Chapter 4

Issues and Findings

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Chapter 4

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INTRODUCTION

This chapter is a summary and comparison of major results from the analyses discussed later in the report. It also contains additional analyses where needed to put the results in perspective.

It begins with a discussion of the true cost of imported oil. Increased automobile fuel efficiency, synfuels, and conservation and fuel switching in stationary petroleum uses are then compared according to the speed with which they can act to reduce oil imports and their respective investment costs. Increased auto fuel efficiency and synfuels are compared according to their environmental, social, and economic impacts. Estimated consumer costs for increased automobile fuel efficiency and synfuels are also given in separate boxes, but the uncertainties are too large for any meaningful comparison. In addition, there is a box discussing the uncertainties in total consumer costs for each of the oil displacement options.

Following the comparisons, several issues related specifically to increased automobile fuel efficiency or to synfuels are covered. For automobiles, the issues include the effects of incentives for increased fuel efficiency on the evolution and health of the U.S. auto industry, the possibilities for a highly fuel-efficient car, the safety of small cars, current demand for fuel efficiency in cars, and the prospects for electric vehicles. For synfuels, probable environmental dangers, water constraints, and compatibility of synfuels with existing end uses are considered.

Each separate entry in this chapter is designed to stand alone and generally does not build on other material in the chapter. The chapter is not designed to be read from beginning to end; rather, each reader can turn directly to those comparisons and issues of interest without loss of context or regard for the way the entries are ordered.

WHAT DO OIL IMPORTS COST?

The private U.S. consumer pays the going market price for imported oil, but that is not its only economic cost. In the last decade, the Nation has been forced to pay a substantial additional "premium" because of its strategic dependence on a small number of foreign oil producers. During especially unstable periods, such as the 1973-74 Middle East War and the 1978-79 Iranian Revolution, this import premium payment is highly visible and, when measured in terms of the incremental cost for that segment of demand which clearly exceeds available supplies, it can greatly exceed the actual market price.

It is reasonable to attribute an exceptional premium payment to oil, and not to other imported goods and services, because uninterrupted oil supplies are critical to economic stability (i.e., few substitutes exist at least in the short run) and because the United States has become the prominent importer on the world scene and has assumed major responsibility for protecting world oil trade. No other import constitutes such a vital economic resource that must flow in such a large continuous stream around the world. Although the third quarter of 1981 has witnessed falling oil prices and a modest supply surplus, future shortage risks remain plausible because of the expected longrun depletion of world oil reserves and because of unresolved and potential international conflicts.

The existence of a national premium payment for oil imports can be explained in terms of three economic relationships:

1. the dependence of international price on the quantity of U.S. imports;
2. the loss of U.S. jobs and gross national product (GNP) caused by oil payments abroad and the associated depreciation of the dollar; and

3. the **budgetary cost of military outlays and foreign military assistance related to assuring the security** of oil imports. These are described below.

Dependence of Price on Quantity Imported

Market price is a good measure of real or total cost when markets are competitive and in a state of stable equilibrium. Neither situation is characteristic of international oil markets, which are dominated by a small number of sellers and buyers in an unstable marriage of short-term convenience. Despite the complexity and unpredictability of this relationship, it seems reasonably clear that raising U.S. oil imports drives price upward and vice versa, simply because any movement by such a prominent importer appears to the rest of the world as a shift in the world demand curve. This positive relationship between quantity imported and price means that the cost of incremental U.S. consumption exceeds current price because the increment makes all future consumption more expensive. Conversely, decrements in U.S. consumption save more money than the marginal reduction in purchases.

Eventually, oil markets may anticipate this price/quantity relationship, but market adjustments may not be smooth. Shocks can be expected, leading to domestic inflation and recession, because international relationships between exporters and importers have become politicized and because significant reductions in oil consumption are difficult to achieve over periods of up to several years due to the long lifetimes of energy-related capital stock and the long leadtime for alternative domestic fuels.

Loss of U.S. Jobs and GNP Caused by Rising Oil Payments and by Potential Supply Interruptions

Oil imports accounted for 26 percent of U.S. payments for imports in 1979, which is about twice the level of the second largest item. Consequently, compared with equivalent rates of growth or decline for other imports, changes over time in oil payments have a relatively large impact on the U.S. balance of trade, and, hence, a relatively large impact on the exchange value of the dollar.

In periods when the dollar is relatively strong, as it has been recently (second half of 1981), it is due in part to declining oil payments. In periods when the dollar is weak, as it was during most of the 1970's and especially after 1975 because of large deficits in merchandise trade, growing oil payments increase selling pressure on the dollar, lowering its foreign exchange value. While this makes U.S. exports more attractive to foreign buyers, export sales may not increase elastically because of stagnant world economy or failure of U.S. goods to meet quality standards. Therefore, market adjustments, including both higher prices and undoubtedly reduced purchases, are forced on U.S. importers.

Furthermore, the declining value of the dollar has relatively little effect on oil imports, again due to the long lifetimes of capital related to oil consumption. Barring economic recession, oil consumption significantly declines only with the slow replacement of capital. Thus, even though rising oil imports or sharply rising oil import prices may be clearly responsible for dollar depreciation, oil consumption may not bear the brunt of the resulting short-term adjustment.

Overall, adjustments in the U.S. balance of payments also affect domestic economic activity. A sharply rising oil import price directly increases domestic inflation while at the same time larger foreign payments can lower total demand for domestic goods and services if, as is likely in the short run, oil exporters do not spend their larger receipts in the United States. This combination of rising inflation and declining total demand puts the Federal Government in a difficult position because corrective policies are contradictory. If control of inflation is the primary objective, sharp oil price increases may force the Government to brake the growth momentum of the national economy or exaggerate downward cycles in order to limit propagation of inflationary pressures.

In addition to oil price shocks, potential supply interruptions of oil imports present the clearest, most direct threat to national economic activity. As discussed above, few good substitutes exist for oil in the short run, so that reduced flow results in lost production and unemployment as *soon* as stockpiles can no longer make up for the deficit.

The potential premium payment, implied by both unstable oil import prices and supply interruptions, can be illustrated in terms of the 1973-74 shock. In 1974 and again in 1975, real GNP declined by more than a percentage point after having grown at a rate of 5 percent in 1973 and 4 percent in 1972. Although cause and effect in macroeconomics is highly speculative, the losses in 1974 and 1975 are widely believed to have been due in part to the disruption of oil supplies and the associated quadrupling of imported oil prices. If, in fact, real GNP growth had been reduced by just one percentage point by oil-related events, it would have meant a loss of about $15 billion in U.S. production ($1.5 trillion GNP in 1975), which amounts to $6.80 per barrel **(bbl)** for the 2.2 billion bbl imported that year. The price of oil at that time was about $11.

Military Outlays and Foreign Policy Directions Forced by Oil Import Dependence

Military and foreign policy are predicated on many national objectives, but apparently one very important consideration for the United States is protection of oil supply lines. The cost of such protection cannot be ascertained directly, but current debate over defense budget priorities indicates that the United States intends to develop weapons systems and train personnel in order to be able to fight a war in the Middle East, if necessary.

If 10 percent of estimated 1982 defense outlays were justified to meet military threats to Middle East oil supplies, it amounts to about $18 billion or about **$9/bbl** for the 2 billion bbl of oil imported (net of exports) in 1981.

Conclusion

The complexity and unpredictability of world oil markets and world oil politics make it difficult to predict the oil import premium over time. * In OTA's judgment, the possible future import premium could range up to $50/bbl. It could be negligible if world demand continues its sharp downward trend and if major new discoveries are made outside the Middle East, but could be much larger than the current price of oil if hostilities break out which cut off most supplies from the Middle East.

A technical analysis must stop short of greater certainty except to indicate that a significant reduction of imports would drive the premium down by reducing the visibility of the United States in world oil markets and by reducing U.S. dependence on supplies from politically unstable countries. In other words, the premium payment for the last barrel of imports is much higher than for the first, and it is the last barrel which would be displaced by domestic synfuels or by higher fuel efficiency in automobiles.

HOW QUICKLY CAN OIL IMPORTS BE REDUCED?

Options for reducing U.S. oil consumption are considered in detail later in the report. Here, the results of those analyses are summarized and the relative contributions that the various options can make to reducing imports over the next two decades are considered.

Table 9 shows the estimated level of imports in the absence of synthetic fuels and automobile fuel-efficiency increases beyond a 1985 level of 30 mpg. This base case also assumes: 1) the Energy Information Administration's (EIA) high oil price future to 1990 for the consumption of oil

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***A number of estimates for both components of the oil import premium are available. For the most detailed discussion of related economic issues and documentation of results from current economic models, see** *World Oil,* **Energy Modeling Forum, Stanford** University, **Stanford,** Calif., ch. **5 (forthcoming).**

Table 9.-Minimum Oil Imports for Base Case (MM B/DOE)

	1980	1985	1990	1995	2000
Stationary demand[a] (no additional measures past 1990)	8.1	7.3	6.4	6.4	6.4
Transportation demand (other than automobiles	4.5	4.7	5..0	5.4	5.7
Automobiles (with 1985 new-car average of 30 mpg, no change thereafter)	4.3	3.6	3.0	2.7	2.7
Sum of demand	16.9	15.6	14.4	14.5	14.8
Domestic production	10.2	8.6	7.6	7.1	7.0
Imports	6.7	7.0	6.8	7.4	7.8

[a] Includes all nonfuel oil uses such as asphalt, petrochemical feedstock, liquefied petroleum gas, etc., which are projected by the Energy Information Administration to total 3.8 MMB/D by 1990,
[b] Oil plus natural gas liquids.

SOURCE: Office of Technology Assessment,

for stationary uses;[1] 2) the transportation petroleum demand (other than for passenger cars) explained in chapter 5; 3) fuel oil demand by stationary uses is held constant after 1990; and 4) the maximum domestic oil production projected by OTA.[2] For 1995 and 2000, the trends of the 1980's for stationary uses of petroleum other than fuel oil have been extrapolated, while holding fuel oil consumption constant at the projected 1990 level. The assumption of constant fuel oil demand for the 1990's was chosen as the base case to help illustrate the importance of eliminating this demand relative to other options for reducing oil imports in the 1990's.

It should be emphasized that a considerable reduction in oil consumption through increased efficiency and fuel switching in the 1980's is already built into the base case. in particular, achieving an average new-car fuel efficiency of 30 mpg by 1985 saves about 0.8 million barrels per day oil equivalent (MMB/DOE) by 1990, relative to 1980 demand;* and conservation and fuel switching in the EIA high oil price scenario reduce oil consumption by 1.7 million barrels per day (MMB/D) in stationary uses by 1990. However, domestic oil production is likely to drop by at least 2.6 MMB/D during this same time period,[3] thereby nullifying any reduction in oil imports from these measures alone.

Table 10 shows the various reductions in oil consumption that may be achieved beyond the base case. These include contributions from further conservation and fuel switching in stationary uses, increased automobile fuel efficiency beyond a 1985 level of **30** mpg, electric vehicles (EVs), and synfuels. Each of the areas where additional oil savings are possible is discussed below.

By 1990, stationary demand for residual and distillate *fuel* oil is 2.6 MMB/D in the base case. * As explained in chapter 7, a combination of cost-effective conservation measures and switching to natural gas and electricity can eliminate this stationary fuel oil demand without a need to increase gas production or electric generating capacity. How much of this potential actually is reached will depend on such things as individual decisions about conservation investments and

Table 10.—Contributions to the Reduction of Oil Imports Beyond the Base Case (MMB/DOE)

	1980	1985	1990	1995	2000
Conservation and switching in stationary applications	0	0	0	0.8[a]-1.3	l.5[a]-2.6
Increased automobile fuel efficiency beyond 1985 average of 30 mpg	0	0-0.1	0.1-0.5	0.3-1.0	0.6-1.3
(Average new-car efficiency, mpg[b])	(23)	(30-37)	(36-49)	(40-63)	(45-79)
Electric vehicles	0	0	0	0	0-0.1
Synthetic transportation fuels:					
Fossil	0	0-0.1	0.3-0.7	0.7-1,9	1.3-4.5
Biomass	0	(c)	0-0.3	0-0,6	0,1-1.0
Total	0	0-0.20	.4-1.5	1.8-4.8	3.5-9.5

[a] Energy Information Administration forecast.
[b] 55 percent EPA city/45 percent EPA highway test cycles.
[c] Less than 0.05 MMB/D.

SOURCE: Office of Technology Assessment.

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[1] Energy Information Administration, U .S. Department of Energy.

[2] *World Petroleum Availability: 1980-2000— Technical Memorandum, OTA-TM-E-5* (Washington, D. C.: U.S. Congress, Office of Technology Assessment, October 1980).

