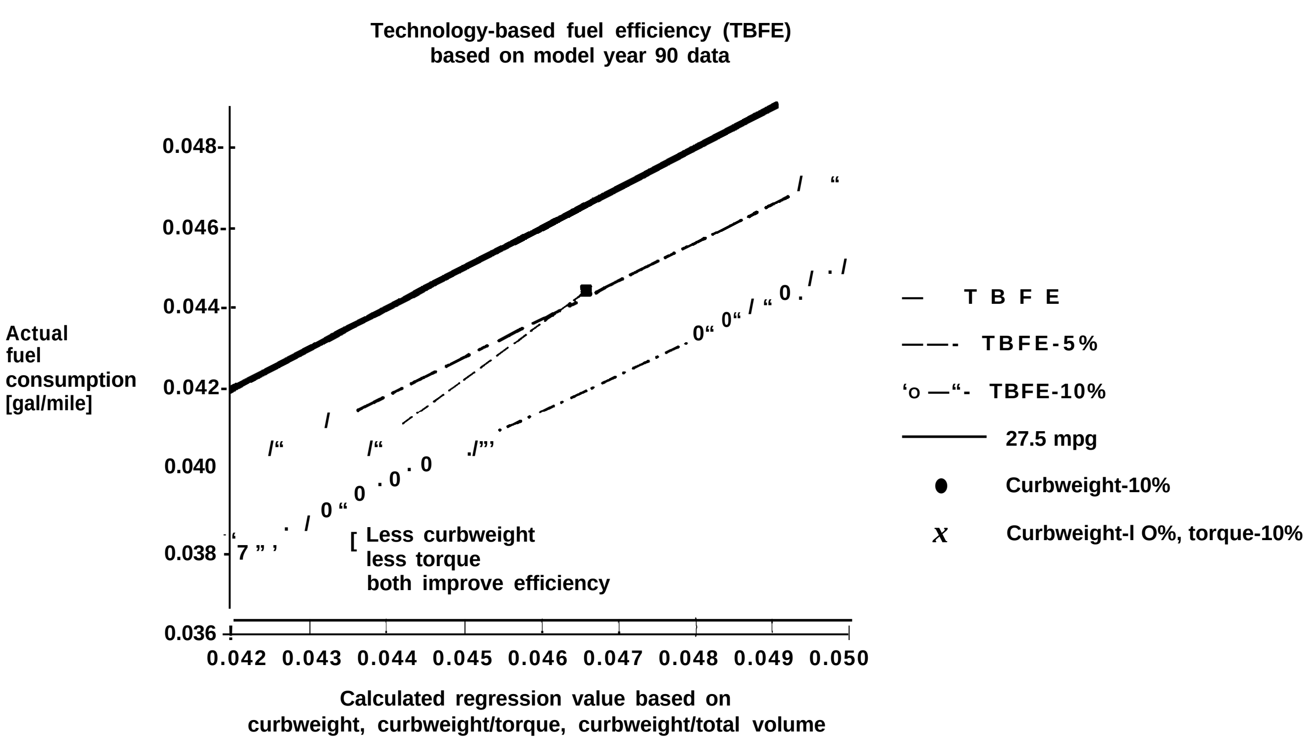
which approximately defines the fuel consumption of vehicles in the 1990 fleet. For a 20-percent improvement in fleet fuel economy, new vehicles have to achieve a fuel consumption level 20-percent lower than given by the formula ***using the new values of curb weight, interior volume, and torque.*** If these values do not change from their 1990 levels, the vehicles must simply attain a 24)-percent reduction in fuel consumption.

This system has the advantage of allowing corn-panies that compete in niche markets to satisfy fuel economy standards by improving technology without abandoning its niche or being forced to add model lines of lighter or lower-power vehicles, as would be the case with other proposed standards. The system also demands technology improvements: simply adding a model line of small cars ***of the same design and technology level*** will not help; the formula will demand the same kind of efficiency improvement from that model as well.

The system has some interesting characteristics. Most important, although increasing a vehicle's torque and weight while holding its interior volume constant will allow the vehicle to be subject to a higher allowable fuel consumption standard, basing the new allowable fuel economy on the regression equation implies that the allowable level will be ***technically*** more difficult to meet. In other words, there is a positive incentive to reduce weight and torque while holding interior volume constant, because it will be easier to meet the allowable fuel consumption level. This is illustrated by figure 9-1. This incentive is important, because high fleet fuel economy levels will be difficult to meet unless the "horsepower race" is ended and unless weight reduction measures continue.

Second (and less favorable to this system's likely attractiveness to Congress), it allows a vehicle that is more powerful than another but otherwise identical to meet a lower fuel economy standard.[5] This may be difficult for a Member of Congress to

Figure 9-1 -Change in Level of Compliance With the Type of Fuel Economy Standard Proposed by Mercedes-Benz, BMW, and Porsche if Curbweight and Torque Are Reduced



The square on the graph represents an automobile with a fuel economy level about 5-percent higher thanthe average automobile of the same weight, Interior space, and torque. If the auto's designers reduce Its weight by 10 percent through design changes and material substitution, the auto will reach a fuel economy level significantly In excess of 5 percent better than the average for a vehicle with its new weight/space/iorque combination, as shown by the dotted line Lowering torque by 10 percent (represented by the solid line between the circle and cross) will allow the auto to Improve still further, to greater than lo-percent higher fuel economy than average.

SOURCE: Mercedes-Benz of North America, Inc., 1991

[5] Though, as noted, the lower standard will be technically more difficult to meet than the standard applied to the lower-power car.

explain to constituents. And third, this system cannot "guarantee" meeting a particular fleet fuel economy level because, like size-based standards, changes in vehicle characteristics (here, weight and performance particularly) will change the magnitude of the standards. Nevertheless, in our view the proposed system is worth further investigation.

DEFINING A FUEL ECONOMY TARGET

Selection of the numerical fleet fuel economy target demands consideration of the following issues:

- Whose analysis of fuel economy potential is to be believed? For that analysis, what assumptions are appropriate for a public policy analysis? And how can the results of that analysis be appropriately translated into an actual target for a fuel economy regulation?
- How should consumer preferences for vehicle size, luxury characteristics, and performance be taken into account in setting a target? In other words, to what extent is Congress willing to demand levels of fuel economy that may require changes in the makeup of the light-duty fleet that might displease consumers? (Or, to what extent is Congress willing to take measures, such as increased gasoline taxes, or vehicle taxes and rebates tied to efficiency levels, that could stimulate changes in consumer preferences?)
- What are the possibilities for new technologies, and how should the uncertainty inherent in projecting the likely success and performance of new technologies be taken into account in standard setting? Should a future fuel economy standard be "technology forcing" in nature?
- How much economic pressure on the industry is reasonable given the importance of reducing U.S. oil consumption, the financial strains on certain companies, and the importance of domestic auto production to the U.S. economy?
- What might the safety effects of new standards be, and how should these effects be taken into account in setting a standard?

SELECTING AND APPLYING AN ANALYSIS OF FUEL ECONOMY POTENTIAL

As discussed in chapter 7, OTA believes the fuel economy analyses performed by Energy & Environmental Analysis, Inc., as modified after discussions with domestic and foreign auto manufacturers, represent the most credible of the available analyses. In our view, the analyses presented by several conservation groups lack an appropriate analytical foundation and, for the 1996 to 2002 timeframe, rely too heavily on unproven technologies; and those of the automakers are skewed toward low fuel economy values by the imposition of assumptions not compatible with a strong regulatory push to higher fuel efficiency.

EEA's previous scenarios for future fuel economy represent two extremes—the "product plan" case represents a guess at a future with no additional regulatory pressures on fuel economy levels and limited economic pressures; the "max technology" case represents a relatively unrealistic scenario imposing "a heavy burden of retooling for the industry and would require unprecedented and risky changes to every product sold."[6] In reality, however, the product plan for 2001 may be considered optimistic, because it assumes an increase in oil (and gasoline) prices, whereas many analysts believe oil prices can remain flat over this timeframe—and because it assumes that post-1995 technological additions will be designed to maximize fuel economy rather than to improve performance. In other words, OTA con-

[6] Energy & Environmental Analysis, *Inc., Analysis of the Fuel Economy Boundary for 2010 and Comparison to Prototypes*, draft final report prepared for Martin Marietta Energy Systems, November 1990.

siders it quite plausible that fleet fuel economy levels could be well below the product plan level of 33 mpg in 2001-though we believe it unlikely that they might remain at today's 28-mpg level.

As discussed previously, OTA's product plan projection for 1995 is 29.2 mpg for the fleet. How much higher could fleet fuel economy be pushed? There is not a great deal of time between now and 1995 for manufacturers to make important changes to their product plans. EEA has not developed a "maximum technology" plan—a scenario that assumes much greater penetration of fuel economy technologies—for the 1995 date, because it feels significant increases in technology penetration are not realistic for this early date. However, the companies are not without some degree of flexibility in this timeframe, since they must be prepared to respond to rapid changes in consumer preferences or unforeseen consumer responses to new products. Further, the fuel economy penalty associated with new emission and safety standards will depend somewhat on market and regulatory pressures to improve fuel economy; the penalty need not be as high as estimated by EEA (nearly 3 percent) for "business as usual." Consequently, we believe Congress could realistically set a 1995 fuel economy goal for the total U.S. fleet somewhat higher than the EEA "product plan" value of 29.2 mpg. Further, companies can achieve fuel economy credits for producing alternative-fuel vehicles, so they can raise their official CAFES by over 1 mpg by producing large numbers of these vehicles.

OTA concludes Congress could realistically set a fuel economy goal for the 1995 model year of 30.0 mpg for the total fleet, to be achieved by some combination of expected increases in penetration of fuel economy technologies coupled with reductions in expected vehicle performance increases and compliance with emissions and safety standards with minimum losses in fuel economy. The companies could also produce alternative-fuel vehicles to reach the goal, though the fleet then would not physically attain the full 30 mpg. If Congress includes the potential to manufacture altfuel vehicles in setting the standard, the standard could be raised to about 31 mpg—but this would transform the alternative-fuel credit from an ***incentive*** to produce these vehicles to a virtual ***requirement.***[7]

This level of fuel economy can be obtained only if each company is required to improve its fuel economy according to the technological potential of its fleet; a uniform standard such as the current CAFE-type standard cannot achieve a total fleet fuel economy this high, since, to be politically acceptable, it will likely have to accommodate the fuel economy achievable by the major domestic companies, whose potential is lower than the above averages.[8]

For 2001, automakers have considerably more flexibility to raise their fleet fuel economy. OTA has defined a "regulation-driven" scenario for 2001 that represents an attempt to define a set of criteria for incorporating societal energy goals into vehicle design decisions. The criteria are:

1. Technologies are selected if they provide fuel savings that, with a 10-percent discount rate, will pay back extra first costs in 10 years at $2.00/gallon gasoline (high price and long payback period selected to reflect societal costs of gasoline consumption*);
2. Some allowance is made for inclusion of new technologies (not yet in the fleet) by 2001;
3. Size and performance of the 2001 fleet is rolled back to 1990 levels; and
4. Penetration rates for technologies are constrained to correspond to normal model redesign schedules, so costs are held down, sufficient time is allowed for recouping ini-

7&d violate the spirit of the alternative fuel credit legislation.

