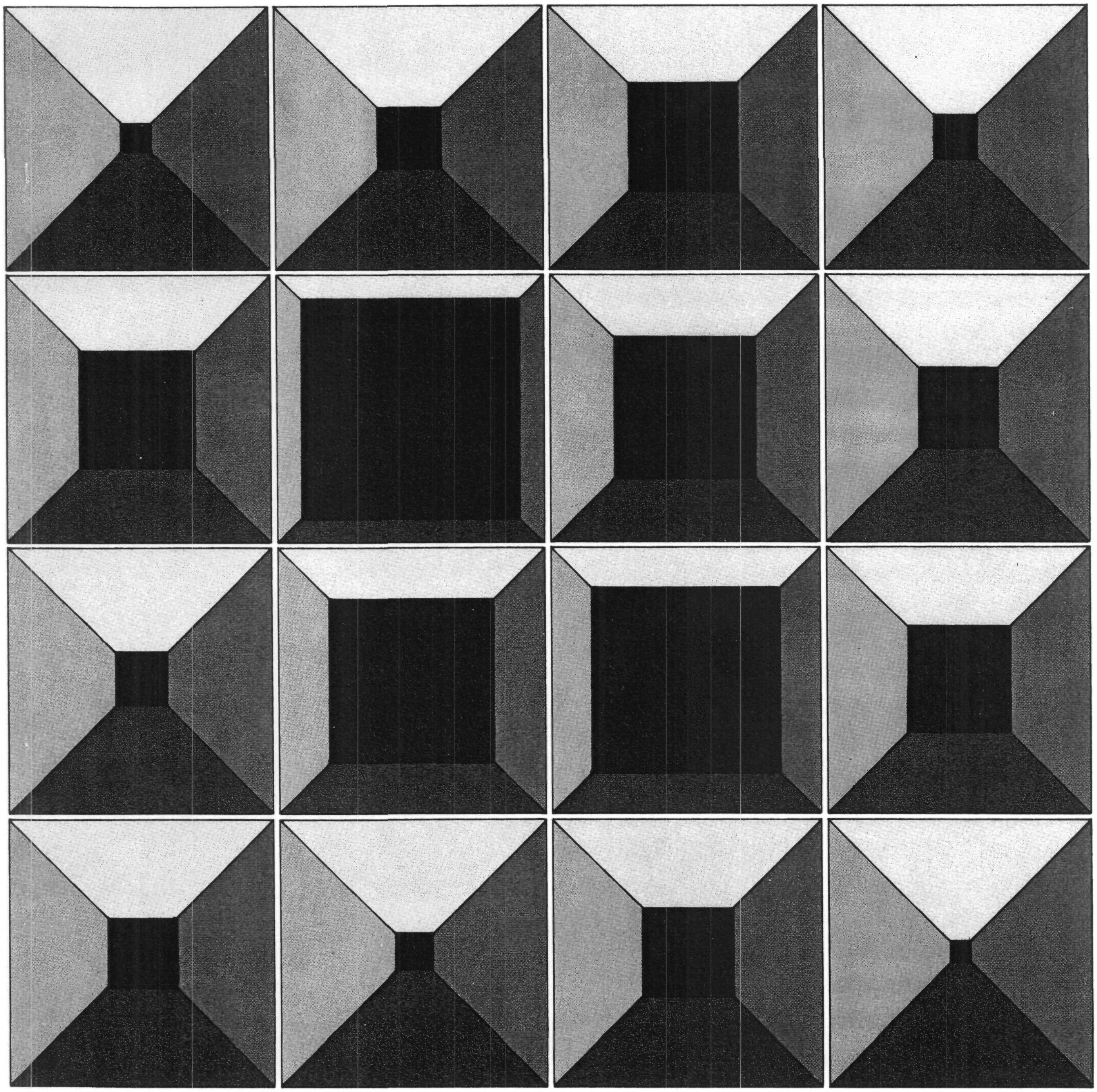
A CBO Study

Fuel Economy Standards for New Passenger Cars After 1985

December 1980

Congress of the United States
Congressional Budget Office



FUEL ECONOMY STANDARDS

FOR NEW PASSENGER CARS

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PREFACE

The 97th Congress is likely to consider legislation establishing new fuel-economy standards for cars sold after 1985. Such standards would be over and above those already set by the Energy Policy and Conservation Act of 1975. In debating post-1985 standards, the Congress will weigh issues of technological feasibility and cost effectiveness, as well as the resulting impact on the U.S. automobile industry.

Undertaken at the request of the Senate Committee on Energy and Natural Resources and the Subcommittee on Science, Technology, and Space, this study examines potential fuel-economy improvements resulting from increased application of existing technologies and the associated benefits and costs. In keeping with the Congressional Budget Office's mandate to provide objective and impartial analyis, the study offers no recommendations.

The paper was prepared by Sally A. Ferris of CBO's Natural Resources and Commerce Division, under the supervision of Damian J. Kulash and Raymond C. Scheppach. Valuable assistance was given by David Lewis, Richard Mudge, and Richard Weissbrod of CBO. The author also acknowledges the contributions of many persons outside CBO, including Richard H. Shackson and James Leach of the Energy Productivity Center, Mellon Institute, Larry Jenney of the Office of Technology Assessment, Leroy Lindgren of Rath and Strong, Inc., and Theodore Taylor of Corporate-Tech Planning, Inc. Johanna Zacharias edited the manuscript. Special thanks go to Kathryn Quattrone who typed the many drafts and prepared the paper for publication.

Alice Rivlin
Director

December 1980

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SUMMARY

Current law, as established by the Energy Policy and Conservation Act of 1975, stipulates that, by 1985, the average mileage of all new cars sold by each auto manufacturer must meet a standard of 27.5 miles per gallon (mpg). A legislative proposal considered during the 96th Congress would have set a still higher fuel-economy standard--40 mpg--to be met by 1995. Although no action was taken on this proposal during 1980, similar ones may well be considered by the 97th Congress. Four issues would likely arise in the course of such deliberations:

- o Is the average new fleet standard of 40 mpg attainable from a technological standpoint?

- o What would be the resultant benefits and costs to consumers?

- o What impact would such improved automotive fuel economy have on the nation's petroleum consumption? and

- o How financially able is the U.S. automotive industry to accomplish this new fuel-economy goal?

The Congressional Budget Office's analysis leads to the conclusion that a 1995 fuel-economy standard of 40 mpg is indeed technologically achievable during the next 10 to 15 years. Further, achievement of this goal could yield substantial benefits to both the consumer and the nation. The greatest uncertainty surrounds the auto manufacturers' ability to sustain the level of capital investment necessary to improve the nation's new car fleet to this level of fuel economy.

POST-1985 IMPROVEMENTS IN FUEL ECONOMY

The conclusion that a 40 mpg standard is within fairly easy reach by 1995 is based on two main assumptions:

- o That manufacturers will increase their application of fuel-efficiency technologies that are either already in production or slated for production within the next several years, and

- o That the recent market shifts to smaller, more fuel-efficient cars will continue or at least stabilize at quite a high level.

The prospect of additional innovative technologies that reduce fuel consumption cannot be discounted. Since such developments are still remote in terms of practical use, however, they are not considered in this analysis, although they have the potential to improve the automotive fuel-economy picture radically.

Previous automotive industry experience provides a substantial base of information concerning the performance and costs of a wide range of existing fuel-economy technologies. CBO has reviewed a number of studies that estimate the additional costs and fuel-economy improvements associated with these technologies. For analytical purposes, CBO has focused on 12 existing technologies.

Substantial improvements in fuel economy are likely to result from two technologies in particular: vehicle weight reduction (achieved by downsizing, materials substitution, and reconfiguration to front-wheel drive) and diesel engines with turbochargers. The remainder of the estimated fuel-economy benefits would derive from improvements in transmission design, electronic controls, aerodynamics, engine lubricants, accessory efficiency, and tire and brake design. The combination of existing technologies could raise the average new fleet fuel economy by an additional 27 percent, from approximately 27.5 to 31 mpg in 1985 to an estimated 35 to 40 mpg by 1995.

Further increases in average fuel economy are also likely to occur as the real price of gasoline rises and consumers continue to switch to smaller cars. On the basis of market experience during the last decade, switches to smaller cars are likely to raise average new car fuel economy by 1 to 1.5 mpg as the price of fuel approaches $2 per gallon. Existing technologies, coupled with market shifts to smaller cars, could thus bring the average new fleet fuel economy to about 37 to 42 mpg by 1995.

BENEFITS AND COSTS TO THE CONSUMER

While improving fuel economy, application of fuel-saving technologies will increase vehicle costs. Such additional costs (including initial purchase and lifetime maintenance costs) are estimated at approximately $600 to $650 per vehicle. Nonetheless, the associated improvements in fuel economy should save a consumer substantial sums in fuel costs over the 100,000-mile life of an average car--savings estimated at $1,100 in lifetime fuel costs. In other words, fuel savings may exceed the added vehicle costs by about $500. The exact amount would depend upon future gasoline prices (here assumed at $2.05 per gallon), interest rates, and the total number of miles a car is driven.

Although the 12 technologies reviewed offer substantial savings when considered in various combinations, several appear less beneficial when considered alone, specifically the diesel engine, the stratified-charge gasoline engine, and the turbocharger. Several factors can significantly magnify the benefits to be gained from these technologies, however. These factors include unanticipated increases in gasoline prices, higher-than-average vehicle use rates, and future reductions in manufacturing costs as production efficiencies are realized. Moreover, both the stratified-charge (such as Ford's PROCO) engine and the turbocharger yield emissions control benefits not accounted for in these cost/benefit calculations.

NATIONWIDE ENERGY CONSERVATION

Improved automotive fuel economy could also lead ultimately to significant reductions in the nation's petroleum consumption. The full benefits of achieving a 40 mpg standard would only be realized, however, after the improved vehicles are completely phased in. Following 10 or so years after introduction of a 40 mpg fleet--that is, around 2005--some 1.1 million barrels of oil per day would be saved relative to a fleet that averaged 27.5 mpg (the standard set for 1985). These savings represent about 20 to 25 percent of currently projected automotive petroleum consumption.

CAPITAL INVESTMENT REQUIREMENTS AND THEIR IMPACT ON THE AUTO INDUSTRY

The total capital investment requirements of the domestic auto industry are estimated in the range of $8.0 to $12.5 billion a year after 1985. The $8.0 billion annual investment level would improve fuel economy to approximately 40 mpg by 1995. The $12.5 billion represents an accelerated investment program in which the 40 mpg range is achieved by 1990.

Approximately $7 billion of these annual investment levels reflects the industry's ongoing annual investment for normal, or business-as-usual, capital replacement requirements. Thus, the remaining $1.0 to $5.5 billion represents the increased annual investment necessitated by post-1985 fuel-economy improvements. The total incremental increase in capital investment attributable to fuel economy is thereby estimated at $10 billion ($1.0 billion annually for 10 years) to $27.5 billion ($5.5 billion annually for 5 years), depending on the speed with which the improvements are achieved. The $10 billion level would bring the average fleet fuel economy to approximately 40 mpg by 1995; the $27.5 billion level would bring fuel-economy levels to the 40 mpg range by 1990.

These estimates are based on an assumption that a portion of the costs for equipment and facilities to produce the fuel-efficiency technologies will be absorbed within the industry's normal capital replacement cycle. Thus, although the total capital cost for producing the fuel-efficiency technologies is estimated at $45 billion, 40 to 80 percent (depending on the rate of application of fuel-economy improvements) of these costs will be absorbed in the industry's ongoing capital investment program. Incremental costs of fuel-economy improvements will thereby be reduced.

Although the estimated capital investment necessitated by post-1985 fuel-economy improvements is roughly comparable to current industry investment levels, the industry's ability to sustain this level of expenditure is uncertain. A continued high rate of capital investment would place significant financial pressure on the industry. On the other hand, failure to make further fuel-economy improvements during the 1985-1995 period could result in a significant decline in the U.S. share of a market already cut into by imports. Thus, although improving fuel economy during the post-1985 period would require a continued high rate of capital investment and could expose the industry to significant financial risk, failure to improve fuel economy could imperil the competitive position of domestic manufacturers.

REGULATION OR MARKET FORCES?

The anticipated demand for more fuel-efficient cars and the keen competition offered by imports in meeting this demand will, in all likelihood, combine to push the industry toward further fuel-economy improvements, regardless of government regulations. For this reason, domestic manufacturers resist standards as needless government intervention. Legislated standards can, however, impose a steadying force in an area of the U.S. market that is otherwise subject to the external and profoundly influential uncertainties of fuel supplies and prices.

CHAPTER I. INTRODUCTION

The Energy Policy and Conservation Act of 1975 (Public Law 94-163) established an average fuel-economy standard of 27.5 miles per gallon for new passenger cars sold--that is, the "new car fleet"-- by each manufacturer in 1985 and thereafter. The legislation also authorized the Secretary of Transportation to establish tighter standards for subsequent years, pending a finding of "economic feasibility." During the 96th Congress, the Senate Committees on Energy and Natural Resources and on Commerce, Sci ence, and Transportation reviewed the possibility of legislating still higher standards for the post-1985 period. Senators Henry Jackson and Warren Magnuson introduced an amendment to Senate bill S.2015 (the Transportation Energy Efficiency Act of 1979) that would have set an average fuel-economy standard of 40 miles per gallon (mpg) for new cars sold in 1995. Standards for interim years 1985 to 1995 would have been established by the Secretary of Transportation. Although no action was taken on this bill during 1980, this legislative proposal or a similar one will likely be considered by the 97th Congress.

Consideration of more stringent post-1985 fuel-economy standards raises several questions about the feasibility and associated effects of attaining further improvements. Four specific questions arise in this context: Are further improvements beyond the currently mandated 27.5 mpg level technologically feasible? Will such improvements--certain to affect the costs of cars--ultimately benefit consumers? Will stricter standards have a significant influence on overall nationwide petroleum consumption in the United States? And what effects would such standards have on the U.S. automobile industry?

This paper presents an assessment of the feasibility and cost effectiveness of further improvements in automotive fuel economy. For purposes of analysis, the paper's focus is restricted to the potential fuel-economy improvements resulting from increased use of existing technologies and from market shifts to small, fuel-efficient cars. The potential for technological breakthroughs--that is, the development and application of innovative technologies now still only in experimental stages--is clearly present over the next 10 to 15 years, however. Thus, the Congressional Budget Office's estimates based on existing technologies must be recognized as conservative.

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The remainder of this chapter describes the events leading to the 1975 legislation and to ongoing Congressional consideration of post-1985 fuel-economy standards. The next chapter examines the feasibility of attaining by 1995 an average fuel economy level of 40 mpg for the new fleet of U.S. cars. This assessment is based on a review of potential fuel-economy improvements resulting from 12 existing types of automotive technologies and from anticipated market shifts to small, fuel-efficient cars. Chapter III examines the net costs and benefits of post-1985 fuel-economy improvements, in terms of savings to the consumer and reductions in national petroleum consumption. Chapter IV estimates the capital requirements for U.S. automobile manufacturers that would be associated with improved fuel economy and explores the industry's ability to meet those requirements. Chapter V reviews the aims and effectiveness of establishing additional fuel-economy standards.

BACKGROUND OF CURRENT CONSIDERATIONS

The OPEC oil embargo of 1973-1974 resulted in massive fuel shortages that gave rise to steep increases in the price of gasoline in the United States. The national concern precipitated by the embargo resulted in the formulation and enactment of the Energy Policy and Conservation Act of 1975. This law was aimed at reducing gasoline consumption through production and sales of fuel-efficient vehicles. The statute stipulated that the average fuel economy of each manufacturer's fleet of passenger cars be calculated using a sales-weighted average of new cars sold by that company in a given model year. 1/

1/ The original provisions of the Energy Policy and Conservation Act required that the average fleet fuel economy be calculated separately for each company's domestically manufactured and imported fleet as though each group were sold by a different manufacturer. "Domestically manufactured" was defined as having at least 75 percent of the automobile's cost attributable to value added in the U.S. or Canada. The Congressional intent in this provision was to protect jobs for workers in the domestic auto industry by forbidding the use of "captive imports" to raise corporate fuel-economy averages. The provision has since been amended to allow a specific set of manufacturers (those producing fewer than 300,000 autos or those that recently began production in the United States) to combine their imported and domestic fleets for total corporate mileage calculations.

Until recently, the prospect of attaining the mandated average standard of 27.5 mpg by 1985 appeared remote. The demand for fuel-efficient cars did, however, increase significantly during 1979 as world oil price increases, coupled with the first phase of oil price decontrol, pushed U.S. gasoline prices to record levels. Given the current pace of fuel-economy improvements, the U.S. auto industry now appears likely to exceed the 1985 standard, approaching 31 mpg by 1985. U.S. manufacturers have directed sizable efforts to developing and producing fuel-efficient technologies for new cars. Moreover, consumers' acceptance of smaller cars has increased substantially. Rising fuel prices and persistant doubts about the future availability of petroleum have resulted in a market-wide shift to smaller cars. The market share held by compact and subcompact models has, in fact, risen from 38 percent of total new car sales in 1970 to more than 60 percent in 1980.