*The fuel saved in cars is 0.9 million barrels per day (MMB/D), but the assumed increase in transportation needs raises consumption in other types of transportation by 0.1 MMB/D.

[3] *World Petroleum Availability: 19802-Technical Memorandum,* op. cit.

*The remainder of the 6.4 MM B/D of stationary oil use includes asphalt, petrochemical feedstocks, liquefied petroleum gas, and refinery still gas.

availability of transmission and distribution systems. The most recent projection of EIA provides a reasonable lower bound on the reduction in fuel oil that can be achieved during the 1990's.

The range of potential savings from increased automobile fuel efficiency corresponds to the low and high estimates derived in chapter **5** and different assumptions about relative future demand for small-, medium-, and large-sized cars, i.e., 1) no shift to smaller cars and pessimistic assumptions about efficiency increases from automotive technologies, and 2) a substantial shift to smaller cars and optimistic assumptions about the technologies. By **2010,** automobiles containing the average technology of 2000 would have replaced most cars on the road and the savings, relative to the base case, would be 0.8 to 1.7 MMB/D (2.3 to 3.2 MMB/D relative to 1980 demand).

It should be emphasized that average new-car fuel efficiencies shown in table 10 do not represent a technical limit to what can be achieved. In any given year, cars with higher (and lower) mileages than those shown would be produced and sold. * Rather, the mileage ranges correspond to what OTA considers to be feasible through a variety of technological improvements.

If a very strong demand for fuel-efficient cars develops, e.g., as the result of continued large oil price increases, consumers may be willing to accept poorer performance or pay the added cost in order to achieve higher fuel efficiency. In this case, the estimated average fuel efficiency shown for 2000 in table 10 could be achieved by the mid- 1990's.

The contribution from EVs was calculated by assuming that O to 5 percent of passenger automobiles would be electric by 2000, growing linearly from O percent at 1985, The savings from EVs is relatively small, however, because of the relatively low consumption of petroleum by automobiles (1.3 to 2.1 MMB/DOE in 2000) and the fact that EVs would be a substitute for the most fuel-efficient cars.

The final category in table 10, synthetic fuels, must be considered carefully to ensure that only the synthetic fuels production that displaces oil is included and technical difficulties are accounted for. To derive the low estimate of synfuels contributions, it is assumed that by the time synthetic fuels become available, the only remaining stationary uses of petroleum are for chemical feedstocks, asphalt, petroleum coke, still gas, and liquefied petroleum gas (LPG). Since these products cannot now be economically converted to transportation fuels, the low estimate in table 10 assumes that their replacement by synthetic fuels (synthetic gas) would not result in additional transportation fuels. * In addition, poor performance of the first round of synfuel plants is assumed, limiting production until the early to mid-1 990's. As a consequence of this, the low synfuels production scenario from chapter 6 is used in the table 10 low estimate.

A more optimistic scenario is possible if it is assumed that market or other forces strongly favor the production of transportation fuels over synthetic fuel gases and that half of the synthetic gas* * plants projected in chapter 6 actually are built to produce synthetic transportation fuels. With these assumptions and the high scenarios presented in chapter 6, one arrives at the upper estimate for oil displacement by synfuels shown in table 10. The high estimate, however, represents a vigorous dedication to synfuels production and what might be termed near "war mobilization" development of the industry.

The range of oil savings from each of these sources is shown in figure 4, alongside the import levels calculated in the base case. As can be seen, under the most favorable circumstances it is technically possible to eliminate oil imports by 2000. However, if domestic oil production[5] is below that shown in table 9 and if only the low estimates of table 10—or even only the low esti-

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*For **example, u p until January 1981, the 1981 model new-car fuel efficiency of cars sold averaged slightly less than 25 mpg, but if the *most* fuel-efficient cars in each size class had been bought, the average would have been about 33 mpg.4**

[4] Derived from data in J. A. Foster, J. D. Murrell, and S. L. Loos, "Light Duty Automotive Fuel Economy . . . Trends Through 1981 ," U.S. Environmental Protection Agency, SAE paper No. 810386, February 1981,

***LPG can, however, be used directly in appropriately modified automobiles.**

****Excluding biogas from manure, which would be used principally on the farms where it is produced.**

[5] ***World Petroleum Availability: 1980-2000- Technical Memorandum,* op. cit.**

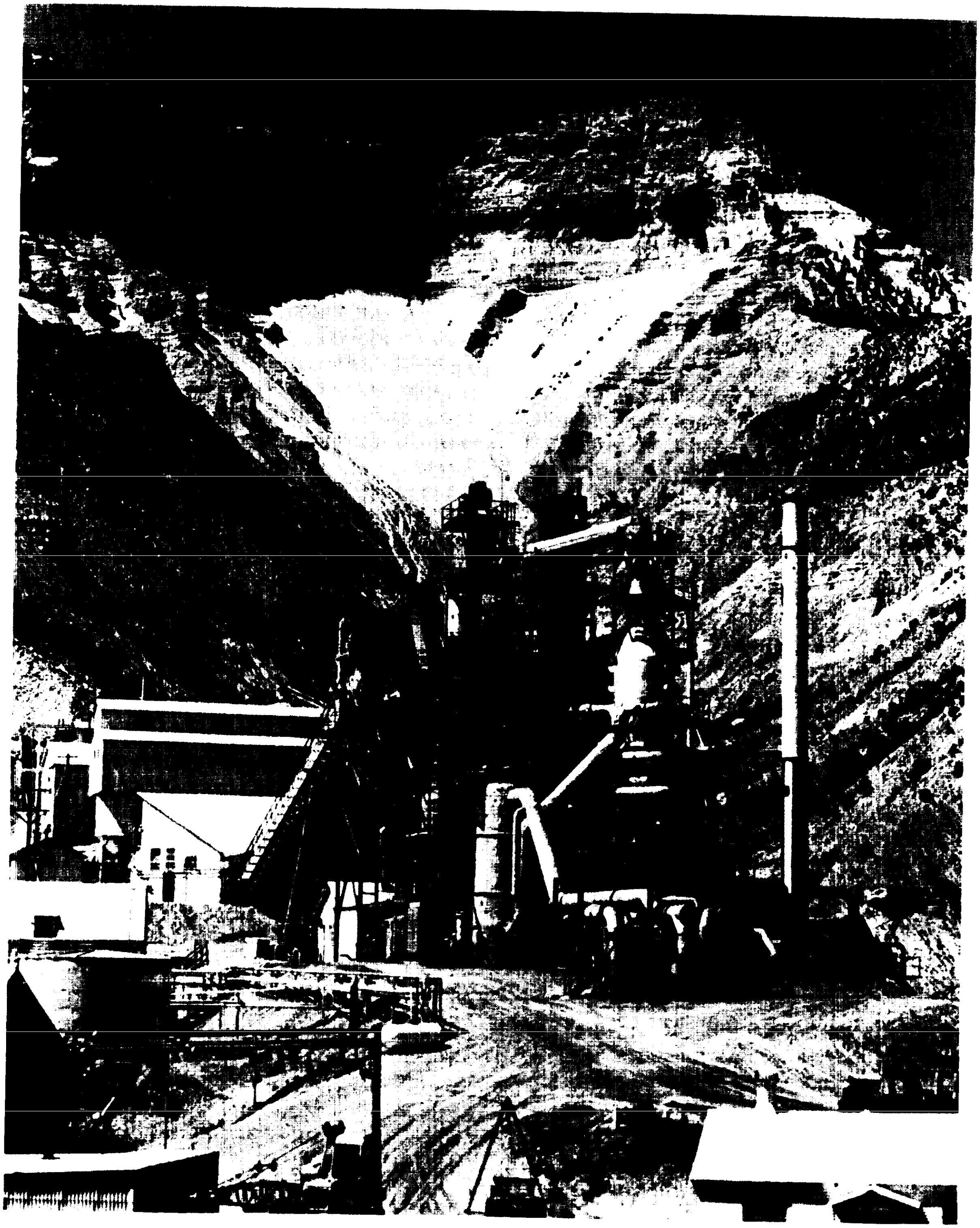
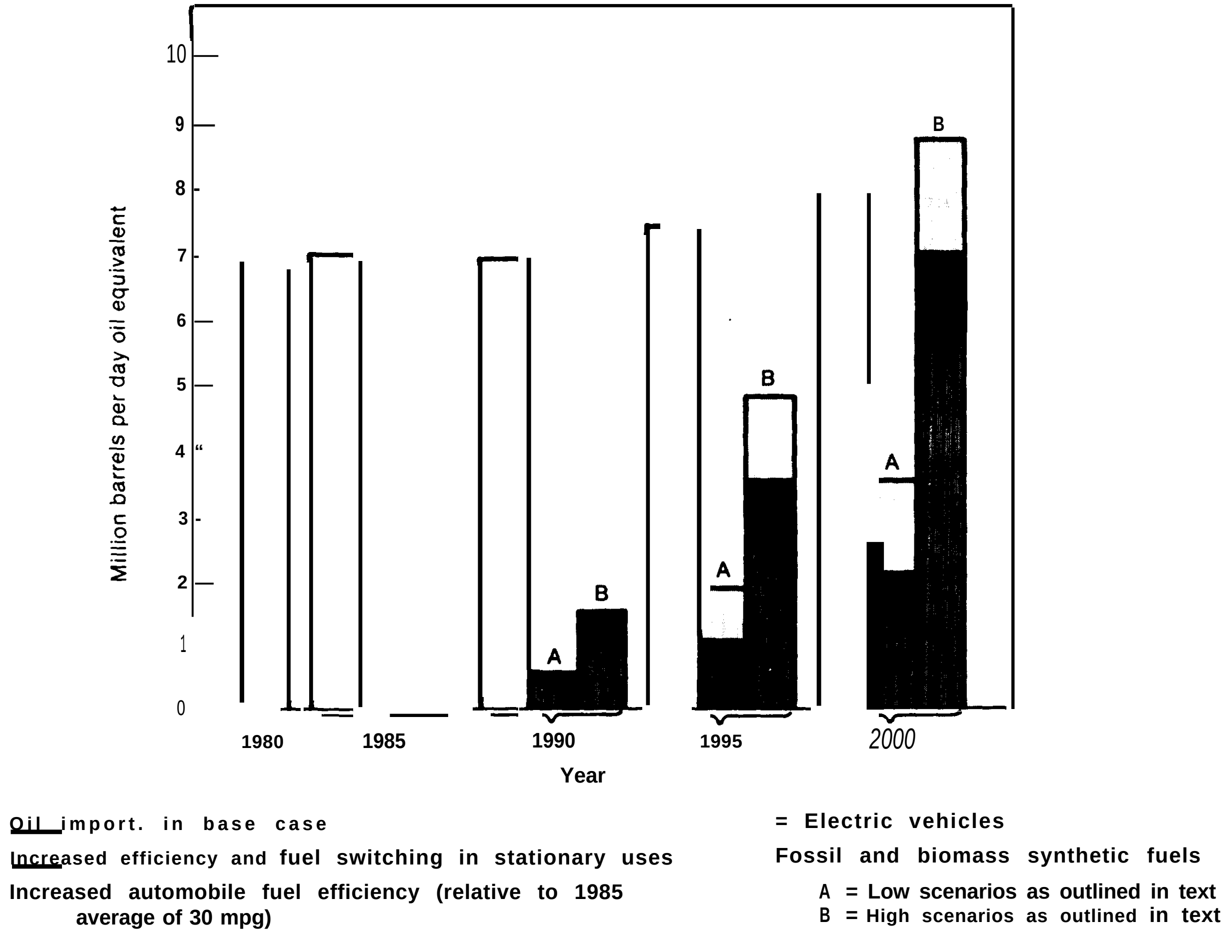


Photo credit: Paraho Development Corp.

The Paraho Semiworks Oil Shale Unit at Anvil Points, Colo.

Figure 4.—Comparison of Base Case Oil Imports and Potential Reductions in These Imports



SOURCE Office of Technology Assessment.

mate for synfuels—are reached, then it is quite unlikely that oil imports can be eliminated before sometime well into the first decade of the 21st century.

Although the large number of noteworthy uncertainties make an exact determination of the course of oil imports impossible, several conclusions can be drawn.

First, increased efficiency and fuel switching in buildings and industry are extremely important for the reduction of oil consumption. Although much of the potential in this area will be achieved through market forces by **2000** under the high oil price scenario of EIA, implementing the necessary changes at an earlier date could significantly reduce oil imports before **2000.** For example, fully implementing the potential for reducing stationary uses of fuel oil by 1990 would save about 15 billion bbl of oil imports or $600 billion (at an average of $40/bbl) for the imports during the period 1981-2000.