8Domestic full-line manufacture do not, however, have the lowest potential among major manufacturers. The companies with the mOSt difficult task are likely to be the European limited-line manufacturers producing luxury and performance vehicles.

*In other words, the $2.00/gal cost-effective price reflects the expected market price plus an additional cost representing national security, pollution, and other concerns associated with gasoline consumption.

tial capital costs of preceding models, and engineering-and-design manpower does not become a limiting factor.

Table 9-1 shows the technology-by-technology details of the OTA scenario for the domestic automobile fleet. The scenario is similar to the maximum technology scenario discussed in chapter 7 in that all technologies associated with that scenario are justified by the combination of $2.00/gallon gasoline and 10-year payback in the OTA scenario. However, the less severe conditions for the rate of technology penetration in the OTA scenario slows down these rates; the level of technology penetration achieved in 2001 by the max technology scenario is not achieved in the OTA scenario until 2005. The slowdown in the rate of technology penetration affects six technologies: weight reduction, drag reduction (improvement in aerodynamics), intake valve control, five-speed automatic transmissions, continuously variable transmissions, and four-valve engines. The details of this slowdown are explained in box 9-C. The net effect of the slowdown is to reduce the total percentage benefit (over 1995 fuel economy levels) in 2001 by 5.58 percent for domestic manufacturers. This yields a net fuel economy benefit (over a 1995 baseline assuming 1990 size and performance) of 17.09 percent versus 22.67 percent for the maximum technology scenario, with a resulting domestic fleet fuel economy of about 34.5 mpg (including a 0.4-mpg test adjustment) by 2001. A similar calculation for imports results in a 37.4-mpg average, with a total fleet fuel economy of 35.5 mpg.

As discussed in box 9-C, all body, engine, and transmission changes can be completed by 2005 within the normal lifecycle limits of these components. Consequently, by 2005, this scenario will resemble the 2001 maximum technology scenario except that weight and drag reduction can have higher levels of penetration than in max technology. Shifting weight reduction from 80 percent (max technology) to 100 percent (regulation-driven) and drag reduction from 80 percent to 90 percent[9] yields an additional 1.55-percent fuel economy benefit. This yields a domestic fuel

Table 9-1 –Potential Domestic Car Fuel Economy in 2001 Under Product Plan and Regulatory Pressure Scenarios (does not include test adjustments)

	Fuel Economy Benefit	Product Plan		Regulatory Pressure	
		Market Pen. 1995-01	Fuel Economy	Market Pen. 1995-01	Fuel Economy
Weight Reduction	3.3/6.6	80	2.64	60	3.96
Drag Reduction	1.15/2.3	80	0.92	60	1.38
Intake Valve Control *	6.0	40	2.40	40	2.40
Overhead Cam Engines	3.0	30	0.90	30	0.90
6-cylinder/4-valve replacing 8-cyl	8.0	4	0.32	5	0.40
4-cylinder/4-valve replacing 6-cyl	8.0	6	0.48	7	0.56
4-cylinder/4-valve replacing 4-cyl	5.0	10	0.50	28	1.40
Multipoint fuel injection (over TBI)	3.0	40	1.20	40	1.20
Front-wheel drive	10.0	5	0.50	13	1.30
5-speed automatic transmission **	2.5	20	0.50	25	0.63
Continuously variable transmission •*	3.5	15	0.52	15	0.52
Advanced engine friction reduction	2.0	100	2.00	100	2.00
Electric Power Steering	1.0	5	0.05	30	0.30
Tire improvements	0.5	100	0.50	100	0.50
Total Fuel Economy Benefit (%)			13.03*		17.09’
Unadjusted CAFE (mpg)			31.65		34.07

NOTE: Product plan scenario starts from a different 1995 base than the regulatory pressure scenario which holds performance and size constant at 1990 levels,

• Synergy of Intake valve control with 5-speed/CVT transmlsslons results In a loss of 2 percent In fuel economy
•* Over 4-speed auto transmission with lock-up

SOURCE: Office of Technology Assessment, 1991, based on analysis by Energy& Environmental Analysls, Inc.,

[9] This is limited because some 1990 cars already have extremely low aerodynamic drag coefficients.

Box 9-C–The OTA Scenario for 2001: Max Technology Without Enforced Early Retirements

OTA's "regulatory pressure" scenario for 2001 postulates that Congress Wishes to incorporate the "societal costs" of gasoline-costs not included in gasoline prices, including environmental damages and national security costs—into the selection of new fuel economy standards. The scenario values gasoline at $2.00/gallon,[1] more than its expected price, and selects technologies that offer 10-year fuel savings at least as high as the added cost of the technologies. Unlike the "maximum technology" scenario, this scenario respects the normal lifecycle requirements of automobile components, allowing automakers to recover their capital costs according to usual product development and sales schedules.

The design and product development lead time is 4 to 5 years, indicating that products for the 1996 model year are now being finalized, while products for 1995 have moved to a stage where tooling orders are being placed. Mainstream products sold at high volumes (over 150,000 units per year)will have a lifecycle of 7 to 8 years prior to redesign, so the 1996 products could last to 2004.

Products with lower sales volumes (30,000 to 100,000 units per year), including sports and luxury cars or specialized "niche-market" ears, have lifecycles of 10 years. These products include Camaro/Firebird (last redesigned in 1982), the Corvette (1984), and the Cadillac Brougham (1978) for GM; the Mustang, MarkVII, and Continental for Ford; and the Dodge Daytona for Chrysler. These models account for about 6 percent of total domestic car sales, and all are well along the product replacement cycle and would not normally be redesigned again by 2001.

Assuming none of the specialty cars (with 6 percent of sales) will be redesigned by 2001 and all high-volume lines will be redesigned between 1996 and 2004, normal turnover of model lines between 1996 and 2001 will be about:

$$0.94 \times \frac{2001-1996}{2004-1996} = 0.587$$

In other words, about 60 percent of all model lines can be redesigned with material substitution and drag reduction without altering the product lifecycle of designs introduced between 1992 and 1996.

Engine and transmission redesigns must be considered separately from body redesign. Engines and transmissions typically have lifecycles of 10 years. However, most domestic OHV engines are based on very old designs which have been improved over the years, and a lifecycle concept cannot be readily applied to estimate the fraction of these engines that will be terminated during any period. Moreover, conversion of OHC engines from two-to four-valve can be accomplished by changing the cylinder head alone. However, a 100-percent conversion to four-valve will require the introduction of smaller engines, to maintain constant performance and get maximum fuel economy benefits, but the domestic industry has no track record of large-scale introduction of several new engines to replace the existing product line (Toyota did introduce four-valve engines into their entire product line from 1987-1990). In the absence of historical benchmarks to guide an estimate, we assume a penetration of 70 percent for four-valve engines without significant disruption by 2001, based on conversion of current and future OHC two-valve engines.

Transmissions have a typical lifecycle of 10 years, and a new generation of electronically controlled four-speed automatic transmissions are being introduced over the 1989-95 period. Conversion to five-speed automatics or CVT's can occur over the 1999-2005 period without disrupting the lifecycle, suggesting that only 30 percent of automatic transmissions [(2001 - 1999)/(2005 - 1999)] can be converted to five-speed automatics or CVT's. Since large car transmissions were the first converted to four-speed designs and will be the first to receive five-speeds, and CVT's can be used on small cars only, we expect five-speed automatics to dominate the 30 percent of transmissions to be converted during the 1999-2001 period. CVT penetration by 2001 should be only about 5 percent.

[1] This value is *not* OTA's estimate of the true societal cost of gasoline. We have not attempted to estimate such a value. Also, we believe the such a value would have a large subjective component, so that individual policymakers would select different values even if they had complete knowledge of the physical and societal impacts of gasoline use. The $2.00/gallon figure is simply one value out of a wide range of possibilities.

continued on next page

30X 9-C–The OTA Scenario for 2001: Max Technology Wtihout Enforced Early Retirements-Continued

The 2001 penetration rates (beyond 1995 levels) of key fuel economy technologies will be:

● weight reduction	60 percent
• drag reduction	60 percent
• intake valve control	40 percent
● five-speed automatic	25 percent
• CVT	5 percent
● four-valve engine	40 percent

It appears that all body, engine, and transmission changes can be completed by 2005 without disrupting the normal lifecycle of these components. Consequently, by 2005 this scenario should start resembling the maximum technology scenario, because the economic assumptions of the regulatory push scenario would have matched the max technology scenario had lifecycle disruptions been allowed. In 2005, however, weight and drag reduction can reach 100 percent and 90 percent, respectively, versus the limit of 80 percent penetration of these technologies allowed in the max technology scenario because of insufficient industry design and retooling capacity. Further, addition of new technologies is more likely between 2001 and 2005, so that two-stroke engines and possibly other technologies may enter the fleet.

economy increase of 24.22 percent over 1995, or **36.55** mpg (including a 0.4-mpg test adjustment). The corresponding import fleet average would be about 38.4 mpg, for a 37.1-mpg overall fleet average assuming imports capture about one-third of U.S. sales volume.

The two-stroke engine is one of the most promising technologies for this timeframe, with some companies claiming such engines could enter the fleet by the mid-1990s. The primary benefit of the two-stroke would be more to allow high efficiency at relatively low cost than to greatly increase efficiency. However, advanced four-stroke engines with four-valves per cylinder and intake valve control will be almost as efficient as the two-stroke though at much higher cost. If the two-stroke is successful in demonstrating commercial reliability and satisfactory emissions control, it could add about another mile per gallon to the fleet average, primarily by its use in small cars that might not use intake valve control. To make a significant contribution by 2001, however, this engine would have to demonstrate its emissions capability within the next few years. Expecting a major contribution by 2005 might be more realistic.

Translating the scenario results into an effective fuel economy target demands consideration of both the structure of fuel economy regulations and the credits available to the automakers. The results represent the fuel economy obtainable by the fleet if all manufacturers use the full complement of technology derived by the analysis. However, each manufacturer would not attain the fleet fuel economy level specified by the scenario analysis —manufacturers building a range of cars smaller than the fleet average would tend to reach a higher-than-fleet-average fuel economy at this level of technology, and manufacturers with larger vehicles would attain a less-than-average fuel economy. Further, to the extent individual manufacturers build vehicles with higher or lower acceleration performance than the fleet average, their company fuel economies will tend to be lower or higher. Consequently, a standard similar in structure to the current uniform CAFE standard of 27.5 mpg and set at the fleet average mpg would not be achievable by several major automakers without radical changes in their size and performance mixes. They would have to sell a greater proportion of small or low-performance-cars than they currently do.