The overall market swing toward smaller cars has concentrated sales in a segment of the market where U.S. manufacturers have historically competed on a very limited basis. In contrast, foreign manufacturers, long accustomed to higher fuel costs in their own countries, have offered a variety of small, fuel-efficient models for sale at home and, to an increasing extent, abroad. Imported autos--most notably Japanese and German ones--have captured a record share of the U.S. market, climbing from 18 percent of new car sales in 1978 to 29 percent in mid-1980. The imports' share of new car sales is likely, however, to decline as a greater number and variety of fuel-efficient domestic cars come onto the market.

The domestic auto companies are currently engaged in massive product-redesign efforts. The industry plans to have the capacity to produce more than 10 million newly designed cars by 1984. Concern about continued U.S. vulnerability to gasoline price increases and future disruptions in the supply of foreign petroleum has, however, precipitated Congressional consideration of further increases in mandatory fuel-economy standards.

CHAPTER II. TECHNOLOGICAL IMPROVEMENTS AND MARKET SHIFTS IN THE POST-1985 PERIOD

The U.S. automobile industry's efforts, combined with consumers' increased willingness to buy smaller, more fuel-efficient cars, have raised the average fuel-economy level of new U.S.-built cars by more than 35 percent in the past five years. The average fuel economy of new, domestically produced cars sold in model year 1975 was 14.8 mpg; in model year 1980, the level had risen to more than 21 mpg. On the basis of this experience, which provides a substantial foundation for projecting future technological and marketplace developments, CBO estimates that a minimum fuel-efficiency standard of 40 mpg for the 1995 new car fleet is achievable. (Some of the analytical problems in making such projections are discussed in Appendix A.) This chapter reviews the analysis underlying this estimate.

In the course of the next 15 years, improvements in automotive fuel efficiency could come from three sources:

- More extensive use of fuel-efficiency technologies that are already in production or planned for production,

- Further market shifts to smaller, more fuel-efficient cars, and

- Totally new technologies and production processes that are still being developed.

Among analysts of the U.S. automobile industry, there appears to be considerable consensus that existing technologies, coupled with market shifts to smaller cars, will be the likeliest source of fuel-efficiency improvements in the next 15 years. Technological innovations, such as alcohol-powered engines, electrically-powered ones, or continuously variable transmissions, could also have profound effects on fuel efficiency. General Motors (GM), for example, has announced tentative plans to market an electrically powered car by 1984. Widespread application of such innovative technologies could radically improve the future fuel efficiency of U.S.-produced cars. However, because such technologies are still relatively remote in terms of day-to-day use, they are not considered in this analysis. This chapter examines only the potential fuel-economy improvements that existing technologies and further market shifts could yield.

Most of the existing technological improvements affecting fuel efficiency involve either weight reduction, engine design and operation, or transmission or drivetrain function. Other factors involve aerodynamics, lubrication, or improved tire and brake design.

A car's weight figures greatly in its fuel consumption. The heavier a car is, the more engine power it needs to accelerate and to overcome "rolling resistance" (defined in the glossary on p. 8). Since 1975, the U.S. auto industry's efforts to build lighter cars, combined with market shifts to smaller vehicle size classes, have resulted in a 19 percent reduction in the average weight of domestically produced cars. Weight reduction can be achieved in various ways, including reducing vehicle dimensions (called "downsizing" in the industry), substituting lighter-weight materials for heavy ones, (for example, aluminum and plastics for steel), and reconfiguring to front-wheel drive, which allows the car to be smaller and lighter while retaining interior space. Most of the industry's efforts to date have centered on downsizing and materials substitution. Over the next three to four years, the industry will pursue an intensive redesign program to convert most new cars to front-wheel drive.

Engine operation can be improved through electronic control of fuel injection, ignition timing, valve timing, and carburetion. "Turbocharging" (described in the glossary) can also improve engine operation by boosting power. Alternate engine designs (including diesel-powered and "stratified-charge" gasoline engines) also offer significant potential for fuel economy. These improvements generally result from a reduction in internal engine friction, higher compression ratios, and more efficient combustion chamber characteristics.

Transmission design plays an important role in fuel economy, since the transmission conveys power from the car's engine to its driving axle(s). The transmission determines the efficiency with which engine power is converted to vehicle motion. Conversion efficiency is generally determined by the degree of slippage in the transmission and by the transmission's gear ratio (which affects engine speed and torque.) Thus, manual transmissions as well as torque converter lock-ups (see the glossary) on automatic transmissions improve fuel economy by eliminating slippage. 1/ Gear ratio is improved by additional gears or overdrive.

1/ CBO's analysis is restricted to improved automatic transmissions, rather than "standard" (manually shifted) transmissions for several reasons. First, only one domestic car in 10 now has a manual (Continued)

THE POTENTIAL OF TWELVE EXISTING TECHNOLOGIES

Much of the technical analysis done to date points to 12 existing technologies as the most probable sources of significant gains in fuel efficiency for the new post-1985 fleet of domestic cars. 2/ This section reviews those technologies.

The following pages describe the 12 technologies in greater detail and give the Congressional Budget Office's estimates of fuel-economy benefits and costs for each technology. These estimates were derived largely from the various studies reviewed in Appendix B and, for the most part, they fall within the range of these study results. At the start of each section, a short table presents CBO's estimates of market penetration (the percentage of new domestically produced cars equipped with any particular technology), fuel-economy benefits (percent by vehicle), consumer cost increases (both initial purchase price and lifetime maintenance cost increases per vehicle), and capital investment requirements (for 400,000 unit production capacity). Costs are presented in undiscounted 1980 dollars.

A major share of the anticipated improvements in fuel efficiency between 1985 and 1995 are likely to derive from weight reduction. Several factors are likely to restrict the post-1985 benefits realized by weight reduction programs, however. First, a given percentage weight loss results in a smaller percentage fuel-economy improvement in lightweight cars than

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(continued) transmission. Second, the on-road fuel efficiency of a manual transmission is greatly affected by driving habits. Third, and most important, automatic transmissions offer significantly greater potential for improved fuel economy over the long run, particularly as the industry moves toward widespread use of electronic controls.

2/ Appendix B summarizes various estimates of market penetration, fuel-economy benefits, and associated increases in initial vehicle costs to the consumer and capital investment costs to the auto manufacturers for each of these technologies. The sources of these estimates include several automobile companies, research institutions, private consultants, and government agencies. The studies summarized show considerable agreement regarding the effects that each of the technologies can be expected to have on fuel economy and vehicle costs. These estimates were not all derived independently, however, and reliability should not necessarily be inferred from the apparent agreement of study results.

GLOSSERY OF TERMS

MATERIAL SUBSTITUTION (for weight reduction): Replacement of car's heavy component materials, such as steel, with lighter-weight materials, including aluminum and plastic.

FRONT-WHEEL DRIVE (for weight reduction): A design that enables a front-mounted engine to deliver power directly to the car's front wheels instead of its rear wheels, as has been conventional in U.S. cars. Front-wheel drive allows for a shorter engine compartment and eliminates the heavy drive shaft and the differential mounted on the rear axle. Besides reducing weight, this design permits efficient use of space; the car's exterior can be smaller with no sacrifice of interior space.

DOWNSIZING (for weight reduction): A reduction in body dimensions to lighten the car. Usually involves shortening the wheel base and cutting length by reducing body overhang beyond the chassis. "Downsizing programs" (the industry's term) involve various weight reduction features and improvements in aerodynamic design (see below).

TORQUE CONVERTER LOCK-UP: Used with automatic transmissions, the torque converter lock-up mechanically locks the engine and drivetrain at cruising speeds, decreasing the need for constant or repeated infusions of fuel to maintain speed and thus conserving fuel.

FOUR-SPEED AUTOMATIC TRANSMISSION: Transmits power from the engine to the axle(s) by means of four instead of three forward gears that shift automatically. Use of four gears reduces fuel consumption by permitting slower engine speeds.

ELECTRONIC CONTROLS: Electronic controls, rather than mechanical ones, can optimize such features as air/fuel ratio, ignition timing, engine valve timing, exhaust-gas-recirculation, and fuel injection. By increasing flexibility, electronic controls can enhance fuel efficiency and at the same time reduce exhaust emissions.

STRATIFIED-CHARGE ENGINE: A type of engine wherein combustion is initiated in a rich fuel/air mixture and diffused through a leaner mixture. Instead of being uniform, the fuel/air mixture is stratified from higher to lower fuel concentrations. The overall mixture is leaner and thus conserves fuel. Different types of stratified-charge engines include the diesel and Ford Motor Company's PROCO (see below).

DIESEL ENGINE: A type of stratified-charge engine that uses the heat of air compression, rather than an electrical spark, to ignite the fuel/air mixture. Compression ignition requires a special fuel—middle-distillate, or diesel, fuel. Diesel fuel contains about 10 percent more energy per gallon than gasoline.

PROCO ENGINE: A type of single-chamber, direct-injection stratified-charge gasoline engine being developed by Ford. Unlike the diesel, the PROCO engine is spark-ignited.

TURBOCHARGER: A feature that boosts engine power by forcing more fuel/air mixture into the engine cylinders. The greater power generated by the turbocharger permits use of smaller engines and thereby increases fuel economy.

IMPROVED LUBRICANTS: Synthetic engine lubricants and modified petroleum-base oils that reduce friction between moving parts (particularly at extreme temperatures) and thereby improve fuel economy.

AERODYNAMIC DESIGN: Body configuration to minimize wind resistance and the resultant fuel-consuming drag.

IMPROVED ACCESSORIES: Enhanced efficiency of components (such as air conditioning compressors, emissions control devices, power steering units, and radiator cooling fans) that divert engine power and thereby consume fuel.

REDUCED ROLLING RESISTANCE: A reduction, by means of improved tire and brake design, in fuel-consuming friction associated with the movement of a vehicle's wheels.

in heavy cars. Second, weight reduction is more difficult to achieve on small cars than on large ones, since smaller cars in general are designed more efficiently than large cars. Third, small weight reductions have little impact on fuel economy, since engines and axle ratios cannot be adjusted for every small weight decrement. Finally, most of the relatively inexpensive and easy-to-achieve weight reductions will have been incorporated in the domestic auto fleet before 1985. 3/ The growing market share held by small, lightweight cars during the post-1985 period, and the resultant difficulty in attaining additional fuel-economy benefits, will restrict potential gains from further weight reduction efforts during the post-1985 period. The fuel-economy gains estimated for the post-1985 period reflect these factors.

Estimates of the overall benefits from weight reduction range from 3 percent to 22 percent (see Appendix B). This wide range results in large part from differing definitions of the term. The fuel-economy benefits (as well as costs) vary, depending on whether acceleration performance is assumed to remain constant by reducing engine size along with automobile weight. Some studies define weight reduction as including all the accompanying changes brought about by reducing vehicle dimensions and replacing engines; such definitions therefore encompass secondary effects. Other studies appear to define weight reduction primarily as material substitution and restyling, accounting only for the primary effects. For this analysis, CBO has examined three components of weight reduction separately: material substitution, conversion to front-wheel drive, and downsizing.

Material Substitution

Market Penetration		Fuel Economy	Purchase Cost	Maintenance Cost	Capital Investment
1985	1995	Improvement	Increase	Increase	(In millions)
50%	100%	4%	$131	None	$377

3/ Energy and Environmental Analysis, Inc., Technological Cost Relations to Update DOE/Faucett Model: Draft Final Report (October 1979) pp. 2-28 and 2-29.

The gain in fuel economy to be derived from material substitution is estimated at 4 percent per vehicle between 1985 and 1995. This relatively low number reflects the increasing difficulty of attaining fuel-economy improvements through weight reduction in a fleet that is increasingly dominated by lightweight cars. The estimated fuel-economy benefits of material substitution take into account only the primary effects of weight reduction. Estimated post-1985 improvements resulting from material substitution assume no engine replacement. Fuel-economy benefits resulting from engine replacement are addressed below in the analysis of front-wheel drive and downsizing.

The introduction of substitute materials is likely to follow the scheduling of major redesign or downsizing programs. New materials are generally introduced in small quantities in order to gain production experience and evaluate their performance. The extent of material substitution varies by manufacturer and model. Some current uses of lightweight materials include plastic bumper systems, aluminum brake drums and wheels, and high-strength, low-alloy doors. For purposes of this analysis, market penetration of material substitution programs is estimated at 50 percent in 1985 and 100 percent in 1995, assuming that half of the domestic car fleet will be subject to a major redesign effort during the period 1985-1995.

The increase in initial vehicle cost to buyers associated with a material substitution is estimated at $131 per vehicle. This estimate assumes that material substitution during the post-1985 period will require extensive modification of body manufacturing and assembly facilities, which raises initial production costs.

The effects of a material substitution program on vehicle maintenance costs are unclear. The U.S. Department of Transportation (DOT) estimates that material substitution programs will decrease maintenance costs to the consumer by $157 over the life of a car 4/, assuming there is a direct relationship between maintenance costs and vehicle weight. 5/ GM argues that any decline in maintenance requirements (which GM considers

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4/ Maintenance cost estimates were adjusted to 1980 dollars using the consumer price index for private transport, maintenance and repair.

5/ U.S. Department of Transportation, Final Impact Assessment of the Automotive Fuel Economy Standards for Model Year 1981-1984 Passenger Cars (June 30, 1977), p. I-6.

unlikely) as a result of weight reduction would be offset by increased replacement costs of redesigned components. 6/ This analysis assumes no change in maintenance costs over the average vehicle's life as a result of material substitution programs.

Reconfiguration to Front-Wheel Drive

Market Penetration 1985	Market Penetration 1995	Fuel Economy Improvement	Purchase Cost Increase	Maintenance Cost Increase	Capital Investment (In millions)
80%	100%	12%	$166	None	$780

Domestic auto manufacturers are currently redesigning cars from the prevailing front-engine, rear-wheel drive configuration to a front-engine, front-wheel drive configuration. In the new design, the engine is mounted sideways (in a "transverse" position) above the front axle so that power goes directly from the engine to the front wheels. This configuration uses space more efficiently and helps to reduce weight--the engine compartment is shortened and the drive shaft and rear differential are eliminated. Without the drive shaft and rear differential, a car can be both roomier inside and lighter. Fuel economy is improved through both primary and secondary (substitution of smaller engines and lighter components) weight reducing effects.

The transverse front-wheel drive technology is fully developed and is currently being marketed. Transverse front-wheel drive is now offered on numerous models, including Volkswagen's (VW) Rabbit, Ford's Fiesta, Chrsyler's Omni and Horizon models as well as its new K-cars (Dodge Aries and Plymouth Reliant), and GM's Oldsmobile Toronado, Cadillac Eldorado, Buick Riviera, and "X-Car" series (the Chevrolet Citation, Pontiac Phoenix, Buick Skylark, and Oldsmobile Omega). Manufacturers currently plan to incorporate the transverse front-wheel drive design on several additional models, including GM's Monza and Chevette and Ford's Fairmont and Zephyr. In addition, Ford is now marketing a new transverse front-wheel drive subcompact, the Escort/Lynx series.

6/ General Motors Corporation, Analysis of NHTSA's July, 1977 Rule-making Support Paper and June 30, 1977 Final Impact Assessment of the Automotive Fuel Economy Standards for Model Year 1981-1984 Passenger Cars (February 1, 1979), p. 13.

Market penetration of the transverse front-wheel-drive design is estimated to reach 80 percent in 1985 and 100 percent by 1995. The 1985 estimate is based on the manufacturers' announced product plans, which indicate that 90 percent of GM's fleet, 50 percent of Ford's fleet, and 100 percent of Chrysler's fleet will have front-wheel drive by 1985. The only apparent impediments to large-scale production of front-wheel-drive cars (aside from capital investment constraints) arise from difficulties in mounting V-6 or V-8 engines transversely because of space limitations and resultant maintenance problems. Given that GM is currently marketing front-wheel drive V-8 engines on the Eldorado and Toronado models, this problem appears to be surmountable, and it should not limit the future market penetration of the front-wheel-drive design.

Front-wheel drive should improve fuel economy by roughly 12 percent (net of benefits resulting from material substitution and improved aerodynamics, which are accounted for elsewhere in this chapter). The increase in initial cost to consumers is estimated at $166, based on recent experience with the Chevrolet Citation. 7/

Vehicle Downsizing (Second Round)

Market Penetration		Fuel Economy	Purchase Cost	Maintenance Cost	Capital Investment
1985	1995	Improvement	Increase	Increase	(In millions)
60%	80%	10%	$146	None	$700

Downsizing is a composite reduction of vehicle dimensions and weight. GM has completed a "first round" of downsizing and plans to complete a second round by 1985. Ford and Chrysler plan to complete their first round of downsizing by 1982 and will probably make some weight reducing sheet metal changes by 1985. 8/ If the four domestic manufacturers maintain their 1979 shares of sales, 60 percent of all new cars will incorporate improvements resulting from a second round of downsizing

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7/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-76.