Second, synthetic fuels development has approximately the same importance as the conservation and fuel switching options but its contribution to reduced imports will not be as large until at least the late 1990's. Further, if a large part of the synfuels is used as a substitute for increased efficiency and for conventional fuel switching in stationary uses or as a substitute for petroleum products not readily converted to transportation fuels, elimination of oil imports is likely to be delayed.

Third, increases in automobile fuel efficiency beyond a 1985 average of 30 mpg could reduce automobile fuel consumption 20 to sO percent (0.6 to 1.3 MMB/D) by 2000 below the fuel consumption of a 30-mpg fleet. in addition, because fuel efficiency increases in automobiles (to and beyond **30** mpg) could reduce the automobile's share of transportation fuel needs from so percent (in 1980) to 20 to 25 percent (in 2000), it is likely that efficiency increases in various nonautomobile transportation uses beyond those assumed in the base case could also make significant contributions to reducing transportation fuel needs. This option has not been analyzed by OTA.

In summary, it probably will be necessary to implement fully all of the options for reducing oil consumption if one wants to eliminate net oil imports before the first decade of the next century. This will require full implementation of charges needed for increased efficiency in all uses of oil and fuel switching in stationary uses, as well as directing synfuels production to transportation fuels.

WHAT ARE THE INVESTMENT COSTS FOR REDUCING U.S. OIL CONSUMPTION?

Introduction

investment costs are an important consideration when comparing alternatives for reducing U.S. oil consumption. OTA's analysis indicates that synfuels production, increased fuel efficiency in automobiles, and conservation and fuel switching in stationary uses of oil all will require investments of the same order of magnitude for comparable reductions in oil. consumption in the **1990's;** whereas, synfuels production appears to require larger investments than the other alternatives for the 1980's. Uncertainties in the cost estimates as well as the fundamental differences in the nature of the investments are too large, however, to allow a choice between approaches on this basis alone.

In order to compare investment costs, they have been expressed as the investment needed to either produce or save 1 barrel per day oil equivalent* of petroleum products. This method 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.** In addition, from a national perspective the per unit investment cost is important in that it is the parameter used in the aggregate to make choices among competing investments. Conventional oil and gas exploration are considered first to provide a reference point. Following this, OTA's estimates for the investment costs for increased automobile fuel efficiency, EVs, synfuels, and increased efficiency and fuel switching in stationary uses are discussed briefly.

Conventional Oil and Gas Production

Two estimates of recent investment costs for conventional oil and gas exploration and development in the United States are shown in table 11. The data in this table were developed from estimates of the annual investments in oil, gas, and natural gas liquids exploration and development per barrel of increased proven reserves of these fuels (corrected for depletion). These latter estimates were then converted to investments for an increase of 1 barrel per day (bbl/d) of production (corrected for depletion) using the 1980 ratio of crude oil reserves to crude-oil production and assuming an 8 percent refining loss. **The ratio of** reserves to production for natural gas was not used because price controls on natural gas tend to inflate this ratio and thus the estimated costs; and investments for oil exploration and development were not separated from those for natural gas because there is no practical way to do so.

***One barrel of oil equivalent = 5.9 MMBtu.**

****It does not, however, avoid the problem that the different parties making the investments will have fundamentally different constraints on and perspectives about these investments and thus will react quite differently in the face of investments of the same size.**

Table 11.—Estimated Investment Costs for Conventional Oil and Natural Exploration and Development

Year	Estimated investment cost (thousand 1980 dollars per barrel per day of petroleum production[a])	
	Estimate A[b]	Estimate B[c]
1974	13	15
1975	17	19
1976	20	17
1977	22	20
1978.	29	18
1979.	31	57[d]
1980.	Not available	39”
Extrapolated to 1985[f].	53	49

a Assumes 8-percent refining loss and a 1980 ratio of crude oil reserves to production of 3.07 x 10’ barrels of reserves per barrel per day production. If EIA data for petroleum reserves are used, the figures are increased by about 10 percent.

b Investment cost per barrel of increased reserves from A. T. Guernsey, “Economics of Domestic Crude Oil and Natural Gas Exploration and Development 1959-1976,” December 1977, and “1977 and 1976 Addendum,” June 1979, Prepared for Exploration and Production Department, Shell Oil Co., Houston, Tex.; and W. C. Hamber, Manager, Forecasting, Exploration and Production Economics, Shell Oil Co., Houston, Tex., private communication, Nov. 11,1981

c Investment cost per barrel of increased reserves fOr the 26 major energy corn. panies in the United States calculated for OTA by John Rasmussen, Economics and Statistics, Energy Markets and End Use, EIA, October 1981, based on EIA and American Petroleum Institute data See also “Performance Profiles of Major Energy Producers 1979,” EIA, U.S. Department of Energy, DOE/EIA-0206(79), July 1981.

d This estimate is anomalously high due to downward revision Of estimated reserves by Texaco during the year and because Ashland Oil sold aome of its crude oil reserves to a company not included in a sample of 26 major energy companies.

e This estimate may below because petroleum reserve additions are overstated due to the purchase of Texas Pacific Oil & Gas (not one of the 26 major companies included in the calculation) by Sun Oil Co. (one of the 26 major energy companies Included in the calculation).

f Based on least squares fit of 1974-80 data, exclusive Of 1979 data in estimate B. Correlation coefficient la 0.985 for estimate A and 0.82 for estimate B.

SOURCE: Office of Technology Assessment.

There are significant uncertainties in these estimates due to numerous anomalies in the data, some of which are detailed in footnotes to table 11, and because the ratio of reserves to production changes with market prices, production techniques (e. g., enhanced oil recovery), and the nature and quantity of reserves. Nevertheless, these data do indicate that it is reasonable to expect costs of $50,000/bbl/d or more for conventional petroleum exploration and development by the mid-1 980’s if recent cost trends continue.

Automobile Fuel Efficiency

OTA’s estimates of the investment plus associated product development costs for increased automobile fuel efficiency are shown in table 12. There are notable technical, accounting, and market uncertainties associated with this type of cost analysis, however.

The estimates in table 12 were derived by first estimating the efficiency gains that can reasonably be expected over time from various changes in the automobile system. They are based on both published estimates and OTA’s analysis. The rates at which these technologies may be incorporated into new cars were then estimated and resultant schedules for capital turnover derived. Next, the investment cost calculations were based on published estimates for the cost of replacing the applicable capital equipment (e.g., facilities for producing a new engine or transmission, etc.). The actual investment cost and resultant fuel efficiency increases, however, will depend on a number of factors specific to individual production plants (and their future evolution), the way various production tradeoffs are resolved, and the results of future product development programs.

In addition to capital investment, development costs have been included as part of the investment necessary to produce modified vehicles. During the 1970’s, domestic auto manufacturers’ R&D (mostly development) costs averaged from 40 to 60 percent of their capital investments.[6] In table 12, development costs are assumed to be 40 percent of the capital investment allocated to fuel efficiency (see below), but the actual costs of developing the technologies for producing more efficient cars at minimum cost are highly uncertain. *

Beyond the uncertainties in the investment and development costs, there is the problem of determining what fraction of the investments should be ascribed to fuel efficiency. This arises because some of the investments can be used not only to increase fuel efficiency, but also to make other

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[6] G. Kulp, D. D. Shonka, and M. C. Halcomb, “Transportation Energy Conservation Data Book: Edition 5,” Oak Ridge National Laboratory, ORNL-5765, November 1981.

*It should be noted that R&D costs are not included for synfuels because several essentially identical synfuels plants could be constructed with little additional R&D costs beyond those needed for the first plant, whereas product and process development are necessary for each major change in automobiles.

Table 12.—Capital Investment Allocated to Fuel Efficiency Plus Associated Development Costs

			Average capital investment plus associated development costs[b]	
Time of investment	Mix shift	New-car fuel efficiency at end of time period[a] (mpg)	Thousand 1980 dollars per barrel per day oil equivalent of fuel saved[c]	1980 dollars per car produced[d]
1985-1990	Moderate[e]	38-48	20-60[g]	50-1909
	Large[f]	43-53		
1990 -1995	Moderate[e]	43-59	60-1309	70-1809
	Large[f]	49-65		
1995-2000	Moderate[e]	51-70	50-1509	50-1509
	Large[f]	58-78		

a EPA rated 55/45 percent city/highway fuel efficiency of average new car.

b Development costs assumed to be 40 percent of capital investment allocated to fuel efficiency (see text). One barrel of oil equivalent contains 5.9 MMBtu.

c Averages are calculated by dividing average investment for technological improvements by fuel savings for average car at end of time period relative to average car at beginning of time period. The resultant average cost per barrel per day is lower than a straight average of the investments for each car size because of mathematical differences in the methodology (i.e., average of ratios v. ratio of averages) and because extra fuel is saved due to demand shift to smaller cars. The averaging methodology used is more appropriate for comparisons with synfuels because it relates aggregate Investments to aggregate fuel savings. It should be noted that the cost of adjusting to the shift in demand to smaller-sized cars is not included. Only those investments which increase the fuel efficiency of a given-size car are included.

d Assuming investment is used to produce cars for 10 Years, on the average.

e Moderate shift in demand to smaller cars. Percentage Of new cars sold in each size class are:

Year/size class	*Large*	*Medium*	*Small*
1985	*35*	*60*	*5*
1990	25	60	15
1995	20	55	25
			35

[f] Large shift in demand to smaller cars. Percentage of new cars sold in each size class are:

Year/size class	*Large*	*Medium*	*Small*
1965	*15*	*75*	10
1990	*5*	*65*	*30*
1995	*5*	*45*	50
2000	5.	25	70

[g] Within uncertainties, the costs are the same for both mix shifts.

SOURCE: Office of Technology Assessment.

changes in the car. * The cost allocation problem associated with multipurpose investments is well known in accounting theory, and there is no fully satisfactory solution to it.[7]

For table 12, it was assumed that 50 percent of the cost of engine and body redesign, **75** percent of the cost of most transmission changes, and 100 percent of the cost of advanced materials substitution and energy storage and automatic engine cutoff devices should be allocated to fuel efficiency. This results in between 55 and 80 percent of the investments being allocated to fuel efficiency, depending on the time period and scenario chosen. For further details on how this and other problems in estimating the cost of fuel efficiency were resolved, see chapter 5.

During the period 1985-2000, total capital investments in changes associated with increasing fuel efficiency (i.e., allocating 100 percent of the multipurpose investments to fuel efficiency) could average $2 billion to $5 billion per year, depending on the number of new cars sold and the rate at which fuel efficiency is increased. However, if one deducts the cost of changes that would have been made under "normal" circumstances, * the added capital investment needed to achieve the lower mpg numbers in table 12 would be $0.3 billion to $0.7 billion per year. The higher mpg numbers in table 12 would require added capital investments (above "normal") of $0.6 billion to $1.5 billion per year. Adding 40 percent of the capital investment for development costs results in added outlays of $0.4 billion to $0.9 billion per year and $0.8 billion to $2 billion per year for the low and high scenarios, respectively.

A detailed examination of the scenarios presented in chapter 5 shows that a 1990 new-car

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*For example, automobile designs with low aerodynamic drag may be preferred by consumers on esthetic grounds; front wheel drive may be introduced to improve traction and increase interior volume; microprocessor control of carburetion or fuel injection, spark advance, exhaust gas recirculation, and other operating conditions can be used to reduce exhaust emissions, improve performance, and enable the use of lower octane fuels; continuously variable transmissions may be introduced to produce smoother acceleration and improve performance. These and many other changes can also be exploited to improve fuel efficiency.

[7] A. L. Thomas, "The Allocation Problem in Financial Accounting Theory, " American Accounting Association, Sarasota, Fla., 1969, pp. 41-57, and A. L. Thomas, "The Allocation Problem: Part Two, " American Accounting Association, Sarasota, Fla., 1974.

*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.

average fuel efficiency of 35 to 45 mpg (depending on the proportion of small, medium, and large cars sold) probably can be achieved with what is termed here "normal" rates of capital turnover. However, the validity of this conclusion and of the above incremental investment and development cost estimates will depend on market demand for fuel efficiency, and, in OTA's judgment, there is no credible way to predict future market demand for fuel efficiency.

Electric Vehicles

Use of EVs more nearly approximates synfuels than increased automobile fuel efficiency, in that EVs involve switching from conventional oil to another energy source rather than reducing energy consumption. Consequently, the costs (per barrel per day of oil replaced) for EVs are included in table 13 with synfuels. As shown in table 13, the costs for EVs appear to be significantly higher than for the various synfuels options, due to the high purchase price of the vehicle (relative to a comparable gasoline-fueled car) and the fact that EVs would be replacements for relatively fuel-efficient cars (because of an EVs limited size and acceleration). Furthermore, if batteries must be replaced at regular intervals and the cost of this is included as an investment cost, the total investment per barrel per day rises dramatically.

