Chapter 1

Executive Summary

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Chapter 1
Executive Summary

INTRODUCTION

In 1981, U.S. oil imports averaged 5.4 million barrels per day (MMB/D)–approximately 34 percent of its oil consumption and 15 percent of its total energy use. This is potentially a serious risk to the economy and security of the United States. Furthermore, recovery from the current recession will increase demand for oil and, although currently stable, domestic oil production is likely to resume a steady decline in the near future.

Several options exist for reducing oil imports. However, even with moderate increases in automobile fuel efficiency, moderate success at developing a synthetic fuels industry and the expected reduction in stationary use of fuel oil, U.S. oil imports could still be over 4 MMB/D by 2000, if the U.S. economy is healthy and has not undergone unforeseen structural changes that might reduce oil demand well below projected levels.

Only with vigorous promotion of all three options and technological success can the Nation hope to eliminate oil imports before 2010.

Congress faces several decisions on how to reduce the U.S. dependence on imported petroleum. Two options, increased automobile efficiency and synthetic fuels, are particularly likely to be subjects of congressional debates. First, Congress may want to consider new incentives to increase auto fuel efficiency beyond that mandated by the 1985 CAFE (Corporate Average Fuel Efficiency) standards. Second, Congress will have to decide whether to continue into the second phase of the program to accelerate synfuels development under the Synthetic Fuel Corp. (SFC). The purpose of this report is to assist Congress in making these decisions and comparing these options by exploring in detail the major public and private costs and benefits of increased automobile fuel efficiency and synthetic fuels production. A third option for reducing imports-increased efficiency and fuel switching in stationary (nontransportation) oil uses—is examined briefly to allow an assessment of potential future levels of oil imports. Finally, electric-powered automobiles are examined.

CONCLUSIONS AND COMPARISONS

Import Reductions

In the judgment of the Office of Technology Assessment, increased automobile fuel efficiency, synthetic fuels production, and reduced stationary (nontransportation) use of oil can significantly decrease U.S. dependence on oil imports during the next two to three decades. indeed, reducing oil imports as quickly as possible requires that all three options be pursued. Electric cars are unlikely to play a significant role, however.

Although a precise forecast of the future contributions of the import reduction options is not feasible now, it **is** possible to draw some general conclusions about their likely importance and to estimate what their contributions **could be** under specific circumstances (see fig. 1).

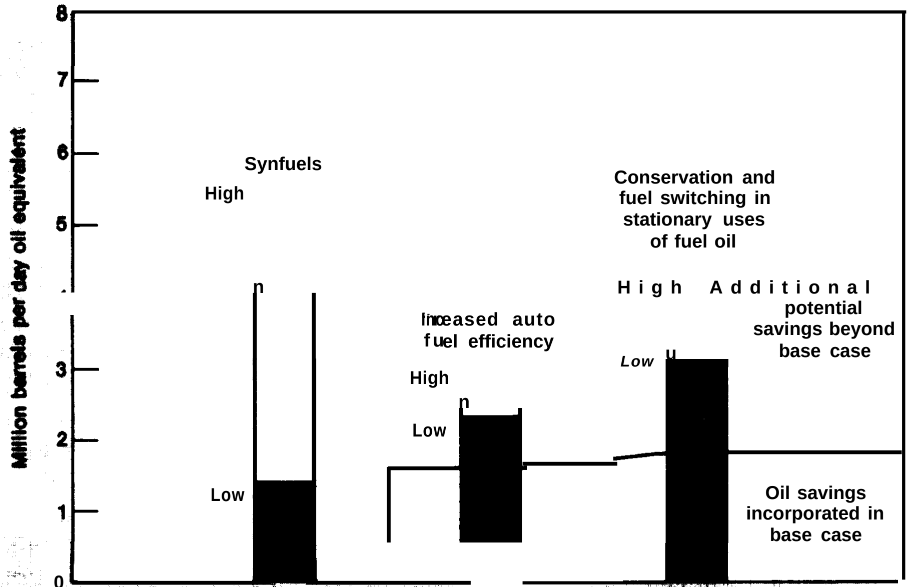
First, **increases in auto fuel efficiency will continue, driven by market demand and foreign competition.** OTA believes that, with strong and consistent demand for high fuel efficiency, there is a good chance that actual average new-car fuel efficiencies would be greater than OTA's low scenario in which average new-car fuel economy* was projected to be:

30 miles per gallon (mpg) . . . . in 1985
38 mpg . . . ., in 1990
43 mpg . . . ., in 1995
51 mpg . . . . in 2000

with a moderate shift in demand to smaller cars. Although this scenario is based on modest technical expectations, it is dependent on favorable market conditions. Domestic automakers are unlikely to commit the capital necessary to continue

***EPA values, based on 55 percent city, 45 percent highway. On-the-road fuel economy is expected to average about 10 percent less.**

Figure 1 .—Potential Oil Savings Possible by the Year 2000[a] (relative to 1980 demand)



[a] These potential oil savings (or synfuels production) are for the year 2000. Their costs as well as a description of the technologies and other characteristics of the high and low scenarios are given in this summary.

SOURCE: Off Ice of Technology Assessment.

the current rapid rate of increase in efficiency unless they improve their sales and profits.

If the industry is able to attain the fuel efficiency levels shown above, the United States would save 800,000 barrels per day (bbl/d) of oil by 2000 compared with the case where post-1 985 new-car efficiency remained at 30 mpg. The savings would increase to at least 1.1 MMB/D by 2010 because of continued replacement of older, less fuel-efficient automobiles.

With a poorer economic picture and weaker demand for high fuel efficiency, new-car efficiencies could be 40 mpg or less by 2000, with correspondingly lower savings. Achieving 60 to 80 mpg by 2000 would require not only favorable economic conditions and strong demand for fuel efficiency, but also relatively successful technical development.

Second, **substantial contributions to oil import reductions from production of synthetic fuels appear to be less certain than substantial contributions from the other options.** Potential synfuels producers are likely to proceed cautiously for the following reasons: 1) investment costs are very high (even with loan guarantees covering 75 percent of project costs); 2) there is a fairly small differential between the most optimistic of OTA's projected synfuels production costs and the current price of oil; 3) investors are now unertain about future increases in the real price of oil; and 4) there are high technological risks with the first round of synfuels plants (possibly exacerbated by the cancellation of the Department of Energy's (DOE) demonstration program).

OTA projects that, even under favorable circumstances, fossil-based production of synthetic *transportation fuel* could at best be 0,3 to 0.7 MMB/D by 1990 and 1 to 5 MMB/D by 2000. Biomass synfuels could add 0.1 to 1 MMB/D to this total by 2000. In less favorable conditions—for example, if the SFC financial incentives were withdrawn—it appears unlikely that even the lower fossil synfuels estimate for 1990, and perhaps 2000, could be achieved unless oil prices increase much faster than they are currently expected to.

Achieving much more than 1 MMB/D of synfuels production by 2000 would require fortuitous technical success and either: 1) unambiguous economic profitability or 2) continued financial incentives requiring authorizations considerably larger than those currently assigned to SFC. Achieving production levels near the upper limits for 2000 are likely to be delayed, perhaps by as much as a decade, unless there is virtually a "war mobilization' '-type effort.

Third, **there are likely to be large reductions in the stationary use of fuel oil (currently 4.4 MMB/D) in the next few decades.** With just cost-effective conservation measures, stationary fuel oil use could be reduced significantly. Additional conservation measures by users of electricity and natural gas could make enough of these fuels available to replace the remaining stationary fuel oil use by **2000.** Total elimination of stationary fuel oil use by **2000** is unlikely, however, because site-specific factors and differing investor payback requirements will mean that a significant fraction of the numerous investments needed for elimination will not be made.

Fourth, **even a 20-percent electrification of the auto fleet—a market penetration that must be considered improbable within the next several decades—is unlikely to save more than about 0.2 MMB/D.** Electric cars are most likely to replace small, low-powered–and thus fuel-efficient—conventional automobiles, minimizing potential oil savings.

Plausible projections of domestic oil production—expected by OTA to drop from 10.2 MMB/D in 1980 to 7 MM B/D or lower by 2000—suggest that oil imports could still be as high as 4 to 5 MM B/D or more by 2000 unless imports are reduced by a stagnant U.S. economy or by a resumption of rapidly rising oil prices. * Achieving low levels of imports-to perhaps less than 2 MM B/D within 20 to 25 years–is likely to require a degree of success in the three major options that is greater than can be expected as a result of current policies.