8/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-42.

before 1985. An additional 20 percent of the new car fleet will undergo this second round of downsizing during the post-1985 period as part of the front-wheel-drive reconfiguration program. Given that 60 percent of the fleet will undergo a second round of downsizing by 1985, while an additional 20 percent will be downsized as part of the front-wheel-drive reconfiguration program, only 20 percent of the new car fleet can be assumed to be affected by a second round of downsizing during the post-1985 period.

Fuel-economy benefits associated with a second round of downsizing are estimated at 10 percent (net of improvements associated with material substitution and improved aerodynamics). Estimated costs of downsizing are somewhat less than those for reconfiguration. The impact of a downsizing program on lifetime maintenance costs is unclear. DOT, assuming a direct relationship between weight and maintenance costs, has estimated downsizing will decrease maintenance expenses by $341 per vehicle. 9/ On the other hand, GM argues that maintenance schedules have not changed appreciably in downsized cars and that any savings attributable to such features as fewer spark plugs and smaller tires are likely to be offset by increased maintenance costs associated with more complex vehicle design and more costly components. 10/ Given the limited data available, CBO projects no change in lifetime maintenance costs from downsizing.

Four-Speed Automatic Transmission with Torque Converter Lock-Up

Market Penetration 1985	Market Penetration 1995	Fuel Economy Improvement	Purchase Cost Increase	Maintenance Cost Increase	Capital Investment (In millions)
27%	54%	6%	$198	$52	$216

The torque converter lock-up enhances fuel efficiency by improving engine/transmission matching. It mechanically locks the engine and drivetrain at cruising speeds, which eliminates slippage and thus conserves fuel. The torque converter lock-up is technologically well developed and is

9/ U.S. Department of Transportation, Final Impact Assessment, p. I-6.

10/ General Motors Corporation, Analysis, 1981-1984 Passenger Cars, p. 12.

currently marketed on several 1981 models. Lock-ups on the third gear are now standard equipment on all Chrysler cars with automatic transmissions. Ford and GM introduced them on their 1980 models. Given manufacturers' current plans, the torque converter lock-up (for either four-speed or three-speed transmissions) will probably reach maximum market penetration by 1985.

Any incremental benefits in fuel economy resulting from improved transmission design in the 1985-1995 period will thus derive from the use of additional gears, particularly four-speed rather than three-speed automatic transmissions. A four-speed transmission (that is, one with four forward gears) improves engine/transmission matching; its lower gear ratio improves torque and permits lower engine speeds, yielding considerable potential fuel-economy benefits.

The four-speed automatic transmission is already a well developed technology, and it is currently being marketed on several 1981 models. With the torque converter lock-up feature, the four-speed automatic transmission is standard equipment on all Ford's 1981 Lincoln and Marquis models, and it is offered as an option on the 1981 Cougar XR-7s. GM introduced the four-speed automatic transmission on its 1981 Chevrolet Caprice and Impala and Oldsmobile 88 and 98 models. It is also available on GM's full-size Buick models.

The industry's own plans will probably limit the market penetration of four-speed automatics before 1985. A major retooling effort to convert powertrains to four-speed automatic transmissions before 1985 would make inefficient use of capital, since further downsizing and/or eventual reconfiguration to front-wheel drive would render premature production-line adaptions for four-speed automatics obsolete. For this reason, GM in particular has expressed reluctance to invest heavily in such retooling for its intermediate and full-size rear-wheel-drive cars. 11/ Thus, to estimate the incremental fuel-economy benefits associated with the increased market penetration of four-speed automatic transmissions, this study assumes that 27 percent of new domestic cars in 1985 (or 30 percent of all domestically produced automatics) will have four-speed automatic transmissions.

The 1995 market penetration of the four-speed automatic transmission is estimated at 54 percent of the new domestic fleet (or 60 percent of those vehicles equipped with automatic transmissions.) (This estimate

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11/ General Motors Corporation, Analysis, 1981-1984 Passenger Cars, p. 14.

rests on the assumption that 90 percent of all domestic cars will be built with automatic transmissions in 1995.) The estimate only accounts for those cars that could demonstrate significant fuel-economy gains when equipped with a four-speed transmission; it therefore understates the likely extent of actual market penetration. The 1995 market penetration of the four-speed automatic transmission is likely to exceed this estimate, since widespread use of smaller engines (which lack low-end torque) may necessitate the use of four-speed transmissions to enhance engine performance. In such instances, however, fuel-economy gains would be limited and would result largely from the use of smaller engines themselves, not from the transmissions. 12/ A 54 percent market penetration level is applied in computing the impact of the four-speed transmission on future fuel economy.

Incremental fuel-economy benefits of the four-speed transmission are estimated at 6 percent. The estimated increase in initial consumer costs for the four-speed transmission is $198 (based on observed market prices). The four-speed automatic transmission can be expected to increase maintenance costs per car by about $52 over a 100,000-mile lifetime. 13/

Electronic Controls

Market Penetration 1985	Market Penetration 1995	Fuel Economy Improvement	Purchase Cost Increase	Maintenance Cost Increase	Capital Investment (In millions)
5%	25%	15%	$179	None	$25

Conventional mechanical engine systems are relatively inflexible. To improve engine flexibility and adaptability, electronic engine controls such as sensors, actuator mechanisms, and microprocessors have recently been introduced. These innovations can optimize engine operation and enhance fuel efficiency. Digital electronics (microprocessors) provide an almost unlimited range of control. Analog electronics have somewhat less potential but still offer significant improvements over mechanical systems.

12/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-19.

13/ U.S. Department of Transportation, Final Impact Assessment, p. I-6.

At present, electronic control systems are widely used to control three engine operating characteristics--the air-to-fuel ratio, the ignition spark timing, and the rate of exhaust-gas-recirculation--all of which are important factors in determining fuel-efficiency and exhaust emission levels. Other potential uses of electronics extend to computer-controlled airflow or throttle (which is coordinated with fuel flow for improved performance), variable valve timing (wherein valve timing is continually adjusted, based on engine load and speed, to minimize throttling losses), selective cylinder cut-off (which disables cylinders under part-load conditions in order to enhance the operating efficiency of the remaining cylinders), and automatic transmission control (wherein transmission shift points are subject to electronic control). This analysis, however, is restricted to technologies that are currently in production or planned for production during the next several years.

All domestic manufacturers now offer some form of electronic spark control. GM has introduced digital spark control (termed MISAR), electronic fuel injection, and electronic knock sensors that automatically retard spark when an engine is knocking badly. The company also introduced its Computer Command Control (CCC) system on all its 1981 gasoline-burning models. This system automatically keeps the engine tuned for maximum fuel economy at lowest emissions levels. Ford has developed a spark timing and exhaust-gas-recirculation control called EEC I and plans to introduce more advanced systems (EEC II and EEC III) between 1980 and 1985. American Motors reportedly is purchasing the Ford systems. Chrysler has incorporated an analog spark control system in most of its models since 1976.

Increasingly stringent emission standards will necessitate across-the-board use of spark control, knock limiters, and fuel injectors by 1985, which will limit any incremental post-1985 fuel-economy improvements that could be associated with these technologies. More advanced electronic controls do, however, offer significant potential for further improvements in fuel economy after 1985. Specifically, GM has introduced a valve selector device on its 1981 Cadillac V-8 engine, which cuts off either two or four cylinders when they are not needed. Fuel-economy savings of 15 percent are eventually expected from the valve selector technology. 14/

14/ "Ward's Automotive Reports," Volume 55, No. 13, March 3, 1980, p. 69.

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Market penetration of the variable cylinder selector is estimated at 5 percent in 1985, climbing to 25 percent in 1995. The 1995 figure is not higher because four-cylinder engines would presumably not benefit significantly from this feature. 15/ Variable cylinder selectors are assumed to improve fuel economy by 15 percent. The incremental increase in initial vehicle costs is estimated at $179. No impact on maintenance costs is anticipated.

Diesel Engine

Market Penetration 1985	Market Penetration 1995	Fuel Economy Improvement	Purchase Cost Increase	Maintenance Cost Increase	Capital Investment (In millions)
7%	30%	15%	$679	None	$430

The diesel engine is an internal combustion engine that runs on diesel fuel (a middle distillate petroleum product) instead of gasoline. The diesel fuel is ignited by the heat of compression in the cylinder rather than by electrical spark. In a diesel powered car, no spark plugs or carburetor are necessary. The diesel engine uses fuel more efficiently than the gasoline engine because of higher compression ratios (which enhance thermodynamic efficiency) and reductions in pumping losses associated with throttled engines (the diesel engine is unthrottled).

Diesel engines are currently being marketed in the United States by several domestic and foreign manufacturers, including GM, Peugeot, and VW. 16/ Despite the large estimated fuel-economy gains associated with diesel engines, market penetration of the diesel has been relatively low. Diesel engines accounted for only 3.8 percent of total U.S. auto sales during

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15/ This figure is based on a survey of auto industry analysts, which indicated that approximately 25 percent of auto engines in 1990 will be either six-cylinder or eight-cylinder. See Arthur Andersen & Co., U.S. Automotive Industry Trends for the 1980s: A Delphi Forecast (1979), p. 3.

16/ The Environmental Protection Agency's 1980 Gas Mileage Guide listed 32 diesel models.

the first four months of 1980. 17/ Several factors have hindered the market penetration of the diesel to date: engine noise, sluggish performance, and high nitrogen oxide and particulate emission levels. Until recently, diesel-powered passenger cars have shown poorer acceleration than gasoline-burning cars. Recent design developments have significantly improved some diesels' performance, however, and the acceleration of GM and VW diesels now compares favorably with that of gasoline-powered cars. 18/ Nonetheless, the engine noise and exhaust emissions problems may remain major obstacles to the diesel engine's market penetration, at least in the immediate future. Market penetration of the diesel engine is estimated at 7 percent during 1985, climbing to 30 percent by 1995. One recent survey indicates that diesel engines will hold 25 percent of the U.S. automobile market by 1990. 19/

Various sources' estimates of fuel-economy gains associated with the diesel engine range from 10 percent to 35 percent, depending upon assumptions regarding fuel characteristics, emission standards, tolerable performance levels, and the base engine against which improvements are measured. For the purpose of forecasting fleetwide fuel-economy gains, CBO assumed an improvement of 15 percent per vehicle. The diesel engine attains about a 25 percent improvement in terms of mileage per gallon of fuel. But since the energy content of diesel fuel is about 10 percent higher than that of gasoline, the diesel yields only a 15 percent fuel-efficiency improvement. This estimate is based on a 1 gram-per-mile nitrogen oxide emission standard and is measured against a gasoline engine of comparable performance.

The costs of diesel engines appear to vary both with engine size and with an individual manufacturer's ability to convert existing plant and facilities now used for gasoline engine production. For example, GM agrees that DOT's estimated capital cost of $189 million per 400,000 diesel units 20/ roughly approximates recent cost experience in the conversion of the company's 260 and 350 V-8 engine plants. GM argues, however, that other production facilities are not readily convertible, and that new facility investment of at least $430 million would be required to produce 400,000

17/ "Ward's Automotive Reports," Volume 55, No. 11, May 12, 1980, p. 148.

18/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-5.

19/ Arthur Andersen & Co., U.S. Auto Industry Trends for the 1980s, p. 3.

20/ U.S. Department of Transportation, Final Impact Assessment, p. I-6.

units of newly designed diesel engines per year. 21/ CBO's estimate, like GM's and DOT's, is that diesel production costs will total roughly $190 million per 400,000 units until 1985, climbing to $430 million per 400,000 units by 1995. The incremental increase in the initial vehicle cost is assumed to average approximately $679. This estimate assumes that the diesel technology will be applied to 6-cylinder engines. This cost is reasonably consistent with observed market prices. The diesel was available as an option on the 1980 Oldsmobile 88 (350 CID/8-cylinder engine) for about $926; VW offered the diesel on the 1980 Rabbit (4-cylinder engine) for $400.

Maintenance cost estimates for diesel-powered cars vary widely. The fact that the diesel is ignited by air compression, and needs no spark plugs, distributor, carburetor, or periodic tune-ups, results in some cost savings. On the other hand, greater internal engine friction and heat necessitate more frequent oil and filter changes. (New emission-control technology and/or standards could further increase the need for more frequent oil changes.) There appears to be substantial disagreement about the extent to which the diesel's maintenance savings and costs offset one another; estimates range from a savings of $262 over a 100,000-mile vehicle life (DOT's figure) to an incremental cost of $330 (GM) over the same span. 22/ Dealers of the GM and VW diesel models now on the market claim that the net costs of diesel maintenance are less than those of gasoline-powered cars. CBO expects the diesel's maintenance savings and costs to cancel each other out, yielding a net figure of zero.

Stratified-Charge Gasoline Engine

| Market Penetration | | Fuel Economy | Purchase Cost | Maintenance Cost | Capital Investment |
1985	1995	Improvement	Increase	Increase	(In millions)
None	12%	15%	$679	None	$430

21/ General Motors Corporations, Analysis, 1981-1984 Passenger Cars, p. 14.

22/ U.S. Department of Transportation, Final Impact Assessment, p. I-6, estimates savings of $262. General Motors Corporations, Analysis, 1981-1984 Passenger Cars, pp. 14-15 claims an increased cost of $330.

In a stratified-charge engine, ignition occurs in a relatively rich fuel/air mixture (a mixture with a high concentration of fuel) and is diffused through a leaner mixture with a lower concentration of fuel. The air/fuel mixture is "stratified," not homogenous. A leaner overall mixture can thus be obtained, thereby increasing fuel efficiency.

Ford is currently developing a type of stratified-charge gasoline engine--the PROCO (or programmed combustion) engine. Stratified-charge engines are also being developed by Texaco and GM. One Japanese firm, Honda, has already developed a type of stratified-charge engine that is currently being marketed--the Honda CVCC (Compound Vortex Controlled Combustion). To date, however, Ford is the only domestic manufacturer that has announced plans to produce and market a stratified-charge engine in the near future. For purposes of analysis, this study therefore considers only the Ford PROCO engine.

The PROCO is a single-chamber engine in which gasoline is injected directly into the combustion chamber in such a way as to produce a rich air/fuel mixture near the spark plug and a leaner mixture elsewhere. The spark plug ignites the rich mixture, which in turn ignites the lean mixture. The process promotes more complete combustion and lowers engine temperatures. The process makes cleaner, more efficient use of fuel than the traditional gasoline engine design.

Ford originally planned to introduce a limited number of 8-cylinder PROCO engines during May 1983. It has recently changed its plans and will produce a PROCO V-6 instead of a V-8. It now appears that initial introduction will be delayed past 1983, with the PROCO V-6 not expected on the market until the mid-1980s. 23/

Estimates of fuel-economy improvements associated with the PROCO engine range from 8 percent to 20 percent, depending on assumptions regarding engine size and emission levels. Capital cost estimates range from $105 million to $323 million for 350,000 units.

For the purposes of this study, the capital costs of the PROCO engine are assumed to total approximately $430 million for an annual production capacity of 400,000 units. Lower estimates of capital costs appear to be based on converting existing capacity for conventional V-8 engines to the production of V-8 PROCO engines. The company presumably does not have

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23/ "Ward's Automotive Reports," Volume 55, No. 13, March 13, 1980, p. 99.

excess V-6 capacity to support facility conversion to the production of V-6 PROCO engines, however, thus compelling Ford to invest in a new engine line. The initial cost to consumers is scaled up to $679 per unit (comparable to the estimate for diesel) in order to account for the additional capital costs.

Fuel-economy benefits to be derived from the PROCO are estimated at 15 percent. Market penetration is estimated at zero in 1985 and 12 percent in 1995, assuming that the PROCO engine will be used in approximately half of Ford's car fleet.

The impact of the PROCO engine on maintenance costs cannot be estimated at this time. Given the cleaner burn of the PROCO engine, the maintenance costs associated with add-on emission control devices may be eliminated. This reduction may, however, be offset by unanticipated maintenance costs associated with the new technology.

Turbocharger

Market Penetration		Fuel Economy	Purchase Cost	Maintenance Cost	Capital Investment
1985	1995	Improvement	Increase	Increase	(In millions)
7%	30%	10%	$332	$190	$24

A turbocharger is an air compressor used to force a greater amount of air/fuel (either gasoline or diesel) mixture into an engine's cylinders, thereby boosting the power of the engine. The turbocharged gasoline engine provides more power but less fuel economy than a naturally aspirated gasoline engine of the same size. Turbochargers can, however, contribute to fuel economy by permitting the use of smaller engines.

The diesel engine responds well to turbocharging. Turbochargers operate most effectively under unthrottled conditions. Given that the diesel engine is unthrottled, the turbocharger's power is available during much of the engine's operating cycle. Gasoline engines, in contrast, operate under partial throttle conditions during most of the time, which restricts the effectiveness of the turbocharger. Accordingly, the turbocharger provides greater fuel-economy benefits when coupled with a diesel engine. Turbocharged diesels have demonstrated large fuel-economy gains, estimated at 10 percent--the estimate applied here.