Synfuels

The best available estimates for the investment costs for various liquid synthetic transportation fuels are shown in table 13. Because of uncertainties in the cost estimates, no meaningful intercomparison among synfuels on the basis of cost is currently possible. In addition, as discussed in chapter 6, the final investment in synfuels is likely to be different from these estimates. As the processes approach commercial production, they will be revised as costs to overcome problems encountered in demonstration units are determined. Construction costs will inflate at an unknown rate relative to general inflation. And delays during construction due to such possibilities as lawsuits, strikes, late delivery of construction materials, or other causes can increase the investment cost. In sum, current investment estimates provide a very tentative guide to what synfuels plants constructed in the 1990's will cost. In addi-

Table 13.—Investment Cost for Various Transportation Synfuels and Electric Vehicles

	Thousand 1980 dollars per barrel per day oil equivalent to end users				
	Shale oil	Methanol from coal	Coal to methanol and Mobil methanol to gasoline	Direct liquefaction	Electric vehicle
Mining	(Included in conversion plant)	4-15	4-15	4-15	5-19
Conversion plant	49-73[a]	47-93[a]	53-110[a]	67-100[a]	0-69[b]
Refinery.	0-10'	O-2[e]	0	4-22[d]	0
Distribution system.	0		0	0	
End use.	0	0-11[f]	0	0	320°3909
Total	49-83	51-121	57-125	75-137	325-478

[a] Range of investments in ch. 6 plus possible 50-percent cost overrun and assuming plants operate at 90 percent of rated capacity

[b] Upper limit corresponds t. case where new coal-fired electric generating capacity would be needed. That is not currently the case, however.

[c] Upper limit corresponds to a dedicated refinery.

[d] Upper limit from UOP and Systems Development Corp., "Crude Oil v. Coal Oil Processing Comparison Study," DOE/ET/03117, TR-80/009-001, November 1979. Inflated by 12 percent to reflect 1980 cost. Assumes a refinery dedicated to conversion facility. Lower limit from "SRC-II Demonstration Project, Phase Zero, Task No. 3, Market Assessment Transportation Fuels From SRC-II Upgrading," Pittsburgh and Midway Coal Mining Co., prepared for U.S. Department of Energy, July 31, 1979. Assumes only upgrading of liquid for use as feedstock in an existing refinery.

[e] Upper limit assumes that half of capacity must use newly constructed or expanded facilities, as follows: 500-mile pipeline at $1 million Per mile, 500,000 bbl/d capacity; tank truck (9,200 gal) costing $90,000, 10 runs per week; storage tanks and pumps costing $700/bbl/d of throughput.

[f] Upper limit assumes new engine design costing $540 million for a 500,000 car per year factory; 0.15 capital recovery factor; replacing car consuming 250 gal of gasoline/yr. Beyond the initial investment in new engine production facilities, the Investments are the same as for a gasoline engine, making the added investment zero, relative to gasoline vehicles.

[g] Assumes an electric vehicle costs $3,000 more than a comparably performing gasoline-powered car and the electric vehicle replaces 8,000 to 10,000 miles/yr that would have been driven in a 60-mpg gasoline- or diesel-fueled car. if batteries must be replaced every 10,000 miles (nine times over life of car) at a cost of $2,000 each time, the total investment becomes $2.7 million/bbl/d replaced. These calculations assume that no oil is used in the electric generating facilities; however, if oil is used to generate part of the electricity, the investment costs per barrel per day of oil displaced grow rapidly,

SOURCE: Office of Technology Assessment, tion, they most likely represent a lower limit of the synfuels investment costs. *

Stationary Uses of Petroleum

OTA has also considered the costs of conservation and fuel switching in stationary uses of oil, although not in the same detail as for synfuels and increased automobile fuel efficiency. The major candidates are the residual and distillate fuel oils still used in stationary applications after 1990. Other stationary uses of petroleum—asphalt, petrochemical feedstock, still gas, and liquefied petroleum gas (LPG)—were not considered to be major potential supplies of increased transportation fuels. Although LPG can technically be used as a transportation fuel, and petrochemical feedstocks can be replaced by synthesis gas from coal, a preliminary analysis indicates that the fuel oils are more economically attractive alternatives for increasing supplies of transportation fuels in most cases.

OTA's estimates for the investment costs of fuel switching and increased energy efficiency in stationary uses during the 1990's are shown in table 14. Although only single numbers are shown, in fact there will be a range of costs depending on development costs for new energy supplies, installation costs for end-use equipment, the extent of changes needed at oil refineries, and variations in conservation investments. Of the fuel switching options the range is narrowest for fuel switching to electricity because of the fairly well-defined cost of producing electricity from coal and largest for fuel switching to natural gas because of differences in the cost of developing various unconventional gas supplies.

In deriving the numbers in table 14, it was assumed that the lower cost opportunities for fuel switching and conservation would already have been carried out by 1990. To the extent that this does not occur, the per-unit investment cost estimates for the 1990's would be lowered somewhat. Also, increased end-use efficiency of electricity for heat and hot water would reduce the investment needed for electric powerplants; and if large supplies of relatively inexpensive gas are found, fuel switching to gas could be a very attractive option, in terms of capital investment. Because of these uncertainties and site-specific differences in installation costs, one cannot clearly choose among the alternatives on the basis of investment costs alone. All of the options to eliminate stationary fuel oil use seem to require the same order of magnitude of investments.

Conclusion

Three principal conclusions emerge from OTA's analysis of investment costs for the various ways of reducing oil consumption. First, there is a great deal of uncertainty about investment costs due to technological unknowns, lack of experience, and site-specific cost differences. * Second,

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"Decisions about whether and how quickly to proceed with investments in synfuels production, however, will be strongly influenced not only by estimated costs but by corporate strategy.

***The situation is further complicated by the different nature of the investments. Synfuel plant construction requires large investments over a number of years before any product is sold. Auto industries tend to make incremental changes in capital stock, with the sum of several such investments sometimes costing more than one abrupt changeover in capital stock. Investments in fuel switching and conservation are paid back through future fuel cost savings rather than product sales.**

Table 14.—Estimated Investment Cost of Fuel Switching and Consecration in Stationary Petroleum Uses During the 1990's

	Thousand 1980 dollars per barrel per day of oil replaced or saved				
Investment at	Conversion to natural gas	Conversion to electricity	Conversion of boilers from residual fuel oil to coal		Increased efficiency and fuel switching
End use equipment	24	32	37	(51)[a]	88
New production of fuel	90	78[b]	16[c]	(22)[a]	0
Total	114	110	53	(74)[a]	88

The number in parenthesis is corrected for the 72-percent efficiency of refining residual fuel oil and is the Investment per barrel per day of resultant distillate oil produced from the residual 011.

[b] Construction of coal-fired powerplant ($74,000) Plus new coal mining (S4,400).

[c] Modification of refineries to upgrade residual oil to distillate fuels, $14,000, and increased coal production, $2,000. The refinery modification is based on data presented in ch. 6, assuming that 0.6 MMB/D of domestically produced residual oil is already being upgraded in 1990.

SOURCE: Office of Technology Assessment.

even if more certain cost data were available today, different inflation rates in different sectors of the economy or modest technical developments could change any conclusions about relative costs by the 1990's. Finally, once the initial investments to reduce oil consumption have been made, the annual capital investment needed to maintain all aspects of liquid fuel production and use will depend on the level of fuel efficiency actually achieved. In particular, high levels of efficiency in end uses will require lower levels of annual capital investment.

Box A.-Consumer Cost of Increased Automobile Fuel Efficiency

For the purposes of this section, the consumer cost of increased fuel efficiency was defined to be the added cost of producing a more fuel-efficient car (relative to an otherwise comparable but less efficient car) per gallon of fuel saved by using the more efficient vehicle. The added cost of producing more fuel-efficient cars will depend not only on the investments needed to change automobile production facilities and the production volumes, but also the resultant changes in the variable costs* of production, such as changes in materials and labor costs.

As discussed *on page* 75, the capital investments that are needed to increase fuel efficiency also produce other changes in automobiles; and allocation of costs among fuel efficiency and the other changes is somewhat arbitrary. In addition, if market demand for fuel efficiency is strong, many changes that increase fuel efficiency would be incorporated into the normal capital turnover of the industry. For the purpose of calculating consumer costs, however, essentially the same approach was taken as with the investment cost estimates. The fraction of investments allocated to fuel efficiency are the same as for the investment costs per barrel per day of fuel saved; and only the average costs per average gallon saved have been calculated-relating each 5-year period to the previous 5-year period —rather than compounding errors by assuming some market-driven scenario as a point of reference.

In addition, it was assumed that production volumes are sufficiently large so that there are no significant diseconomies from small-scale plants or losses from underutilized facilities. Weak demand for fuel efficiency and/or for new cars in general could of course result in additional costs of this sort.

A key factor in consumer costs is the change in variable costs associated with producing more fuel-efficient vehicles. Variable cost estimates, however, are generally proprietary and can vary considerably from one company to another. Furthermore, changes in variable costs with increased fuel efficiency will depend, to a large extent, on the success of efforts to develop production technologies that can hold down production costs. Some of the uncertainties in variable cost changes are discussed below, followed by illustrative examples of plausible consumer costs for increased fuel efficiency.

Some changes that increase fuel efficiency will lower variable costs; some will increase some variable costs while lowering others; and still other changes are likely only to increase variable costs.* However, factors which are only peripheral to the nature of the technology incorporated in the car often dominate the change in variable costs, These factors include: 1) the existing nature and layout of equipment in the plant being modified to produce the new car, 2) various specific production decisions (e.g., which of various processes is used in manufacturing a component, what equipment will be modified, what will be the production volume), and 3) the success of developing new, lower cost procedures for producing a component and assembling it in the vehicle. In other words, the net change in variable costs depends not only on the nature of the new technology and the way it is produced, but also on the path the manufacturer has chosen to evolve from the current production facilities and configurations to those needed to produce the more advanced technol-

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● Variable production costs are those that vary in proportion to the number of units produced as opposed to fixed costs such as capital charges.

*For example, reducing automobile size and weight by reducing the quantity of materials reduces variable costs. Switching to lighter weight materials has the side effect of reducing the needed size of axles, auto frame, ate,, which reduces costs; but the higher cost of the new material and increased difficulty of handling that material (e.g., molding, casting, welding, finishing, painting, heat treating) can increase variable costs. Similarly, producing a more efficient engine may enable reduction in engine size, number of cylinders and complexity of the pollution control equipment, which reduces costs; *but* the need for more precise machining and possibly added equipment (e.g., turbochargers) can raise thevariabie costs. Finally, changes such as going from a three-speed transmission to a four-speed, five-speed, or continuously variable transmission are likely to increase variable costs because of increased complexity and materials and processing requirements.

ogy. Furthermore, as with capital investment, there is the problem of deciding what fraction of an increase in variable costs should be ascribed to fuel efficiency. Because of these problems and ambiguities, anything more than a brief overview of the range of possibilities would not be justified.

Various recent estimates of variable cost changes can serve to illustrate the effect of this component on the overall consumer cost of producing more fuel-efficient cars. For example, successful development of production techniques and continued market pressure on automobile companies could hold down production costs so that more fuel-efficient cars can be produced without any large change in manufacturing variable costs. Although some costs will go up, others will drop and the net effect will be little or no change.[1] On the other hand, data presented in a recent analysis based on proprietary automobile industry estimates indicates a substantial increase in variable costs.[2] The apparent increase in variable costs ranges from 60 to 250 percent and averages 170 percent of the costs associated with the capital investments (capital charges) during the period 1985-2000.

To illustrate the effect of this range of variable costs on the ultimate cost to the consumer, a series of calculations were made in table 15. It is assumed that the consumer does not discount future fuel savings and that each car is driven 100,000 miles over its lifetime. The range is calculated by first assuming that the increase in variable costs is negligible, and second that it is twice the capital charges allocated to fuel efficiency (see p. 76). The apparent consumer cost per gallon of fuel saved would be about 2.5 times as large as the numbers shown if the consumer discounts future fuel savings at 25 percent per year.* Similarly, the apparent cost per gallon of fuel saved will decrease if the car is driven more than 100,000 miles and increase if the car is driven less than that.**

As these examples illustrate, the consumer cost of increased automobile fuel efficiency can vary over a wide range. The cost will depend not only on technical developments and the success automakers have at holding down production costs, but also on consumers' perceptions and accounting procedures, which change with time. As a result, accurate consumer costs probably cannot be derived until production techniques have been developed and proven in practice and market preferences of consumers can be determined.

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[1] Richard L. Strombotne, Director, Office of Automotive Fuel Economy Standards, National Highway Traffic Safety Administration, U.S. Department of Transportation, private communication, 1981.