*Rapidly rising oil prices are unlikely to occur simultaneously with a stagnant U.S. economy unless the economies (and oil import requirements) of Europe and others are thriving at the same time.

costs

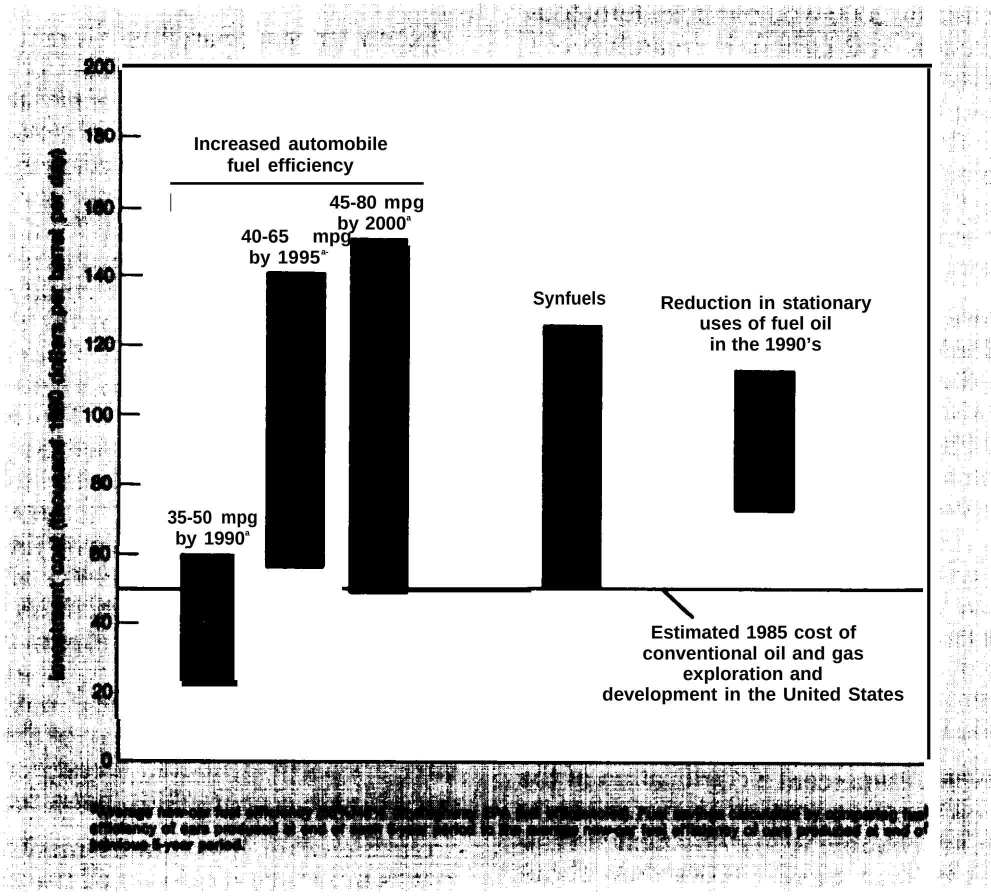
Except for stationary fuel oil reductions, economic analysis of the options for reducing oil imports involves a comparison of **tentative** cost estimates for mostly **unproven** technologies that will **not be deployed for 5 to 10 years or more.** Even if costs were perfectly estimated for today's market (and the estimates are far from perfect), different rates of inflation in the different economic sectors affecting the options could dramatically shift the comparative costs by the time technologies are actually deployed. Figure 2 presents OTA's estimates for the investment costs for all options except electric cars. The costs are expressed in dollars per barrel per day, which is the amount of investment needed to reduce petroleum use at a rate of 1 bbl/d. * In OTA's judgment, **the estimated investment costs (in dollars per barrel per day) during the** 1990's **of automobile efficiency increases, synthetic fuels production, and reduction of stationary uses of oil are essentially the same, within reasonable error bounds. If Congress wishes to channel national investments preferentially into one of these options, differentials in estimated investment costs cannot provide a compelling basis for choice.**

On the other hand, **investments during the 1980's to reduce stationary oil use** (from the current 4.4 to 3 MM B/D or less by 1990) **and increase automobile fuel efficiency** (to a 35 to 45 mpg new-car fleet average by 1990) **are likely to cost less than the 1990-2000 investments in any of the options.**

Electric vehicles are likely to be very expensive to the consumer—costing perhaps $3,000 more per vehicle than similar, conventional automobiles or $300,000 to $400,000/bbl/d of oil saved, (The latter is not strictly comparable to investment costs for the other options.) If batteries must be replaced at moderate intervals, which is necessary today, the total costs of electric cars would escalate.

*This measure was chosen in order to avoid problems that arise when comparing investments in projects with different lifetimes and for which future oil savings may be discounted at different rates.

Figure 2.—Estimated Investment Costs for the Oil Import Reduction Options



SOURCE: Office of Technology Assessment.

Technological and Economic Risks

The general perception of the technological and economic risks of the import reduction options is: 1) that the reduction of stationary oil use has comparatively predictable costs and few technological risks; 2) that synthetic fuels have severe economic and technological risks; and 3) that increased auto fuel efficiency has moderate economic and technological risks. OTA's analysis indicates that these perceptions are correct only to a limited extent.

- Although the costs and technology of fuel switching are well known and involve little risk, the success of retrofitting a given building to increase its energy efficiency often cannot be accurately predicted because of site-specific considerations that cannot be adequately quantified.
- The differences in risks between synfuels development and increased automobile fuel efficiency are less a matter of overall magnitude than of timing.
- Synfuel production involves considerable technical and economic risks for the first round of commercial-scale facilities, but once full-scale process units have been demonstrated the risk for future plants should drop substantially.
- Some increases in automobile fuel efficiency can be implemented with negligible technological and small economic risks, but increases to very high efficiencies do involve significant

technical and economic risks. Also, as the number and rate of changes in automobiles increases, there is increased risk that consumers will not accept the automobiles and that insufficient development and testing will lead to poor on-the-road performance and/or product recalls.

Additional Bases for Comparison—Environmental, Social, and Economic Effects

Increased auto fuel efficiency may reduce vehicle safety as cars are made smaller and lighter. But in all but extreme cases of vehicle size reduction, improvements in vehicle design and increased passenger use of safety restraints have the potential to offset any effects of reduced size and weight on the vehicle's protection of its occupants in a crash.

Continued pressure for increased fuel efficiency will dictate new plant investments which will reinforce the ongoing restructuring of the U.S. auto industry. This restructuring involves a shift in manufacturing away from the traditional production centers to the Sun Belt and overseas, and stronger industry ties with foreign manufacturers. The composition and size of the manufacturing work force may evolve towards a greater proportion of skilled workers but fewer workers overall. Increased sophistication and capital investment may be required for vehicle maintenance. A reduction in the number of suppliers to the auto industry may also result.

Large-scale synthetic fuels production would generate significant amounts of toxic substances, posing risks of health damage to workers and possible risks to the public through contamination of ground waters or by small amounts of toxics left in the fuels. There should not be any technological barrier to adequate control of these substances, but OTA concludes that there are substantial reasons to be concerned about the adequacy both of proposed environmental protection systems and of the existing regulatory structure.

Other important effects of synfuels production stem from the very large scale of both the individual projects and, potentially, the industry as a whole. These may overwhelm the social and economic resources of nearby population centers, especially in sparsely populated areas of the West. At national production levels of a few million barrels per day, impacts from coal and shale mining and population pressures on wilderness areas and other fragile ecosystems can be substantial even in comparison with major industries such as coal-fired power generation. On the other hand, conventional air pollution problems from such plants are likely to be considerably less than those associated with similar amounts* of coal-fired power generation.

Finally, although water requirements for synfuels are a small fraction of total national consumption, **growth of a synfuels industry could either create or intensify competition for water, depending on both regional and local factors.** Such competition is of special concern in the arid West. Unfortunately, a reliable determination of both the cumulative impacts on other water users and, in some instances, the actual availability of water for synfuels development is precluded by physical and institutional uncertainties, changing public attitudes towards water use priorities, and the analytical shortcomings of existing studies.

However, in areas where there are relatively few obstacles to transferring water rights (e.g., as is currently the case in Colorado), developers should be able to obtain the water they need because their consumption per barrel of oil produced is small enough to enable them to pay a relatively high price without significantly affecting the final cost of their products.

Electric vehicles, if they are ever produced in large quantities, could have an important positive environmental effect-the reduction of automobile exhaust emissions and resulting improvements in urban air quality.

*On a "per unit of coal used" basis.

POLICY

OTA's analysis points to two conclusions that may warrant congressional consideration of changes in current Federal energy policy.

First, current policies affecting investments in energy conservation and domestic energy production are not likely to result in levels of oil imports below 4 MMB/D in 2000, if the U.S. economy is healthy and has not undergone unforeseen structural changes that might reduce oil demand well below projected levels. During the next **20** years, OTA expects that, under these policies, oil import reductions due to synthetic fuels production and decreased stationary and automobile oil use will be partially offset by a decrease in domestic production of conventional oil. Reducing net oil imports to 1 or 2 MMB/D or less by 2000 is likely to require more vigorous pursuit of all options for reducing domestic consumption of conventional oil products. On the other hand, elimination of current conservation and synthetic fuels production policies could cause imports to range from **5** to **6** MMB/D by 2000 under these same economic conditions.

Second, current policies may not provide society with adequate protection from some of the adverse side effects of synthetic fuels development and increased automobile fuel efficiency. Of particular concern are possible reductions in automobile crash safety (as the number of smaller, more fuel-efficient cars increases), inadequate control of toxic substances from synfuels development, and adverse socioeconomic effects from both options.

Because of the large technical, economic, and market uncertainties inherent in the analyses of oil displacement options, Congress may wish to emphasize flexible incentives with provisions for periodic review and adjustment. A stable commitment to oil import displacement will be necessary, however, to maximize the effect of such policies.

Stimulating Oil Import Reductions

The level of oil imports at the turn of the century will be determined by market forces, modified by Government policy towards oil supply and demand. The imposition of Federal policy on the workings of the private market generally is justified on the basis of the market's failure to value public costs and benefits. A particularly important public cost of U.S. dependence on imported oil, for example, is the national security problem imposed by political instability in the Middle East and the resulting potential for oil cutoffs. Although the precise magnitude of these costs is debatable, most people would agree that they are significant ($5 to $50/bbl depending on various circumstances) and that the private market generally does not take them into account.