The turbocharger is already a well developed technology. Turbocharged engines were offered on many domestic 1980 models, including GM's Pontiac Firebird, Chevrolet Monte Carlo, and Buick Century, Le Sabre, Regal, and Riviera; and Ford's Mustang, Fairmont, Lincoln-Mercury Capri and Zephyr. Chrysler plans to offer turbochargers in its Dodge Omni and Plymouth Horizon. 24/

CBO estimates the 1985 market penetration of turbochargers at 7 percent, based on an assessment of the auto manufacturers' published plans. For the purpose of estimating the turbocharger's post-1985 fuel-economy benefits, it is assumed that application of the turbocharger will be limited to diesel engines resulting in market penetration of 30 percent by 1995. This figure assumes an increase in diesel engines.

Cost estimates of turbochargers vary considerably according to computation methods. Several estimates apparently account for the turbocharger only and do not include the costs of hardware necessary for the use of a turbocharger, such as adjustments to the manifold, carburetor, cooling system, and spark retard mechanisms. 25/ Other estimates measure the incremental cost of turbochargers against engines of comparable size; that is, a turbocharged 6-cylinder engine is compared with a naturally aspirated engine with the same number of cylinders. Ideally, incremental cost estimates, like fuel-economy benefits, should be based on comparison of engines with roughly equal performance capacity. For example, the turbocharged 1978 Buick Regal V-6 was deemed comparable in performance ability with the naturally aspirated Buick 305 V-8. Since the turbocharger in the V-6 cost roughly $553, and the additional two cylinders in the V-8 cost $221, the incremental cost of the turbocharger was calculated to be $332 per car ($553 - $221 = $332). On the other hand, the price differential between a turbocharged 1979 V-6 Buick Riviera and the same year's 350 V-8 Riviera was only $84. 26/ For the purposes of this study, CBO estimated the incremental cost of the turbocharger at $332 per vehicle. 27/

24/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-32.

25/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-37.

26/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-34.

27/ This figure is consistent with recent estimates provided by GM and Chrysler. See statements by General Motors and Chrysler representatives at EPA Public Hearings on Proposed Diesel Particulate Emission Standards, Arlington, Virginia, March 19, 1979.

The maintenance costs associated with turbochargers are difficult to estimate because on-road experience to date is limited. The Council on Wage and Price Stability has estimated, however, that a turbocharger will probably require replacement sometime during the life of the average vehicle. 28/ This assertion is based on data from the replacement-parts market, which indicate that fuel pumps and water pumps (which the Council on Wage and Price Stability consider roughly comparable to turbochargers) are replaced approximately once over the life of the average car. Maintenance costs for the turbocharger are thus estimated at $190; that cost is likely to be incurred in a car's sixth year.

Improved Lubricants

Market Penetration 1985	Market Penetration 1995	Fuel Economy Improvement	Purchase Cost Increase	Maintenance Cost Increase	Capital Investment (In millions)
20%	70%	3%	$1.25 to $15	$12.50 to $150	Not Applicable

Synthetic engine lubricants and modified petroleum-base oils can improve fuel economy chiefly by reducing friction at extreme temperatures. Improved axle and transmission lubricants, as well as synthetic coatings for parts also offer significant potential for improved fuel economy through reduced friction. For the purposes of this study, however, consideration is limited to the benefits gained from improved engine lubricants.

Improved lubricants are now commercially available, although they are not used in the engines of new cars. Several factors have hindered their market penetration. Emission standards have raised one of the main impediments. In a February 1, 1979 statement before the National Highway Traffic Safety Administration, representatives of GM indicated that the company's plans to recommend that customers use improved engine oils by model year 1981 were changed because of tests indicating that some oils

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28/ Comments by Council on Wage and Price Stability before the EPA regarding particulate regulation for light-duty diesel vehicles.

caused increased oil consumption rates, which adversely affect the performance of catalytic converters and, in turn, emissions levels. 29/ Given the stringent emission standards for model year 1981, GM reported that application of improved oils would be delayed past that year, at least until model year 1983. In addition, current EPA regulations restrict the use of synthetic oils during the certification process for new car fuel-economy ratings, pending the development of a system to grade the relative fuel efficiency of different lubricants. 30/ EPA is currently in the process of developing such a grading system.

Market penetration of improved engine oils is assumed to be 20 percent in 1985, climbing to 70 percent by 1995. It is assumed that improved engine oils will not be used in diesel-powered cars, since diesel engines usually require more frequent oil changes and result in increased oil fouling from particulates.

The estimated fuel-economy benefits from improved lubricants range from 2 percent to 10 percent. Most studies estimate the improvement at 2 to 3 percent on EPA's city/highway driving cycle. This study assumes fuel-economy benefits at 3 percent during the 1985-1995 period.

The increase in initial vehicle cost is estimated to range from $1.25 to $15. Synthetic oil prices currently average $3 per quart more than conventional oil, 31/ and other friction modified petroleum-base oils are approximately 25¢ to 50¢ per quart more expensive (based on current price premiums for fuel-efficient oils). 32/ Assuming that a typical crankcase holds five quarts, this represents an incremental first-cost to the consumer of $1.25 to $15.00. Assuming that 50 quarts of oil are necessary for lifetime scheduled maintenance, the additional maintenance cost of the improved oils ranges from $12.50 to $150. Of course, lifetime costs will vary with differing frequencies of oil changes.

29/ General Motors Corporation, Analysis, 1981-1984 Passenger Cars, p. 8.

30/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-45.

31/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-45.

32/ General Motors Corporation, Analysis, 1981-1984 Passenger Cars, p. 15.

Improved Aerodynamic Design

Market Penetration 1985	Market Penetration 1995	Fuel Economy Improvement	Purchase Cost Increase	Maintenance Cost Increase	Capital Investment (In millions)
60%	100%	5%	$17	None	Not Applicable

Aerodynamic drag--that is, resistance to vehicle motion resulting from wind intensity and direction--is a function of a car's frontal area and overall body shape. A car with a broad, blunt front advancing at high speed into a strong wind will encounter significant aerodynamic drag. Minor changes in body styling or other details can improve aerodynamics in the near term. Long-run benefits can be achieved through total redesign.

Estimates of fuel-economy benefits associated with improved aerodynamic design range from 3 to 5 percent for the period ending 1985 (reflecting short-term detail and styling changes), with an additional 5 to 8 percent improvement by 1990 (resulting from more comprehensive redesign programs). GM's recent experience in developing the X-car series indicates a fuel-economy gain of 6 percent attributable to improved aerodynamics. 33/ For the purpose of estimating post-1985 fuel-economy benefits associated with improved aerodynamic design, this study assumes an average gain of 5 percent per vehicle. Higher estimates appear too large for several reasons. First, smaller cars, which will account for an increasing share of the new car fleet, have less potential for aerodynamic improvements. Second, the full benefits of improved aerodynamic design are only realized at high speeds that are not typical of average driving conditions.

The market penetration of aerodynamic design improvements will be determined by the manufacturers' downsizing schedules. As stated earlier in this chapter, GM will complete its second round of downsizing by 1985; Ford and Chrsyler will complete their first rounds, plus some additional sheet metal changes, by 1985. CBO assumes that potential long-term aerodynamic improvements associated with a second round of downsizing will attain 60 percent market penetration by 1985 and 100 percent by 1990.

33/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-43.

The increase in initial consumer cost is estimated at $17. The capital cost of improved aerodynamic design is subsumed under "front-wheel drive" and "downsizing." No impact on vehicle maintenance costs is anticipated.

Improved Accessories

Market Penetration 1985	Market Penetration 1995	Fuel Economy Improvement	Purchase Cost Increase	Maintenance Cost Increase	Capital Investment (In millions)
50%	100%	2%	$16	None	$22

An automobile's accessories--including air conditioning compressors, emissions control devices, power steering units, and radiator cooling fans--consume fuel by diverting power away from the crankshaft, which conveys power from the engine to the transmission to propel the car. The diversion of power results in less fuel efficiency, since some engine power is being used for purposes other than propelling the vehicle. The greater the number of accessories and the worse their efficiency, the more power is diverted from the crankshaft. Improved design of accessories can reduce demand on the engine's horsepower and can enhance overall fuel economy.

It is assumed here that improved accessories will achieve 50 percent market penetration by 1985 and 100 percent by 1995. This study assumes a 2 percent gain in fuel economy at an increase in consumer cost of $16 per vehicle. Again, no impact on vehicle maintenance costs is anticipated.

Reduced Rolling Resistance

Market Penetration 1985	Market Penetration 1995	Fuel Economy Improvement	Purchase Cost Increase	Maintenance Cost Increase	Capital Investment (In millions)
50%	100%	2%	$26	None	$78

Rolling resistance--the energy lost to friction between the tires and road surface, and between wheels and brake linings--can be overcome by various means. Measures to lessen rolling resistance include reducing "tire stress" (by means of decreased vehicle weight, increased tire pressure, and larger tires), improving tire design (through use of radial ply construction and improved rubber), and reducing "brake drag" (the friction from contact between the brake linings and wheels when the brake is not in use).

A significant fuel-economy gain can be achieved by using radial tires in place of bias belted tires. Radial tires are already standard equipment on 82 percent of all domestic new cars and are expected to be standard equipment on all vehicles by 1985. 34/ Post-1985 reductions in rolling resistance will be limited to reductions in brake drag and marginal improvements in tire design.

This study estimates potential post-1985 fuel-economy improvements of 2 percent for reduced brake drag and improved tire design, at an incremental cost increase of $26 to consumers. Market penetration of these measures to overcome rolling resistance is estimated at 50 percent by 1985 and 100 percent by 1995. No impact on vehicle maintenance costs is anticipated.

CUMULATIVE FUEL ECONOMY EFFECTS OF EXISTING TECHNOLOGIES

CBO estimates that widespread market penetration of the 12 technologies reviewed above could improve the average new car fuel economy by 26.9 percent over the 1985 fleet. This improvement would raise lifetime vehicle costs to the consumer by $600 to $654 per car (see Table 1).

The 1985 market penetration estimates summarized in Table 1 would result in a new car fuel-economy level of approximately 27.5 to 31 mpg. A 26.9 percent improvement in fuel economy resulting from the widespread market penetration of the 12 technologies would thus increase the average fuel economy of the new car fleet to 35 to 40 mpg by 1995.

34/ Energy and Environmental Analysis, Inc., DOE/Faucett Model, p. 2-51.

FURTHER MARKET SHIFTS TO SMALL CARS

Continued market shifts toward smaller, more fuel-efficient cars, precipitated by future increases in gasoline prices, could have sizable effects on the fuel economy of post-1985 cars. This section estimates the effect that gasoline prices may have on the sales of vehicles in each size class and the implications of this effect for average new car fuel-economy levels. A review of the market experience over the past decade should help define the level of demand for more fuel-efficient cars and develop some estimates concerning the future distribution of new car sales and the resulting impact on average fleetwide fuel-economy levels.

Sales records from the last 10 years show that new car sales have made two rather distinct adjustments with respect to car size. Substantial shifts followed the large embargo-caused increases in gasoline prices during 1973-1974, and further shifts occurred when fuel prices took another substantial jump late in 1979 (see Table 2). In both instances, the market share of small cars (that is, compacts and subcompacts) grew. Although it is often argued that the 1973-1974 shift in market shares was transitory, and that large cars subsequently regained their hold on the market 35/, new car sales trends over the last 10 years indicate that the market share captured by small cars has increased substantially relative to the share held by full-size cars and that these patterns have been sustained. Although these shifts may be attributed in part to a decline in household size, changing consumer tastes, and increases in the number of two-car households (in which one car generally is small), fuel prices appear nonetheless to have been a leading cause.

If the real price of gasoline continues to rise--and most projections now assume that it will--consumers are likely to continue switching to smaller, more fuel-efficient cars. From the consumers' standpoint, however, further improvements in the fuel economy of larger cars will partially offset increases in the real price of gasoline. As fuel efficiency improves, a given increase in the real price of gasoline will have less impact on the consumer in terms of cost per mile traveled; the effect may therefore be a lower rate of shifting between size classes. Similarly, future market shifts

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35/ Statement of General Motors Corporation to the Senate Select Committee on Small Business, presented by W.R. Brush, Washington, D.C. (April 21, 1980), p. 3; and "Ford Needs Better Ideas--Fast," Fortune Magazine (June 16, 1980), p. 83.

TABLE 1. CBO ESTIMATES OF FUTURE FUEL ECONOMY IMPROVEMENTS AND COSTS OF TWELVE EXISTING TECHNOLOGIES

Technology	Percent Market Penetration			Percent Improvement in Fuel Economy	
	1985	1995	Increase from 1985 to 1995	Per Vehicle b/	Average Vehicle
Weight Reduction					
Material substitution	50	100	50	4	2.0
Front-wheel drive	80	100	20	12	2.4
Downsizing	60	80	20	10	2.0
Four-Speed Automatic Transmission	27	54	27	6	1.6
Electronic Controls c/	5	25	20	15	3.0
Diesel Engine	7	30	23	15	3.5
Stratified Charge Engine	0	12	12	15	1.8
Turbocharger	7	30	23	10	2.3
Lubricants	20	70	50	3	1.5
Aerodynamics	60	100	40	5	2.0
Accessories	50	100	50	2	1.0
Rolling Resistance	50	100	50	2	1.0
Total					26.9 e/

(Continued)

SOURCE: Congressional Budget Office.

a/ Maintenance costs are pro-rated on a per-mile basis (unless otherwise noted) and discounted at a 10 percent annual rate.

b/ Estimates for mutually exclusive technologies are not additive. For example, estimates for the diesel engines are not additive since these technologies cannot both be applied to the same vehicle. On the other hand, the benefits and costs of a major reconfiguration program could be determined by adding the estimated fuel-economy and cost increases for several programs, including material substitution, front-wheel drive, and aerodynamics. Based on the estimated costs and benefits summarized above, a major reconfiguration program would result in a fuel-economy gain of

Consumer Cost Increases (1980 dollars)				
In Initial Vehicle Cost		In Maintenance Costs a/		
Per Unit b/	Average Vehicle	Per Unit	Average Vehicle	Total for Average Vehicle Lifetime
131	66	0	0	66
166	33	0	0	33
146	29	0	0	29
198	53	36	10	63
179	36	0	0	36
679	156	0	0	156
679	81	0	0	81
332	76	112 d/	26 d/	102 d/
1 to 15	1 to 8	9 to 103	5 to 52	6 to 60
17	7	0	0	7
16	8	0	0	8
26	13	0	0	13
	559 to 566		41 to 88	600 to 654

approximately 21 percent at an incremental vehicle cost of $314. This is reasonably consistent with GM's X-car experience, the Chevrolet Citation having a fuel economy of 18 percent and cost increment of $282 over the Chevrolet Nova, which it replaced. (Energy and Environmental Analysis, Inc., Technological/Cost Relations to Update DOE/Faucett Model: Draft Final Report, October 1979, pp. 2-75 and 2-76.)

c/ Only includes variable valve selector for the post-1985 period.

d/ Maintenance costs of the turbocharger are incurred in year six of the vehicle's life.

e/ Percentages are compounded (multiplied) to total 26.9 percent.

TABLE 2. MARKET SHARES OF NEW CAR SALES BY SIZE CLASS, SEASONALLY ADJUSTED: APRIL 1970-MARCH 1980

Sales Period	Size Class (In percents) Small	Inter-mediate	Full	Total Sales (In millions of units)	Gasoline Prices (1980 dollars)
4/70-9/70	36.8	22.5	40.7	4.40	0.722
10/70-3/71	41.3	19.7	39.0	4.33	0.709
4/71-9/71	40.2	19.1	40.7	5.03	0.683
10/71-3/72	38.2	21.5	40.3	5.33	0.683
4/72-9/72	38.5	21.6	39.8	5.38	0.670
10/72-3/73	39.6	22.3	38.1	6.10	0.687
4/73-9/73	42.2	22.5	35.3	5.71	0.688
10/73-3/74	48.5	22.7	28.8	4.91	0.765
4/74-9/74	47.7	25.2	27.0	4.65	0.850
10/74-3/75	54.3	22.0	23.8	4.00	0.786
4/75-9/75	52.5	24.5	23.0	4.19	0.814
10/75-3/76	48.4	25.9	25.7	4.94	0.809
4/76-9/76	49.0	26.1	24.9	4.96	0.799
10/76-3/77	45.3	29.6	25.2	5.42	0.804
4/77-9/77	47.7	26.8	25.5	5.57	0.801
10/77-3/78	48.7	27.2	24.1	5.52	0.785
4/78-9/78	47.5	28.6	23.9	5.77	0.770
10/78-3/79	51.5	24.9	23.6	5.82	0.803
4/79-9/79	57.1	23.0	19.9	5.28	0.971
10/79-3/80	60.6	21.4	18.0	4.93	1.140

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis.

will probably reflect greater consumer resilience to gasoline price increases, since the most price-sensitive consumers will already have switched. The remaining buyers of large cars are likely to be less responsive to gasoline price rises.