[2] Richard H. Shackson and H. James Leach, "Maintaining Automotive Mobility: Using Fuel Economy and Synthetic Fuels to Compete With OPEC Oil," Energy Productivity Center, Mellon Institute, Arlington, Va., Interim report, Aug. 18, 1980. Variable cost changes were deduced from the estimates of capital investment and changes in consumer costs by assuming an annual capital charge of 15 percent of the investment and deducting this capital charge from the consumer cost estimates.

*In other words, the consumer values next year's fuel savings 25 percent less than this year's; savings that will occur during the year after next are valued 25 percent less than next year's, and so on.

**Although the person who buys a new car is unlikely to own it for the full 100,000 mile life of the car, the resale value of a more expensive car is also likely to be higher. The cost of a more fuel-efficient car will, in practice, depend on the difference between the purchase and (later) resale price of that car, relative to a less fuel-efficient one. Once the car has been sold and resold several times and finally junked, however, the total cost to all owners per gallon of fuel savings will depend on how far the car has been driven in total.

Table 15.—Plausible Consumer Costs for Increased Automobile Fuel Efficiency Using Alternative Assumptions About Variable Cost Increase

			Consumer cost[a] ($/gal gasoline saved)	
Time period	Mix shift[b]	Average fuel efficiency at end of time period (mpg)	Assuming no variable cost increase relative to 1985 variable costs of production	Assuming variable cost increase equal to twice the capital charges
1985-90	Moderate	38-48	0.15-0.40[c]	0.40-1.10[c]
	Large	43-53		
1990-95	Moderate	43-59	0.35-0.85[c]	1.10-2.60[c]
	Large	48-65		
1995-2000	Moderate	51-70	0.30-0.95[c]	0.90-2.80[c]
	Large	56-76		

[a] Assumes capital charges of 0.15 times capital investment allocated to fuel efficiency, life cycle costing, and car driven 100,000 miles during its lifetime.
[b] See table 12 for definitions of mix shifts.
[c] Within the uncertainties the costs are the same for each mix shift.

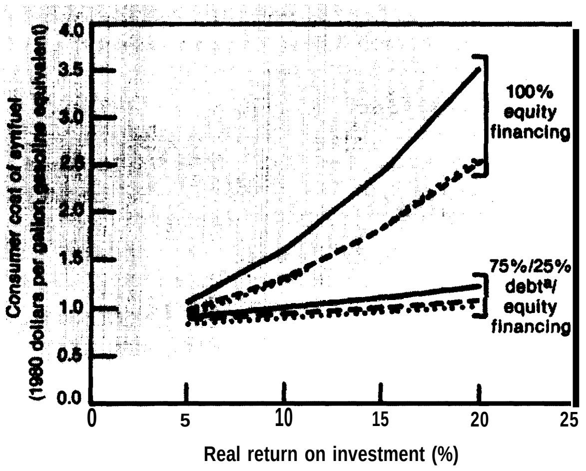
SOURCE: Office of Technology Assessment.

Box B.-Consumer Cost of Synfuels

The consumer cost of synthetic transportation fuels will depend on a number of factors. The most important of these are the actual capital investment needed to build the synfuels plant, the way plant construction is financed, the required return on investment, the cost of delivering the fuel to the end user, and the end-use efficiency of the synthetic product. For the first generation of synfuels plants, the costof producing the synfuel will also depend critically on plant performance, specifically the amount of time the plant is operated Mow its rated capacity due to the technical problems. (See ch. 6 for a more detailed sensitivity analysis.) Depending on assumptions about these factors, one can derive a wide variety of consumer costs.

Table 16 shows two sets of consumer costs for various fossil synfuels. These costs are based on the best available investment and operating cost estimates and assume no cost overruns, good plant performance (90 percent of rated capacity), a lo-percent real return on equity investment* and two financing schemes: 100-percent equity financing and 75/25 percent debt* */equity financing. Figure 5 shows how these con-

Figure 5.-Consumer Cost of Selected Synfuels With Various After-tax Returns on Investments



[a]5% real interest rate on debt.

SOURCE: Office of Technology Assessment.

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*In other words, a return on investment that is 10 percent higher than general inflation.

● *The debt must be.project.specific, i.e., the money is loaned for the specific project and is not general debt capital whose payback is guaranteed by other company assets.

Table 16.-Estimated Consumer Cost of Various Fossil Synfuels Using Two Financing Schemes

	Cost of Synfuel delivered to end user[a] ($/gallon gasoline equivalent)	
Liquid transportation fuel	100% equity financing[b]	75% debt, 25°A equity financing
Reference cost of gasoline from $32/bbl crude oil	1.20	
Shale oil		
Methanol from coal	1.30[d](1.10)[e] 1.60[f](1.30)[e]	0.95[d](0.80)[e] 1.10 (0.90)[e]
Coal to methanol with Mobil methanol to gasoline	1.25[d] 1.60[g]	0.80[d] 1.00[g]
Coal to gasoline via Fischer Tropsch Synthesis	1.30[d]	0.85[d]

[a]Assumes $0.20/physical gallon delivery charge and service station mark-up. Note that delivered methanol usually costs more per gallon of gasoline equivalent (gge) than delivered gasoline from methanol because the delivery charge per gge is twice as high for methanol as for gasoline, due to the lower energy content of the former.
[b]10-percent real return on investment
[c]10-percent real return on equityinvestment, 5-percent real investment on debt.
[d]Involves coproduction of synthetic natural gas.
[e]Numbers in parentheses assume methanol ueed In engine designed for methanol use which is 20 percent more efficient than ● amapondmg gasoline engine.
[f]Methanol is principal product.
[g]Gasoline is principal product.

SOURCE: Office of Technology Assessment.

sumer costs change with the required rate of return on investment.

As mentioned above, plant performance is an important determinant of the cost of synfuels from the first generation of plants. Because the selling price of the synfuels probably will be determined by the competing price of petroleum fuels, poor plant performance may translate into a low return on investment or a financial loss. In recognition of this possibility and the large number of very profitable investments currently available to the energy industry, most investors are likely to require a high potential rate of return on investment before proceeding with a synfuels project.

In other words, in the absence of loan guarantees to enable high debt financing, conventional liquid fuel prices could easily have to exceed $2.00/gal of gasoline equivalent (1980 dollars) before synfuels would be widely perceived as a good risk.* Once the technologies are commercially proven, however, fuel prices shown in table 16 could provide adequate incentives for investment, provided that the solution of any technical problems uncovered in the first commercial plants does not significantly increase the required plant investment.

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*Some companies in a good capital position might be willing to take the higher risk to gain experience and/or an early market share, however.

Box C.—Total Cost and Investment Cost

In comparing the costs of the various options for reducing conventional oil consumption, we have, for three reasons, emphasized investment costs, rather than total costs (or consumer costs) per unit of oil saved or replaced. First, consumer costs are considerably less certain than investment costs because of site-specific factors and technical and financial uncertainties. Second, because different consumers will discount future fuel savings at quite different rates, the total costs seen by consumers will be highly variable (even for the same option). Furthermore, the costs of the various options require different proportions of investment costs (which may be discounted) to changes in operating costs (which are not discounted). Finally, each of the options for reducing oil consumption is capital-intensive and it will require hundreds of billions of dollars in investments to reduce oil imports significantly; these investments will come at the expense of other investments in the economy and direct consumption. From a national perspective, it is important to compare the options with respect to the investment needed per unit reduction in oil use to see if any of the options is significantly less capital-intensive than the others.

Total cost to consumers (per unit oil saved or replaced) does, however have a strong influence on the extent to which each option actually is implemented. Although specific values for the total cost to consumers are not given here, some of the uncertainties in, and factors influencing, total cost are discussed below. It should be emphasized, however, that the costs of some of the options may not equal the price. Price will be determined by market forces.

Increased Automobile Fuel Efficiency

Fuel efficiency cannot be neatly separated from other attributes of a car, and there is always a certain ambiguity in determining what fraction of production costs should be ascribed to fuel efficiency. In addition, depending on the demand for fuel efficiency, varying fractions of the investments associated with increasing fuel efficiency could be ascribed to and incorporated in "normal" capital turnover in the auto industry.

Beyond these accounting difficulties, there are uncertainties in the investments needed to make various changes in automobile production facilities and in the size of the resultant fuel-efficiency increases. And another important factor affecting total cost is any change in variable costs (materials and labor) associated with producing more fuel-efficient cars. Whether or not variable costs increase will depend on the success of adapting and developing low-cost processes for manufacturing the more fuel-efficient cars, and the outcome of the development efforts cannot be readily predicted.

A final area of uncertainty involves the rate that consumers discount (i.e., how much they value) future fuel savings. For example, discounting future fuel savings at 25 percent per year increases the apparent cost of fuel efficiency per gallon saved by a factor of 2.5 over the situation where no discount is applied to future fuel savings. In practice, there will be a wide variety of discounting rates used by various consumers, and the rates will change with market conditions (including oil prices and interest rates) and consumers' beliefs about future oil prices and availability, among other things.

Synthetic Fuels

For synfuels processes that produce sizable quantities of different fuel products (e.g., synthetic natural gas and fuel oil), one encounters accounting problems similar to those discussed under increased automobile fuel efficiency-i.e., how to allocate production costs to the various synfuels products. However, these problems are less severe for synfuels than for automobiles because all of the major products of the former are separate consumer products with known current prices. Furthermore, the accounting problems can be largely avoided by considering only processes that produce only fuels of similar quality (e.g., gasoline, jet, and diesel fuel), and avoided entirely by considering processes that produce only one major product.

Variations in operating and maintenance costs and future coal prices produce some uncertainty in the cost of synfuels. The more important uncertainties, however, involve the cost of building a synfuels plant, how this cost will be financed, and investors' required rates of return on investment. The cost of synfuels from the first generation of synfuels plants will also depend critically on plant performance, with frequent shutdowns and repairs increasing costs dramatically. Presumably, later generations of plants will perform reliably.

Fuel Switching and Conservation

The total cost of switching utility boilers from fuel oil to coal is fairly welt known. There are, however, some areas of the country where coal is not readily available, and there is insufficient space to accommodate coal handling facilities at some electric generating plants.

The major variability in the cost of switching to natural gas and electricity for buildings and in industry results from widely varying required rates of return on investments in different industries and for different building owners or renters. At some sites, though, natural gas is not available or space limitations prevent the installation of gas facilities. There is also uncertainty in the cost of finding and processing unconventional natural gas (from tight sands, etc.).

The total cost of conserving heat and hot water in buildings is probably the least certain of the measures for reducing stationary oil use. Not only are there large uncertainties and variability in the savings that can be achieved through various conservation measures, but also consumers will discount future fuel savings at widely differing rates.

HOW DO THE ENVIRONMENTAL IMPACTS OF INCREASED AUTOMOBILE FUEL EFFICIENCY AND SYNFUELS COMPARE?

The synfuels, auto fuel efficiency, and electric auto alternatives for displacing imported oil have sharply different potential impacts on public health and safety, on workers, and on ecosystems. In addition, probabilities of these impacts actually occurring—few of them are inevitable—are also quite different. Both the potential impacts and their risks are briefly compared below. The nature of some of the risks, however, is obscured by the brevity of the following discussion. For example, the actual risk associated with possible contamination of drinking water by synfuels production is heavily dependent on the degree of prior recognition of the risk and response to this recognition –for example, development of ground water monitoring systems. Also, risks that are similar in magnitude are often valued differently because of the degree of choice involved (e.g., willing exposure to the risks of auto travel v. unwilling exposure to accidental toxic spills) and the precise nature of the risks (e.g., multiple automobile accidents involving only a few people **at a time v. a serious accident or control failure at a large synfuels plant).**

Public Health and Safety

Reductions in vehicle size, part of the auto fuel-efficiency measures, could have the strongest effect on public health and safety through their potential adverse effects on vehicle safety. The effect is difficult to estimate because of a lack of comprehensive traffic safety data that would allow an evaluation of the relative effect of car size and other key safety variables on vehicle crash-' worthiness and accident avoidance, and because of uncertainty about the compensatory measures that might be taken by the vehicle manufacturers and by drivers. Although the National Highway Traffic Safety Administration has projected vehicle size reductions to cause an additional 10,000 annual traffic deaths by 1990 if compensatory measures are not taken, this and other quantitative estimates of changes in traffic safety are based on limited data and relatively crude models. Nevertheless, an increase in traffic deaths of a few thousand per year because of vehicle size reductions does seem plausible.

Diesel use could have an adverse effect on emissions of nitrogen oxides (NO_x) and particulates, and conceivably could cause public health problems in congested urban areas. The risk is moderated, however, because: 1) controls for NO_x and particulate are under active development, although success is not assured and it is possible that the current level of effort will not be continued; and 2) the evidence for health damage from diesel particulate is equivocal.