Efforts to displace imports also have both public and private costs. In addition to the potential side effects just mentioned, Government interference in the oil marketplace can cause significant misallocations of resources. Congress will have to balance costs and benefits, which cannot be reduced to common measures and which change with time, in a complex tradeoff.

One policy option to displace imports is an energy tax, either on oil imports or on oil in general. Both taxes have the advantage of encouraging alternatives to conventional oil consumption without predetermining which adjustments would be made. They could be used to provide consistent price signals to the market—to assure the auto industry, for example, that demand for fuel-efficient cars would continue and to assure synfuels developers that they would receive at least a constant real price for their products. imposing a tax only on transportation fuels would send the same signal to both the auto industry and to producers of synthetic transportation fuels, but this preferential treatment would be at the expense of other conservation or synfuels production investors.

All of these petroleum taxes also have a number of other effects which must be considered. For example, a tax only on oil imports leads to an income transfer from domestic oil consumers to domestic oil producers; and all oil taxes can lead to reduced international competitiveness of domestic industries heavily dependent on oil, such as the petrochemical industry.

policies can also be directed specifically at the automobile or synfuels industries. The most effective of these options will be those that directly address the factors that shape, direct, and limit the contributions that the automobile and synfuels industries can make to import displacement.

The critical factors that determine the pace of **increased automobile fuel efficiency** are consumer demand for fuel efficiency and the financial health of the domestic auto industry. If the industry is uncertain about demand, it will be reluctant to make the expensive investments. And with continued poor sales, the industry will be less able to afford them.

Aside from energy taxes, Congress can maintain and stimulate consumer demand for fuel efficiency by a variety of measures that would raise the relative costs to consumers of owning inefficient cars. For example, registration fees (one time or annual) and purchase taxes or subsidies are incentives that can be directly linked to fuel efficiency. However, fuel-efficiency incentives that do not discriminate with respect to car size would tend to increase sales of small cars at the expense of larger cars. Such discrimination might hurt domestic manufacturers, which have been most vulnerable to foreign competition in the small-car market.

Congress can also choose policies aimed at auto production such as continuing to require manufacturers to improve fuel efficiency by means of stricter CAFE or similar standards that would ensure increased fuel efficiency even if demand for this automobile attribute is low. This regulatory route might reduce some risks to automakers by requiring all to make similar investments. On the other hand, car sales may suffer if the costs of the fuel savings—either in higher sticker prices or reductions in some desirable vehicle attributes–are higher than consumers are willing to pay. Fuel-economy requirements are likely to be perceived by the industry as exceedingly risky unless the requirements are accompanied by measures to stimulate demand or to ease the resulting financial burden on the automakers.

To help ensure that the fuel-efficient cars are actually bought and that the automakers can acquire the capital needed for increasing fuel efficiency, Congress may also wish to directly promote sales of fuel-efficient cars. A low-interest-rate loan program (with interest rates tied to fuel efficiency) is one potentially effective mechanism. Congress may also wish to consider awarding direct grants or loan guarantees for qualifying investments in auto manufacturing facilities.

The factors that determine the pace of **synfuels development** are the high degree of technical uncertainty and the continuing uncertainty about future oil prices. Both areas of uncertainty contribute to doubts about profits.

Current Federal policy maintains the valuable incentives associated with SFC, but reemphasizes DOE's research, development, and demonstration programs. The loan guarantee mechanism offered by SFC significantly improves the probability of financial success for a developer and probably will be necessary to ensure even a few hundred thousand barrels per day of synfuels production by the early 1990's. Several major risks to synfuels investors remain, however. Cost overruns could nullify any potential profits because developers must base their product prices on the market prices of competing fuels rather than on synfuels production costs. It is also probable that several first generation commercial-scale units will function poorly, and rapid expansion of the industry may thereby be delayed.

Since the SFC program appears to be attracting the capital needed to build and demonstrate a series of first generation commercial-scale production units, cancellation of DOE's programs may not turn out to be particularly harmful to synfuels development **if the first plants perform well.** However, cancellation of the demonstration program probably will mean that fewer technologies reach the stage where SFC support is possible. Reemphasis of development programs may also delay findings that would be useful in fixing the technical problems that are likely to arise in the first commercial-scale units. To hedge against the possibility of poor operation delaying expansion, Congress may wish to support development programs intended to demonstrate the technical feasibility of a variety of processes and to gain basic knowledge of and experience with these processes. Although these demonstration programs support second and third generation processes, they will also provide engineering information that may be useful for correcting technical faults and reliability problems that may arise in first generation plants.

Dealing With Other Effects

An important effect of increasing automobile fuel efficiency is the potential for decreased automotive safety due to size and weight reduction. There may also be major employment-related side effects associated with the restructuring of the auto industry and the accompanying accelerated rates of capital investment by the industry. There are familiar policy instruments that can deal with both of these effects. For the safety effects, Congress can choose among safety standards for new cars, educational programs, and support of safety R&D. Employment effects may be eased by minimizing plant relocations (through tax breaks or direct assistance to the industry), or by ameliorating the effects of employment reductions through aid to communities and affected workers and other individuals.

potential environmental and worker-related problems associated with synfuels development are substantial, and there is cause for concern about the adequacy of future regulation of the synfuels industry. The Government can help to assure that the private sector takes account of these problems. Specific areas worthy of congressional attention include: the environmental research and regulatory programs of the Environmental Protection Agency (EPA), DOE, the Office of Surface Mining, and the Occupational Safety and Health Administration, in light of recent budget cuts and changes in program direction; the dismantling of DOE's demonstration program for synfuels technologies; and the progress of SFC in demanding appropriate consideration of siting, monitoring, pollution controls and occupational safety as a condition for financial assistance. Congressional options range from holding oversight hearings to increasing the resources of the environmental regulatory agencies and shifting their program emphases by legislation.

To mitigate the socioeconomic effects on communities from synfuels development, Congress may wish to consider several forms of growth management assistance, including loan guarantees, grants, and technical assistance. Any new Federal initiatives in this area will be complicated, however, by continuing arguments about relative responsibilities of Federal, State, and local governments and private industry. And new initiatives need to be sensitive to the substantial differences from location to location in the severity of impacts and the resources already available for mitigation.

OVERVIEW OF THE IMPORT REDUCTION OPTIONS

Increased Automobile Fuel Efficiency

Automobile fuel efficiency can be increased through a variety of measures, including:

- reductions in vehicle weight;
- improvements in conventional engines, transmissions, and lubricants;
- better control of engine operating parameters;
- new engine and transmission designs;
- reduced aerodynamic drag;
- improvements in accessories; and
- decreases in rolling resistance.

Projections of Fuel Economy

Future oil savings from increased automobile fuel efficiency depend, first, on the magnitude and character of future auto sales. In the past few years, consumer preferences for such fuel-economy-related characteristics as vehicle size and performance have fluctuated while new car sales have dropped significantly. Both the long-term sales average and consumer preference for fuel efficiency will be critical determinants of the rate of penetration of fuel efficiency technology.

Second, in response to changing consumer preferences and foreign competition, the rate of change of vehicle technology has accelerated and old rules about how long it takes to put a new technology into place* are no longer valid. The present rapid rate of replacement of capital equipment puts a great strain on the domestic auto industry. During the next several years, competitive forces will push toward continued rapid technological change, but the financial weakness of the domestic auto industry will pull toward slower technological change. The strength of future foreign competition and consumer perceptions of the future price and availability of gasoline and diesel fuel, among other factors, will influence the balance of these opposing forces, and, consequently, whether rapid increases in fuel efficiency of domestically produced cars continue.

Third, the efficiency increases are not fully predictable. There can be discrepancies between test results and the results obtained in actual use. Technical compromises that affect ultimate performance have to be made to allow better integration with existing equipment, easier and cheaper production and assembly, and resistance to extreme operating conditions and incorrect maintenance procedures. Development problems are not always solved satisfactorily; such problems could occur more frequently if technological change accelerates.

OTA developed projections (table 1) of plausible ranges of average new-car fuel economy based on varying expectations of the relative demand for different-sized cars and the effectiveness and rate of development and introduction of new fuel-economy improvements. As reflected in these projections, both technology and vehicle size are critical factors for future fuel savings. Marketplace uncertainty is reflected even as early as the 1985 projections—manufacturers' plans and the technology are already established, but the projections still range from 30 to 37 mpg* (compared to the 1981 level of 25 mpg).

*For example, previous assumptions were: 5 years to move from initial production decision to introduction of a technology in a model line; 5 to 10 years to diffuse the technology throughout the new car fleet; and 10 to 15 years of production to pay for the investment. The estimate of 5 years to move from initial production decision to introduction may now be a bit too low, while increased rate of change of vehicle technology would necessarily reduce the other two estimates.

Table 1.- Projected Average New-Car Fuel Economy,[a] 1985.2000 (mpg)

	1985	1990	1995	2000
No further shift towards smaller cars beyond 1985	30-34	36-45	39-54	43-62
Moderate further shift to smaller cars	30-34	38-48	43-59	51-70
Rapid shift to small cars	33-37	43-53	49-65	58-78

[a]Based on EPA *city/highway* (55/45 percent) cycle. Each of the mileage ranges (e g., 3034) reflects relative expectations of the performance and rate of development and deployment of new technologies. The lower value represents OTA's "low estimate" scenario, the upper value represents a "high estimate" scenario.