By 1995, the price of gasoline (expressed in 1980 dollars) could easily climb to $2.05 per gallon. Consumers are likely to respond by continuing to elect to buy smaller, more fuel-efficient cars, albeit at a slower rate than has been observed in the past. With gasoline costs at $2 per gallon, CBO projects that the market share of 58 percent that small cars commanded in

1979 would rise to 71 percent. The 23 percent held by intermediate-size cars would fall to 17 percent. And large cars, holding 19 percent of the market in 1979, would drop to just 12 percent of the new car fleet. Such a pattern would imply additional gains in the fuel economy of the new car fleet, averaging approximately 1 mpg. In addition to these shifts between size classes, downward shifts within each size class could yield an improvement in fuel economy of at least half this magnitude. Thus, market shifts to smaller, more fuel-efficient autos could improve the average fuel economy of the new car fleet by an additional 1.5 to 2 mpg over the estimated 1995 average of 35 to 40 mpg.

FEASIBILITY OF ATTAINING AN AVERAGE FUEL ECONOMY LEVEL OF 40 MPG BY 1985

Increased market penetration of the current technologies reviewed in this chapter, coupled with continued market shifts, could raise the average fuel economy of the new car fleet to a minimum of 37 to 42 mpg by 1995. This estimate represents a base level of potential fuel-economy improvements, since it only accounts for the increased use of existing technologies. Further improvements in automotive fuel economy are likely to occur as rising fuel prices and consumer demand for fuel-efficient autos stimulate additional technological innovations. At a minimum, an average fuel-economy level of 40 mpg appears technologically achievable by 1995.

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CHAPTER III. BENEFITS AND COSTS OF IMPROVED AUTOMOTIVE FUEL ECONOMY

Continued improvements in automotive fuel economy could yield substantial savings to consumers, as well as a significant reduction in the nation's petroleum consumption. This chapter evaluates the cost savings that could accrue to consumers and compares them with the increases in lifetime vehicle costs generated by fuel-saving technologies. The benefits of improving the average new fleet fuel economy to 40 mpg are also evaluated in terms of national petroleum consumption levels.

SAVINGS TO CONSUMERS

Increased market penetration of the fuel-saving technologies reviewed in Chapter II could yield substantial savings to consumers. In order to estimate the magnitude of these savings, it is useful to contrast a base 1985 vehicle (rated at 27.5 to 31 mpg) with one equipped with these technological improvements. Unless otherwise noted, the calculations in this chapter are based on the assumption that the average passenger car is driven 100,000 miles over its lifetime. 1/ The actual on-road fuel-economy performance of the average car was assumed to be 80 percent of the EPA mileage rating. 2/ Benefit calculations were based on a hypothetical fuel price of

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1/ The estimated vehicle miles per year is based on U.S. Department of Transportation, Cost of Owning and Operating Automobiles and Vans, 1979.

2/ All calculations assume that on-road performance is 80 percent of the EPA mileage rating, roughly consistent with estimated on-road performance during recent years. The 1976-1979 new car fleets had the following average estimated EPA composite fuel economies: in 1976-17.5 mpg; 1977, 18.3 mpg; 1978, 19.6 mpg; 1979, 20.1 mpg. The estimated in-use fuel economy of the 1976-1979 fleets were: 1976, 14.1 mpg (80.6 percent of the EPA estimate); 1977, 14.7 mpg (80.3 percent of the EPA estimate); and 1978, 15.8 mpg (80.6 percent of the EPA estimate). Preliminary data indicate that the in-use fuel economy of the model year 1979 fleet was in the range of 15.7 to 17.2 mpg (approximately 81.8 percent of the EPA estimate.) Data based on EPA, Passenger Car Fuel Economy: EPA and Road, Draft Report to the Congress (January 1980).

$2.05 per gallon. 3/ A 15 percent discount rate was assumed in order to express future benefits in terms of their present value. 4/

Increased market penetration of current technologies could improve the fuel economy of an average new car by an estimated 26.9 percent (7.5 to 8.5 mpg) at an additional lifetime cost of $600 to $654 per vehicle. 5/ The improved vehicle rated at 35 to 40 mpg could, however, save the consumer something in the range of $1,045 to $1,174 in lifetime fuel costs, resulting in net savings between $445 and $520 per car. These estimates vary depending

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3/ See CBO, Technical Note: Preliminary Projections of Fuel Savings and Revenues Associated with Increased Taxes on Motor Fuels (December 1979). The $2.05 per gallon fuel cost estimate represents a composite price for both gasoline and diesel fuel.

4/ Costs and benefits that occur in the present are usually regarded as relatively more important than costs and benefits expected to occur in future. The 15 percent discount rate is therefore used to convert (or discount) future benefits into their current worth as a lump sum available today. The 15 percent discount rate is a real rate of discount--that is, it assumes that the inflation rate is zero. (The nominal discount rate incorporates the rate of inflation and the real discount rate.) The 15 percent rate is an usually high discount rate and therefore results in a very conservative valuation of future benefit streams. Such a high discount rate was chosen because there is evidence that consumers may place comparatively little value on future fuel cost savings.

5/ This estimate overstates the cost of improved fuel economy, since the full costs of the individual technologies are allocated to the fuel-economy improvement program. A portion of these costs should rightfully be allocated to emissions control. For example, the PROCO engine currently being developed results in approximately the same fuel-economy benefits as the diesel engine (see Chapter II). The stated advantage of the PROCO engine is, however, its clean burn characteristics that result in lower pollutant emission levels. It therefore follows that at least some portion of the PROCO engine's costs should be attributed to emissions control rather than fuel economy. Similarly, the turbocharger, when coupled with the diesel engine, apparently yields some benefits in terms of emissions control. Thus, a portion of the turbocharger costs should rightfully be ascribed to emissions control.

on future fuel prices, vehicle use rates, and the relationship between the mileage rating and on-road performance. Despite differing assumptions and the resulting variation in calculations, however, the estimated savings are of notable magnitude.

Because such a long-run forecast is subject to many uncertainties, it is helpful to test how sensitive this projected lifetime saving is to the particular cost and performance assumptions on which it is based. For example, so long as fuel prices exceed $1.28 per gallon, the savings in fuel costs invariably outweigh the costs of the technological improvements (computed at $654). Likewise, even if a vehicle is driven only 75,000 miles over a 10-year period, the improved fuel economy would still result in net savings to the consumer of approximately $66 to $206. CBO also constructed a "pessimistic", or conservative, analysis of the potential fuel-economy improvements and incremental costs associated with the given technologies by taking the lowest estimated fuel-economy improvement and the highest estimated vehicle costs (including initial purchase and maintenance costs) from the various study estimates summarized in Appendix B (see also Table 3). Under these assumptions, the average fleet fuel-economy rating increases by 17.6 percent at an average cost of $764 per vehicle. The fuel savings associated with the 17.6 percent improvement are estimated at $806 over the life of the vehicle, resulting in a net benefit of $42 per vehicle. Thus, even given these conservative assumptions, the saving in fuel costs over the life of the average car justify the increase in lifetime costs.

In evaluating the benefits of improved fuel economy, however, it is important to recognize that each additional mile-per-gallon improvement results in less fuel savings (and hence fewer benefits) than the preceding mile-per-gallon improvement. For example, improving fuel efficiency from 27.5 to 28.5 mpg (obviously, an improvement of one mpg) results in fuel savings of 128 gallons over the life of the average vehicle. By comparison, one-mpg improvement from 30.5 to 31.5 mpg produces total savings of only 104 gallons over the average vehicle life. Improving fuel efficiency from 37.5 to 38.5 mpg results in savings of only 69 gallons. The declining benefits of each incremental improvement in fuel efficiency are reflected in Table 4.

The above calculations of net savings are based on a comparison of total lifetime vehicle costs and benefits resulting from an improvement of 7.5 to 8.5 mpg above the base example. These calculations assume that on-road performance equals 80 percent of the official EPA vehicle mileage rating. They do not, however, account for the diminishing mile-per-gallon benefit of incremental fuel-economy improvements. It is also important to evaluate the incremental benefits and costs of each fuel-economy improvement.

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TABLE 3. CBO'S CONSERVATIVE ANALYSIS OF FUEL ECONOMY BENEFITS AND COSTS, BY TECHNOLOGY: 1985-1995

	(In percents)			Cost Increases to Consumer (In 1980 dollars)				
	Increased Market	Improvements in Fuel Economy		Initial		Maintenance		Total Increase in Lifetime
Technology	Penetration 1985-1995	Per Car	New Car Fleet	Per Car	Average Car	Per Car	Average Car	Costs per Average Car
Weight Reduction								
Material substitution	50	3.0	1.5	95	48	0	0	48
Front-wheel drive	20	12.0	2.4	166	33	0	0	33
Downsizing	20	8.0	1.6	166	33	0	0	33
Four-Speed Automatic Transmission	27	5.0	1.4	210	57	36	10	67
Electronic Controls	20	5.0	1.0	179	36	0	0	36
Diesel Engine	23	10.0	2.3	878	202	227	52	254
Stratified-Charge	12	8.0	1.0	386	46	0	0	46
Turbocharger	23	4.0	0.9	552	127	112	26	153
Improved Lubricants	50	2.0	1.0	27	14	103	52	66
Improved Aerodynamics	40	3.0	1.2	17	7	0	0	7
Improved Accessories	50	2.0	1.0	16	8	0	0	8
Rolling Resistance	50	2.0	1.0	26	13	0	0	13
Total			17.6		624		140	764

SOURCE: Congressional Budget Office.

TABLE 4. INCREMENTAL FUEL ECONOMY IMPROVEMENT BENEFITS PER VEHICLE

MPG Rating			On-Road Performance at 100 Percent of EPA Rating		On-Road Performance at 80 Percent of EPA Rating	
Base	Improved Mileage	Improvement	Lifetime Fuel Saving (In gallons) a/	Discounted Savings (In Constant 1980 dollars) b/	Lifetime Fuel Savings (In gallons) a/	Discounted Savings (In Constant 1980 dollars) b/
27.5	28.5	1.0	127.6	153.8	159.5	192.2
28.5	29.5	1.0	118.9	143.3	148.6	179.2
29.5	30.5	1.0	111.1	134.1	138.9	167.5
30.5	31.5	1.0	104.1	125.3	130.1	156.9
31.5	32.5	1.0	97.7	117.8	122.1	147.2
32.5	33.5	1.0	91.8	110.7	114.8	138.3
33.5	34.5	1.0	86.5	104.1	108.1	130.4
34.5	35.5	1.0	81.7	98.4	102.1	123.0
35.5	36.5	1.0	77.2	93.0	96.5	116.3
36.5	37.5	1.0	73.0	88.2	91.3	110.1
37.5	38.5	1.0	69.3	83.5	86.6	104.4
38.5	39.5	1.0	65.7	79.2	82.1	99.0

SOURCE: Congressional Budget Office.

a/ Assumes 100,000 vehicle miles over a 10-year lifetime.

b/ Assumes price of gasoline at $2.05 per gallon and discount rate of 15 percent.

The cost of each mile-per-gallon improvement in fuel economy will vary considerably according to which technology is used to achieve the given improvement. Thus, any analysis of the costs and benefits of incremental improvements must necessarily deal with one technology at a time. Table 5 summarizes the net benefits resulting from the application of each technology to a base 27.5 mpg vehicle. When applied to a vehicle rated at 27.5 mpg, each of the technologies results in positive net benefits to the consumer ranging from $11 to $115 over the average vehicle life. In contrast, when these same technologies are applied to attain the last increment of fuel economy necessary to bring the new fleet average to 40 mpg, several of the technologies do not appear cost effective (see Table 6). The costs of the diesel engine, the stratified-charge engine (PROCO), and the turbocharger appear to exceed their benefits at the 40 mpg level. Moreover, innovative technologies to be developed during the next 15-year period are likely to be more costly than current technologies and hence less cost-effective at the 40 mpg level.

TABLE 5. COST EFFECTIVENESS OF INDIVIDUAL TECHNOLOGIES AT THE 27.5 MPG LEVEL

Technology	Percent Improvement in Fuel Economy of Average Car	Average Mileage of Improved Car a/	(In constant 1980 dollars) Average Lifetime Fuel Cost Savings	Average Increase in Lifetime Costs	Net Benefit
Weight Reduction					
Material substitution	2.0	28.1	122	66	56
Front-wheel drive	2.4	28.2	145	33	112
Downsizing	2.0	28.1	122	29	93
Four-Speed Automatic Transmission	1.6	27.9	74	63	11
Electronic Controls	3.0	28.3	145	36	109
Diesel Engine	3.5	28.5	192	156	36
Stratified-Charge Engine	1.8	28.0	98	81	17
Turbocharger	2.3	28.1	122	102	20
Improved Lubricants	1.5	27.9	74	6 to 60	14 to 68
Improved Aerodynamics	2.0	28.1	122	7	115
Improved Accessories	1.0	27.8	49	8	41
Rolling Resistance	1.0	27.8	49	13	36

SOURCE: Congressional Budget Office.

a/ Assumes each technology is applied to a base vehicle rated at 27.5 mpg.

These estimates do, however, appear to understate the net benefits of the various technologies. Several factors are likely to improve the cost effectiveness of the individual technologies in future years. These factors include:

- o Further increases in fuel prices (beyond the assumed \$2.05 per gallon),
- o More intensive use of individual cars,
- o Reductions in manufacturing costs, as market penetration increases and production efficiencies are realized, and
- o More accurate allocation of technology costs to other program goals, particularly emissions control.

The first two of these factors would increase the benefits to the consumer. The cost effectiveness of the technologies is, in fact, highly dependent on future gasoline prices and vehicle use rates. The benefits of the individual technologies would be significantly enhanced if gasoline prices were to exceed the projected \$2.05 per gallon cost. If the price of gasoline were to climb to \$2.50, each of the current technologies would become cost effective at the 40 mpg level. Likewise, cars that are used more intensively (that is, driven more than 100,000 miles over a 10-year span) would accumulate greater fuel savings, thereby enhancing the cost effectiveness of the individual technologies. For instance, the diesel engine becomes cost effective at 110,500 miles. 6/ Those consumers who drive a great deal more than average, thus accumulating larger fuel cost savings over the life of their cars, would benefit from the application of these three technologies.

Alternatively, the cost effectiveness of the individual technologies could be significantly improved by reductions in unit costs. As the market penetration of the individual technologies increases and production efficiencies are enhanced, economies of scale that result in lower unit costs may be realized. Moreover, the estimates presented in Table 6 may, in some instances, overstate the additional consumer costs attributable to improved fuel economy. As noted previously, some portion of the costs of both the turbocharger and the stratified-charge engine should rightfully be attributed to emissions control rather than fuel economy (see Footnote 5 in this

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6/ Assumes the additional miles are driven during the first year of the vehicle's life.

TABLE 6. COST EFFECTIVENESS OF INDIVIDUAL TECHNOLOGIES AT THE 40 MPG LEVEL

Technology	Percent Improvement in Fuel Economy of Average Car	Average Mileage of Base Car	(In constant 1980 dollars) Average Lifetime Fuel Cost Savings a/	Average Increase in Lifetime Costs	Net b/ Change
Weight Reduction					
Material substitution	2.0	39.2	71	66	+5
Front-wheel drive	2.4	39.1	84	33	+51
Downsizing	2.0	39.2	71	29	+42
Four-Speed Automatic Transmission	1.6	39.3	71	63	+8
Electronic Controls	3.0	38.8	121	36	+85
Diesel Engine	3.5	38.6	134	156	-22
Stratified-Charge Engine	1.8	39.3	71	81	-10
Turbocharger	2.3	39.1	84	102	-18
Improved Lubricants	1.5	39.4	60	6 to 60	0 to +54
Improved Aerodynamics	2.0	39.2	71	7	+64
Improved Accessories	1.0	39.6	37	8	+29
Rolling Resistance	1.0	39.6	37	13	+24

SOURCE: Congressional Budget Office.

a/ Each technology improves the fuel economy of the base vehicle to 40 mpg.

b/ Plus sign indicates a net benefit; minus sign indicates a net cost.

chapter). Thus, if only 12 percent of the PROCO engine's costs and 18 percent of the turbocharger's costs were attributed to emissions control, then their fuel-economy benefits at the 40 mpg level would justify the additional vehicle costs.

NATIONWIDE REDUCTIONS IN PETROLEUM CONSUMPTION

Improved automotive fuel economy by means of existing technologies would ultimately lead to significant reductions in the nation's petroleum consumption. The full benefits of improved fuel economy would only be fully realized in the long run, however. Since, in any given year, less than 10 percent of all cars on the road are new, at least a decade must elapse before the cumulative conservation resulting from recently introduced technologies has a significant nationwide impact.