If Congress wished to use a uniform CAFE target that would not force widespread violations, it would have to set the target a few mpg below the scenario results. As an alternative, it could allow credit trading between companies, so that a company exceeding the standard could sell its accumulated credits to another unable to meet the standard. However, it is not clear that credit trading would be effective with a standard set at the level defined by the scenario. This level considerably exceeds the level that would be chosen according to consumer values alone. In other words, unless credits have a very high monetary value, a company would likely choose a lower fuel economy level by retaining more consumer-desirable attributes (or by avoiding the most expensive fuel economy technologies, thereby obtaining the opportunity to sell its vehicles at a significantly lower price), rather than exceeding the standard and selling credits. Box 9-D briefly discusses the nature of this decision.

If regulations take the form of a size-class or interior-volume (VAFE) standard, Congress should be able to use the results directly in defining a target, since both the regulatory structure and the analytical method seek to give each automaker an equal technological challenge. In this case, a series of size-class standards or a single VAFE standard that would reach the target fuel economy can be constructed based on the projected size-class distribution of the fleet.

If regulations take the form of a uniform percentage increase over a baseline year, as in the Bryan proposal, Congress could likely set a standard fairly close to, though somewhat below, the percentage that would yield the scenario target and still make the standard achievable by most or

Box 9-D–CAFE Fines and the Availability of Mileage Credits

The fine for failure to comply with Federal fuel economy standards currently is $50 for each mile/gallon under the standard multiplied by the number of vehicles in an automaker's fleet. The proposed Senate Energy bill raises the fine to $200 for each mile/gallon by the year 1996. Although the Priciple of harmonic. averaging of fuel economy values complicates the arithmetic, the size of the fine means *roughly* that, if a company is out of compliance, it should be willing to pay at least $200 per car to add a technology that would improve fuel economy by 1 mpg, assuming the technology does not adversely affect other vehicle attributes. If consumers value fuel economy and will pay more for a more efficient car, or if the technology affects other important vehicle attributes positively, the company might be willing to pay more than $200 for the technology; if the technology adversely affects performance or other vehicle attributes; the company might pay less.

What does this mean in real terms? A 5-percent fuel economy improvement is a large improvement, given today's advanced designs. For a 30 mpg car, 5 percent equals 1.5 mpg or $300 in avoided fines at the $200 rate, only $75 at the current rate.

The size of the avoided fine and likely low values for mileage credits (if credit trading is allowed) call into question the probability that significant credits will be available for trading. A company with the opportunity of accumulating credits also has the opportunity of using the fuel economy potential to instead boost the performance of its fleet. It is quite possible that the performance increase available by "trading off" 1.5 mpg—perhaps 1 or 2 seconds in O-to-60-mph time—might be worth more to the company than $300 in mileage credits.

To gain another perspective on the decision, it is worth examining the value of fuel economy gains in terms of gasoline savings. The example cited above, a potential 1.5-mpg savings from a 30-mpg-base vehicle, represents a gasoline savings of about 19 gallons per year based on 12,000 miles of driving. Assuming gasoline prices in the $1.10-$1.50/gallon range, this is a very low savings. It implies that a company could justifiably add fuel economy technology well past the "consumer cost-effective" point if the potential payback from selling credits is $300. Put another way, the payback from selling credits justifies adding technology that would otherwise (without credits) require a high gasoline price, perhaps $3.00/gallon or more, for a cost-effective return.

all companies. The gap between an "attainable" standard and the scenario result is caused by differences in the level of technology among companies in the baseline year (see box 9-B) and changes in company size mixes that may have occurred in the intervening years. Credit trading may reduce this gap and allow a higher standard to be set, assuming marketable credits become available (box 9-D).

Congress may also wish to account for available CAFE credits in setting new standards. In particular, manufacturers may produce alternative-fuel vehicles and gain CAFE credits equivalent, for flexfuel vehicles, to half the gasoline theoretically saved if the vehicles are fueled exclusively with the alternative fuel, or to all the gasoline saved for vehicles dedicated to alternative fuels. The credits for flexfuel vehicles are capped at 1.2 mpg for 1995 and 0.9 mpg for 2001, so Congress could add these values to the scenario results to reach an attainable (adjusted) fuel economy. Congress should note, however, that adding the potential value of these credits to the estimated value of attainable fuel economy is contrary to the letter and spirit of the legislation establishing the credits: the legislation demands that the potential to earn credits ***no?*** be used as an excuse to increase fuel economy standards. Such use would change the establishment of credits from a reward to manufacturers producing altfuel vehicles to essentially a requirement to produce those vehicles, since the standards would not be attainable without such production.

CONSUMER PREFERENCES

As shown, a significant shift in the new car fleet away from higher performance and larger vehicles and toward high fuel economy could yield very large increases in fleet fuel economy even without advances in technology.

Potential for large fuel economy gains through shifts in basic consumer-oriented attributes of the fleet poses a dilemma for policymakers. On one hand, if these changes can be accomplished by changing consumer preferences, the United States will achieve significant conservation benefits without likely long-term negative impacts on the industry-assuming domestic automakers maintain relative competitiveness.

On the other hand, if Congress tries to accomplish such changes ***through regulation,*** it risks reducing the attractiveness of new cars to consumers and possibly slowing vehicle turnover as consumers keep their old cars longer. Substantial difference between the fuel economy of new and old cars—1975 cars had fuel economies about half those of new cars—makes fleet turnover a powerful though diminishing force in increasing total fleet fuel economy. The danger of a standard high enough to require significant changes in consumer-oriented vehicle attributes is that it conceivably could ***slow*** net improvement of total fleet fuel economy. Further, making vehicles smaller does represent a potential safety problem, though one that can be mitigated by improvements in design and safety equipment (see discussion below).

Thus, if Congress wishes to set new fuel economy standards at levels likely to require large changes in vehicle performance and size characteristics, it must consider measures that would help shift consumer preferences toward high fuel economy. Obvious measures include gasoline taxes and vehicle purchase incentives ("gas sipper" rebates, "gas guzzler" taxes). This report does not evaluate the likely effectiveness and cost of such measures. However, given the relatively small difference between U.S. fleet fuel economy and those of the various European and Japanese fleets, with their much higher gasoline prices, and the limited sales success of domestic manufacturers in promoting smaller, more fuel-efficient models through favorable pricing and rebates, we believe shifting consumer preferences through economic measures will be difficult. The highest potential for success is likely to be sales shifts to higher-fuel-economy cars ***within*** market classes.

DEALING WITH NEW TECHNOLOGIES

Those analyses projecting fuel economy potential that have played a major role in the ongoing CAFE debate–analyses based either on the EEA model or on industry or industry-sponsored technology estimates—generally deal with relatively low-risk technologies that have already begun to penetrate the fleet (e.g., four-valve engines, roller cams, aerodynamic improvements, and so forth). By the year 2001 or 2002 (commonly chosen target years for the second stage of new fuel economy standards), technologies not now in the fleet, and thus ***not included in analyses now being used to inform policy choices,*** may play an important role in determining fleet fuel economy. This belief is bolstered by a simple examination, in retrospect, of what a list of "available technologies" (as defined in the EEA analysis) ***would not have*** included had it been compiled 10 or 15 years ago. In particular, the list would not have included four-valve-per-cylinder engines and electronically controlled transmissions, important components of fuel economy improvement today. It may not have included multipoint fuel injection either, a critical component of improved engines. An analysis based on existing technologies used to project fuel economy potential will likely miss key components of the actual fuel economy potential of the fleet of 10 to 15 years in the future. Further, since the EEA technology list excludes diesel technologies, a revival in market fortunes for this technology also could substantially alter the fleet's fuel economy potential.

To be evenhanded, we should note that the theoretical list could have included at least one technology-diesels —that plays almost no role in today's new car fleet. Although no technologies on the current list appear likely to be sidetracked by regulatory changes or performance problems, it is conceivable that some will not play a role, possibly because of style (advanced aerodynamics) or technical complexity (intake valve control). OTA believes the "upside" potential–the probability of additions to the list–outweighs the downside, or likelihood that current technologies will be dropped.

Potential new technology(and the possibility of a diesel revival) implies that ***estimated*** fuel economy potential for 2001 or beyond, when calculated using only available technology, may understate these values. For example, successful development of two-stroke engines could lead to their introduction into the fleet in the 1996 to 1997 timeframe. By 2001, if the first examples performed well, two-strokes could be used on several model lines. Developers of two-stroke engines claim fuel economy increases over current four-stroke engines as high as 30 percent;[10] this estimate appears optimistic. The more appropriate comparison is with advanced four-stroke engines with intake valve control that would likely be available in the same timeframe; this yields about a 3- to 4-percent improvement coupled with a substantial cost reduction. Similarly, drive-by-wire technology (i.e., the mechanical linkage of accelerator pedal and throttle is replaced by an electronic linkage with computer adjustment of throttle) could become widely available by 2001, especially for larger vehicles, yielding a speculative 2-or 3-percent "per vehicle" improvement in fuel economy. And improved turbo diesel engines, though not a new technology, could yield substantial benefits—up to 22 percent "per vehicle" —if they gained consumer acceptance now widely denied to diesels and could satisfy new emission standards.

What is the likely timing of these new technologies? Estimating the year any particular technology will be introduced into the fleet is difficult. Much of the information needed for the estimate is guarded by manufacturers and the decision to introduce depends on variable factors such as the company's competitive situation around the time of potential introduction, consumer preferences at that time, and so forth. However, certain technologies seem advanced enough to begin entering the market by or before 2001-weight reduction through extensive use of aluminum and Fiber-

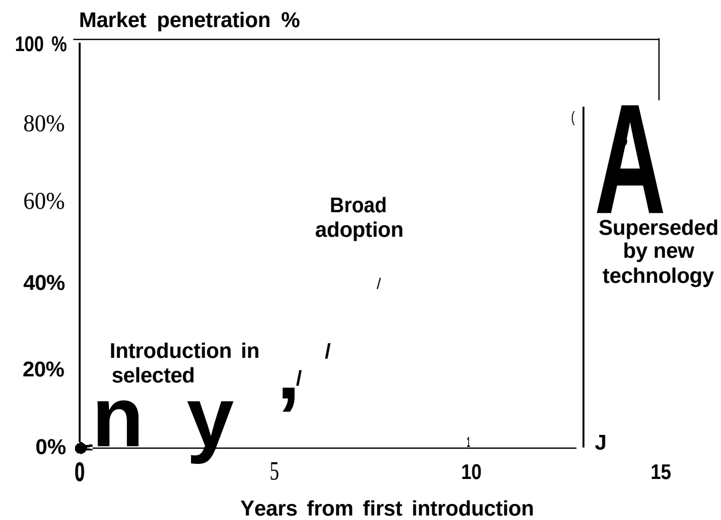
[10] The fuel economy increase is caused by a combination of improved engine efficiency, reduced engine and associated vehicle weight, and aerodynamic improvements made possible by the engine's greatly reduced size.

glas-reinforced plastics in standard parts; major reductions in aerodynamic drag, with fleet average drag coefficients dropping well below 0.3; tires with reduced rolling resistance; and a variety of engine improvements, including use of five valves per cylinder, variable compression ratio engines, two-ring pistons, and use of lightweight ceramic or composite-material reciprocating parts. As noted, there are indications that two-stroke engines may be introduced by the middle 1990s, though compliance with tighter emission standards remains a significant roadblock for this technology.