SOURCE: Office of Technology Assessment

Note on Table 1: Can We Do Better?

The projections in table 1 do not represent the *technological* limit of what could be achieved in this century. The most efficient automobiles in each size class are likely to achieve considerably better fuel economy than the average; for example, technologies are available that probably can allow a new-car fleet average of 60 mpg by the mid-1990's with the same mix of vehicle sizes as today's and adequate vehicle performance (compared with the table's 1995 "same size mix" projection of 39 to 54 mpg). *This ignores consumer preferences for vehicle features that conflict with fuel economy maximization, however.* By the same argument, the 1981 new-car fleet average *could have been 33* mpg if consumers had consistently chosen the most efficient vehicle in each of the nine EPA size classes and producers had been able to meet the demand. Instead, the actual 1981 model average to January 1981 was 25 mpg.

Interestingly enough, if consumers had chosen only the most fuel-efficient gasoline-powered automobiles in each size class, over 90 percent of the vehicles would have been U, S.-manufactured cars or captive imports. The market problems of U.S. manufacturers in 1981 cannot be traced primarily to an inability of U.S. manufacturers to produce fuel-efficient cars, but depend on factors such as differences in perceived value between American and imported automobiles.

The difference between *average fuel efficiency,* which is a function of consumer preference, and *potential fuel efficiency,* which assumes that every car in the fleet embodies the most fuel-efficient choice of technologies available, is critical to understanding why OTA's projections may differ from other projections that apply a single choice of technologies to the entire fleet. The latter assumption is realistic only if future consumers value fuel economy, relative to other automobile attributes, much higher than they do today.

How much fuel can be saved by improved fuel economy? Assuming 30 mpg as a base and using the projections in table 1, **continued developments in automobile fuel efficiency could save** 0.6 **to 1.3 MMB/D of oil by 2000.** The lower value represents pessimistic expectations about the advance of automobile technology and the shift towards smaller cars; the higher value represents optimistic technological expectations and continued substantial shifts to small cars. **Contin-**

* Based on a weighted average of 55 percent EPA city test cycle and 45 percent EPA highway cycle, the formula used to measure compliance with currently mandated CAFE requirements.

ued diffusion of these technologies into the overall fleet could save 0.8 to 1.7 MMB/D by 2010 with no further technological advances beyond 2000. *

costs

OTA's cost analysis of auto fuel-efficiency improvements concentrates on investment costs in total dollars as well as dollars per barrel per day of oil saved. Estimates of the costs for associated technology and product development are included in the investment costs,** because they are part of the normal outlays needed to put any new vehicle in production and represent a sizable fraction of the fixed costs (i.e., costs independent of production levels).

It is not possible to make highly accurate estimates of the investment costs (per barrel per day of oil saved), due to the uncertainty associated with predicting actual efficiency increases that will be achieved. In addition, the cost of developing technologies to the point where they can be reliably mass-produced has been highly variable and is difficult to predict.

Accurate cost estimation also is complicated by the difficulty of separating the cost of increasing fuel efficiency from the other costs of doing business. Increases in fuel efficiency are inextricably intertwined with other changes in the car. For example, the engine redesign for fuel efficiency may incorporate other changes, to improve other automobile attributes, at little additional cost. Design changes that increase efficiency may improve or degrade other attributes such as emissions or performance.

If it is the industry's judgment that consumers do value fuel efficiency, the normal cycle of capital turnover and vehicle improvement would result in an increase in fuel efficiency automatically. Unfortunately, the "normal" rate of fuel efficiency increase is not really predictable because it depends on marketplace preferences and corporate strategies.

Because of the difficulty of separating out the marginal fuel efficiency investments from the "normal" investments, OTA's investment cost estimates (in dollars per barrel per day) in table 2 are the **total** investments (including development costs) **allocated to increasing fuel efficiency,** divided by the total fuel savings rate expected. (See footnote c of table 2 for the details of the cost al location.) These investment rates may be somewhat lower than the marginal rates would be because, in designing their "normal" investment programs, manufacturers probably will select those investments with the highest potential payoff in efficiency increase per dollars spent.

In any case, the range of investment rates for increased fuel efficiency for each time period overlap the rates for investments in synfuels plants (see Synthetic *Fuel* section below), although the 1985-90 fuel-efficiency rates would be lower than the synfuels rates if widespread expectations for overruns in early synfuels investments are proved correct,

The total domestic capital investment associated with increased fuel efficiency would be about $25 billion to $70 billion between 1985 and 2000, or less than $2 billion to $5 billion annually during the period. This level of investment can be compared with recent and projected capital investment by the industry* remembering that part of the fuel-efficiency investment could be included in "normal" capital expenditures if consumer demand for fuel efficiency is high enough. For the period 1968-77, annual capital investment by General Motors (GM), Ford, and Chrysler averaged $6.68 billion in constant 1980 dollars. Investments by these companies rose to $10.4 billion in 1979 and $10.8 billion in 1980, and are projected by some analysts to rise to $12 billion per year during 1980-84. The ability of the domestic industry to maintain their expected schedule of capital expenditures is dependent on

*Assuming 1.26 trillion vehicle miles (automobile only) traveled annually in 2000, 1.31 trillion in 2010, and an on-the-road fuel efficiency 10 percent less than EPA rated fuel efficiency.

**In this context, development means all of the engineering activities needed to prove a design concept and determine how it can best be integrated into the vehicle system and mass-produced.

*The two sets of figures are not fully analogous. A portion of the domestic industry's costs are for overseas investments, while a portion of the 1985-2000 fuel efficiency costs will be borne by outside suppliers rather than the major manufacturers.

Table 2.—Domestic[a] Investment for Increased Fuel Efficiency

Time	Car sales (mill ion/yr)	New-car fuel efficiency (mpg)[b]	Efficiency investment (thousand 1980 $/bbl/day)	Total investment (billion 1980$ during time period)
1985-1990	8.6	38-48	20-60	8-29
1990-1995	8.8	43-59	60-140	9-20
1995-2000	9.1	51-70	50-150	7-18

[a]Assumes 75 percent of all cars sold are manufactured domestically.
[b]Fleet average miles per gallon at end of time period, with moderate shift in demand to W?' Idler cars,
[c]Represents costs allocated t. fuel efficiency, including associated development costs of 40 percent of capital spending. Investment was allocated in the following way: 50 percent of the total engine investment is assumed to be for fuel efficiency; 75 percent of the total investment for conventional transmissions is for fuel efficiency; and all of the investment for advanced materials substitution, automatic engine on/off, and energy storage devices is for fuel efficiency.
[d]Includes all capital costs associated with fuel efficiency, including fraction allocated to other attributes, but excluding development costs,

SOURCE: Office of Technology Assessment.

a resumption of their former levels of sales and profitability. There are already signs that U.S. auto manufacturers are beginning to cut back on planned investments in the face of continued poor sales and declining cash reserves.

If consumer demand for fuel efficiency is consistently strong, domestic manufacturers are likely to respond by **at least** incorporating into their "normal" * rate of capital turnover as many fuel-efficiency features as possible. if capital turnover is limited to its historical "normal" rates, then the fuel efficiencies shown in table 1 could still be achieved, but it would take longer to implement the changes than is indicated by the schedules shown in that table. In particular, implementation of the low scenario could require **25** percent longer (relative to 1985) than the schedule in table 1; and the high scenarios could require 45 percent longer. Whether the high or the low scenario is eventually achieved, however, also depends on the success of technical developments.

If demand for fuel efficiency were high enough, however, the manufacturers would increase their redesign/replacement rates. By adding $5 billion to $10 billion in capital expenditures during 1985-2000, or $0.3 billion to $0.7 billion per year (5 to 10 percent above "normal"), capital turnover can be speeded up to allow the low scenarios to be achieved on the schedule in table 1. Similarly, if technology developments are successful, the high scenario could be achieved as shown in table 1 with capital expenditures of $9 billion to $23 billion above "normal" during the period 1985-2000, or $0.6 billion to $1.5 billion per year (10 to 20 percent above "normal").

If future demand for fuel efficiency is not high enough to support these rates of change, increases in fuel efficiency will be further delayed unless required by new CAFE standards. On the other hand, CAFE standards **without** analogously high consumer demand for efficiency would require the manufacturers to either defer expenditures for other improvements that might help car sales or to incur additional capital costs.

The consumer costs of increased fuel efficiency, measured in dollars per gallon of gasoline saved, are speculative because the variable costs —mostly material and labor costs—are even more difficult than investment costs to determine accurately. OTA's analysis is based on alternative assumptions about the degree of change in material and labor costs. A direct calculation of these costs would have been expensive and the results difficult to defend because the source data is proprietary and highly dependent on judgments about the success of adapting technologies to mass production. Table 3 shows the range of costs attributed to fuel efficiency assuming that consumers value future gasoline savings as highly as today's savings (i.e., without discounting future savings*) and that manufacturers pass through the full costs. Conceivably, foreign competition could force the manufacturers to absorb part of these costs.

*Assuming "normal" capital turnover is: engines improved after 6 years, on average, redesigned after 12 years; transmissions same as engines; body redesigned every 7.5 years; no advanced-materials substitution.

*The cost perceived by consumers would be about 2.5 times as high as those shown if the consumer discounts future fuel savings at 25 percent per year, i.e., each future year's savings during the life of the car is valued at 25 percent less than the previous year's savings.