Electric passenger vehicles are likely to be small, and thus should share safety problems with radically downsized high-mileage conventional automobiles. Additional safety problems caused by the batteries, which contain toxic chemicals that may be hazardous in an accident-caused spill, are offset somewhat by eliminating the fuel tank with its highly flammable contents. Also, electric cars should have a positive effect on air quality, especially in urban areas, because the reductions in automobile emissions outweigh increased emissions from powerplants, except for sulfur dioxide (SO_2).

Synfuels plants may expose the general public to health and safety hazards in a variety of ways: contamination of drinking water from leaching of wastes, accidental spills, or failure of effluent controls; accidental release of toxic vapors; exposure to contaminated fuels; and routine emissions of conventional air pollutants such as SO_2 and NO_x. Only the routine emissions are essentially inevitable, however, and health and safety problems from these should be minimized by Federal ambient air quality standards and by the relative magnitude of these emissions, which should be considerably lower than emissions from projected levels of development of coal-fired electric generation during the same time frame. The extent of risk from the other sources is not well understood because the toxic waste streams from the plants have not been fully characterized, the effects of some of the known and suspected waste products are not yet well understood, and the effectiveness and reliability of some critical environmental control systems have not been demonstrated under synfuels plant conditions (see issue on p. **95). Chemical industry** sources believe that few problems will arise, but, as discussed in the above-mentioned issue, some areas of concern remain.

Worker Effects

With the possible exception of some worker exposure to toxic materials in battery manufacture, the only significant occupational health and safety problem associated with the automobile measures appears to be mine safety and health effects involved in any increased mining of coal for electricity needed for recharging electric car batteries, and, to a lesser extent, for aluminum manufacture. These impacts are not trivial, because the amount of coal needed per *barrel of oil* saved for electric cars is of the same order of magnitude as that needed for synfuels production (assuming coal-fired electricity and coal-based synfuels). The coal-to-oil balance for aluminum use is somewhat less certain, although some analyses have calculated it to be similarly high. The use of aluminum is not the major part of the efficiency measures, however, and the actual amount of coal required is not likely to be significant in comparison with the coal used for synthetic fuels.

As noted, synfuels production has a coal requirement similar to that of electric autos, and thus shares similar mineworker problems. It has important additional problems. The sources of moderate risks to public health and safety—fugitive emissions, spills, plant accidents, and contaminated fuels–pose more serious risks to workers because of their frequency and severity of exposure. For example, workers will be continuously exposed to low levels of polynuclear aromatics and other toxic substances because fugitive emissions cannot be reduced to zero. Another important source of possible worker exposure is the maintenance requirements of synfuels reactors; the materials that must be handled in these operations are likely to have the highest concentrations of dangerous organics.

Exposure to hazardous substances is common in the petrochemical industry, and worker-protection strategies developed in this and related industries will be used extensively in synfuels plants. These strategies clearly will reduce the hazards, but the degree of reduction is highly uncertain (see issue on p. 95).

Ecosystem Effects

The only significant sources of ecosystem effects from the automobile measures are likely to be the changes in air quality caused by the use of electric autos (which probably will be positive) and diesels, and the air, land, and water pollution associated with the mining and processing of both coal for electricity (for battery recharging or aluminum production) and battery materials such as lead and lithium. Obtaining the new battery materials is thought unlikely to cause important environmental problems, but there are many different kinds of potential battery materials, and final judgment probably should be withheld at this time. Nevertheless, with the exception of the electric-car coal-mining requirements, any adverse ecosystem effects of the automobile measures appear likely to be mild.

Synfuels production is likely to cause significantly greater adverse effects, because it will have coal-mining damages per barrel of oil roughly similar to electrical autos *as we//as* several additional and potentially important adverse impacts. These include substantially increased mining and waste disposal requirements if oil shale is the synfuels feedstock, and a variety of potential adverse impacts stemming from the possibility that toxic materials generated during the conversion processes will escape to the environment. The pathways of potential damage from toxics are essentially identical to those threatening public health and safety—surface and ground water contamination, toxic vapors, and exposure (in this case from spills) to contaminated fuels. Unfortunately, probability of the damage actually occurring is equally difficult to evaluate.

An additional concern is that synthetic fuels from biomass sources–which in general have similar or less severe environmental problems than coal-based synfuels—may have more severe ecosystem effects because of the very extensive nature of their resource base. The adverse ecosystem effects of large increases in grain production to produce gasohol, for example, can be quite serious, and, given the nature of the current agricultural system, the probability of such effects occurring is high.

Summary

The environmental impacts of increased automobile fuel efficiency and synthetic fuels development will be quite different and difficult to compare. The major impacts of auto efficiency improvements are likely to be increases in crash-related injuries and fatalities from auto size reductions. The severity of these impacts is heavily dependent on vehicle design and driver behavior (especially seatbelt usage). Synthetic fuels development's major impacts will include the well-known ecosystem effects as well as public and worker health and safety effects of large-scale mining and combustion of coal. Oil shale development will have many similar effects; a most serious environmental risk may come from inadequate disposition of the spent shale. In addition, there are *potentially* serious impacts on people and ecosystems from the escape of toxic substances from synfuels conversion processes. The severity of these impacts is unclear because important waste streams have not been characterized and environmental control effectiveness and reliability has not been demonstrated.

HOW WILL THE SOCIAL IMPACTS OF SYNFUELS AND INCREASED AUTOMOBILE FUEL EFFICIENCY COMPARE?

Identifying, assessing, and comparing the social impacts of synfuels development and improved automobile fuel efficiency are difficult because these impacts will not be distributed evenly in time or among regions. Moreover, they cannot necessarily be measured in equivalent (e.g., dollar) terms, and they are difficult to isolate and attribute to specific technical choices. Both beneficial and adverse social consequences will arise from these two approaches to reducing oil imports.

Employment

Synthetic fuels production presents two major considerations about social impacts related to employment. First, there is the possibility of shortages of experienced chemical engineers and skilled craftsmen. A rapid growth in synfuels would likely put increased pressure on engineering schools, which are now suffering from insufficient numbers of faculty. The second concern arises from the large and rapid fluctuations in labor requirements for construction. While no shortages of construction workers are expected, on the average, fluctuating labor requirements during construction and startup can have severe secondary effects on communities at the construction sites. A population increase of about three to five people per new worker could occur, leading to possible population fluctuations of 30,000 to 60,000 people for some synfuels construction.

The changing structure and markets of the established automobile industry are likely to lead to a long-term, permanent decline in auto-related industrial employment. The nature of this decline will depend on import sales, the growth rate of the U.S. auto market, the competitiveness and labor intensity of U.S. manufacturing, the use of foreign suppliers and production facilities, and the adoption of more capital-intensive production processes and more efficient management practices. The skill mix will also shift increasingly towards skilled labor. Scarcities of experienced engineers and certain supplier skills could inflate the prices of skilled manpower resources for both synfuels and changing automotive technology.

Community Impacts

Synfuels development will have its most immediate effect in relatively few small and rural oil shale communities in the West, as well as in the small rural communities located near many of the Nation's dispersed coal resources. In the long term, local communities should benefit from synfuels in terms of expanded tax bases and increased wages and profits. However, in the near term, there are risks of serious disruptions in both the public and private sectors of these communities. The nature and extent of these disruptions will be determined by the community's ability to absorb and manage growth, and the rate and scale of local synfuels development.

Automobile production jobs are presently concentrated in the North-Central region of the Nation. The geographical distribution can be expected to change as inefficient plants are closed and new production facilities are established in other parts of the United States. New plants will provide new employment opportunities with accompanying community benefits (e. g., tax revenues); plant closings in areas heavily oriented towards the auto industry would deepen the existing economic problems of the North-Central region, i.e., high unemployment, rising social welfare costs, and declining tax base.

HOW DO THE REGIONAL AND NATIONAL ECONOMIC IMPACTS OF SYNFUELS AND INCREASED AUTO EFFICIENCY COMPARE?

In addition to comparisons on the basis of cost per barrel, environmental impacts and local social impacts, increased automobile fuel efficiency and synfuels can be compared on the basis of their potential regional and national economic impacts. The latter comparison is important because each type of investment implies an alternative national strategy to achieve the goals of price stability, national economic growth, and equity as well as oil import reduction.

Regional and national aggregation are also important because both industries are capital-intensive. Large blocks of investment must be mobilized, with key investment decisions made by a relatively small number of firms, based on very uncertain longrun predictions about the future. As summarized below, a variety of important national and regional issues are raised by the uncertainties and inflexibilities inherent in these decisions.

Inflation and Economic Stability

Inflation may be dampened and the economy stabilized if either type of investment is successful. In the case of synfuels, if first generation plants demonstrate competitive costs, the mere prospect of rapid deployment could moderate oil import prices and thus help to control what has been one of the major inflationary forces during the last decade. In the case of autos, if increased fuel efficiency helps domestic firms to hold or perhaps increase their market share, this would keep U.S. workers employed and at least stabilize foreign payments for autos. Higher employment also tends to reduce Federal transfer payments, which either reduces the Federal deficit or lowers taxes. Reductions or stabilization of foreign payments tends to strengthen the value of the dollar in foreign exchange markets. Both changes, in the Federal budget and on foreign accounts, reduce inflationary pressure.

On the other hand, attempts to displace oil imports too quickly may be inflationary. Risks of inflation, technical errors, and market miscalculations all increase with the rate of synfuels deployment and with shortening the time taken to convert the domestic auto fleet to high fuel efficiency.

in the case of synfuels, rapid investment growth in the next decade, beyond construction of demonstration projects, could cause inflation by creating suppliers' markets in which prices for construction inputs, especially chemical engineering services, can rise more rapidly than the general inflation rate. Deployment prior to definitive testing in demonstration plants also compounds potential losses due to design errors.

In the case of autos, rapid large-scale investments can inflate prices of vehicles as firms attempt to amortize capital costs quickly. However, if these attempts fail, presumably because buyers stop buying high-priced domestic autos, then newly invested capital must be written off prematurely, resulting in the waste of scarce resources for the firm and the Nation. Furthermore, if rapid fuel-efficiency improvements are forced by abrupt, real fuel price increases or by aggressive foreign auto competition, then the domestic auto industry and owners of fuel-inefficient cars will both be forced to absorb lump sum losses in the real value of current assets. Low prices for new cars resulting from competition do, however, benefit purchasers of these cars.

Employment and International Competition

If improved fuel economy makes domestically produced autos more competitive with imports, there will be two major national economic payoffs besides fuel savings. First, this improved competitiveness will protect traditional U.S. jobs; second, it will reduce the drain of foreign payments to auto exporting countries as well as to oil exporters. Synfuels do *not* present a similar coupling of economic possibilities.

There are major doubts, though, about the longrun success of U.S. automakers with foreign competition. The United States may not be able to compete in the mass production of fuel-efficient autos for a variety of reasons—such as high wages, low productivity, and inefficient or out-of-date management. All such explanations are speculative, but together they have raised serious doubts about U.S. competitiveness in the context of the recent, rapid increase in the market share of auto imports. If foreign automakers continue to drive domestics out of the market for fuel-efficient autos, synfuels investments may be preferred over investments in fuel efficiency even if the apparent cost per barrel of the former are higher.

Assuming investment in either industry does lead to increased U.S. production, employment opportunities for synfuels and autos can be compared based on 1976 data (the most recent available). Synfuels production involves mainly mining and chemical processing activities, which in 1976 dollars had $59,000 and $55,000 invested per worker respectively. On the other hand, the transportation equipment sector of the economy (which is dominated by autos) had $27,000 invested per worker and auto suppliers such as fabricators of metal, rubber, and plastic products had about $21,000 per worker. In other words, in the recent past the auto industry created about twice as many jobs per dollar of investment as industrial activities similar to synfuels. The current trend toward automation in automating will undoubtedly lower its labor intensity, but the auto industry should continue to employ more workers per unit of investment.

Income Distribution Among Regions

Another question concerns the likely regional distribution of incomes from autos and synfuels. An analysis of location factors was not carried out, but two points can be made. First, to the extent that the auto industry could use existing plants or build nearby, current employment patterns and established communities could be maintained. This would preclude costly relocation and would tend to favor the North-Central region of the United States, which has been losing its industrial base.

Second, new auto plants can be located in more areas of the country than new synfuels plants because of the high cost of transporting synfuels feedstocks, especially oil shale, compared with the cost of transporting manufactured materials and parts for automobiles. Transportation costs are likely to concentrate synfuels investments in regions of the Nation with superior shale and coal reserves. Biomass options are least likely to be concentrated, because resources are dispersed, and coal-based options are much more flexible than shale because coal is more widely dispersed.