Technology introduction and ***market penetration*** are not synonymous. Prudent automakers introduce new technologies into specific market niches, perhaps a single model, and then gain experience with it over the next few years. Only when consumer reaction has been positive and no significant reliability or performance problems arise do automakers begin to move the technology broadly into their fleet. For domestic manufacturers, this will take an average of about 8 years, during which they will redesign virtually their entire product line. For the Japanese, the redesign period is shorter, perhaps as short as 4 years for some companies. However, an incentive such as a new fuel economy standard clearly could accelerate this process. Figure 9-2 illustrates a market penetration profile typical of recent experience for a domestic manufacturer. Although widespread introduction of the technology would, of course, lag behind the curve of the company introducing the technology, other automakers would likely take less time in proving out the technology in their fleets because they would have access to the experience of the first company. In other words, a curve for the fleet as a whole would begin to overtake the curve for the introducing company.

The implication of this profile is that technologies introduced by 1995 or so will achieve only modest market penetrations by 2001, but can achieve high levels of penetration within only a few years later.

Figure 9-2–Typical Market Penetration Profile of New Technology



SOURCE: Energy & Environmental Analysis, Inc., 1991,

Congress is faced with an important dilemma in crafting fuel economy standards for the longer timeframe: how to encourage development of new technologies while accounting for inherent uncertainty in their future potential? This dilemma may be eased by incorporating administrative discretion in future standards enforcement—i.e., by setting standards that assume a significant degree of success in technology development, but including an escape clause that permits enforcing agencies to lower standards if such success does not materialize. This strategy will work only if individual companies vigorously compete for technological dominance, and if they know that the technological success of one company will rule out an administrative delay in the standards.[11] Further, Congress must be able to trust the administrative agency—presumably, the Department of Transportation-to grant delays only in the face of incontrovertible evidence that standards are not achievable.

A final note to this part of our discussion:

The relative short-term inflexibility of automaker manufacturing strategies due to their need to make orders for outsourced components and

[11] It should be noted that GM and Ford successfully won a rollback in the 27.5-mpg standard even though Chrysler fought the rollback and planned on meeting the standard.

manufacturing dies and other equipment years in advance of the model year, coupled with the substantial risk involved in prematurely moving new technologies into the fleet, presents Congress with a significant dilemma in specifying fuel economy standards for the relatively near future (e.g., 1996-98). If Congress does not specify stringent standards for this timeframe, it risks a fait accompli of noncompliance by manufacturers later on with little remedy other than massive, and perhaps politically unacceptable, economic penalties. On the other hand, demanding short-term, fleetwide fuel economy increases may expose some automakers to large risks associated with moving new technologies widely into their fleets without testing the technologies for a few years in one or two models. A potential solution to this dilemma is to designate interim milestones for automakers to demonstrate a few high-fuel-economy models with requirements for minimum production runs. In other words, have automakers show they're testing new designs and technologies in a real-world situation, but don't require them to risk their whole fleet.

ECONOMIC PRESSURE ON THE INDUSTRY

New fuel economy standards pose both risks and potential economic benefits to automakers. Risks arise from the capital expenditures necessitated by the standards, possible negative reaction to vehicles meeting the standards and consequently slower purchase rates, and the potential for vehicle reliability problems and other difficulties if the standards force technological change at a rate faster than companies can comfortably accommodate.

The risks associated with increased capital spending and negative consumer reaction appear virtually inevitable unless one assumes that either an oil crisis of some sort will occur or the Federal Government will take important steps to align consumer preferences with the direction that stringent fuel economy standards will take the industry. Such a government effort —which could include a large increase in gasoline taxes, or tax breaks or rebates for buying vehicles with higher fuel economy–could serve well as market adjunct to fuel economy regulation.

Potential benefits to automakers stem from the unstable nature of the world oil market and the difficulty individual manufacturers have in adapting their vehicles in response. If another oil crisis were to send gasoline prices skyrocketing or limit fuel availability, ultra-high-efficiency vehicles clearly would become extremely attractive. Ironically, companies that unilaterally set out to produce such vehicles might, in the short term, have a difficult time competing with companies that focused instead on performance and other vehicle attributes that conflict with high fuel economy but nevertheless are attractive to today's vehicle purchasers. In other words, individual companies may find preparing themselves to deal with a possible energy crisis difficult unless they know other companies were doing the same. A fuel economy standard that requires each automaker to take similar steps to improve fuel economy could provide the type of pressure that would allow this preparation without the competitive risk such preparation would otherwise cost.

The risks of reliability and other problems associated with technology introduction can be reduced or eliminated by sufficient lead times for the standards, allowing companies to pace through the steps necessary to minimize problems with new technologies and designs. Lead times are also critical to allow industry to recover investment on existing models. The costs and risks of any policy that forces the auto industry toward very rapid redesign of all existing models—a so-called "maximum technology" standard—can be understood in the context of industry cost structure, product lifecycles, and product lead-time requirements.

The auto industry has large fixed costs that it incurs in developing and tooling up for a new model. Currently, many high-sales-volume models require spending $1 billion prior to the first car being rolled out of production. The automaker hopes to pay off this investment over the life of the model, which typically has averaged about 8 years (longer for light trucks). Thus, a large part of the "cost" of a new car is amortization of the initial investment. The automaker must guess the sales volume over the 8-year model life to calculate the required per-car payback of this investment. If the car is more successful than the automaker hoped for, the model line will be very profitable, but if it is less successful, the line will lose money. An automaker with several models will usually have winners and losers; on average, he hopes to realize an adequate return on total investment.

The $1 billion initial cost for a new model is spent over the 5-year period when the model is conceived, developed into a prototype, tested, and certified to all applicable safety and emissions standards, and while the manufacturing plant is retooled to build the new model. The 5-year lead time means that new models for 1996 are now in the detailed planning stage. The 1996 models need to remain in production until about 2004 if the automaker is to obtain the expected return on investment. For engines and transmissions, the lifecycle may be longer—some current engines date back to the early 1970s, although they have received evolutionary updates.

A maximum technology scenario requires that automakers redesign all of their products applying all available technologies on or before the target year. It is obvious that such a requirement will be meaningless for 1996, because lead time is insufficient to redesign all products much less produce them.

If the target year is 2001 or 2002, it is possible ***in principle*** to redesign all products to include maximum technology. However, this will lead to two significant burdens on automakers. First, models that will be introduced in 1994/1995 and cannot be withdrawn at this late stage will have to be phased out a few years before the end of their normal lifecycle. If a model loses 2 or 3 years of life, return on investment to the maker will be significantly reduced.

Second, instead of the U.S. industry experience of 13 years, automakers would have only 9 or 10 years to redesign all of their products, including models that have just been redesigned. This can be done if automakers accelerate the process by hiring more engineers (though there is a limited pool of experienced engineers), increase overtime, or make the design process more efficient. However, shortened lead times could result in designs that are not fully tested and would beat increased risk of market failure. The risk is less for Japanese automakers, some of whom have reduced lead time to 4 years[12] and reduced initial costs to the point that their product lifecycle can be 4 years. U.S. automakers have not been able to duplicate this.

The burden associated with an early target year for a standard based on maximum technology requirements may be aggravated by recent Clean Air Act revisions and new safety requirements, which have imposed additional design burdens on all automakers.

Selection of an appropriate target date for a maximum technology scenario involves a tradeoff of the risks and costs associated with accelerated design schedules and shorter product lifetimes and the benefits of moving the fleet more rapidly toward higher fuel economy. Given the U.S. cycle of 8-year model life and 5-year lead time, and the proximity of the 1992 model year, the 2005 model year might seem a good target date for policymakers who are somewhat risk-averse.[13] A model year 2005 target would reduce risks to U.S. automakers and avoid the costs of prematurely introducing technology across all models on an accelerated schedule. On the other hand, U.S. automakers have successfully accelerated product schedules in the past, for example during the middle 1970s and early 1980s, and could do so again, though at high costs (and perhaps at higher risk than previously, because those accelerations

[12] Probably longer for light trucks.

[13] In other words, automakers have already begun design process for 1996 or 1997 models, and these models will not undergo a major change-over until 2004 or 2005.

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were due primarily to market pressures). Also, some potential exists that U.S. automakers can achieve the shorter turnaround schedules of some Japanese makers. Depending on the value they place on the benefits of accelerating fuel economy improvements, some policymakers might prefer an earlier target date for a maximum technology scenario.

POTENTIAL EFFECT OF HIGHER FUEL ECONOMY STANDARDS ON VEHICLE SAFETY

Industry and Administration opposition to new fuel economy standards has included arguments that higher standards, such as proposed by S.279, would force consumers into a new fleet of smaller cars significantly less safe than anew fleet with an unchanged size mix-and perhaps even less safe than the current fleet.[14] In OTA's view, unless sharp fuel economy improvements are demanded over a period too short to allow vehicle redesign, or the fuel economy requirements are so stringent they can be met only with drastic downsizing, it is unlikely that ***absolute*** levels of safety would decrease. Continued introduction of safety improvements and wider use of already-introduced improvements should compensate for adverse effects of moderate downsizing. Further, if given enough time, automakers can significantly improve fleet fuel economy without downsizing (though with some weight reduction), and without any likely safety impact. Nonetheless, there is cause for concern about the relationship between fuel economy and safety, and there is a reasonable probability that further downsizing-especially a reduction in exterior dimensions—would cause the fleet to be less safe than it would otherwise be. However, we also find the debate about the relationship between fuel economy and safety has at times become overheated,[15] and assertions on both sides of the debate seeking to demonstrate the magnitude of risk are frequently flawed or misleading.

Much concern about safety and vehicle size stems from the physics of car crashes and an examination of traffic safety records over the past few decades. Although there are very safe small cars and relatively unsafe large ones, in comparing two similar-design cars of different size, the smaller, lighter car will be inherently less safe, especially in vehicle-to-vehicle collisions. Given similar materials and design, a passenger in the smaller, lighter car will experience greater deceleration forces in such a collision than a passenger in the larger, heavier car. Further, the management of deceleration forces is inherently easier in a large car as there is likely to be greater "crush space" —the volume of deformable structure available to absorb the forces generated by an accident. Also, cars made narrower and shorter without compensating for changes in center of gravity and suspension design–the center of gravity is not easy to change for sedans where passengers sit upright and adequate headroom must be maintained—are more prone to rollover, an accident type that exposes vehicle occupants to a high risk of serious injury and death, particularly if seat belts are not used.