Table 3.—Consumer Costs for Increased Automobile Fuel Efficiency, Without Discounting Future Fuel Savings, Moderate Shift to Smaller Cars

Time period	Average new-car fuel efficiency at end of time period (mpg)	Consumer cost[a] ($/gal saved)	
		No variable cost increase	High variable cost[b] increase
1985-1990	38-48	0.15-0.40	0.40-1.10
1990-1995	43-59	0.35-0.85	1.10-2.60
1995-2000	51-70	0.30-0.95	0.90-2.80

[a]Assumes a capital recovery factor per year of 0,15 times the capital investment allocated to fuel efficiency
[b]Assumes variable cost increase is twice the capital charges associated with the capital investments allocated to fuel efficiency.

SOURCE: Office of Technology Assessment.

The consumer costs of fuel efficiency range from values that are easily competitive with today's gasoline prices to values that are considerably higher, depending on the efficiency gains actually achieved, the success of developing production techniques that can hold down variable cost increases, and the value consumers place on future fuel savings. Investments for increased efficiency for the 1990-2000 model years will look particularly risky if the current soft petroleum market continues for a few more years, or if auto manufacturers have difficulty holding down their labor and materials costs.

Another important measure of the cost to consumers of increased fuel efficiency is the increase in the price of new cars required to recover the industry's increased production costs. If the market demand for fuel efficiency is strong enough to ensure that as much as possible of the capital investment for fuel efficiency increases is incorporated into the normal capital turnover, and if the variable costs of production can be held constant, then the cost* of achieving OTA's fuel-efficiency scenarios can be as low as $60 to $130 per car during the 1985-2000 time period. Under these conditions, an average of 35 to 45 mpg could be achieved by 1990 without increasing new-car costs.

If actual market demand for fuel efficiency is not this high, automakers would be unlikely to incorporate a very high level of fuel efficiency investments into their normal capital turnover. Also, the variable costs of production **are** likely to rise somewhat. The "upper bound" for added costs —assuming large increases in variable costs and **no market-driven** investment for fuel efficiency increases beyond 1985—is **$800** to **$2,300** per car during the 1985-2000 period, and $250 to $500 per car to achieve 35 to 45 mpg by 1990. Therefore, the cost per car of increased fuel efficiency beyond 1985 ranges from "clearly competitive" to "probably unacceptable. "

*Assumes a capital recovery factor of 0.15.

Economic Impacts

The domestic automobile industry is in the midst of a massive investment program aimed at improving the competitiveness of American automobiles. These expenditures are associated with important structural changes in the industry; and accelerating the rate of capital turnover (for increased fuel efficiency or other reasons) may accelerate some of these trends.

Manufacturers are closing older, inefficient plants and building new ones that incorporate extensive use of robots and other labor-saving technology to increase productivity. For a number of reasons, including lower labor and other costs, many of the new facilities may be built in the Nation's Sun Belt or overseas rather than in the current North-Central auto manufacturing centers, although recent labor concessions may change this picture. Because of a shift in U.S. demand to smaller cars, which can be marketed more universally, the incentive to produce in the United States is diminishing. Finally, because rapid capital turnover is raising production costs at a time when consumer demand for automobiles has been sluggish, manufacturer profits have diminished and it has become harder for the firms to secure capital at affordable costs.

American companies are forging more extensive ties with foreign manufacturers to design, produce, and market fuel-efficient cars, and are moving towards producing more nearly standardized automobiles that can compete in international markets. Current trends seem to be toward fewer separate automotive manufacturing and supply firms worldwide; only GM and Ford appear to be reasonably certain of remaining predominantly American-owned.

Certain regions such as the industrial Midwest —and the Nation as a whole—will lose jobs if these structural changes continue. Job losses also would occur, however, if the process is interrupted, because the restructuring represents the industry's response to the conditions that caused its present market problems, and it clearly is aimed at regaining sales.

Social Impacts

As auto manufacturing and supply activities become more efficient and automated, there will be important changes in the workplace environment. Robots and other automated equipment will increasingly be used for the more routine and dangerous jobs, and skilled workers such as engineers and maintenance technicians should become a greater percentage of the smaller total work force. Shifting manufacturing overseas will reduce U.S. employment in primary manufacturing as well as in supplier companies. Although employment losses may be larger in the supplier industries, the effects in these industries will be distributed over a larger geographical area. Employment in related activities such as repair and service will change to accommodate the new auto characteristics—e.g., repairs of plastic body components require adhesives, not welding—and the increasing sophistication and capital investment required for vehicle maintenance will place new demands on shops and dealers.

Fuel efficiency increases also affect automobile owners by changing the physical attributes of the vehicle and the economics of owning cars. For example, a continued reduction in car size could lead to increasing use of rentals for longer trips or for occasional requirements for increased cargo-carrying capacity. Increases in the initial cost of buying a car are likely to lead to a continuation of current trends of keeping cars longer, resulting in a slower growth or reduction in new-car sales.

Environment, Health, and Safety

Increasing automobile fuel efficiency appears likely to have a relatively benign effect on the natural environment and public health, because most of the efficiency measures have few adverse effects on auto emissions, emissions associated with vehicle manufacturing, etc. An important exception may be any shift to widespread use of diesel engines, which could cause problems with vehicle particulate and nitrogen oxide (NO_x) emissions. Also, the increased production of lightweight materials—particularly aluminum—may cause additional impacts, such as increased energy consumption in processing and increased demand for bauxite. On the other hand, significant downsizing of automobiles could allow either lower vehicle emissions or lower control costs to maintain current emission levels.

In contrast to their expected small effect on pollution levels, fuel conservation measures that stress reducing vehicle size may have a significant adverse effect on vehicle safety. This is because of the important role in crash survival played by "crush space"* and other size- and weight-related factors. Even a relatively small decline in vehicle safety could cause hundreds or even thousands of additional deaths and serious injuries per year.

There is no widely accepted estimate of the magnitude of this effect. The National Highway Traffic Safety Administration has projected a 10,000 per year increase in traffic deaths from vehicle size reductions by 1990, but this is based on a limited data set and a number of simplifying assumptions. And a net increase in traffic deaths is not inevitable, since increased usage of passenger restraints and improvements in vehicle design could more than offset the effect of moderate size reductions.

*With a smaller "crush space" (thus, more rapid deceleration of occupants in a crash), factors such as seatbelt and shoulder restraint usage, better driver training and traffic control, and other safety measures, become more important determinants of traffic safety.

Synthetic Fuels

Production of a variety of fossil fuel-based synthetic fuels is planned or under development.

- Oil shale can be heated to release a liquid hydrocarbon material contained in the shale. After further upgrading a **synthetic crude oil** similar to high-quality natural crude oil can be produced. This can be refined into gasoline, diesel and jet fuels, fuel oils, and other products.
- Coal can be partially burned in the presence of steam to produce a so-called "synthesis" gas of carbon monoxide and hydrogen, from which **gasoline, methanol, diesel and jet fuel, and other liquid fuel products** ("indirect liquefaction") or **synthetic natural gas (SNG)** can be produced.
- Coal also can be reacted directly with hydrogen (which is itself generated from a reaction of steam and coal) to produce a **synthetic crude oil** ("direct liquefaction"). This oil can be converted to **gasoline, jet fuel and other products** in specially equipped refineries.

Projection of Synfuels Development

The principal technical deterrent to rapid deployment of a synfuels industry is the lack of proven commercial-scale synfuels processes in the United States. Shale oil, indirect coal liquefaction, and SNG processes currently are sufficiently developed that the demonstration of commercial-scale process units or modules is being pursued, but these first units are likely to require considerable modification before they can operate satisfactorily. Once these commercial-scale modules have been adequately demonstrated, full-size commercial facilities can be constructed (from several modules). in contrast, direct coal liquefaction requires further development before commercialization and probably will not contribute significantly to the synfuels industry before the mid to late 1990's. A major technical obstacle, the handling of high levels of solids in the process streams, is not now understood well enough to allow developers to move directly to commercial- from small-scale units now in operation.

Normal planning, permitting, and construction may take 7 to 8 years for a large synfuels plant, with the last 5 years or so devoted to construction. Consequently, a first round of commercial-scale plants conceivably could be operating by the late 1980's, although these would be quite vulnerable to delays and cost overruns. Beginning a second round of construction before the first set of plants has been fully demonstrated would risk additional costly revisions and delays.

In addition to scheduling constraints caused by technological readiness, shortages of experienced manpower (primarily chemical engineers and project managers) could constrain the pace of synfuels development. On the other hand, problems stemming from shortages of skilled craftsmen, construction materials, or specialized equipment probably can be averted because of the long leadtime before they are needed in large numbers. However, some metals needed for certain steel alloys are obtained almost exclusively from foreign sources.

Many variables affect the rate of development, and predictions are extremely speculative. It is OTA's judgment that **under favorable circumstances, fossil fuel-based production of synthetic transportation fuels could be** 0.3 **to** 0.7 **MMB/D by 1990, growing to 1 to 5 MMB/D by 2000,** depending on the success of the first round of synfuels plants and the fraction of those plants that produce **transportation fuels** as opposed to fuel gases or fuel oils. Achievement of 0.3 MMB/D by 1990 assumes that a sizable commercialization program, such as that being pursued by the Synthetic Fuels Corp., is carried out, but that technical problems limit total production; 0.7 MMB/D would require an increased number of plant commitments within the next year or so, a virtually complete emphasis on liquid transportation fuels, and a high level of technical success with the first plants.