Reductions in national energy consumption would be substantial after the improved 40 mpg vehicles are fully phased in. Following the ten or so years needed to establish a 40 mpg fleet, approximately 1.1 million barrels less oil would be consumed per day relative to a fleet averaging 27.5 mpg. 7/ Gasoline consumption by automobiles is currently running at about 5 million barrels per day. This consumption rate is expected to decline through 1990 as new fuel-efficient vehicles are phased into the fleet. Price-related slowdowns in travel growth are also expected to contribute to a reduction in fuel use. Recent estimates indicate that gasoline use by autos during 1990 will total 4.4 million barrels per day. 8/ Fuel consumption may very well increase during the 1990s, however, as travel growth overtakes improvements in fuel economy. Thus, the projected fuel savings of 1.1 million barrels would total approximately 20 to 25 percent of base consumption levels by a 27.5 mpg fleet.

7/ Assumes new car sales increase by 1 percent per year from 12.5 million in 1995 to 13.8 million in 2005. So-called "scrappage rates" are based on U.S. Department of Transportation estimates contained in "Factors Influencing Automotive Fuel Demand," prepared by Energy and Environmental Analysis, Inc. for U.S. Department of Energy, February 6, 1979. Travel rates per vehicle are assumed to remain constant over the 10-year period and are based on U.S. Department of Transportation, Cost of Owning and Operating Automobiles and Vans, 1979. On-road fuel economy performance is assumed to equal 80 percent of EPA-estimated mileage.

8/ See Congressional Budget Office, Preliminary Projections of Fuel Savings.

CHAPTER IV. CAPITAL INVESTMENT REQUIREMENTS OF POST-1985 FUEL ECONOMY IMPROVEMENTS

Considerable concern has been expressed regarding the domestic auto industry's ability to sustain the level of capital investment necessary to convert the domestic new car fleet to more fuel-efficient vehicles. This chapter estimates the capital costs of improving the average fuel economy of new cars after 1985 and examines the industry's ability to sustain the level of investment needed.

Estimating the capital costs and investment levels necessitated by post-1985 fuel-economy improvements raises a basic definitional problem--namely, what portion of the industry's capital investment should be attributed to fuel-economy improvements? Should any capital investment that results in a fuel-economy improvement be identified as a fuel-economy cost? Or should only those extraordinary capital costs incurred specifically for fuel-economy improvements be so identified? An illustrative example follows. An auto manufacturer invests in tooling equipment expected to last three years, after which the equipment will have to be replaced. When replacement time comes, however, the manufacturer faces the need to upgrade the fuel economy of its new cars (whether in response to consumer demand or government regulations). The phased-out tooling is therefore replaced with equipment that produces more fuel-efficient components. The question then arises--how should the cost of the new equipment be categorized? Should the entire cost be ascribed to fuel economy? Should the expense be regarded simply as a normal capital replacement cost? Or should the cost of fuel economy be identified as the difference between replacing the obsolete equipment with identical tooling and replacing it with tooling that produces more fuel-efficient cars?

This problem is reflected in various capital cost estimates of improved fuel economy. In 1979, GM reported that each one-half mile-per-gallon improvement in the corporation's average new car fleet fuel economy has cost approximately $1 billion. 1/ If this figure is extrapolated and

1/ General Motors Corporation, General Motors Progress in Fuel Economy (November 15, 1979). This cost estimate is assumed to be in nominal dollars.

applied to the period 1974-1980, when GM's average new car fuel economy improved from 12 mpg to better than 21 mpg, then GM's investment in fuel economy appears to total some $18.8 billion. GM's worldwide capital spending for the years 1974-1979 totaled $20.7 billion (in nominal dollars). This implies that GM is attributing virtually its entire capital spending program (both domestic and foreign) over the last six years to improving fuel economy. (The company recently stated, however, that approximately $3.3 billion of its total 1979 capital expenditures of $5.4 billion reflected normal capital replacement costs. 2/) For the industry as a whole, capital expenditures for the period 1975-1979 totaled $31.1 billion (in nominal dollars). At the same time, however, there have been reports that spending for fuel-economy improvements to bring the new car fleet from 14 mpg in 1975 to 20 mpg in 1980 totaled $30 billion. 3/ Again, the industry's entire capital spending program (both domestic and foreign) has apparently been attributed to fuel economy.

CBO addresses this issue by assuming that only extraordinary capital costs (above normal capital replacement) should be identified as the costs of improving fuel economy. This chapter estimates the industry's normal capital investment levels net of increases associated with improved fuel economy. The capital costs of manufacturing fuel-efficient technologies during the post-1985 period, and the portion of these costs that can be accommodated within the industry's normal capital investment cycle, are then assessed. The increase in capital investment necessitated by post-1985 fuel-economy improvements is thereby estimated. The first section of the chapter examines the industry's normal capital investment levels. The second section presents the capital costs of necessary tooling, plant, and equipment to produce the technologies reviewed in Chapter II. The third section estimates the portion of these capital costs that can be accommodated within the industry's base investment levels, thereby determining the total capital investment levels necessary to sustain manufacturers' production levels (including the production of fuel-efficient technologies). The final section briefly reviews the industry's current financial status and its ability to support the necessary level of capital investment.

2/ General Motors Corporation, Economic Issues and Alternatives Associated with the Fuel Economy Program (February 1, 1979), Exhibit 1. This cost estimate is assumed to be in 1979 dollars.

3/ See, for example, "U.S. Autos Losing a Big Segment of the Market--Forever," Business Week, March 24, 1980, p. 80.

BUSINESS-AS-USUAL CAPITAL INVESTMENT

In 1971 and 1972, before the OPEC oil embargo, capital expenditures by the U.S. auto industry averaged approximately $5.9 billion a year (see Table 7). Given that this period predates the massive downsizing program at GM as well as the post-embargo fuel-efficiency improvement programs of other manufacturers, it provides a rough index of "business-as-usual" investment levels without the sharp increases stimulated by rising gasoline prices and fuel-economy standards. The $5.9 billion estimate does not, however, account for any increase in production capacity during the 1971-1979 period, when worldwide sales by the U.S. manufacturers increased by approximately 10 percent from an annual average of 15.6 million in 1971 and 1972 to 17.1 million cars in 1979. Assuming a constant relationship between capital investments and total sales, the base level of normal, ongoing capital expenditures for 1979 is therefore estimated at $6.5 billion (10 percent greater than the 1971-1972 expenditure level of $5.9 billion). This estimate is consistent with a statement by GM indicating that the company's expenditures for normal capital replacement and repairs totaled approximately $3.6 billion in 1979. 4/ Extrapolating GM's rate of investment per vehicle sold, the total U.S. auto industry as a whole invested an estimated $6.8 billion in 1979 simply to repair and/or replace existing production capacity. The base level of capital investment net of increases associated with improved fuel economy is therefore estimated at approximately $6.5 to $6.8 billion annually (assuming a production capacity equal to 1979 levels). Any additional capital spending (above $6.8 billion annually) to improve fuel efficiency after 1985 could be categorized as extraordinary.

CAPITAL COSTS OF EQUIPMENT AND FACILITIES TO PRODUCE FUEL EFFICIENT TECHNOLOGIES

CBO has estimated the cost of equipment and facilities to improve new car fuel economy at approximately $44.5 billion (in constant 1980 dollars). Of that sum, roughly $19 billion, or 45 percent, can be attributed to the special tooling costs of manufacturing the 12 technologies reviewed in Chapter II (see Table 8). The remaining $25.5 billion reflects the cost of land, plant, and heavy machinery such as stamping equipment.

4/ General Motors Corporation, Economic Issues and Alternatives, February 1, 1979, Exhibit 1.

TABLE 7. CAPITAL EXPENDITURES BY THE U.S. AUTOMOTIVE INDUSTRY: 1971-1979, In Billions of Nominal and Constant 1979 Dollars

	1971	1972	1973	1974	1975	1976	1977	1978	1979
General Motors									
Nominal dollars	1.60	1.80	2.10	2.60	2.20	2.30	3.60	4.60	5.40
Constant dollars a/	3.06	3.32	3.73	4.16	3.07	3.07	4.53	5.38	5.82
Ford									
Nominal dollars	1.00	1.20	1.50	1.50	1.00	1.10	1.80	2.50	3.40
Constant dollars a/	1.91	2.22	2.67	2.40	1.40	1.47	2.27	2.92	3.66
Chrysler									
Nominal dollars	0.30	0.30	0.60	0.50	0.40	0.40	0.70	0.70	0.70
Constant dollars a/	0.57	0.55	1.07	0.80	0.56	0.53	0.88	0.82	0.75
American Motors									
Nominal dollars	0.03	0.03	0.07	0.10	0.09	0.05	0.05	0.04	0.05
Constant dollars a/	0.06	0.06	0.12	0.16	0.13	0.07	0.06	0.05	0.05
Total									
Nominal dollars	2.93	3.33	4.27	4.70	3.69	3.85	6.15	7.84	9.55
Constant dollars a/	5.60	6.15	7.59	7.52	5.16	5.14	7.74	9.17	10.28

SOURCE: Based on U.S. manufacturers' annual reports.

a/ Based on the implicit price deflator for nonresidential fixed investment.

These capital cost estimates are based on independent studies and industry statements regarding the capital cost of producing the 12 technologies (see Appendix B). For the most part, however, these sources provide only the special tooling costs incurred by the manufacturers and do not account for the costs of buildings, plant, land, and heavy machinery. To allow for these additional costs, CBO assumed expenditures for special tooling to equal 45 percent of total capital expenditures, consistent with the industry's capital spending patterns during the period 1967-1971. This is the basis of the capital cost estimate for each technology presented in Table 8.

These cost estimates appear to be generally consistent with recent industry experience. For example, GM has stated that the 1980 reconfuguration program to build its X-car series cost $1.7 billion. 5/ In the eight months from January through August 1979, 338,393 X-cars were built. 6/ Adjusting this expenditure to account for capital investment flows over time 7/ and an annual production level of 400,000 cars, this redesign program required a capital investment of $1.54 billion (in constant 1980 dollars) per 400,000 autos. This is only slightly less than the estimated capital costs presented in Table 8, which indicate that reconfiguration to front-wheel drive requires a total capital investment of $1.7 billion per 400,000 units ($780 million for tooling and $955 million for plant and equipment). Likewise, GM estimates the tooling cost of its redesigned, full-size 1977 cars (Chevrolet Impala and Caprice, Pontiac Catalina and Bonneville, Buick LeSabre and Electra, Oldsmobile Delta 88 and 98, and Cadillac DeVille and Fleetwood) at approximately $1.1 billion. 8/ Production of

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5/ General Motors Corporation, General Motors Progress in Fuel Economy. This cost estimate is assumed to be in nominal dollars.

6/ Ward's Communications, Inc., Ward's Automotive Yearbook, 1980 42nd Edition, p. 108.

7/ Assumes that capital investment for X-car series extended over a four-year period with 15 percent expended during the first year of model development, 48 percent during the second year, 34 percent during the third year, and 3 percent during the final year. Based on Harbridge House, Inc., Energy Conservation and the Passenger Car: An Assessment of Existing Public Policy (June 1979), p. IV-14.

8/ General Motors' Corporation, General Motors Progress in Fuel Economy. This cost estimate is assumed to be in nominal dollars.

TABLE 8. ESTIMATED CAPITAL COSTS TO AUTO MANUFACTURERS OF TWELVE EXISTING FUEL EFFICIENCY TECHNOLOGIES: 1985-1995

		(In millions of constant 1980 dollars)			
Technology	Percent Increases in Market Penetration	Annual Number of Units a/	Unit Rate of Invest-ment for Tooling	Tooling Costs	Total Capital Costs b/
Weight Reduction					
Material substitution	50	5,313,000	377 per 400,000	5,007.5	11,127.8
Front-wheel drive	20	2,125,000	780 per 400,000	4,143.8	9,208.4
Downsizing	20	2,500,000	700 per 400,000	4,375.0	9,722.2
Four-Speed Automatic Transmission c/	27	2,869,000	270 per 500,000	1,549.3	3,442.9
Electronic Controls d/	20	2,125,000	22 per 350,000	133.6	296.9
Diesel Engine	23	2,444,000	430 per 400,000	2,627.3	5,838.4
Stratified-Charge Engine	12	1,275,000	377 per 350,000	1,373.4	3,052.0
Turbocharger	23	2,444,000	24 per 400,000	146.6	325.8
Improved Lubricants	50	6,250,000	0 e/	0.0	0.0
Improved Aerodynamics	40	4,781,000	0 f/	0.0	0.0

(Continued)

TABLE 8. (CONTINUED)

Technology	Percent Increases in Market Penetration	(In millions of constant 1980 dollars) Annual Number of Units a/	Unit Rate of Invest-ment for Tooling	Tooling Costs	Total Capital Costs b/
Improved Accessories	50	5,313,000	22 per 400,000 g/	h/	292.2
Rolling Resistance	50	6,250,000	78 per 400,000 i/	h/	1,218.8
Total				19,356.5	44,525.4

SOURCE: Congressional Budget Office (based on estimates summarized in Appendix B).

a/ Assumes 1995 new car sales at 12.5 million and market share of imports at 15 percent.

b/ Assumes tooling costs are 45 percent of total capital costs.

c/ Cost of four-speed transmission net of torque converter lock-up.

d/ Variable valve selector only.

e/ Capital costs of improved lubricants are not incurred by the auto manufacturers.

f/ Capital costs of aerodynamics are included under Front-Wheel Drive and Downsizing.

g/ Total capital costs based on GM's February 1979 statement regarding past experience in developing lighter, more efficient air conditioners.

h/ Tooling costs are subsumed under total capital costs.

i/ Total capital costs based on GM's February 1979 statement. Accounts for costs of changing suspension systems to accommodate higher pressure tires. (GM's 1980 full-size cars required an investment of nearly $2.5 million for 400,000 units.) Also includes $75.5 million for modifications to reduce fuel economy losses associated with disc brake design.

these models totaled 1,793,455 in 1977. 9/ The tooling cost of this weight reduction program (again adjusted for production levels and investment flows) totaled an estimated $345 million (in constant 1980 dollars) per 400,000 units, which roughly equals the tooling cost estimate for a major material substitution program presented in Table 8 ($377 million per 400,000 units).

The capital cost of achieving a 28.2 percent improvement in fuel economy during the 1985-1995 period is estimated at $44.5 billion. Post-1985 improvements in automotive fuel economy will not, however, require a total incremental increase of $44.5 billion over the industry's normal capital investment levels. As noted above, some share of the capital requirements of improving fuel economy can be absorbed in the manufacturers' normal, business-as-usual capital replacement cycle, thereby offsetting the incremental increases above normal capital investment levels. The following section estimates the incremental increase above business-as-usual investment levels necessitated by further improvements in fuel economy.

EFFECTS OF FUEL-EFFICIENCY SCHEDULING ON TOTAL CAPITAL EXPENDITURE PATTERNS

Manufacturers' ability to absorb the capital costs of post-1985 fuel-economy improvements in their normal capital investments will depend on the rate at which the individual product development programs and accompanying fuel-economy improvements are pursued. Accelerating product development programs substantially increases capital requirements.

Domestic auto manufacturers have already accelerated their product development programs dramatically. For example, in 1978, Ford reported plans to launch 22 major new North American product development programs from 1978 through 1985, in contrast to just six over the previous eight years. These programs will necessitate the introduction of one new engine per year from 1980 to 1984, compared with one every 2.4 years between 1968 and 1980; the company will also have to introduce one new transmission per year, compared with one every four years during the preceding 15 years. 10/ Ford's capital investment requirements during the period 1980-1985 will undoubtedly reflect this extreme acceleration in product development.

9/ Ward's Communications, Inc., Ward's Automotive Yearbook, 1980, 42nd Edition, p. 108.

10/ Ford Motor Company, Annual Report 1978, p. 3.

The experience of the last several years indicates the extent to which the capital costs of improving fuel economy can be accommodated within the industry's normal capital replacement cycle. Since 1973, the auto industry has invested a total of $7.9 billion (in constant 1980 dollars) above normal, business-as-usual capital expenditures. Although it is impossible to isolate completely the causes of these extraordinary expenditures (a portion of which may reflect costs of safety features and emissions control, as well as productivity improvements), much of this $7.9 billion increase is probably attributable to fuel-economy improvements. Furthermore, although capital spending in 1975 and 1976 was below normal annual rates (reflecting deferred investment resulting from the economic recession), investment levels during those two years probably would have been substantially lower if extraordinary fuel-economy expenditures could have been deferred. The extraordinary capital expenditures attributable to fuel economy are therefore estimated at $13.1 billion for the period 1973-1979 (see Table 9).

Similarly, the industry now plans to spend some $66.2 billion (in nominal dollars, or $58.0 billion in constant 1980 dollars) during the 1980 through 1984 period. The industry's planned expenditures represent a total incremental increase of $24.0 billion over the base capital investment rate of $6.8 billion annually (see Table 10).