Actual safety records generally bear out this analysis. For example, the Insurance Institute for Highway Safety reports death rates associated with several GM cars that have been downsized since 1977 rose an average of 23 percent. Some safety analysts have questioned the validity of the comparison between old and new versions of the same models, particularly because the Institute did not correct for differences in miles driven.[16] However, the Institute has shown that there have been little or no differences in death rates be-

[14] For example, see J.R. Curry, Administrator, National Highway Traffic Safety Administration, statement before the Subcommittee on Energy and Power, House Committee on Energy and Commerce, Oct. 1, 1990.

[15] The rhetoric has ranged from asserting that safety and vehicle size are essentially unrelated to suggesting that S.279 be referred to as "The Highway Fatality Act."

[16] Aside from driving more, occupants of new cars are more likely to use seat belts than are occupants of older cars. The two factors work in opposing directions in affecting fatality rates.

tween old and new versions of the same model that had ***not*** undergone downsizing-implying that downsizing did have a negative impact on occupants of the affected cars. Of course, it may be possible that accompanying weight reductions made the downsized models less dangerous to other cars on the road, but this type of effect could not be accounted for in the data.

Also, according to the National Highway Traffic Safety Administration (NHTSA), accident statistics show that smaller cars are more prone to rollover[17] and experience far more rollover fatalities than large cars. NHTSA'S recent study of car size and its relationship to fatality and injury risk in single-vehicle crashes found a significant increase in occupant fatalities and moderate-to-serious injuries caused by the general size reduction of the fleet, with up to a 50-percent increase in rollover propensity accounting for the increased fatalities.[18] The data presented in this study appear to pin more blame for the increase in rollovers on the shift from full-size cars to compacts and subcompacts, and to imports, than to downsizing ***within*** vehicle classes,[19] though the data do show some of the downsizing effects observed by the Insurance Institute.

NHTSA'S analyses indicate that small cars are less safe in situations other than rollover. They have calculated that the fleet size reduction is associated with about a 10-percent increase in fatalities and a 15-percent increase in serious injuries in single-vehicle nonrollover crashes, and that a collision between two small cars has about a 10-percent greater likelihood of resulting in serious injuries than a similar collision between two cars that are 1,000 pounds heavier[20] (as discussed later, we believe the differential safety risk is more likely due to size rather than weight differences between the two sets of vehicles). Also, NHTSA concludes that its crash-test data from the New Car Assessment Program indicate that in crashes into a barrier, "small, light vehicles expose the occupants to more danger than large, heavy cars... because crash forces are imposed on the small car occupants quickly and in a concentrated manner, while occupants of large cars experience a more gradual deceleration."[21] (Again, we believe the difference to be due primarily to size.)

NHTSA concluded that the changes in the size composition of the new car fleet between model years 1970 and 1982, which resulted in a shrinkage in median curb weight of new cars involved in fatal collisions by about 1,000 pounds, a wheelbase reduction of about 10 inches, and a track width reduction of 2 to 3 inches, "resulted in increases of nearly 2,000 fatalities and 20,000 serious injuries per year"[22] over the number that would have occurred had no downsizing occurred.

To date, the above evidence may have played a less prominent role in communicating the perceived dangers of vehicle downsizing to Congress—and certainly has played a less prominent role in communicating these perceived dangers to the public—than other, less relevant evidence about crash test results between larger and smaller cars and overall fatality rates of cars of greatly differing size and weight. In reality, the comparatively greater safety of a larger, heavier car demonstrated by this evidence is a two-edged sword, since the higher weight of that car also represents more of a danger to other cars. Conversely, while smaller, lighter cars may offer less protection to their occupants, their lower weight reduces risks

17 C.J. Kahane, "Effect of Car Size on the Frequency and Severity of Rollover Crashes," National Highway Traffic Safety Administration, May 1990.

18 U.S. Department of Transportation, National Highway Traffic Safety Administration, *Effect of Car Size on Fatality and Injury Risk in Single-Vehicle Crashes,* August 1990.

19 Ibid., p. 33, figures 1 and 2.

20 U.S. Department of Transportation, National Highway Traffic and Safety Administration, "Effect of Car Size on Fatality and Injury Risk," 1991, unpublished paper widely distributed to Congressional Committees, hereafter referred to as NHTSA Car Size Summary.

21 Ibid.

22 Ibid.

to other cars. In particular, weight per se may not add to the ***overall*** safety of the fleet, because the advantage of greater weight to a heavy vehicle, that it reduces relative crash forces, is counterbalanced by the greater crash forces it ***transmits*** to any car it collides with.[23] To state it another way, although an individual might wish to choose a heavy car to enhance his or her personal safety, society does not necessarily gain from this choice because the heavier car represents an added threat to other cars on the road.

The broadening of the debate to focus on societal risk—the question of whether or not society as a whole benefits or loses from a shift to smaller, lighter cars—is the needed focus for policymakers trying to decide whether to set new fuel economy standards at levels that might require such a shift. From this focus, evidence about factors such as increased rollover danger, single vehicle collision results, and the like are of dominant importance. Data concerning collisions between cars of greatly different size and weight are important to individual consumer decisions and, hence, are relevant and often stressed in policy arguments,[24] but are of lesser or even little importance to the broader issues of societal risk of fleet downsizing. In a fleetwide downsizing, large cars would get smaller and lighter also, and would be less dangerous to small cars; the weight differences among cars would not necessarily become greater.

Nevertheless, available data and analysis on single-vehicle crashes, on "before and after" fatality rates for downsized cars, and on differential injury and fatality rates between crashes of two small cars versus crashes of two large ones (as noted, occupants in the crash of two large cars generally fare better than those in two small cars[25]) strongly imply that, to the extent that any CAFE legislation leads to significant downsizing of the fleet (a shift to smaller size classes or designs that maintain interior volume but reduce exterior dimensions), safety will be reduced, all other things remaining equal.

This last statement is worded very carefully, with good reason. First of all, policymakers weighing new fuel economy legislation should recognize that improved fuel economy and downsizing are not synonymous, and the extent of any fuel economy/safety tradeoff depends on how much downsizing would be required. According to OTA's analysis, even a year-200l standard of 40 mpg, as proposed by S.279, could be met without significantly reducing average vehicle dimensions (both interior volume and exterior size) –though not without cost.[26] Although average vehicle ***weight*** would be reduced, it is not clear at all this will reduce overall fleet safety. By 2001, the new car fleet could achieve about 38 mpg using existing technology coupled with a reduction in performance and size to 1987 levels (the size reduction is small), and probably gain sufficient credits for the remaining 2 mpg by selling large numbers of flexfuel and dedicated alternative-fuel vehicles. On the other hand, S.279's 34 mpg/1996 standard probably is unattainable without a significant shift in sales to smaller vehicles.

Second, even if new cars ***are*** forced to be smaller than today's, the condition of "all other things

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[23] As discussed elsewhere, some studies do tie vehicle weight to overall fleet safety, but most of these studies use weight as a general measure of size, and don't try to separate out the effects of weight and other size measurements. We believe that variables such as wheelbase and track width, which are strongly "colinear" with weight (i.e., they are closely related to weight, getting larger or smaller as weight gets larger or smaller, so it is hard to separate out their effects from the effects of weight), are more important to overall fleet safety.

[24] For example, NHTSA has widely distributed a videotape of two crash tests between cars of dissimilar size that show the small cars being devastated by the crashes. The videotape states that the crash results demonstrate the danger inherent in new fuel economy standards and vehicle downsizing. However, the videotape shows only that cars are at a serious disadvantage if struck by another vehicle of much larger weight. Unless fleetwide downsizing induced by new fuel economy standards were to lead to a large increase in collisions between vehicles of greatly dissimilar weight, the dramatic crash damage shown in the videotape has little relevance to the societal danger—measured in injuries and fatalities per year– posed by the new standards. It is not at all clear that downsizing would have this effect, except possibly during a transition period. In fact, NHTSA has identified *other* types of crashes–particularly single-vehicle rollover crashes– as the most likely source of increased fatalities from further downsizing.

[25] NHTSA Car Size Summary.

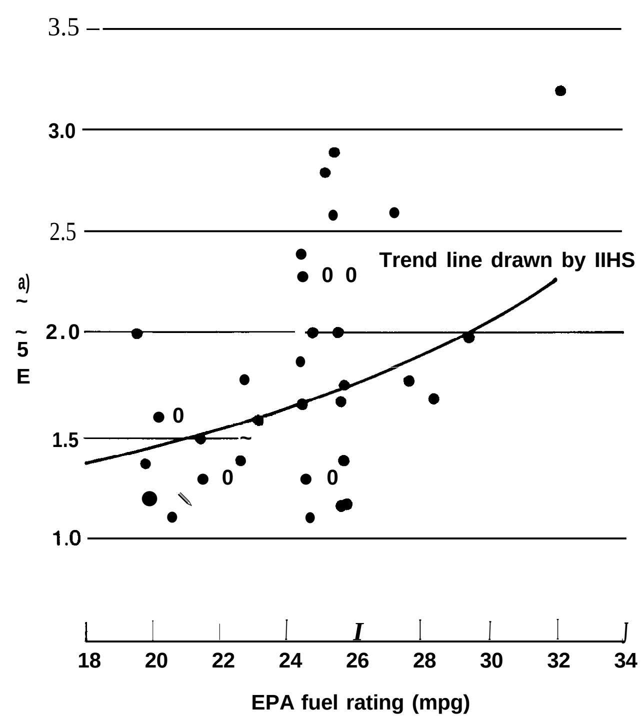
[26] Achieving such a high fuel economy target in this timeframe would require a rollback in vehicle performance to 1987 levels, early retirement of several model lines, and the use of some technologies that could not recoup their costs through fuel savings unless gasoline were $2.00/gallon.

remaining equal" is not likely to apply. A long history of analysis of accident statistics, crash testing, and research into safety systems and prototype safety vehicles demonstrates that vehicle design is extremely important in vehicle crashworthiness and crash avoidance. A great deal of safety equipment has already been added to today's vehicles, and their basic structural designs reflect considerable experience with crash analysis. Considerable "headroom" for further safety improvements still exists, however. In fact, data demonstrate that redesign efforts aimed simply at improving the least safe cars in the current fleet to the level of the most safe could have substantial positive impact on overall fleet safety.

An examination of different models of the same size or fuel economy shows large differences in death rates. As shown by the plot in figure 9-3, which is used by the IIHS to illustrate that better fuel economy can be detrimental to safety, a consumer can pick many cars in the 25- to 26-mpg range that are safer than many in the 20- to 21-mpg range. In fact, although the trend line in figure 9-3, as drawn, implies a direct correspondence between vehicle fuel economy (and size) and safety, the data are so scattered that a substantially different line could be drawn by dropping a few outlying points. The data more clearly illustrate the importance of factors ***other than fuel economy and size*** in determining vehicle safety.[27]

It seems clear that, were significant downsizing of the fleet to occur, a good portion, and perhaps all, of any resulting loss in safety could be balanced by improvements in safety design. However, to the extent the improved designs would work equally well with larger vehicles and provide still greater safety to them, there will have been some safety opportunity ***forgone—i.e.,*** if the improvements were made ***without*** downsizing, the safety of the fleet would be better still.