It **must be stressed that even the "low"** 0.3 MMB/D **production level maybe considered as optimistic** in light of current expectations of at least short-term stability in oil prices, as well as remaining technical and environmental uncertainties. In addition, the dismantling of DOE's demonstration program may increase the perceived and actual technological risks of synfuels development. Thus, **the goals of the National Synfuels Production Program, created by Congress in 1980—0.5 MMB/D by 1987 and 2 MMB/D by 1992—appear unattainable without a crash program that would involve extraordinary technical and economic risks and extensive Government intervention.**

costs

The costs of synfuels are uncertain. First, the factors that limit rapid deployment of the industry also affect its costs. Technical uncertainties complicate cost evaluation, and long shakedown times and potential construction delays would be very expensive at prevailing interest rates. Second, synfuels' relatively high capital costs mean that their total costs are especially sensitive to the type of financing used, the level of interest rates, and the rate of return required by the investors. The present high level of uncertainty in capital markets therefore translates into a high level of cost uncertainty. In addition, the long construction times associated with synfuels plants make them vulnerable to hyperinflation. *

OTA has projected synthetic fuel costs based on the best available cost estimates in the public literature and OTA's previous oil shale study.[1] These sources indicate that, if the potential for cost overruns is not considered, the capital investment (in 1980 dollars) for a 50,000 bbl/d (rated capacity) synthetic fuels plant will range from $2.1 billion to $3.3 billion, or $47,000 to $73,000/bbl/d of production (assuming the plant produces at 90 percent of rated daily capacity). Total plant investments for a 5 MMB/D synfuels industry would thus be about $250 billion to $400 billion. Based on past experience, however, there is a very high probability that final costs will be greater than these ranges.

For example, an extrapolation from recent cost overruns in the chemical industry widens the single plant (50,000 bbl/d) range to $2.3 billion to $4.7 billion (excluding direct liquefaction, for which cost estimates are less reliable), or about $50,000 to $110,000/bbl/d. Other related investments (e.g., coal mining) raise the total to $50,000 to $125,000/bbl/d. The investment costs per barrel per day of production may be further inflated by performance levels below the 90-percent design factor, although presumably this will be a problem only with first generation plants.

The actual selling price of synthetic fuels will be determined in the marketplace by the prices of competing fuels regardless of the costs of production. Using the projected synfuels production costs, however, OTA calculated the price that service stations **would have to charge** in order for the synfuels producer to attain a required return on investment. Table 4 displays these "prices" for a few alternative combinations of financing and real* return on investment.

Based on these estimates, it is clear that **companies that must bear the full investment burden of a new synfuels plant are unlikely to invest in synthetic fuels production unless: 1) they view this investment as one of low risk and worthy of a low expected return on investment, 2) they expect fuel prices to rise very sharply in the future, or 3) they are willing to take a loss or low return to secure an early market share. The first alternative is not credible for the first generation of commercial plants.**

With the large (75 percent of project costs) loan guarantees that are possible under the En-

*Hyperinflation in construction costs of major capital projects is a relatively recent phenomenon, however, and some industry analysts consider it a temporary aberration.

[1] U.S. Congress, Office of Technology Assessment, *An Assessment of Oil Shale Technologies,* OTA-M-1 18 (Washington, D. C.: U.S. Government Printing Office, June 1980).

*The real rate of return is the nominal rate of return minus the inflation rate.

Table 4.—Price of Synthetic Fuels Required To Sustain Production Costs[a] (1980 $/gal of gasoline equivalent)

Price (pretax)	Financing	Real return equity investment
$0.80-$1 .10...	100% equity	50/0
$1.30-$1.60, . .	1000/0 equity	10%0
$1.70-$2 .40...	100% equity	15 "/0
$0.80-$ 1.10...	25°/0 equity, 75°/0 debt	10 "/0

[a] Assumptions: no cost overruns, $1 .20/million Btu coal, 5 percent real interest rate on debt financing, $.20/gallon distribution cost including retailer profit. For more details, see ch. 8, table

SOURCE: Office of Technology Assessment.

ergy Security Act, * **however, investments in synthetic fuels appear to be attractive even at 1981 fuel prices, but only if current capital cost estimates for synfuels plants are correct and there are no cost overruns. Most industry experts, however, consider the chances of substantial cost overruns to be high.** A cost overrun in plant investment of so percent would increase the necessary price of synfuels by 20 to 30 percent, or else reduce the return on investment.

OTA's cost analysis implies that **significant levels of investment in synfuels production are unlikely at this time without the kinds of financial incentives offered by SFC.** Of course, a further—and currently unexpected—rapid escalation in oil prices could change this conclusion.

Uncertainties associated with the cost estimates are too large to allow in-depth comparison of the costs of the various synfuels. Also, in OTA's opinion, significant reduction of these uncertainties cannot be achieved by further study but will require actual plant construction. **There are indications, however, that shale oil and methanol from coal could be the least expensive options for producing transportation fuels.** Shale oil plants are less complex technically than other synfuels processes and shale oil is relatively easy to refine, thereby suggesting a lower cost. Methanol's high octane and burning characteristics make it more efficient than gasoline in specially designed engines. But materials-handling problems for oil shale, engine technology developments that could offset methanol's efficiency advantage, and unforeseen requirements for process changes could negate these apparent advantages.

Economic Impacts

Development of a fossil fuel-based synthetic fuels industry could create a major new economic activity in the United States, particularly in areas with large reserves of coal or oil shale. There are potential drawbacks, though. For example, because of synfuel plants' long lifetimes and construction leadtimes, a liquid fuel supply industry based largely on synfuels would be less able than a natural petroleum-based industry to respond quickly to changing market conditions. Rapid synfuels deployment would create a risk that unforeseen market changes could leave the United States with an outdated, idle, capital-intensive industry.

Development of the industry will have other important consequences. For instance, because of the large capital, technical and marketing requirements, and the high risks, small companies are unlikely to enter the market except as parts of consortia. This contrasts sharply with the large number of small-scale producers currently involved in oil and gas development, although ownership concentration in the oil and gas industry will grow in any case as the more easily recovered resources are depleted.

Rapid deployment of a synfuels industry could lead to temporary shortages of equipment, materials, and personnel, which in turn can lead to construction bottlenecks and local inflation. However, long-term inflationary effects are not expected to be large because, in general, the leadtime is sufficient to expand production capacity and labor supply. An important exception may be the supply of experienced chemical engineers and project managers. If shortages of these personnel develop, poor project management or improper plant design could lengthen construction schedules, delay plant startup, and increase costs for chemical plants and oil refineries as well as synfuels plants.

The financial requirements for rapid growth are very large. For example, the rate of investment required to achieve 5 MMB/D of synfuels by 2000 is likely to be greater than $30 billion per year* after the first few years, about as much capital as was spent for all U.S. oil and gas exploration and development in 1979. Making this large a commitment to synfuels would likely divert some investment capital away from conventional oil and gas exploration and development; and this

*The loan guarantees not only allow synfuels developers to borrow money at somewhat lower interest rates than without them, but the 75 percent debt level is considerably higher than the industry average of about 30 percent. Also, in some cases, the loan guarantee may be necessary to secure any debt capital at all.

*OTA's analysis of reducing stationary uses of fuel oil was done primarily to provide a reference point and was less extensive than its analysis of synfuels and increased automotive fuel efficiency.

could reduce conventional domestic oil production below the **7** MMB/D assumed for **2000.**

Social Impacts

The principal social consequences of developing a synthetic fuels industry stem from shifting large numbers of workers and their families in and out of local areas as development proceeds. These population shifts disproportionately affect small, rural communities such as those that predominate in the oil shale and some of the coal areas. High population growth rates can lead to disruptions and breakdowns in social institutions; systems for planning, managing, and financing public services; local business activities; and labor, capital, and housing markets. Whether the growth rates can be accommodated depends on both **community** factors (e.g., size, location, tax base, management skills, and availability of developable land), and **technology-related** factors (e.g., the type of synfuels facilities, the timing of development, and labor requirements).

On the other hand, communities should realize social benefits from synfuels development, e.g., increased wages and profits and an expanding tax base. A significant portion of these benefits may not be realized, however, until after the plant is built. In the meantime, the community must make significant expenditures and the overall impact depends substantially on the existence of effective mechanisms to provide the "front end" resources needed to cope with rapid growth.

Environment, Health, and Safety

The production of large quantities (2 MMB/D or more) of liquid synthetic fuels carries a significant risk of adverse environmental and occupational health effects, some of which are quite dependent on the effectiveness of as yet unproven control measures.

The industry will cause many of the same kinds of mining, air quality, solid waste disposal, water use, and population effects as are now associated with coal-fired electric power generation and other forms of conventional coal combustion. Table 5 shows the amount of new coal-fired power generation that would produce the same effects as a 50,000-bbl/d coal-based synthetic fuels plant, and also directly compares the effects of this plant with a 3,000-MWe coal-fired powerplant. In general, **the emissions of combustion-related pollutants, especially the acid rain precursors sulfur dioxide (SO_2) and NO_x, and the water use of the synfuels plant are significantly lower than for a powerplant processing the same amount of coal.**

To place these effects into perspective, actual coal-fired generating capacity in the United States is about 220,000 megawatts (MW), and about 200,000 MW are expected to be added by 1995. In comparison, SO_2 and NO_x emissions from a 2 MMB/D coal-based synfuels industry would be equivalent to emissions from less than 25,000 MW of power generation, and water use would be equivalent to that of 30,000 MW or less if conservation practices were followed.