The extraordinary capital investment required to attain the mandated 1985 fuel-economy standard of 27.5 mpg is therefore estimated at $37.1 billion ($13.1 billion for the period 1973-1979 and $24.0 billion for 1980-1984). This figure is less than half the estimated $85 billion cost of tooling, plant, and equipment to attain the projected 1985 market penetration levels of the 12 technologies reviewed in Chapter II (see Table 11). The remaining $48 billion in tooling and equipment costs is absorbed within the industry's ongoing capital replacement program, which lowers the incremental increase in capital spending over normal investment levels. Approximately 60 percent of the industry's base expenditures during the period 1973-1984 contribute to improved fuel economy, while approximately 40 percent is devoted to normal maintenance and capital replacement requirements with no accompanying fuel-economy benefit.

Extrapolating from the industry's past investment patterns, CBO estimates the average annual capital investment requirements for the 1985-1994 period at approximately $7.85 billion. 11/ This investment level would

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11/ This estimate assumes that 50 percent of the industry's base expenditures during the 1985 to 1994 time period will contribute to improved fuel economy while 50 percent will be devoted to normal maintenance (Continued)

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TABLE 9. EXTRAORDINARY AUTO INDUSTRY CAPITAL SPENDING: 1971-1979, In Billions of Constant 1980 Dollars

	Annual Average 1971-1972	1973	1974	1975	1976	1977	1978	1979	Total 1973 to 1979
Business-as-Usual Expenditure Levels a/	5.9	6.0	6.1	6.3	6.4	6.5	6.6	6.8	44.7
Total Capital Spending	5.9	7.6	7.5	5.2	5.1	7.7	9.2	10.3	52.6
Incremental Change over Business-as-Usual	—	+1.6	+1.4	-1.1	-1.3	+1.2	+2.6	+3.5	+7.9
Increment Assumed Attributable to Fuel Economy	—	+1.6	+1.4	+1.4	+1.4	+1.2	+2.6	+3.5	+13.1

SOURCE: Congressional Budget Office.

NOTE: Plus sign denotes a net increase; minus sign denotes a net decrease.

a/ Assumes constant annual growth rate in production capacity.

raise average fuel economy to something in the range of 37 to 42 mpg by 1995. But market pressures resulting from consumer demand and stiff competition from imports are likely to compel the industry to accelerate production of fuel-efficient cars and to raise the mileage of the domestic fleet to that level by 1990. Thus, the capital costs of improving fuel economy could be incurred in five instead of 10 years, resulting in a far larger incremental increase in expenditures during the late 1980s. Annual capital investments for the 1985-1990 period could then total as much as $12.3 billion. The auto industry's capital investment requirements for the post-1985 period are thereby estimated at $8.0 to $12.5 billion annually.

THE FINANCIAL CONDITION AND CAPITAL CONSTRAINTS OF THE AUTO INDUSTRY

The U.S. auto industry's ability to sustain an $8.0 to $12.5 billion level of capital expenditure over the next 10 to 15 years is unclear. The industry's profits picture has generally declined over the last decade. Profits have fallen steadily from 7.5 percent of sales revenue in 1965 to 3.6 percent in 1979, a drop of more than half. 12/ This situation has been further aggravated by unusually high capital expenditure levels during the late 1970s ($10.3 billion in 1979 for example), necessitated by converting to production of more fuel-efficient vehicles. To illustrate the general decline in the industry's profit and the varying financial strength of each company, Table 12 gives a comparative summary of several indexes of the financial health of each domestic auto manufacturer (as well as for all manufacturing corporations) for the period 1973-1979.

Future capital investment requirements are likely to continue to strain the industry's financial capacity. The auto manufacturers will undoubtedly attempt to secure a maximum amount of the necessary capital

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(continued) and capital replacement requirements, with no accompanying fuel-economy benefit. Thus, the $44.5 billion tooling and equipment costs are absorbed within the industry's base level of investment at a rate of $3.4 billion per year (50 percent of the estimated base investment level of $6.8 billion) over the 10-year period.

12/ Based on annual reports of domestic auto manufacturers. Assumes five-year rolling averages with each year representing the last year of the series.

TABLE 10. PROJECTION OF CAPITAL EXPENDITURES BY U.S. AUTO MANUFACTURERS: 1980-1984; In Billions of Nominal Dollars

	1980	1981	Total 1980 through 1984
General Motors a/	8.10	9.06	40.0
Ford b/	4.05	4.53	20.0
Chrysler c/	1.17	1.31	5.8
American Motors d/	0.08	0.09	0.4
Total Capital Expenditures			
Nominal dollars	13.40	14.99	66.2
Real 1980 dollars e/	13.40	13.88	58.0
Percent Distribution of Total Expenditures over Five-Year Period f/	23.00	24.00	100.0
Increment over Base Spending of $6.8 Billion (Constant 1980 dollars)	+6.6	+7.1	+24.0

NOTE: Plus sign denotes a net increase; minus sign denotes a net decrease.

from internal funding sources, specifically internally generated profit and cash flow. They will probably be forced, however, to turn increasingly toward external funding sources, specifically to stock options and long-term debt issues.

The industry's ability to generate sufficient internal profit and cash flow is limited. To meet future capital needs entirely with internal financing, the industry's must generate an average net income of $9.0 billion each year through 1983 (see Table 13). Net annual income requirements for

TABLE 10. (Footnotes)

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a/ Based on remarks by Thomas A. Murphy, Chairman of General Motors Corporation at GM's 72nd Annual Meeting, May 23, 1980.

b/ Based on Ford's 1979 Annual Report. Ford has recently announced reductions in planned capital spending program.

c/ Based on Chrysler's 1979 Report to Shareholders, which indicated that $7.8 billion in capital expenditures would be for product programs for the 1979-1985 period. Capital expenditures by Chrysler during 1979 totaled approximately $.8 billion in 1979. Therefore, capital expenditures for the six-year period 1980-1985 are estimated at $7.0 billion, one-sixth of which is assumed to be expended in 1985. The total expenditure level for the 1980 through 1984 period is therefore estimated at $5.8 billion.

d/ Based on AMC's capital expenditures over last nine years.

e/ Assumes 8 percent annual inflation rate in implicit price deflator for nonresidential fixed investment.

f/ Distribution of investment flows assumes that capital investment for each model year extended over a four-year period with 15 percent expended during the first year of model development, 48 percent during the second year, 34 percent during the third year, and 3 percent during the year of introduction. Based on Harbridge House, Inc., Energy Conservation and the Passenger Car: An Assessment of Existing Public Policy (June 1979), p. IV-14.

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the post-1985 period would average some $7 to $9.5 billion. (A corporation's net income is the profit after the cost of sales and operating expenses, interest on bonds, and tax payments are deducted from total income. Net income represents the manufacturer's profit before capital expenditures and dividend payments.) These net income requirements are significantly greater than the industry's 1979 level of $3.3 billion. The largest net income realized by the auto industry since 1971 was, in fact, $6.5 billion in 1977 (see Table 14). The industry's ability to finance the necessary rate of capital investment internally will require a substantial increase over current profit levels.

TABLE 11. ESTIMATED CAPITAL COSTS FOR TWELVE FUEL EFFICIENCY TECHNOLOGIES, PERIOD ENDING 1985

Technology	Percent Increases in Market Penetration	Annual Number of Units a/	Unit Rate of Investment for Tooling	Tooling Costs	Total Capital Costs b/
		(In millions of constant 1980 dollars)			
Weight Reduction					
Material substitution	150	9,775,000	c/	c/	c/
Front-wheel drive	80	7,820,000	780 per 400,000	15,249.0	33,886.7
Downsizing					
first round	100	9,775,000	700 per 400,000	17,106.3	38,014.0
second round	60	6,900,000	d/	d/	d/
Four-Speed Automatic Transmission	27	3,105,000	270 per 500,000	1,676.7	3,726.0
Torque Converter Lock-Up	100	9,775,000	38 per 500,000	742.9	1,650.9
Electronic Controls e/	100	9,775,000	86 per 350,000	2,401.9	5,337.6
Diesel Engine	7	684,000	189 per 400,000 f/	323.2	718.2
Stratified-Charge Engine	0	0	377 per 350,000	0.0	0.0
Turbocharger	7	684,000	24 per 400,000	41.0	91.1
Improved Lubricants	50	0	g/	0.0	0.0

(Continued)

TABLE 11. (CONTINUED)

Technology	Percent Increases in Market Penetration	Annual Number of Units a/	Unit Rate of Invest- ment for Tooling	Tooling Costs	Total Capital Costs b/
		(In millions of constant 1980 dollars)			
Improved Aerodynamics	160	5,376,000	c/	c/	c/
Improved Accessories	50	4,888,000	22 per 400,000 h/	i/	268.8
Rolling Resistance	50	5,750,000	78 per 400,000 h/	i/	1,121.3
Total				37,541.0	84,814.6

SOURCE: Congressional Budget Office.

a/ Assumes 1985 new car sales at 11.5 million and market share of imports at 15 percent.

b/ Assumes tooling costs are 45 percent of total capital costs.

c/ Capital costs are subsumed under first round of downsizing.

d/ Capital costs are subsumed under front-wheel drive.

e/ Includes fuel injection, knock limiter, and digital spark control. Does not account for variable valve selector.

f/ Assumes conversion of existing facilities and lines.

g/ Capital costs are not incurred by auto manufacturers.

h/ Total capital costs based on GM's February 1979 statement.

i/ Tooling costs are subsumed under total capital costs.

TABLE 12. FINANCIAL INDEXES FOR U.S. AUTO MANUFACTURERS AND ALL MANUFACTURING CORPORATIONS: 1971-1979

	1971	1972	1973	1974	1975	1976	1977	1978	1979
Net Profit Ratio a/									
General Motors	0.07	0.07	0.07	0.030	0.04	0.06	0.060	0.06	0.04
Ford	0.04	0.04	0.04	0.010	0.01	0.03	0.040	0.04	0.03
Chrysler	0.01	0.03	0.03	-0.005	-0.02	0.03	0.010	-0.02	-0.09
American Motors	0.01	0.02	0.05	0.010	-0.10	-0.02	0.004	0.01	0.03
All Manufacturing Corporations	N/A	N/A	N/A	0.050	0.04	0.05	0.050	0.05	0.06
Return on Equity b/									
General Motors	N/A	N/A	N/A	0.080	0.10	0.23	0.240	0.23	0.17
Ford	N/A	0.16	0.15	0.050	0.05	0.15	0.240	0.19	0.12
Chrysler	0.04	0.10	0.11	-0.020	-0.08	0.14	0.040	-0.07	-0.41
American Motors	N/A	N/A	N/A	0.080	-0.07	-0.13	0.030	0.11	0.23
All Manufacturing Corporations c/	N/A	N/A	N/A	0.150	0.12	0.14	0.140	0.15	0.17
Current Ratio d/									
General Motors	N/A	N/A	2.04	1.910	1.99	1.95	1.920	1.79	1.68
Ford	N/A	N/A	N/A	1.280	1.33	1.37	1.380	1.33	1.25
Chrysler	1.46	1.49	1.55	1.360	1.27	1.37	1.340	1.43	0.97
American Motors	N/A	N/A	1.68	1.430	1.27	1.11	1.200	1.29	1.42
All U.S. Corporations	N/A	N/A	N/A	1.620	1.68	1.68	1.650	1.55	1.54

(Continued)

TABLE 12. (CONTINUED)

	1971	1972	1973	1974	1975	1976	1977	1978	1979
Dividend Payout Ratio e/									
General Motors	0.51	0.59	0.63	1.040	0.56	0.55	0.490	0.49	0.53
Ford	0.40	0.31	0.35	0.910	0.75	0.27	0.210	0.26	0.40
Chrysler	0.36	0.21	0.27	-1.520	0.00	0.04	0.330	-0.24	-0.01
American Motors	N/A	N/A	0.00	0.210	0.00	0.00	0.000	0.00	0.03
Operating Margin of Profit f/									
General Motors	N/A	N/A	0.12	0.050	0.07	0.11	0.110	0.10	0.07
Ford	0.08	0.08	0.07	0.030	0.02	0.06	0.070	0.06	0.02
Chrysler	N/A	N/A	N/A	N/A	N/A	N/A	0.020	-0.02	-0.07
American Motors	N/A	N/A	0.04	0.01	-0.02	-0.01	0.003	0.02	0.03
Quick Assets Ratio g/									
General Motors	N/A	N/A	1.17	0.860	1.11	1.16	1.050	1.04	0.86
Ford	N/A	N/A	N/A	0.480	0.57	0.65	0.760	0.72	0.61
Chrysler	N/A	N/A	N/A	N/A	0.43	0.54	0.500	0.64	0.39
American Motors	N/A	N/A	0.92	0.600	0.63	0.48	0.560	0.64	0.73
Inventory Turnover									
General Motors	N/A	N/A	6.92	4.930	6.28	7.46	7.660	8.34	8.21
Ford	N/A	N/A	N/A	5.550	6.31	6.62	7.700	7.58	7.39
Chrysler	N/A	N/A	N/A	N/A	4.14	5.20	4.980	6.88	6.40
American Motors	N/A	N/A	8.64	6.700	7.44	6.81	6.810	7.60	8.02

(Continued)

TABLE 12. (CONTINUED)

	1971	1972	1973	1974	1975	1976	1977	1978	1979
Inventory as Percent of Total Current Assets									
General Motors	N/A	N/A	0.43	0.550	0.44	0.41	0.450	0.42	0.49
Ford	N/A	N/A	N/A	0.620	0.57	0.53	0.450	0.46	0.51
Chrysler	N/A	N/A	N/A	N/A	0.66	0.61	0.630	0.56	0.60
American Motors	N/A	N/A	0.45	0.580	0.50	0.57	0.530	0.51	0.49

SOURCES: Index for auto manufacturers are based on annual reports. Index for all manufacturing corporations and all U.S. corporations from Economic Report of the President: January 1980, pp. 301-305.

NOTES: Plus sign denotes a net increase; minus sign denotes a net decrease. N/A indicates data not available.

a/ Net profit divided by sales.

b/ Net profit (less preferred stock dividends) divided by last year's stockholders' equity (less preferred stock value.)

c/ Based on current year's stockholders' equity.

d/ Current assets divided by current liabilities.

e/ Percentage of net earnings per share paid out to stockholders.

f/ Operating profit (net sales minus operating costs) divided by sales.

g/ Current assets, minus inventories, divided by current liabilities.

TABLE 13. ANALYSIS OF PROJECTED AUTO INDUSTRY PROFIT CONDITIONS NEEDED TO SUPPORT CAPITAL EXPENDITURES: In Billions of 1980 Dollars

	Actual	Estimated				Post-1985
	1979	1980	1981	1982	1983	(Average Annual)
Working Capital at End of Year a/	9.9	10.1	10.3	10.5	10.5	11.1
Change in Working Capital a/	-4.5	+0.2	+0.2	+0.2	+0.2	+0.2
Dividend Payments b/	2.2	2.2	2.3	2.3	2.4	2.5
Capital Expenditures c/	10.3	13.4	13.9	14.0	11.6	8.0 to 12.5
Total Expenditures	12.5	15.6	16.2	16.3	14.0	10.5 to 15.0
Cash Flow Required d/	---	15.8	16.4	16.5	14.2	10.7 to 15.2
Depreciation and Amortization e/	5.7	6.7	7.0	7.0	5.8	4.0 to 6.3
Net Income Required f/	3.3	9.1	9.4	9.5	8.4	6.7 to 8.9
Increase Over 1979	---	+5.8	+6.1	+6.2	+5.1	+3.4 to +5.6

SOURCE: Congressional Budget Office.

NOTE: Plus sign denotes a net increase; minus sign denotes a net decrease.

a/ Assumes 2 percent real annual growth in end-of-year working capital.

b/ Assumes 2 percent real annual growth in total cash dividends. Does not account for any new issues of stock or debt.

c/ Based on projected capital expenditures summarized in Table 9.

d/ Total expenditures plus change in working capital.

e/ At 50 percent of total capital expenditures.

f/ Cash flow required minus depreciation and amortization.

TABLE 14. FINANCIAL HISTORY OF THE U.S. AUTO INDUSTRY: 1971-1979, In Billions of Constant 1980 Dollars a/

	1971	1972	1973	1974	1975	1976	1977	1978	1979
Total Sales	97.6	107.0	117.6	101.2	99.4	121.2	136.5	143.9	135.2
Capital Spending	5.6	6.2	7.6	7.5	5.2	5.1	7.7	9.2	10.3
Net Income	5.0	5.9	6.2	2.0	1.9	5.6	6.5	5.8	3.3
Working Capital	N/A	N/A	N/A	12.6	12.4	14.6	14.9	14.4	9.9
Retained Earnings	N/A	N/A	N/A	N/A	26.6	28.4	30.4	31.5	30.1

SOURCES: Annual reports of U.S. auto manufacturers.

NOTE: N/A indicates data not available.

a/ Total sales, net income, working capital, and retained earnings were adjusted to 1980 dollars using the gross national product deflator. Capital spending was adjusted to 1980 dollars using the implicit price deflator for nonresidential fixed investment.