Figure 9-3–Relationship Between Deaths Per 10,000 Registered Cars and Fuel Economy, 1985-87 Four-Door Models



SOURCE: Insurance Institute for Highway Safety, 1990

Even when safety improvements work equally well on small and large cars, improving the relative safety of all cars will shrink the ***absolute*** safety gap between large and small cars (measured in deaths per 100 million miles traveled or per million vehicles). But not all safety improvements work equally well on all car sizes. Safety improvements that focus particularly on problems that afflict small cars more—e.g., rollover—would tend to shrink the absolute ***and relative*** safety gaps between large and small cars. As an example: wider use of anti-lock brakes will provide greater directional stability in emergency braking. Since loss of directional control is often a precursor to rollover, wider use may also provide a greater absolute benefit to lighter cars. Further,

[27] A statistical analysis of the IIHS model demonstrates that the significance of the fuel economy/safety relationship described in the model is low; that the shape of the curve is dominated by a few outlying data points–inexcusable in an analysis that attempts to distinguish immutable truths in a field where simple design flaws ean cause high death and injury rates well out of proportion to what otherwise could be expected from vehicle size characteristics; and that the model ignores variables clearly shown to play a major role in traffic fatality rates. J.D. Khazzoom, supplemental material to testimony before the Consumer Subcommittee, U.S. Senate Committee on Commerce, Science and Transportation, Apr. 10, 1991.

current safety performance standards—as opposed to requirements for specific equipment additions—demand the same performance (e.g., passenger survival in a 30-mph frontal crash) from all cars regardless of size. Compliance with these standards should further shrink the safety gap. ***To the extent that such differential improvements occur, shifting to a smaller fleet will be less damaging to safety than a simple extrapolation from past trends would project.***

As a corollary to this point, in the past, identification and examination of safety problems often yielded relatively simple solutions that could be applied to the next generation of car designs, or even retrofitted to current model lines. Acceptance of the statistical results of studies examining past behavior of vehicles does not imply that this behavior is unchangeable. The letter accompanying the NHTSA study states, "The increase in rollover rates could be expected because of the physical characteristics of smaller cars. It's a simple law of physics. The reduced weight and shorter wheelbase leaves smaller cars more difficult to keep on the road in emergency maneuvers. And once off the road, they are more likely to rollover, which in turn increases the risk of fatal injury."[28] This is not sound physics. There is certainly no immutable law of physics that makes small, light cars inherently more difficult than large, heavy cars to keep on the road in emergency maneuvers.[29] Although we are not aware of any studies that compare the handling characteristics of cars in different size and weight classes, many cars rated highly in emergency maneuvering by test organizations such as Consumer Reports are small, light sedans. And to the extent that added rollover risk in small cars is associated with their narrower wheel track, during 1970-1982 the median track width of the U.S. auto fleet narrowed by only two to three inches;[30] reversing this shift should reduce rollover rate but not create an impossible tradeoff with fuel economy.[31] We expect that identification of vehicle rollover as a serious problem in smaller cars (and likely future NHTSA rulemaking on rollover) will lead to compensatory measures—improved suspensions, possibly some increase in track width, measures to reduce passenger ejection—that will alleviate the rollover risk difference between small and large cars measured by NHTSA.

We note that NHTSA has rated rollover as its number one vehicle safety issue and has done extensive analysis of the rollover phenomenon, but claims it has been unable, as yet, to define a clear "fix" for the problem[32] . . . implying that OTA's confidence in a timely solution may be misplaced. In its summary report, NHTSA bolsters this position by stating that its analysis methods do not identify which individual vehicle size parameter (track width, curb weight, wheelbase, etc.) is the principal "cause" of the added rollover proneness of small cars. We agree, in general, that it is difficult to draw precise conclusions from statistical analyses when several variables are related to each other, as is the case here. However, analysis results appear to point quite strongly to track width as the primary characteristic affecting rollover,[33] and thus suggest widening track width as having clear potential to reduce rollover risk.

It is clear that the mechanisms of problem identification and solution and continual design changes have been at work in the recent past. During the period CAFE standards have been in effect, when the weight of the average automobile dropped by about 1,000 pounds and exterior di-

[28]U.S. Department of Transportation, National Highway Traffic Safety Administration, "Vehicle Downsizing Hurts Auto Safety, Skinner Says," press release of Sept. 14, 1990, quoting NHTSA Administrator J.R. Curry.

[29]Large, heavy cars may have more directional stability than small, light cars, but tend to be less nimble. The relative tradeoff between 'he in the wide range of situations where vehicles are at risk of leaving the road is unclear. Further, improved tires and more widespread use of anti-lock brakes, which will improve directional stability during braking for *all* cars, may lessen small cars' disadvantage in directional stability.

[30]NHTSA Car Size Summary.

[31]The tradeoff exists because widening a car's wheel track will somewhat increase its aerodynamic drag and weight, reducing its fuel economy.

[32]D.C. Bischoff, Associate Administrator for Plans and Policy, NHTSA, letter to S.E. Plotkin, OTA, June 14, 1991.

[33]C.J. Kahane, U.S. Department of Transportation, National Highway Traffic Safety Administration, *An Evaluation of Door Locks and Roof Crush Resistance of Passenger Cars-Federal Motor Vehicle Safety Standards 206 and 216,* DOT HS 807489, November 1989.

mensions shrank as well, and when the supposed adverse safety impacts were felt, the safety record of the U.S. fleet improved substantially—between 1975 and 1989, death rates for passenger cars declined from 2.43 per 1O,000 registered cars (2.5 per 100 million miles)to 1.75 per 10,000 registered cars (1.7 per 100 million miles).[34] In other words, ***at worst*** the fleet changes somewhat reduced the fleet's overall improvement in safety during this period. Not surprisingly, this outcome is interpreted in radically different ways: by proponents of more stringent standards, as indicating that better fuel economy was achieved without compromising safety, in fact with substantially improved safety; by opponents, as indicating that nearly 2,000 lives per year that could ***have been saved*** were not, because of forced downsizing of the fleet.[35]

Similarly, this past record is being used to predict and interpret, from different viewpoints, the likely outcome of future standards: in support (of new fuel economy standards), that increases to CAFE standards, even if accompanied by significant downsizing, would not necessarily be accompanied by a net reduction in vehicle safety and thus do not represent a compromise of safety; and in opposition, that some portion of expected improvements in safety will be nullified (and possibly, that overall safety will actually decline, though we consider this doubtful except in extreme circumstances) by further downsizing if new standards are legislated. Both viewpoints are, at least in part, correct. The first focuses on multiple goals (better fuel economy and improved safety) and implicitly accepts the possibility of balancing one against the other; the other focuses on safety as the primary goal, not to be traded off against fuel economy.

Third, to our knowledge, no statistical analysis has examined the effect of overall weight and size ***distribution*** on safety. Yet in multiple car accidents, a major factor in overall fleet safety appears to be wide differences in weight among vehicles on the road, with collisions between vehicles of grossly unequal weight resulting in extreme danger to the occupants of the lighter (and generally smaller) vehicle. If the entire fleet were to be reduced in weight, the weight ***distribution*** of the fleet need not become wider, and it might become narrower–except, perhaps, during a transition phase when old (heavy, large) cars and new (light, small) cars share the road. In fact, general weight reduction of the fleet over the past decade and a half has been characterized by a tendency for the fleet to become more uniform in weight, with fewer vehicles at the extremes-during 1978 to 1987, for example, cars in the 2,500 to 3,000-pound weight category, in the middle of the market, soared in market share from 19.6 percent to 58.7 percent.[36] We note, however, that the continued presence of trucks sharing the roadway with autos, and the greater popularity of light trucks, will act against this effect.

Fourth, the magnitude of the effect on injuries and fatalities estimated by NHTSA for 1970 to 1982 cars may be a poor predictor of—and, we believe, would likely overstate—the potential effect of future downsizing of similar magnitude, ***even if contrary to our expectations, the extended use of airbags and other safety technologies fails to narrow the safety gap between large and small vehicles.*** This is because, except for rollover accidents, the NHTSA analysis lumps together data from the earliest years of downsizing and shifts in size mix-when safety implications of downsizing may not have been fully understood by vehicle designers and when designs of some small import cars had not yet incorporated modern concepts of crash protection—with data from later years when vehicle designs began to incorporate improved understanding of crash protection (gained in large part through NHTSA testing). We are not aware of NHTSA analyses examining ***trends*** in the effect of downsizing on fatality and

[34] National Highway Traffic Safety Administration, ***Fatal Accident Reporting System 1989,*** draft, table 1-2B. For ***all*** motor vehicles, death rates declined from 3.23 per 10,000 vehicles (3.4 per 100 million miles) to 2.38 per 10,000 vehicles (2.2 per 100 million vehicles), table 1-1.

[35] NHTSA Car Size Summary.

[36] From data in R.M. Heavenrich, et al., "Light Duty Automotive Fuel Economy and Technology 'Rends Through 1987," U.S. Environmental Protection Agency, 1987, compiled and analyzed by J.D. Khazzoom.

injury rates (again, except for rollover accidents), but we hypothesize that the magnitude of the effect likely became smaller over the 1970-82 period. In other words, we expect redesign and downsizing of an older model or a shift downward across size classes during the end of the time period would have had substantially less impact on fatality and accident rates than a similar shift at the beginning.

As an interesting footnote to this point, NHTSA has examined changes over time and across weight classes of its crash-test results,[37] but has not evaluated how differences among weight classes have changed with time. This type of analysis would be necessary to detect unequal improvement of crash safety across weight classes, the effect we suspect should have happened during the 1970 to 1982 model years, and perhaps later as well. However, the paper describing the NHTSA analysis does comment that, "from closer examination of the individual data. . . many of the poorer performing small cars were tested in the early years of the NCAP (Federal crash testing program) and . . . attrition is gradually eliminating these vehicles."[38] In other words, for the smaller cars, the combined data for all years during which downsizing occurred does not reflect rapid learning and vehicle improvement during the overall time period.

Fifth, the point of view that focuses on safety forgone implicitly assumes future safety measures will be taken essentially independent of circumstance—i.e., whether or not further downsizing were to occur. Thus, if the fleet downsizes, it loses safety from the downsizing but gains from other measures ranging from the implementation of side-impact standards to increased sales of anti-lock brakes. If the fleet does not downsize, it will gain the safety benefits of maintaining its current *size* mix *and* retain all the safety benefits that would have accrued with downsizing. This ignores the reality that consumers respond to their perceptions of highway safety and adjust buying habits accordingly, automakers similarly adjust designs to consumer demands, and governments adjust regulatory behavior to perceived public dangers as well as voter concerns. In other words, if new fuel economy standards lead to downsizing and the potential for a reduction in safety, future consumer, government, and automaker behavior will likely act to compensate.