Capital Intensity and Ownership Concentration

Finally, both strategies for oil import substitution affect the number of profitable firms in each industry. In both industries, the number of competitive firms is severely constrained by the size of investment outlays and by the acquired knowledge of those already in the business.

In liquid fuels, the introduction of synthetic fuels sharply increases the amount of capital investment required per barrel of liquid fuels production capacity. For example, in the case of one major oil company, present capitalized assets per average daily barrel of oil equivalent of production from old reserves of conventional oil and natural gas is less than 20 percent of OTA's estimate of the similar ratio for oil shale. * However, new reserves of conventional oil and gas will also require much larger capital outlays than old reserves, due to depletion of finite natural resources.

***Value of assets for Exxon was obtained from its 1980 Annual Report.**

From the investor's viewpoint, the sequence of investments for conventional petroleum resources is very different from synfuels projects. For conventional petroleum, small operators can explore for new reserves, at least on shore, with only a relatively small amount of high-risk money and the limited technical staff required to rent a drilling rig and to determine where the wildcat well should be drilled. If a discovery is made, subsequent, much larger investments in development wells and pipelines can be made at relatively low risk. In synfuels, a firm simply cannot enter the business without command of all capital requirements up-front, or without a very large staff of technicians and managers.

In summary, investment options to discover and develop conventional oil and gas will be exploited before synthetics even if estimated total capital outlays are the same, because the former confine major risks to the front-end of projects before the largest blocks of capital must be committed.

As a result, it is likely that only a very small fraction of the hundreds of firms currently producing conventional oil and gas will have the financial and technical means to produce synfuels when conventional resources are depleted. While this growing concentration of ownership may not lead to the classical problem of price fixing by domestic producers, because oil and gas are traded on worldwide commodity markets, it does at least make the industry appear to be more monolithic, since synfuels project managers will command very large blocks of human and material resources.

In domestic automating, ownership may become more concentrated because at least two out of the three major U.S. companies are being forced, by lack of capital and perhaps by high production costs, to curtail the number of different vehicles made. Although foreign automakers are increasing their U.S. manufacturing activities, the growing dominance of one major U.S. automaker over the other two may decrease price competition in certain types of cars and possibly reduce profitmaking opportunities for domestic suppliers to auto manufacturing because of the market leverage of the one dominant buyer.

WHAT DO INCENTIVES FOR INCREASED FUEL ECONOMY IMPLY FOR THE EVOLUTION AND HEALTH OF THE U.S. AUTO INDUSTRY?

The auto industry began a process of structural changes in the 1970's which complicates evaluation of how fuel economy policy might affect the industry, auto manufacturing communities, and the national economy. Regardless of fuel economy policy, the U.S. auto industry is undergoing a long-term decline in terms of employment, the number of domestic firms (including suppliers), and the proportion of global auto production sited in the United States. Recent consumer demand for fuel economy and other auto characteristics have supported these trends by motivating costly product changes to meet competition from foreign firms. Factors such as the relatively fast sales growth in foreign auto markets and lower costs of labor and capital abroad have induced U.S. manufacturers to increase investments in foreign production activities.

Increases in demand and other pressure on U.S. firms to raise fuel economy will reinforce and perhaps accelerate current industry and market trends. Although large spending needs will motivate reductions in the number of independent firms and, perhaps, the breadth of their operations, the size and financial health of the U.S. auto industry in the future will depend, to a great degree, on its ability to compete with foreign firms–particularly in the small-car market. The competitiveness of U.S. auto firms depends not only on product designs and production facilities but also on total manufacturing costs, which reflect labor costs and the efficiency of production, organization, and management. Incentives for accelerating fuel-efficiency increases will not only directly affect the investment requirements, but a combination of high perceived investment needs, possible rigidity in U.S. costs, and a slow-growing competitive U.S. market may discourage U.S. firms from investing in U.S. capacity.

There are some auto company activities that should be relatively invulnerable to fuel economy-motivated market changes and should continue in the United States. These activities include production of specialty cars and nonautomotive projects such as defense contracting. U.S. auto companies may continue to conduct some activities in the United States at historic or greater levels, while they may reduce the levels of others or eliminate them entirely.

A decline in U.S. auto production, especially one that is not substantially offset by growth in foreign-owned capacity in the United States, poses a major policy dilemma. On the one hand, the auto industry metamorphosis may result in a more economically efficient domestic industry that is more competitive with strong import competition. On the other hand, the process of industry change results in loss of jobs for current autoworkers and loss of employment and business activity for local economies, losses which are relatively large and regionally concentrated in the already economically depressed North-Central region. These concerns can be dealt with through industrial and economic development policies, but it should be recognized that policy to accelerate fuel economy improvements may aggravate them. In addition, many of these changes may occur even in the absence of strong demand for fuel efficiency, but possibly at a slower rate.

CAN WE HAVE A 75= MPG CAR?

There are no *technological* barriers to designing and building a four-passenger automobile that could achieve 75 mpg on the combined **55/45** percent highway/city EPA driving cycle. Such a car would take at least 5 years to design and develop and might be costly to manufacture, but it is technically feasible. It should be noted, of course, that the appearance of one or a few models that get 75 mpg would have little immediate effect on *fleet* average fuel economy, or on the Nation's petroleum consumption.

High fuel economy entails tradeoffs and compromises that affect other features of vehicle design–carrying capacity, performance, safety, comfort, and related amenities. Technology is a critical factor in managing these tradeoffs. Some routes to improved passenger car fuel economy also increase manufacturing costs (diesel engines, more complicated transmissions, lightweight materials). Here again, better technology can help to improve fuel economy at the least cost.

If a 75-mpg car can be made sufficiently attractive to consumers in terms of the other features beyond fuel economy that affect purchasing decisions—including price, but also the variety of less tangible factors that contribute to perceived value—then automakers will build such cars, confident that they will find a market. The interplay between consumer demand and automotive technology will determine when 75-mpg cars will appear. Consumer expectations concerning fuel costs and the possibility of future shortages of fuel, as well as their judgments of the practicality of such cars, will be important factors affecting the rate at which these cars would be introduced.

An automobile designed to achieve 75 mpg might look much like a current subcompact—e.g., a General Motors Chevette—but, as discussed in chapter 5, would be considerably different under the skin. It would have to be lighter, and might also be somewhat smaller—with a curb weight of perhaps 1,600 lb as opposed to about **2,000** lb for the Chevette. The actual weight depends not only on the size of the car, but also on the materials from which it is made. By using materials with high strength-to-weight ratios wherever possible—or, where strength or stiffness are not important, materials of low density—a four-passenger car could weigh, in principle, even less than the 1,600 lb suggested above. Costs are the limiting factors in the use of such materials—both the costs of the materials themselves and the costs of the required manufacturing processes.

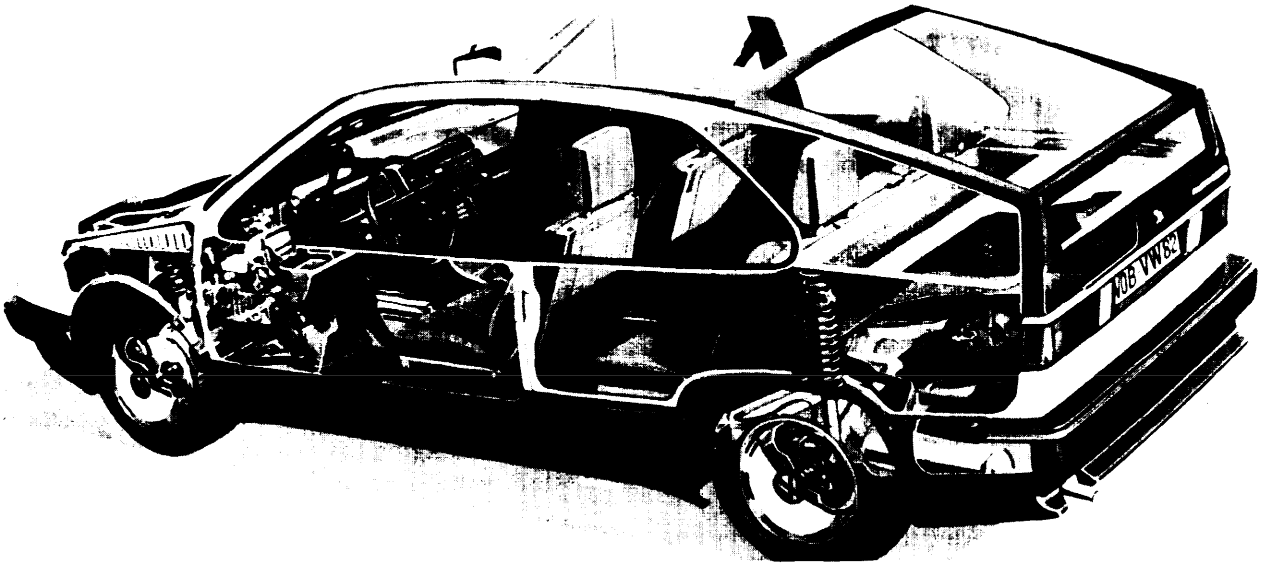

Photo credit: Volkswagen of America

Artists drawing of the VW2000, a three-cylinder diesel test vehicle that has achieved over 60 mpg in standard fuel-efficiency tests

The other essential element in a 75-mpg car is an efficient powertrain. For a car weighing 1,600 lb or less, a relatively small diesel engine–one with a displacement in the range of 0.9 to 1.3 liters–would suffice. The transmission could be either a manual design or a considerably improved automatic, perhaps a continuously variable transmission.

To get 75 mpg would also require a great deal of attention to the detailed design of many aspects of the car—low aerodynamic drag, low rolling resistance, use of microprocessor controls, minimal accessories, and parasitic loads—with careful engineering development throughout the vehicle system. None of this depends on technological breakthroughs.

Given equally good design practices, the resulting car would not be as safe as a larger vehicle. Nor would it be luxurious. It might not have air conditioning. It would probably not be able to pull a camping trailer through the Rocky Mountains. But it could *get 75* mpg. When automobile manufacturers—here, in Europe, and in Japan—decide that American consumers want such a car, they will build it.

ARE SMALL CARS LESS SAFE THAN LARGE CARS?

One of the easiest ways to increase the fuel economy of passenger cars is to make them lighter. Although it is possible to make cars somewhat lighter without making them smaller, in general size and weight go together. Thus, cars with increased fuel economy are typically smaller—a downward trend in the size and weight of cars sold in the U.S. market began in 1977 and will continue through the 1980's, although gradually leveling off.

Size is the more critical variable for safety, although weight also affects the dynamics of collisions. *A great deal of improvement in the safety of cars of all sizes is possible through improved design–but given best practice design, a big car will always be safer than a small car in a collision.* As a result, making cars smaller to improve fuel economy will, everything else being equal, increase risks to drivers and passengers. Assuming no change in the way the cars are driven, there will be more injuries and fatalities than would occur with bigger cars embodying equivalent design practices and having identical accident avoidance capabilities.

Size affects safety because when an automobile hits another object–whether another car, a truck, or a roadside obstacle—the car itself slows, or is decelerated (the "first collision"), and the occupants must then be slowed with respect to the vehicle (the "second collision"). To minimize the chance of injury, the decelerations of the occupants with respect to the passenger compartment during the second collision must be minimized, The occupants must also be protected against intrusion or penetration of the passenger compartment from the outside. But controlling decelerations during the second collision depends on the deceleration of the entire vehicle during the first collision. Given good design practices, the severity of both the first and the second collision can be lowered, on the average, if the car is made larger.

Ideally, the vehicle structure will deform in a controlled manner around the passenger compartment during a collision, so that the average deceleration of the passenger compartment in the first collision will be low. The larger the car, the more space the designer can utilize to manage the deformations and decelerations—e.g., by using a crushable front-end. In a small car, there is less room for controlled deformation without intruding on the passenger compartment. Within the passenger compartment, more space means more room to control the deceleration of the passengers—using belts, harnesses, padding, and other measures—with less risk of hitting unyielding portions of the vehicle structure. More room also makes penetration or other breaches of the integrity of the compartment less likely. One pathway to increased fuel economy without sacrificing collision protection is therefore to make cars lighter by design changes and/or different materials while preserving as much space as possible for managing the energies that must be dissipated in the first and second collisions.

Because vehicle size and weight are not the only significant factors in determining vehicle safety, and because "all other things being equal" does not apply in actual real-world situations, any conclusion about the relative safety of large and small cars should be tempered with the following observations:

1. The recent series of crash tests sponsored by the National Highway Traffic Safety Administration demonstrated that vehicles of approximately equal size can offer remarkably different degrees of crash protection to their occupants. In many cases, differences between cars of equal size overshadowed differences between size classes in the kind of accident tested (35-mph collision head-on into a barrier).
2. Crash-avoidance capabilities of large and small cars are unlikely to be the same, and any differences must be factored into an evaluation of relative safety. Unfortunately, the effects of differences in such capabilities are difficult to measure because they represent both physical differences in the vehicles and driver responses to those differences.
3. Available traffic safety data and analysis is often confusing and ambiguous on the subject of large car/small car safety differences.