External financing differs from internal financing in that it is obtained through issues of stocks and bonds, as opposed to revenues and operating profits. The internal funding capability of the industry is, however, a critical determinant of the industry's ability to secure external financing. In order to attract external capital, the industry's internal operations most hold the prospect of sufficient payback to investors. The industry's access to external capital markets depends on future prospects for increased profits and cash flow.

The prospect for significantly increased profits and cash flow is somewhat limited, however. The domestic car market will grow more slowly in future years than it has during the past decade. Growth in the

1970s averaged 2.7 percent a year, but annual growth rates of 2 percent or less appear more likely in the future. The bulk of future new car sales will come from three sources, each of which is likely to contribute only modestly to increased demand. First, replacement demand, which has accounted for the majority of auto sales in the 1970s, will remain relatively static. Second, growth in population will be relatively small for persons of driving age, particularly in contrast to the tremendous growth that occurred over the past 15 years as the post-war baby boom entered the market. Finally, further increases in real income are likely to contribute less to auto sales than they have in the past. Gains in "disposable income" have a progressively diminishing effect on automobile sales, since more and more families have their car needs fulfilled and spend additional income on other goods and services.

The international market, in contrast, is likely to grow much faster, since there are far fewer cars per person elsewhere in the world. Average annual worldwide growth has been projected by auto suppliers at 4 percent, with the fastest growing markets being in Latin America (6 percent of the total), Africa and the Middle East together (5 percent), and Eastern Europe (4 percent). 13/ These estimates are based in part on historic trends, however, and they may not allow for the effects of recent and future OPEC oil price increases, which could dampen demand in developing countries that lack oil reserves.

The speed with which U.S. companies turn to producing more fuel-efficient vehicles will be critical to their future sales volume and hence, their financial health. The large share of new car sales captured by foreign manufacturers during the past year or so, and the concurrent decline in domestically-manufactured car sales, is largely attributable to the generally superior fuel economy of the imports. This contention is supported by the increasing share of domestically produced new car sales captured by subcompact and compact cars. Failure by domestic auto manufacturers to make further improvements in fuel economy between 1985 and 1995 would therefore likely result in a continued decline in the market share held by domestic auto manufacturers and a concurrent decline in the industry's sales revenue. Thus, building new cars with substantially improved fuel economy after 1985 will require a continued high rate of capital investment which, in turn, will strain the industry's financial resources, exposing manufacturers and investors to significant risk. On the other hand, failure by the domestic manufacturers to improve their products' fuel economy is likely to weaken the U. S. automotive industry's long-run competitive position.

13/ Congressional Budget Office, Current Problems of the U.S. Automobile Industry and Policies to Address Them, (July 1980) p. 28.

CHAPTER V. CONCLUSIONS

Achieving a 1995 automotive fuel-economy standard of 40 mpg appears to be technologically feasible during the next 10 to 15 years. Moreover, improvements above the 27.5 mpg level mandated for 1985 would yield substantial benefits to both consumers and the nation. Improved fuel economy would reduce the lifetime cost to consumers of owning and operating cars and in the long run, would contribute significantly to a reduction in the nation's petroleum consumption.

The greatest hindrance to achieving further fuel economy improvements is the U.S. auto industry's ability to support the capital investment levels that would be necessary. Failure to improve mileage performance significantly, however, could seriously undermine the industry's competitive position with respect to foreign manufacturers. Gasoline price rises and resulting market shifts toward small, fuel-efficient cars have enabled foreign manufacturers to capture a record share of new car sales during the last year. Whereas foreign manufacturers had a ready supply of smaller, more fuel-efficient cars to offer to consumers, U.S. manufacturers had relatively few competitive models. As gasoline prices continue to climb in the future, the demand for fuel-efficient cars will probably grow, or at the very least stabilize at quite a high level. The speed with which U.S. companies turn to producing more fuel-efficient cars will thus be critical to the industry's future strength.

Given the expected demand for more fuel-efficient autos and the compelling competition of imports, the policy question then becomes whether there is a need for additional post-1985 fuel-economy standards. What purpose would government-imposed standards serve? Without such legislated standards, would the market just naturally push the industry to invest in fuel-economy improvements? Past experience and predictions for the short term based on that experience suggest that it would.

Until recently, it was widely believed that average U.S. new car fuel economy in 1985 would fall short of the 27.5 mpg standard. This belief reflected a presumption that car buyers did not sufficiently value fuel economy. Recent demand for fuel-efficient cars, spurred by interruptions in the oil supply and rising gasoline prices, now promises to drive new-car fuel efficiency levels in 1985 beyond the 27.5 mpg standard set by current law. Market forces have overtaken governmental regulations in promoting automotive fuel economy. This experience would argue for allowing the market to determine, without regulation, the extent of future fuel economy improvements, thereby freeing the auto industry of needless interference.

Nevertheless, it is often argued that the standards established under the 1975 Energy Policy and Conservation Act set the auto industry on a decisive path to improve fuel economy and that, without these standards, the domestic manufacturers would be in a much worse market position than they are at present. Similarly, advocates of standards maintain that additional government-imposed standards could guide the industry to improve fuel efficiency further by 1995 and would introduce an element of certainty into an otherwise unstable environment in which oil supplies and prices fluctuate sharply. This may be particularly significant given that the auto industry cannot respond rapidly to vascillating market conditions. (The industry requires a long lead-time to develop and produce new product lines.) Moreover, since changes in new car fuel economy only gradually affect the energy consumption of the total auto fleet (see Chapter III), the nation as a whole would benefit from a steady and sustained course to improve automotive fuel efficiency.

APPENDIXES

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APPENDIX A. ANALYTICAL BASIS

Estimating the costs and benefits of future fuel-economy improvements on the basis of historical experience raises several problems. First, as the size composition of the new car fleet shifts, the incremental fuel economy benefits of a given technology may change. For example, the benefits associated with weight reduction vary according to which size class is considered. The percentage fuel-economy gain from a given percentage weight reduction is greater for a large car than a small car. Second, differing combinations of technologies may result in differing fuel-economy benefits. For example, a four-speed automatic transmission offers sizable fuel-economy benefits when used in conjunction with an eight-cylinder engine. When the four-speed transmission is used with a four-cylinder engine, however, the fuel economy benefits are much less. Third, the operating efficiency of a given technology may improve with time and experience. The performance characteristics of diesel engines, for example, have been significantly improved in recent years. And finally, as the market penetration of a given technology increases, the cost per unit of that technology may decline as economies of scale are realized and manufacturing productivity is enhanced.

The estimates used in CBO's analysis to project post-1985 fuel-economy improvements attempt to compensate for these problems. Fuel-economy and market penetration estimates account for anticipated changes in the mixes of car sizes and technologies. No downward adjustments in cost estimates are made, however, since it is assumed that any cost savings realized through enhanced production efficiencies may be offset by other cost increases.

APPENDIX B. OTHER STUDIES

The following table summarizes several studies' estimates of future automotive fuel-economy improvements. Among the studies, there is considerable agreement regarding which technologies are likeliest to yield the greatest gains. The analyses are also fairly consistent in their predictions of the effects of each technology. Their estimates of the associated costs tend to be somewhat more varied, but they are close enough to permit some rough approximations.

These study estimates were not all derived independently, however, and reliability should not necessarily be inferred from the apparent clustering of results. To the extent that there is some variation in the individual study estimates, these differences can be explained by several factors. First, different studies encompass different elements under a given technology group. Second, the fuel-economy benefits and costs of a given technology may be calculated in relation to differing baselines. Finally, the studies may incorporate different assumptions about the strictness of exhaust emission standards, acceptable performance characteristics, and total production levels.

The studies represented in the table include:

- DOT

    1. U.S. Department of Transportation, National Highway Traffic Safety Administration, Office of Automotive Fuel Economy, Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards: Document 3, Automobile Manufacturing Processes and Costs, (February 28, 1977).

    2. U.S. Department of Transportation, Data and Analysis for 1981-1984 Passenger Automobile Fuel Economy Standards: Document 2, Automotive Design and Technology, Volume 1, (February 28, 1977).

    3. U.S. Department of Transportation, Final Impact Assessment of the Automotive Fuel Economy Standards for Model Year 1981-1984 Passenger Cars, (June 30, 1977).

o Corp Tech

Pioneer Engineering & Manufacturing Co. under subcontract to Corporate Tech Planning Inc., Manufacturing and Consumer Costs of Selected Engines and Engine Improvements at Automotive Fuel Economy Contractors Coordination Meeting, April 24-26, 1978: Summary Report. (Prepared for U.S. Department of Transportation)

o EEA

Energy and Environmental Analysis, Inc., Technological/Cost Relations of Update DOE/Faucett Model: Draft Final Report. (Paper prepared for U.S. Department of Energy, October, 1979).

o Harbridge House, Inc., Energy Conservation and the Passenger Car: An Assssment of Existing Public Policy, (June 1979).

o GM

1. Genral Motors Corporation, Analysis of DOT Report to the Congress on the Automotive Fuel Economy Program of January 1979, (March 1979).

2. General Motors Corporation, Analysis of NHTSA's July, 1977 Rulemaking Support Paper and June 30, 1977 Final Impact Assessment of the Automotive Fuel Economy Standards for Model Year 1981-84 Passenger Cars, (February 1, 1979).

3. General Motors Corporation, Economic Issues and Alternatives Associated with the Fuel Economy Program, (February 1, 1979).

4. General Motors Corporation, General Motors Progress in Fuel Economy, (November 15, 1979).

- South Coast

  South Coast Technology, Inc., Specific Technologies for Improved Fuel Economy of Spark Ignition Piston Engines

- AMM

  "American Metal Market"; various issues, 1976.

- Ford

  Ford Motor Company, Annual Report 1979.

- Road and Track

  "Road and Track Magazine", October 1978.

- GM and Crysler

  Statement by General Motors and Chrysler at EPA Public Hearings on Proposed Diesel Particulate Emission Standards. Arlington, Virginia. March 19, 1979.

- Automotive Engineering

  "Automotive Engineering", July 1978.

TABLE B-1. SUMMARY OF STUDY ESTIMATES OF FUEL ECONOMY IMPROVEMENTS AND COSTS

Technology and Estimate by Source	Percent Market Penetration by Date a/	Percent Fuel-Economy Gain	Initial Cost Increase b/	Capital Cost (In millions) c/
Weight Reduction				
Material substution				
DOT	1981-1985	5 to 7	51	189 to 315 (400,000 units) to convert body manufacturing and assembly 26 to 38 (400,000 units) for component changes
EEA	1985	4 to 7	48	---
	1985-1995	4 to 7 (additional)	95	---
Harbridge House	100 by Mid-1980s	3	---	---
Front-wheel drive				
EEA	---	12 to 13	166	---
Harbridge House	60 GM, 40 Ford, and 40 Chrysler, by Mid-1980s	15 to 20 after 1st round downsizing d/	---	754 to 808 (400,000 units)
GM	---	---	---	754 to 808 (400,000 units)
Downsizing				
DOT	---	---	---	503 (400,000 units)
Harbridge House	1985	17 to 22—1st round 8 to 10—2nd round	---	539 to 647 (400,000 units)
GM	---	---	---	647 to 754 (400,000 units)

(Continued)

TABLE B-1. (CONTINUED)

Technology and Estimate by Source	Percent Market Penetration by Date a/	Percent Fuel-Economy Gain	Initial Cost Increase b/	Capital Cost (In millions) c/
Automatic Transmission				
TCLU e/				
DOT	---	5	30	---
EEA	---	3.5	29	---
Harbridge House	40 of automatics by Mid-1980s	---	---	32 to 43 (500,000 units)
Chrysler	---	5	27	---
South Coast	---	6.7	---	---
AMM	---	---	---	27 to 40
Four-speed with TCLU e/				
DOT	---	10	24	252 (500,000 units)
EEA	---	9.5	226	---
Harbridge House	60 of automatics by Mid-1980s	8—upper limit	—	269 to 296 (500,000 units)
GM	---	---	---	269 to 296 (500,000 units)
GM	---	8 to 11	---	323 (500,000 units)
South Coast	—	14.3 (with lock-up in 3rd and 4th gear)	---	---
AMM	---	---	---	199 to 240
Corp. Tech.	---	---	72	117 to 135 (350,000 units)

(Continued)

TABLE B-1. (CONTINUED)

Technology and Estimate by Source	Percent Market Penetration by Date a/	Percent Fuel-Economy Gain	Initial Cost Increase b/	Capital Cost (In millions) c/
Electronic Controls				
Digital spark				
EEA	100 by 1981	2 to 3	77	---
Knock limiter				
EEA	50 to 100 by 1985	3	33	---
Fuel injection				
EEA	50 to 100 by 1985	5	149 to 221	---
Corp. Tech.	---	---	61 to 185	17 to 42 (350,000 units)
Valve selector				
Corp. Tech.	---	---	126 to 179	20 (350,000 units)
GM MISAR				
Corp. Tech.	---	—	75	23 (350,000 units)
Ford EECI				
Corp. Tech.	---	---	81	24 (350,000 units)
Harbridge House	100 by 1985	5 to 12	---	32 to 130
Diesel Engine				
DOT	---	25 at 1.0 gpm Nox f/	371	69 to 126 (300,000 units) —conversion costs 116 to 185 (300,000 units) —new engine line

(Continued)

TABLE B-1. (CONTINUED)

Technology and Estimate by Source	'Percent Market Penetration by Date a/	Percent Fuel-Economy Gain	Initial Cost Increase b/	Capital Cost (In millions) c/
Diesel Engine (Continued)				
EEA	---	15 at 1.0 gpm Nox f/ 25 at 2.0 gpm Nox f/	386 —4 cyl. 608 —6 cyl. 878 —8 cyl.	---
Harbridge House	Maximum 20 to 30 during 1980s	15 to 20 at 1.5 gpm Nox f/	---	86 to 431 (400,000 units)
GM	---	---	---	86 to 162 (400,000 units) —conversion costs 216 to 431 (400,000 units) —new engine line
Corp. Tech.	---	10 to 12 at 1.0 gpm Nox f/ 20 to 25 at 2.0 gpm Nox f/	318	55 (350,000 units)
Proco Engine				
EEA	---	15	386	---
Harbridge House	All Ford V-8 some V-6	---	---	162 to 323 (350,000 units)

(Continued)

TABLE B-1. (CONTINUED)

Technology and Estimate by Source	Percent Market Penetration by Date a/	Percent Fuel-Economy Gain	Initial Cost Increase b/	Capital Cost (In millions) c/
Proco Engine (Continued)				
Corp. Tech.	---	12 to 15 (current emissions) 8 to 12 (1981 emissions)	383	105 (350,000 units)
Ford	---	20	---	162 to 323 (350,000 units)
Turbocharger				
EEA	---	5 (gasoline) 10 (diesel)	544	---
Harbridge House	10 to 15 of gas engines by Mid-1980s	5 to 10	104 to 131	22 (400,000 units)
GM & Chrysler	---	---	313	---
South Coast	---	slight	155 to 199	---
Corp. Tech.	---	5 to 8 (current emissions) 4 to 6 (stringent emissions) over comparable gasoline engine	172 to 233	24 (300,000 units)

(Continued)

TABLE B-1. (CONTINUED)

Technology and Estimate by Source	Percent Market Penetration by Date a/	Percent Fuel-Economy Gain	Initial Cost Increase b/	Capital Cost (In millions) c/
Improved Lubricants				
DOT	---	2	6	---
EEA	1990	4 to 5	6 to 27	---
South Coast	---	5 to 10	---	---
Corp. Tech.	---	3 to 5	---	---
Road & Track	---	2 to 3	---	---
Aerodynamics				
DOT	1981-1984	4	17	---
EEA	---	e to 5	16	---
Harbridge House	100 by 1985	5	---	---
GM "X-car"	1980	6	---	---
Corp. Tech.	1985-1990	10.8	---	---
Automotive Engineering	1980-1985	3 to 5	---	---
	1980-1990	10 to 12	---	---
Improved Accessories				
DOT	---	2	16	---
EEA	Continuous	2	16	---
Corp. Tech.	---	---	16	---

(Continued)

TABLE B-1. (CONTINUED)

Technology and Estimate by Source	Percent Market Penetration by Date a/	Percent Fuel-Economy Gain	Initial Cost Increase b/	Capital Cost (In millions) c/
Rolling Resistance				
DOT	---	3	22	---
EEA	---	4	26	---
Harbridge House	100 by 1985	2 to 5	---	---
Corp. Tech.	1980-1985	7	26	---

a/ Where actual market penetration levels are not specified, only the time period during which the given technology will be used is shown.

b/ Consumer purchase costs expressed in constant 1980 dollars, adjusted with the implicit price deflator for auto output, final sales.

c/ Capital costs expressed in constant 1980 dollars, deflated with the implicit price deflator for nonresidential fixed investment.

d/ Assumes first round of downsizing completed before reconfiguration to front-wheel drive.

e/ Torque converter lock-up.

f/ Grams of nitrogen oxide emissions per mile.