We note that NHTSA'S rating of rollover as their primary focus of regulatory attention is an excellent example of a response to the effects of a shifting market, in this case, increasing sales of light trucks and small cars. If this focus leads to rulemaking that improves auto safety, it will be disingenuous to claim that the fleet *could have been safer* had the market never shifted in a way that led to the rulemaking in the first place.

Another example of this process is occurring today, this time based on public reaction. Although in the recent past many Americans did not rate safety very high as an attribute they demanded in a new car, this attitude clearly has begun to change. Consumer surveys report new interest in safety[39] and automakers have responded with increased advertising emphasis on safety features and plans to add more. Automakers clearly are adjusting their plans to move airbags and anti-lock braking systems into lower-price models as inclusion of these systems provides a major marketing advantage. It seems reasonable to project that any new safety concerns associated with new fuel economy standards will accentuate this process.

We have a number of additional comments about the safety/size issue. First, although weight may be a factor in determining relative decelera-

[37] J.R. Hackney, W.T. Hollowell, and D.S. Cohen, "Analysis of Frontal Crash Safety Performance of Passenger Cars, Light Trucks and Vans and an Outline of Future Research Requirements," National Highway Traffic Safety Administration, International Technical Conference on Experimental Safety Vehicles, 1989.

[38] Ibid., p. 6.

[39] For example, an Insurance Institute for Highway Safety survey of new cardealers in the Washington, DC area found that dealers report quality and safety as the top considerations of their customers, and a national survey conducted by the Roper Organization in June 1990 for the Insurance Research Council found that occupant protection has emerged as a leading factor in deciding which car to buy. B. O'Neill, President, IIHS, personal communication, June 10, 1991.

tion forces on passengers in vehicle-to-vehicle crashes, weight reduction by substituting lighter-weight but equally strong materials need not affect safety in other crashes (single-vehicle collisions), and may conceivably yield a net safety gain if substitute materials have strength and flexibility characteristics superior to original materials.[40] In other words, it may not be correct to assume that weight reduction per se will compromise safety. In fact, in its testimony to Congress, IIHS has carefully refrained from identifying weight as the vehicle characteristic of primary significance to safety, instead focusing on exterior dimensions—length and width. Given the importance of adequate crush space and the role of vehicle track width in rollover propensity, this makes sense.

A number of studies have tied average vehicle weight to overall fleet safety. However, vehicle weight is closely correlated with vehicle size variables such as wheelbase and track width, so it is difficult to separate out individual effects of size and weight on fleet safety. Unfortunately, many of the statistical studies identifying weight as a critical fleet safety factor do not consider size variables,[41] and thus cannot conclude that weight is the key factor in the fleet safety equation.

Second, although we are basically optimistic that changes in design can compensate for considerable downsizing, we must also note that some safety equipment adds weight to vehicles or takes up interior space; and those setting CAFE standards must recognize that future government requirements for equipment such as anti-lock brakes, side-impact protection, padding to reduce head injuries, and air-bags will somewhat reduce the potential for efficiency improvements. However, some of the immediate negative impacts of new standards, such as increased weight, may be reduced or eliminated over time as manufacturers innovate or adopt superior designs of competitors. An interesting case-in-point: manufacturers fought bumper standards designed to guard against property damage in low-speed collisions, primarily on the grounds of added weight and expense, and eventually managed to get standards rolled back. Recent tests of numerous vehicles in low-speed collisions show that the vehicle offering the best protection, the Honda Accord, also has one of the lightest bumpers[42]—the Accord's bumper design achieves maximum protection with minimum weight gain. If Honda's competitors adopted its bumper design, the fleet could achieve significantly more damageability protection at minimal weight increase, and in some cases, at a weight reduction.

Third, although traffic accidents kill about 45,000 Americans, injure an additional 4 million, and cost society about $70 billion (in 1986 dollars) each year, research to improve automobile safety is funded at a low level in comparison to other life-threatening problems. As discussed in a recent Transportation Research Board report,[43] Federal funding for safety research has been cut by 40 percent since 1981 despite growing problems of an older driving population, use of larger trucks, and an increasingly inadequate highway system. Currently, annual Federal funding is only about $35 million. Given the recent history of the Federal safety research effort and reports that significant opportunities still exist for improving vehicle safety," any arguments that more strin-

[40] Also, as noted, weight's *protectiveness* for passengers of the heavier vehicle in a crash translates into added danger to Passengers of the other vehicle. The net effect of weight on overall safety may be neutral.

[41] A key analysis by Crandall and Graham (R.W. Crandall, and J.D. Graham, "The Effect of Fuel Economy Standards on Automobile Safety," *Journal of Law and Economics*, April 1989), does not examine the size variables. Also, according to an analysis of the Crandall-Graham models by J.D. Khazzoom (who is currently expanding this work under contract to the Congressional Research Service), the models use average weight only and take no account of the distribution of weight changes in the fleet. In fact, most analysts believe that narrowing the weight distribution of the fleet (i.e., reducing weight differences among the various models) will improve fleet safety, and previous changes in average weight were accompanied by large changes in weight distribution.

[42] Insurance Institute for Highway Safety, *Status Report; Special Issue: Annual Low-Speed Crash Tests,* vol. *26 No. 2,* Feb. 16, 1991.

[43] Transportation *Research* Board, *Safety Research for a Changing Highway Environment,* Special Report 229, Washington, DC.

[44] Ibid.

gent fuel economy standards will lead to vehicle downsizing and more crash-related deaths and injuries should be reexamined in the light of the existing potential to counteract some of this negative impact with continued improvements, facilitated with added research funding, in vehicle crash avoidance capabilities, occupant protection, highway safety design and operation, and other safety factors.

Fourth, some of the oft-used arguments about the relationship of CAFE, fuel economy, and vehicle safety are internally inconsistent. Many organizations and individuals claiming that CAFE standards have been ineffective in gaining large fuel economy benefits (i.e., most increases in fuel economy, thus, most physical changes in the fleet, are said to have been associated with rising oil prices not regulations) also have been claiming that CAFE standards have adverse safety impacts because they have forced downsizing. These claims clearly are contradictory, since CAFE standards causing little fuel economy benefit would have caused little downsizing. Indeed, most downsizing over the past decade and a half occurred in the first half of the period, when oil prices were both rising and uncertain and CAFE standards arguably may ***not*** have been the primary cause of fuel economy improvements. During the latter half of the period (1980-88), when oil prices were falling and the only clear motivator for increased fuel economy was the standards, little downsizing occurred-new car fleet fuel economy improved 20 percent while fleet average vehicle weight remained essentially constant.

Fifth, although NHTSA has claimed in testimony to Congress[45] that their NCAP crash tests show that smaller cars fare less well than larger cars in barrier collisions, NHTSA'S own examination of the crash-test data, weighted ***to account for difference in vehicle sales,*** shows virtually ***no*** differences in occupant danger across weight classes.[46] This effect occurs both because poorer-performing vehicles have lower sales volumes and because many of the poorer-performing small cars are earlier models gradually being eliminated from the fleet.[47] In OTA's view, one credible interpretation of this effect is that small cars are less forgiving of poor design, but there is little difference in barrier-crash protection among ***well-designed*** small and large cars.

We conclude that potential safety effects of fuel economy regulation will most likely be a concern if sharp increases in CAFE are required over a period too short to allow substantial vehicle redesign–forcing manufacturers to try to sell a higher percentage of small cars of current design. In our view, significant improvements in CAFE should be possible over the longer term—by 2001, for example—without compromising safety. Over this time period, there are opportunities to improve CAFE without downsizing, and there also are opportunities to redesign smaller cars to avoid some safety problems currently associated with them. However, ***the potential*** for safety problems will still exist if automakers emphasize downsizing over technological options for achieving higher fuel economy and if they do not focus on solving problems such as the apparent increased rollover propensity of small cars of current design.

As a final point, we note that any safety concerns associated with new CAFE regulations will be relevant ***to any*** incentives to improve fuel economy, including gasoline taxes, gas guzzler or sipper taxes and rebates, and even simply higher oil prices, though compared to regulations, economic incentives allow automakers more latitude to make clearer tradeoffs based on consumer concerns. Consequently, if the United States desires to save gasoline through improved fuel efficiency, it needs to face the safety issue regardless of the energy conservation policy chosen.

[45] NHTSA Car Size Summary.

[46] Hackney et al., 1989, Op. cit., P. 5.

[47] Ibid.

FUEL SAVINGS OF S. 279

The magnitude of fuel savings likely from a new fuel economy standard is both a critical component of the decision calculus for the policy debate about standards and a source of great controversy because of large differences in estimates prepared by opposing interests. The source of these differences is the set of assumptions associated with each estimate. Critical assumptions affecting the magnitude of estimated savings include:

1. ***Fuel economy values without new standards.*** Alternative assumptions about the fuel economy of the new car fleet ***in the absence of new standards*** will play a critical role in estimating fuel savings associated with new standards. Factors affecting future fleet fuel economy include future oil prices and price expectations, fuel availability, consumer preferences for vehicle size and power, new safety and emissions standards, and progress in technology development. The span of credible assumptions about future fuel economy is likely to be quite wide, especially for the late 1990s and beyond.

2. ***Use of alternative fuel credits.*** Manufacturers can claim up to 1.2 mpg in CAFE credits by producing vehicles capable of using alternative fuels. In other words, using such credits, automakers can satisfy fuel economy standards while attaining about 1 mpg less in ***actual*** fuel economy. Assuming that automakers ***would*** make full use of credits if stringent new standards were passed—highly likely, in OTA's view-the validity of reducing the estimated fuel savings by the fuel "lost" because of the lower actual fleet fuel economy hinges on the likelihood of the credits being captured ***in the absence of*** the new standards. If alternative fueled vehicles would have been produced by the automakers solely because of the Clean Air Act requirements, with or without new fuel economy standards, then it is correct to subtract the "lost" fuel. If, on the other hand, it is the new fuel economy standards themselves that would provide the primary incentive for the vehicle production, then the standards should be given credit for any fuel savings associated with the alternative fuel use. It is worth noting that a high baseline value for fleet fuel economy implies that the credits will be worthless to the automakers, since they should all be well above the existing 27.5 mpg standard.

3. ***Magnitude of a "rebound" in driving.*** Because the magnitude of driving is at least partly a function of driving costs, an increase in fuel economy, by reducing "per mile" costs, may stimulate more driving and thus reduce the savings associated with the increased fuel economy. The magnitude of a "rebound" effect is controversial because it is estimated using historical driving trends that were influenced by a variety of factors aside from fuel costs, and many of these factors have changed over time. We would guess that a reasonable estimate for a likely rebound would be about 10 percent—in other words, for each 10 percent decrease in fuel consumed per mile, the vehicle is driven 1 percent more, and 10 percent of the expected fuel savings from higher fuel economy is lost to increased driving.