On the other hand, **a 2-MMB/D industry (equivalent in coal consumption to 110,000 to 160,000 MW of coal-fired electric generating capacity) would mine hundreds of millions of tons of coal each year, with attendant impacts on acid drainage, reclamation, subsidence and occupational health and safety, and would have substantial population-related impacts such as severe recreational and hunting pressures on fragile Western ecosystems.**

Oil shale development using aboveground retorts has the added problem of disposing of large quantities of spent shale. Although successful short-term stabilization of shale piles has been achieved on a small scale, uncertainty remains about the long-term effects of full-scale development. **The major concern about shale disposal as well as in-situ shale processing is the potential for contamination of ground waters.**

Despite the relatively moderate level of emissions per unit of production, an intense concentration of synfuels development within relatively small areas may yield air quality problems and violations of existing air quality regulations. Such concentration is more likely with oil shale, because of the concentrated resource base. As a result, air quality restrictions may limit oil shale development to under 1 MMB/D unless there are changes in the restrictions or improvements in

Table 5.—Two Comparisons of the Environmental Impacts of Coal-Based Synfuels Production and Coal-Fired Electric Generation[a]

Type of impact	A. Coal-fired generating capacity that would produce the same impact as a 50,000 bbl/d coal-based synfuels plant (MW(e))	B. Side-by-side comparison of environmental impact parameters: 3,000 MW(e) generator	B. Side-by-side comparison of environmental impact parameters: 50,000 bbl/d synfuels	Units
Annual coal use	2,500 -3,600[b]	6.4-15.0	5.3-17.9	million tons/yr
Annual solid waste	(2,500-3,600)±[c]	0.9-2.0+	0.6-1 .8+	million tons/yr
Annual water use:				acre-ft/yr
Current industry estimate	640-1,300	25,000	5,400-10,800	
Conservation case	400-700		3,400-5,900	
Annual emissions:				tons/yr
Particulate	120-2,800	2,700	100-2,500	
Sulfur oxides	90-500	27,000-108,000	1,600-9,900	
Nitrogen oxides	60-300	63,000	1,600-7,800	
Hourly emissions:				lb/hr
Particulate	90-2,200	880	30-800	
Sulfur oxides	70-40	8,800-35,200	500-3,200	
Nitrogen oxides	60-300	20,500	500-2,500	
Peak labor	4,100-8,000	2,550	3,500-6,800	persons
Operating labor	2,500	440	360	persons

a In example A, the powerplant uses the same coal as the synfuels plant, new source performance standards (NSPS) apply, sulfur oxide emissions assumed to be 0.6 lb/10^6 Btu. In B, NSPS aiso apply but sulfur oxide emissions can range from 0.3-1.2 lb/10^6 Btu. In both cases, the synfuels piant parameters represent a range of technologies, with a capacity factor of 90 percent and an efficiency range of 45 to 65 percent; the powerplant is a baseload plant, with a capacity factor of 70 percent, efficiency of 35 percent. The major data source for this table was M. A. Chartock, et al., *Environmental Issues of Synthetic Transportation Fuels From Coal: Background Report*. University of Oklahoma Science and Public Policy Program, contractor report to OTA, July 1961.

b In other words, the amount of coal–and thus, the amount of mining–needed to fuel a 50,000 bbl/d synfuels plant is the same as that required for a 2,500-3,600 MW(e) powerplant.

c A synfuels plant will have about as much ash to dispose of as a coal-fired powerplant using the same amount of coal. It may have less scrubber sludge, but it may have to dispose of spent catalyst material that has no analog in the power plant thus the ±.

SOURCE: Office of Technology Assessment.

control technology. In most cases, however, the restrictions do not involve possible violations of the health standards, but rather visibility or other standards.

Aside from these effects, **synfuels development creates a potential for occupational, ecological, and public health damage from the escape of toxic substances formed during the conversion processes.** These include cancer-causing organic compounds, chemically reduced sulfur and nitrogen compounds, and inorganic trace elements. The occupational risks, generally acknowledged as the most serious, are mainly associated with "fugitive" emissions and leaks from valves, gaskets, etc., and with the handling of fuels and plant cleaning. The major ecological and public health risks are associated with contamination of surface and ground waters—from inadequate treatment of wastewaters, leakage from holding ponds or solid-waste landfills, and disruption of aquifers by mining operations—as well as with spills and exposure to contaminated fuels. Fugitive emissions and leaks from the plants also pose some risk to public health, but at a far lower level than to the plant workers; a potentially important impact of the public's exposure to these substances, however, is likely to be discomfort from their odor.

The risks associated with these toxic substances, although possibly the most serious of synfuels' potential environmental risks, are **not** quantifiable at this time. However, it does appear possible to differentiate, at least tentatively, among some of the basic process groupings in terms of their comparative risk. Direct processes (e.g., Exxon Donor-Solvent, SRC II) appear to present the greatest risk because of their comparatively large number of potential sites for fugitive emissions, high production of toxic hydrocarbons, and abrasive process streams. Indirect processes using low-temperature gasifiers (such as Lurgi) maybe intermediate in risk because they produce relatively large quantities of toxic hydrocarbons. Indirect processes using high-temperature gasifiers (e.g., Koppers-Totzek, Shell, Texaco) appear to be the cleanest group of coal-based processes. Finally, if the risks from spent shale are excluded, the risks from toxics yielded by oil shale processes probably are no worse than those of indirect, high-temperature coal processes.

There is little doubt that it is **technically** feasible to moderate a synfuels industry's adverse impacts to the satisfaction of most parties-of-interest. in OTA'S judgment, however, **despite substantial industry efforts to minimize adverse impacts, the environmental risks associated with toxic substances generated by synthetic fuels production are significant and warrant careful Government attention.**

Current development plans and existing legislation call for strong measures to reduce many of the potential adverse environmental impacts from synfuels plants through intensive application of emission controls, water treatment devices, protective clothing for workers, monitoring for fugitive emissions, and other measures. Virtually all of these measures have been adapted from controls used with some success in the petroleum refining, petrochemical, coal-tar processing, and electric power-generation industries. Synfuels industry spokesmen are confident that the planned controls will adequately protect worker and public health and safety as well as the environment.

Spokesmen for labor and environmental organizations are far less confident, however, and there remain important areas of doubt concerning the adequacy of environmental management. The full range of synfuels impacts–especially those associated with the toxic substances created or released in the conversion processes—may not be effectively regulated. Existing regulations do not cover many of these toxic substances, and extending regulatory controls to provide full coverage will be difficult. Critical stumbling blocks are the large number of separate compounds that must be controlled, and the recent reductions in the budgets of Federal environmental agencies and reemphasis of their synfuels research programs. Detecting synfuels environmental damages and tracing them to their sources—a key requirement in establishing and enforcing control standards—may be difficult because many of the damages will occur slowly and the relationship between cause and effect is complex.

Another important concern is the possibility that the industry's environmental control efforts may not be sufficient to avoid environmental surprises. Federal Government personnel are concerned that many developers are focusing their control programs on meeting immediate regulatory requirements and are reluctant to commit resources to studying and controlling currently unregulated pollutants. Also, despite pollution control engineers' optimism that all synfuels waste streams are amenable to adequate cleanup, there are still doubts about the reliability of proposed control systems. These doubts are aggravated by differences in process conditions and waste streams between synfuels plants and the refineries, coke ovens, and other facilities from which the proposed controls have been borrowed, and also by a lack of testing experience with integrated control systems.

Water Availability for Synfuels Development

When aggregated nationally, water requirements for synfuels development are small (producing 2 MMB/D oil equivalent requires only about 0.2 percent of estimated total current national freshwater consumption). Nevertheless, these requirements may have significant impacts on competing water uses. In each of the river basins where major coal and oil shale resources are located, there are hydrologic as well as political, institutional, and legal constraints and uncertainties involving water use (e.g., conflicts over the use of Federal storage, Federal reserved water rights including Indian water rights claims, interstate and international compacts and treaties, State water laws). In addition, existing water resource studies vary in the extent they consider water availability factors and cumulative impacts.

Given the uncertainties that surround the question of water availability generally, only limited conclusions about possible constraints on future synfuels development can be drawn. This is especially true in areas where institutional rather than market mechanisms play a dominant role in obtaining and transferring water rights. Where efficient markets do exist, however, water is not likely to constrain synfuels development because developers can afford to pay a relatively high price for water rights.

In the major Eastern river basins where coal reserves are located (the Ohio, Tennessee, and Upper Mississippi River Basins), **water should be adequate on the main rivers and large tributaries,** without new storage, to support planned synfuels development. In the absence of appropriate water planning and management, however, **localized water shortages could arise during abnormally dry periods or from development on smaller tributaries.**

In the West, competition for water already exists and is expected to intensify with or without synfuels development. In the coal-rich **Upper Missouri River Basin,** the magnitude of the legal and political uncertainties, together with the need for major new water storage projects to average-out seasonal and yearly streamflow variations, **make it impossible to reach an unqualified conclusion as to the availability of water for synfuels development.**

In the **Upper Colorado River Basin,** where both oil shale and coal are located, **water could be made available to support initial synfuels development—as much as a few hundred thousand barrels per day of synfuels production by** 1990—but political and legal uncertainties in the basin make it difficult to determine which sources would be used and the actual amount of water that would be made available. Water availability after 1990 will depend both on how these uncertainties are resolved and on the expected continuing growth in other uses of water.