4. ***Magnitude of vmt growth.*** Over the period during which new fuel economy standards will take effect, small differences in the growth rate of vehicle miles traveled (vmt) can make a significant difference in the fuel savings estimated to occur from a new standard. As discussed in Chapter 4, actual vmt growth rates over the past few decades have been much higher than the future growth rates projected by the Energy Information Administration and others, and the credible range of future rates is fairly broad, perhaps from 1 to 3 percent per year. Even with no rebound effect (a large rebound would tend to exaggerate the effect of differences in the underlying vmt growth rate), the range in vmt growth rates can yield very large differences in calculated fuel savings. For example, in the year 2010 the estimated fuel savings from achieving the S. 279 standards

vary by 1.3 mmbd as the assumed vmt growth rate changes from 1 to 3 percent.[48]

5. ***Effects of new standards on vehicle sales.*** Some opponents of new fuel economy standards have argued that stringent standards will have the effect of slowing vehicle sales (because of higher vehicle prices and reduced customer satisfaction with smaller, slower, less luxurious cars), reducing vehicle turnover and the positive effect this has on fleet fuel economy. Others consider the likelihood of a sales slowdown large enough to affect fleet fuel economy in a significant manner to be very small. Clearly, an effect on turnover is theoretically possible, and would be likely if policymakers were to miscalculate and set a standard beyond automakers' technical capabilities.

There have been a number of different estimates of the effects of S.279, Senator Bryan's fuel economy legislative proposal. The Findings of the proposed bill state that attainment of the 20 percent (1996)/40 percent (2001) improvements in fuel economy levels will save 2.5 mmbd by 2005.[49] In contrast, the Department of Energy has estimated the fuel savings of S.279 to be about 0.5 mmbd in 2001 and about 1 mmbd by 2010.[50] Finally, the Congressional Budget Office (CBO) has estimated the fuel savings under three scenarios, with the base-case scenario having savings of 0.88 mmbd by 2006 and 1.21 mmbd by 2010[51] CBO'S full range of estimates is 0.45 to 1.42 mmbd by 2006 and 0.59 to 1.82 mmbd by 2010.[52]

The differences among the above estimates can be readily understood by examining their assumptions. For example, ACEEE'S calculations for Senator Bryan assume that fuel economy levels will remain unchanged from today's in the absence of new standards, i.e., about 28.5 mpg for cars and about 21 mpg for light trucks. The Department of Energy has assumed that, without new standards, new vehicle fleet fuel economy will rise to about 33 mpg for cars and 24 mpg for light trucks by 2001, and remain at that level thereafter.[53] This difference in baseline mpg assumptions is the most important factor in accounting for the difference between the DOE and ACEEE estimates. The DOE assumption is in line with EEA's "product plan" estimates for 2001 with higher oil prices and optimistic assumptions about the performance of fuel economy technologies. In fact, DOE's baseline oil prices are $29/barrel (1990$) in 2000 and $39/barrel in 2010–relatively high values. ACEEE'S assumptions of "frozen" new car fuel economy assume continued low oil prices and a continuation of consumer preferences for more horsepower, larger vehicles, and more luxury options. They clearly are technologically pessimistic, and we believe that new car fleet fuel economy is unlikely to stay this low. CBO has chosen baseline mpg values of 30 mpg (range 28.5 to 33.0 mpg) for 2001, which appears more realistic as a midline estimate, though we believe even this value to be somewhat pessimistic.

For other factors, DOE has consistently chosen assumptions that would tend to yield lower estimated fuel savings than ACEEE. For example, DOE assumes that the automakers will capture alternative fuel credits with or without new fuel economy standards, and thus register an offi-

[48] Assuming that the baseline (no new standards) case has an unchanging new car fleet fuel economy of 28 mpg, using a simplified model with 15 year vintaging (i.e., cars older than 15 years are retired, all other vintages assumed to drive the same amount)

[49] S.279, reported Apr. 25, 1991, sec. 2 (Findings). This value was derived by J. DeCicco of ACEEE (J. DeCicco, Technical Memorandum of Mar. 19, 1991, "Sensitivity Analysis of Oil Savings Projected for New CAFE Standards," American Council for an Energy-Efficient Economy, Washington, DC).

[50] Letter of June 5, 1991, A.E. Haspel, Director, Office of Economic Analysis, DOE, to R. Friedman, Office of Technology Assessment, Attachment: Summary of DOE Bryan CAFE bill analysis.

[51] R. D. Farmer, Natural Resources and Commerce Division, Congressional Budget Office, Staff Memorandum, "Fuel Savings from ~fernative Proposed Standards for Corporate Average Fuel Economy," June 1991.

[52] Ibid.

[53] There has been confusion about DOE's baseline assumptions, and some analysts have concluded that DOE assumed that fleet fuel economy would continue to grow after 2001 in the absence of standards. The assumption of constant new car fleet fuel economy after 2001 was confirmed by Barry McNutt, DOE Office of Policy and Planning, personal communication, Aug. 16, 1991.

cial fuel economy value about 1 mpg less than ***actual*** fuel economy. The ACEEE does not consider credits in its calculation, apparently assuming that automakers are unlikely to build many vehicles without the incentive of new standards. With the new California and Clean Air Act requirements for alternative fuels, the DOE position may be more realistic.

Similarly, DOE assumes a 20 percent rebound from lower fuel costs, whereas ACEEE ignores any potential for a driving rebound. In OTA's view, it seems realistic to assume that a rebound will occur, though we are skeptical that the effect will be as large as DOE assumes. As noted, we would choose 10 percent as a better estimate of the probable effect.

Finally, DOE has assumed a lower vmt growth rate than ACEEE, resulting in an estimated year 2010 vmt that is about 20 percent lower than that estimated by Senator Bryan.[54] This accounts for about 10 percent of the difference between the two estimates.[55]

OTA concludes that the DOE baseline estimate of 1 mmbd fuel savings from S.279 by 2010 is analytically correct but very conservative. Although none of its assumptions are extreme, virtually ***all*** push the final result towards a low value.[56] In our view, the likelihood of such uniformity is small, although much less improbable if oil prices follow their assumed (upwards) path. For example, most analysts believe that future fuel economy levels will be very sensitive to oil prices (and price expectations). The auto fuel economy levels assumed in the Energy Information Administration's Annual Energy Outlook 1991[57] exhibit this sensitivity-the assumed year 2000 new car fuel economy is 34.7 mpg with oil prices at $31.10/bbl (1990$) that year, and 31.4 mpg with oil prices at $20.10/bbl.

In contrast to the DOE estimate, the Bryan/ACEEE estimate of 2.5 mmbd by 2005 appears very optimistic because it discounts the potential for a driving "rebound" and, more importantly, accepts unusually pessimistic assumptions about likely fuel economy improvements in the absence of new standards.

Although the range of potential fuel savings from S. 279 is wide, OTA believes that the "most likely" value for year 2010 savings lies between 1.5 mmbd and 2 mmbd. For a 10 percent rebound effect, 2 percent/year vmt growth rate, baseline fuel economy of 32.9 mpg in 2001 (frozen for the next decade), and no accounting for alternative fuel vehicles, we calculate the fuel savings to be 1.64 mmbd in 2010.[58] Although the 32.9 mpg baseline (no new standards) value is optimistic unless oil prices rise substantially, it is also likely that the automakers will gain some alternative fuel credits in the baseline; these two factors will tend to cancel one another. Figure 9-4 displays the projected U.S. oil consumption over time for the baseline and S.279 cases discussed above. The figure also displays the consumption projected under OTA's "regulatory pressure" scenario for new car fuel economy.

[54] Letter of June 5, 1991, A.E. Haspel, Director, Office of Economic Analysis, DOE, op. cit.

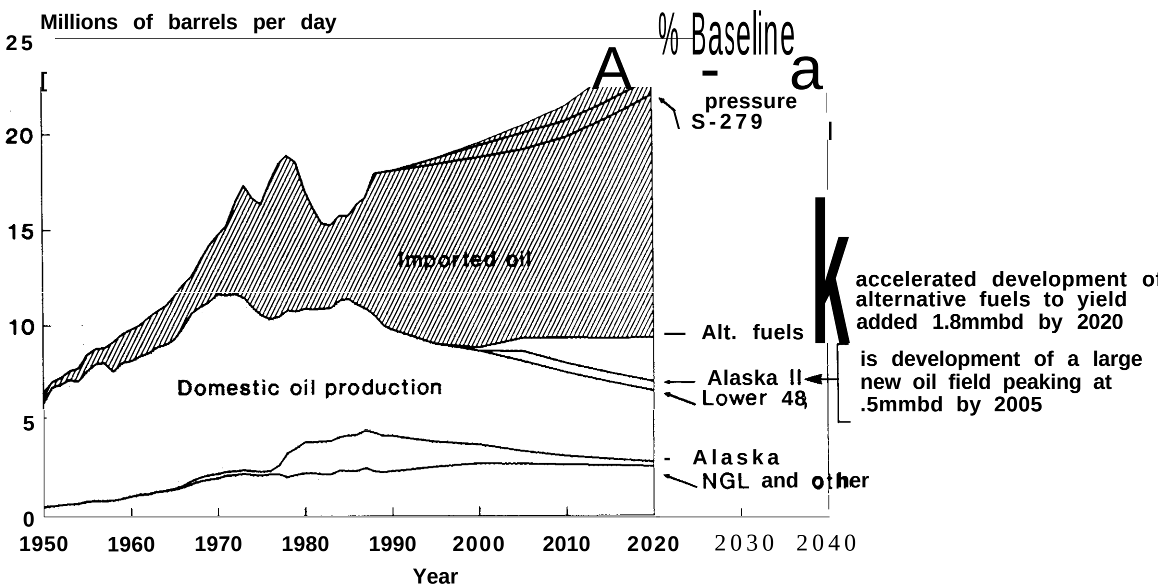
[55] Ibid.

[56] This may not be true for later years. The DOE assumption that post 2001 fleet fuel economy levels will not continue to improve may be overly pessimistic. Any DOE estimates of savings in years past 2010 may shift from conservative to optimistic because of this flat baseline fuel economy assumption.

[57] Energy Information Administration, *Annual Energy Outlook 1991*, DOE/EIA-0383(91), March 1991.

[58] Other assumptions: 15 year vintaging, fuel economy assumed to keep rising after 2001 (in regulated case) to 50 mPg by 2020.

Figure 9-4-U.S. Oil ConsumptionUnder Ahlternate Scenarios–with or Without Higher Fuel Economy Standards



ASSUMPTIONS:

1, Baseline assumes no new pollcy measures, new car fuel economy reaches 32.9 mpg In 2001 and stays constant thereafter.
2. S 279 assumes new car fuel economy reaches 40 mpg by 2001 and 50 mpg by 2020
3. Regulatory pressure assumes new car fuel economy reaches 35 mpg by 2001 and 45 mpg by 2020.

SOURCE: Office of Technology Assessment, t991