Reducing Stationary Uses of Oil

Stationary uses of oil include space heating and cooling of buildings, electricity generation, production of industrial process heat, and use as a chemical feedstock. These currently account for nearly half of the oil used in the United States—about 8.1 MMB/D out of a total of 16.8 MMB/D in 1980. Of this, about 4.4 MMB/D are fuel oils—middle distillates and residual oil. The remainder include liquefied petroleum gas, asphalt, petroleum coke, refinery-still gas, and petrochemical feedstocks.

Only reductions in the fuel oil portion of the stationary oil uses are likely to lead to actual reductions in imports. The other oil products are difficult to upgrade to premium fuels or use directly in transportation applications and, consequently, a reduction in their use probably would have little effect on the supply of transportation fuels. On the other hand, the crude oil fractions normally used to produce residual and distillate fuel oils can instead be converted profitably into transportation fuels by refining.

Reductions in fuel oil use can be accomplished by fuel switching and conservation. In the buildings sector, natural gas and electricity can replace distillate oil, and insulation, furnace improvements, and other conservation measures can reduce fuel use in general. For utilities, conservation in all sectors that use electricity can reduce generation requirements, coal and nuclear can replace residual oil for baseload operation, and natural gas can replace distillate oil in peaking turbines. industrial oil use can be reduced by increases in process efficiency and fuel switching to coal, * natural gas, and electricity.

Projection of Oil Savings

The Energy Information Administration projects that the fuel oil consumed in stationary uses will decline from today’s 4.4 MM B/D to 2.6 MM B/D in 1990, assuming a 1990 price of $41/bbl of oil (1979 dollars). This 2.6 MMB/D is the target for further stationary use reduction OTA has assumed for this study.**

OTA has evaluated two approaches to eliminating the remaining 2.6 MM B/D stationary fuel oil use by 2000. One approach involves total reliance on fuel switching. Table 6 shows the energy needed to displace the 2.6 MMB/D, substituting coal for residual oil and natural gas and/or electricity for distillate oil.

***The Energy Information Administration has predicted that, by 1990, most of the industrial processes that can use coal (primarily large boilers) will have been converted. Therefore, OTA’S calculations of post-1990 fuel-switching opportunities do not include coal switching in the industrial sector.**

*** “If oil prices continue to decline in real dollars or stabilize at current levels, 1990 stationary oil use is likely to be greater than projected.**

Table 6.—Summary of Annual Energy Requirement To Displace 2.55 MMB/D of Stationary Fuel Oil Use

Sector	Oil (M MB/D)	replaced by Coal (106 tons)	plus (tfc)	or Electricity (10' kWh)
Buildings	1.2	—	2.4	425
Industry	0.3	—	0.6	120
Utilities.	0.9 (resid.)	100	—	—
	0.15 (dist.) . .	—	0.3	—
Total	2.55	100	3.3	545

SOURCE: Office of Technology Assessment.

The **technical** capability to accomplish this level of switching depends on two factors. First, if natural gas is to play a major fuel-switching role, production of unconventional gas sources* will be needed. A key to this is the future price of gas. Second, production of additional electricity and switching to coal in utility boilers depends primarily on the utility industry's ability to solve its current financial problems and gain access to capital. Either of these potential constraints could severely restrict fuel switching.

A second approach combines fuel switching with measures to conserve oil, natural gas, and electricity. If conservation measures can save enough natural gas and electricity to replace the (reduced) oil requirement, additional gas and electricity production may not be needed. An analysis by the Solar Energy Research Institute (SERI) indicates that conservation measures in the buildings sector alone could save about 1.5 times as much natural gas and electricity as would be required to replace all remaining stationary uses of distillate and residual fuel oil by 2000.** This combined approach has fewer technical constraints than the "fuel switching only" approach. In OTA'S judgment, **a significant fraction of the 2.6 MMB/D of stationary fuel oil use expected in 1990 can be eliminated by 2000 by conservation and fuel switching taken together.**

Despite the lack of absolute constraints, however, it is unrealistic to expect total elimination or near-elimination of stationary fuel oil uses by 2000. First, average capital costs are high enough to discourage those investors who apply a high discount rate to their investments. Second, the site-specific variability and the large number of different types of measures imply that some of the individual measures will be far more expensive than the average. * Third, the record of oil-to-coal switching in industry during the past decade has not been a good one despite apparently favorable economic incentives. Finally, the continued reduction in supplies of high-quality "light" crude may lead to excess supplies of residual oil in the 1990's, driving down its price and making conversion from residual oil to coal uneconomical in some cases. To a certain extent the latter effect will be offset by the economic attractiveness of retrofitting oil refineries to produce less low-priced residual oil and more gasoline, jet fuel, and diesel fuel.

costs

The investment costs for the two strategies for reducing stationary oil uses are similar. OTA has calculated the investment cost of the strategy that relies mainly on fuel switching to be roughly $230 billion, or an average of $90,000/bbl/d of oil saved. Using SERI'S cost analysis, the strategy that combines strong conservation measures and replacement of the remaining oil use with electricity and natural gas was calculated to cost roughly $225 billion, or $88,000/bbl/d of oil saved. The difference between the estimated costs for the two strategies is too small to be meaningful.

Both the investment costs and the operating costs paid by individual investors will vary over an extremely wide range, This is particularly true because the "strategies" are actually a combina-

*These sources include tight sands formations, geopressurized methane, coal seam methane, and Devonian shale formations.

**Assuming that all such stationary uses are reduced by conservation as well.

*By the same reasoning, many will be less expensive than the average.

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tion of several markedly different kinds of investments. For example, conversion of oil-burning utility boilers to coal has an average investment cost of $74,000/bbl/d of oil replaced, whereas conversion of distillate-using facilities to natural gas averages $114,()()()/bbl/d (including the cost of obtaining the new gas). Also, the costs of each type of investment will vary from site to site.

Electric Vehicles*

Automobiles can be powered by rechargeable batteries that drive an electric motor; indeed, some of the first automobiles used battery-electric powertrains. Present concepts of electric passenger vehicles generally envision small vehicles for commuting or other limited mileage uses, with recharging at night when electricity demand is low.

Projections of Use

OTA does not expect electric cars to play a significant role in passenger transportation in this century. Battery-electric cars are likely to be very expensive, costing about $3,000 more in 1990 than comparable gasoline-fueled autos. And this consumer investment may not yield any savings in fuel costs. If batteries must be replaced every 10,000 miles, as required with current technology, total electricity plus battery costs will actually be considerably higher than gasoline costs for a comparable conventional auto, even at $2.00/gal gasoline prices (1980 dollars).

Another reason that OTA is not optimistic is that progress in electric vehicles remains severely limited by battery performance. Currently available batteries and components require 6 to 12 hours for recharging and limit electric vehicles to a range of less than 100 miles between charges. Acceleration is limited to about O to 30 mph in 10 seconds, which is lower than the poorest performing (O to **40** mph in 10 seconds) gasoline and diesel fuel cars and may not be adequate for many traffic conditions. Although predictions of significant reductions in battery size and weight continue, in OTA'S judgment current understanding of battery performance does not permit accurate predictions of future improvements.

Even if sufficient progress is made in battery development to encourage extensive usage of electric cars, **electrification of automobile travel does not offer the same potential for oil savings as the other options.** Under the best of circumstances, **most electric passenger vehicles are likely to be small, limited-performance vehicles that will substitute for small, fuel-efficient conventional autos.** Consequently, **a 20-percent electrification of the auto fleet is not likely to save more than about** 0.2 MMB/D. *

Environment, Health, and Safety

If technical developments, severe liquid fuel shortages, and/or Government promotion were to result in significant sales of electric vehicles, the major environmental impacts probably would be the air quality and other effects associated with reducing auto emissions and increasing electricity generation. **The overall effects of widespread use of electric vehicles on urban air quality should be strongly positive, because the electric cars would tend to be clustered in urban areas, many of which have chronic automobile-related air pollution problems that would be eased by the displacement of conventional automobiles.** There would be, however, a small net increase in regional and national emissions of SO_2, because conventional autos have few or no SO2 emissions to offset the SO_2 emissions from fossil-fueled electric power generation for battery recharging. Additionally, when coal is the fuel source for recharge electricity, the amount of coal mined per unit of oil replaced is comparable to that for synfuels production,** with similar coal mining impacts. Material requirements for batteries could add substantially to the demands for certain minerals, e.g., lead, graphite, and lithium.

Electric passenger vehicles are likely to be small and thus should share safety problems

[2]See, *Synthetic Fuels for Transportation: The Future Potential of Electric and Hybrid Vehicles–Background Paper No. 1,* OTA-BP-E-13 (Washington, D. C.: U.S. Congress Office Of Technology Assessment, April 1982).

*Assuming no oil is used for electricity production and the average gasoline- or diesel-powered vehicle replaced gets 60 mpg.

**That is, 1 ton of coal yields the same oil savings in either technology.

with small conventional automobiles. Additional safety and health problems may be caused by the batteries, which contain toxic chemicals that may pose occupational problems in manufacturing and recycling and may be hazardous in an accident-caused spill; this latter problem is balanced somewhat by eliminating the fuel tank with its highly flammable contents. Finally, extensive outdoor charging of vehicle batteries may pose public safety problems from the electrocution hazard.