Although analyses of car-to-car crashes tend to agree that occupants of large cars are at a lesser risk than those of smaller cars, there is no such firm agreement about the other classes of accidents that account for three-quarters of all passenger vehicle occupant fatalities. A probable reason for the ambiguity of results is the shortage of consistent, nationwide data on accident incidence and details; only fatal accidents are widely recorded. Another reason is the multitude of factors other than car size that might affect injury and fatality rates. Important factors include differences (among different size classes) in driver and occupant age distribution, general types of trips taken, average annual mileage, vehicle age distribution, and seatbelt usage.

HOW STRONG IS CURRENT DEMAND FOR FUEL EFFICIENCY IN CARS?

An extremely important factor influencing future new-car average fuel efficiency is the market demand for this attribute, relative to the other features the new-car buyer wants. Although it is, at best, only an approximate measure of future market behavior, examination of recent demand patterns in the new-car market can provide some insights about current demand for fuel efficiency. In particular, the importance of fuel efficiency as compared with car size, price, and performance is examined for 1981 model gasoline-fueled cars* sold through January 5, 1981.

Table 17 presents a comparison of the average fuel efficiency of new gasoline-fueled 1981 model cars sold through January 5, 1981, with the fuel efficiency of the most efficient car in each of the Environmental Protection Agency's (EPA) nine size classes. Also shown are the sales fractions and the nationality of the manufacturer of the most efficient vehicle, These data show that the average fuel efficiency of new cars sold was 25 mpg, but if consumers had bought only the most fuel-efficient car in each size class* (and manufacturers had been able to supply this demand),

Table 17.—Comparison of Average and Highest Fuel Efficiency for 1981 Model Gasoline-Fueied Cars in Each Size Class

EPA size class	Sales fraction (percent)	Sales-weighted average fuel efficiency of cars sold through Jan. 5, 1981 (mpg)	Fuel efficiency of most fuel-efficient model in size class (mpg)	Nationality of manufacturer of most fuel-efficient model
Two-seater.	2	22	30	Italian
Minicompact	3	34	45	Japanese
Subcompact	30	28	42	United States (Captive Import)
Compact	9	27	37	United States
Midsize	37	23	31	United States
Large	9		24	United States
Small wagon	4	30	37	Japanese
Midsize wagon	5	23	30	United States
Large wagon	1	18	20	United States
Sales-weighted average		25	33	

SOURCE: Data from J. A, Foster, J. D. Murrell, and S. L. Loos, US. Environmental Protection Agency, "Light Duty Automotive Fuel Economy . . Trends Through 1981," SAE papar No. 810388, February 1981.

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*The results of the analysis would change somewhat if diesels were included, primarily with respect to nationality of manufacturers because U.S. manufacturers did not offer diesels in several size classes in 1981. U.S. manufacturers, however, are beginning to offer diesels in most size categories; but the relevant data are not now available. In 1981, about 95 percent of the automobiles sold were gasoline-powered.

*Interestingly, this would also have resulted in U.S. manufacturers and captive imports capturing over 90 percent of sales, rather than 74 percent of sales that they actually achieved in this period. If diesels are included, however, average fuel efficiency could have been slightly higher than 33 mpg, but less than 60 percent of the cars purchased would be domestically produced.

the **average fuel efficiency would** have been 33 mpg (a 33 percent increase). Because EPA's size classes are based on cars' interior volume, it is clear that demand for large interior volume in cars is not currently preventing a significantly higher average fuel efficiency in new cars than is actually being purchased.

Similarly, a comparison of prices shows that the most fuel-efficient 1981 model cars generally had a base sticker price in the middle or lower half of the price range of cars in each size classification. * Thus, there is no evidence that price is constraining the purchase of fuel-efficient cars either.

A further comparison of the average and most fuel-efficient cars in each size category shows that the average cars are heavier and have more powerful engines than the most fuel-efficient models. However, OTA's analysis indicates that the greater engine power found in the average car sold is, to a large extent, needed simply because the car is heavier.** There is no indication that the most fuel-efficient car in most size categories performs (e.g., accelerates) significantly worse than the averge 1981 model car actually sold in that category. Although there are exceptions to this in certain size categories (e.g., two-seaters, large cars, and possibly midsized station wagons), these exceptions account for only about 10 to 15 percent of total sales.

This analysis indicates that interior volume, price, and performance cannot account for the large difference between the fuel efficiency of cars actually sold and what was available. As in' the past, consumers consider features such as style, quality, safety, ability to carry or haul heavier loads, and energy-intensive accessories to be of comparable importance to fuel economy. It is probable, therefore, that new-car average fuel efficiency could be significantly increased if consumer demand for fuel economy were strengthened.

“Sales-weighted average sticker prices for comparably equipped cars are not currently available.

****For example, in subcompacts and midsized cars (accounting together for 67 percent of sales), the average car weighed about 33 percent more and had about 50 percent larger engine displacement (which is correlated to power) than the most fuel-efficient car. A further comparison of specific fuel efficiency (ton miles per gallon, or the mpg of an equivalent car weighing 1 ton) shows that, for midsized cars (37 percent of sales), the difference in fuel efficiency between the average and the most fuel-efficient car can be explained solely on the basis of weight. Thus, there is no indication that the average car has better performance characteristics (e.g., acceleration) than does the most fuel-efficient model. A similar comparison of subcompacts indicates that, if anything, one would expect the most fuel-efficient model to perform better than the average.**

WHAT ARE THE PROSPECTS FOR ELECTRIC VEHICLES?

EVs were among the first cars built, but they had almost vanished from the marketplace by the 1920's, **primarily because they could not compete with gasoline-powered vehicles in terms of price and performance. Due to concern over automobile emissions, the increasing price** of oil and recent oil supply disruptions, however, there has been a renewed interest in this technology. The advantages of EVs are that they derive their energy from reliable supplies of electricity, which can be produced from abundant domestic energy sources, and they operate without exhaust emissions. Their disadvantages are their high cost and poor performance and the increased sulfur dioxide emissions that result from increased electric generation.

From the consumer's point of view, the problems with EVs are principally centered on battery technology. Current batteries are expensive and heavy, relative to the energy they store; they require several hours to recharge; and they must be replaced approximately every 10,000 miles at a cost of $1,500 to $3,000. The weight of batteries limits vehicle range, * performance, and cargo- and passenger-carrying capacity. Because of the cost of batteries and electric controls, a new EV is estimated to cost about $3,000 more than a comparable gasoline-powered vehicle. And replacing batteries every 10,000 miles because of limited life would add more than $().10/mile to

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***Usually 100 miles or less between recharging.**

operating costs, which is equivalent to gasoline costing more than $4 to $6/gal for a 40- to 60-mpg car.

Future developments in battery technology could improve the prospects for EVs, and several approaches are being pursued. But the understanding of battery technology is not adequate to predict if or when significant improvements will occur.

If battery problems persist, sales of EVs could be limited to a relatively few people and firms that can afford to pay a premium to avoid transportation problems that would arise if liquid fuel supplies were disrupted. On the other hand, if gasoline prices increase by more than a factor of four or five or if gasoline and diesel fuel are rationed at levels too low to satisfy driving needs even with the most fuel-efficient cars, then EVs could be favored—provided electricity prices do not also increase dramatically.

Prospects for EVs may also be influenced by Government incentives based on national and regional considerations. One such consideration is the oil displacement potential of EVs. EVs are most nearly a substitute for small cars, which are likely to be relatively fuel efficient in the 1990's; but the limited range of current and near-term EVs prevents them from being a substitute for all of the yearly travel needs supplied by a small gasoline-driven car. As a result, oil displacement by EVs is likely to be relatively small; probably no more than 0.1 million barrels per day (MMB/D) with a 10-percent market penetration, even assuming no oil consumption by those electric utilities supplying electricity to EVs.

At current levels of utility oil consumption, however, the net oil displacement would be less than 0.1 MMB/D (see ch. **5** for details). Future reductions in utility oil consumption will improve the oil displacement potential of EVs, while increased fuel efficiency in petroleum-fueled cars will reduce any advantage EVs might have in this connection.

A final consideration is the reduced automotive emissions and other environmental effects of EV use. Because that use would be concentrated in urban areas and the necessary increased electric power generation would be well outside of these areas, cities with oxidant problems that replace large numbers of conventional vehicles with EVs will significantly improve their air quality. This incentive could improve the prospects for EV sales and use. Emissions and other impacts of increased power generation may cancel some of this benefit, but the positive urban effects are likely to be considered the most important environmental attributes of EVs.

IF A LARGE-SCALE SYNFUELS INDUSTRY IS BUILT . . . WILL PUBLIC AND WORKER HEALTH AND SAFETY AS WELL AS THE ENVIRONMENT BE ADEQUATELY PROTECTED?

It is virtually a truism that all systems designed to produce large amounts of energy will have the *potential to* adversely affect the environment and human health and safety. It is equally true that, with few exceptions, it is technically feasible to reduce these effects to the point where they are generally considered an acceptable exchange for the energy benefits that will be obtained. In current arguments concerning synthetic fuels development, as with many other such arguments, the environmental community has focused on the potential damaging effects, while the industry has focused on the controls and environmental management procedures available to them. Gaining a perspective on the correct balance between these two points of view—on the likelihood that some of the potential damages will *actually occur* —is especially important in the case of synfuels development because environmental dangers have become a genuine public concern.

As shown in the evaluation of potential environmental impacts in this report, many of the important impacts of a large synfuels industry will be similar in kind to those of coal-fired electric power generation. The magnitude of these impacts (acid drainage and land subsidence from coal mines, emissions of sulfur and nitrogen oxides and particulate, effects of water use, population increases, etc.) is likely to be similar to and in some cases less than the likely impacts of the new, tightly controlled electric-generating capacity projected to be installed in the same time frame.

A second set of impacts–those associated with the toxic materials present in the process and waste streams of the plants and possibly in their products—are not predictable at this time but are, nevertheless, very worrisome. Factors that should be useful in gaging the risk from these impacts include the technical problems facing the designers of environmental controls, the availability of adequate regulations and regulatory agency resources, past industry and Government behavior in implementing environmental and safety controls, and difficulties that might be encountered in detecting adverse impacts and tracing them to their sources. A brief discussion of these factors follows:

1. *Technical* Problems.—Virtually all the controls which are planned for synthetic fuels plants are based on present engineering practices in the petroleum refining, petrochemical, coal-tar processing and power generation industries, and industry spokesmen appear confident that they will work satisfactorily. Problems may be encountered, however, because of differences between these industries and synfuels plants—the latter have higher concentrations of toxic hydrocarbons and trace metals, higher pressures, and more erosive process streams, in particular, As yet, few effluent streams have been sent through integrated control systems, so it has not yet been demonstrated that the various control processes will work satisfactorily in concert, Technical personnel at the Environmental Protection Agency (EPA) and the Department of Energy (DOE) have expressed particular concerns about control-system reliability.

   Judging from these indications, it appears possible that a considerable period of time–possibly even a few years–will be necessary to solve control problems in the first few plants and get the environmental systems working with adequate performance and reliability. Delays are especially likely for direct-liquefaction plants, which have some particularly difficult problems involving toxic substances and erosive process streams. These delays may be aggravated by a potential gap in control technology development. Recent Federal policy has left the development of environmental controls largely to industry. The major concern of the synfuels industry, on the other hand, is to clean up waste streams so that existing regulations may be met. Less emphasis is placed on controlling pollutants such as polynuclear aromatics that are not currently regulated. It appears certain that there will be considerable pressure to regulate these and other pollutants, but it is not certain that the industry will be able to respond quickly to such regulations.
2. *Detecting and Tracing Impacts.* —One of the major potential dangers of synfuels plants will be low-level emissions of toxic substances, especially through vapor leaks (primary danger to workers) or ground water contamination from waste disposal (primary danger to the public and the general environment), Current ground water monitoring probably is inadequate to provide a desirable margin of safety, although presumably knowledge of this danger will result in better monitoring systems. A major problem may be the long lag times associated with detecting carcinogenic/mutagenic/teratogenic damages—a major concern associated with trace hydrocarbons produced under the physical and chemical conditions present in most synfuels reactors.
3. *Regulation.* –The regulatory climate facing an emerging synfuels industry is mixed. On the one hand, ambient standards for particulates, sulfur oxides, and other pollutants

associated with conventional combustion sources are in place and should offer adequate protection to public health with respect to this group of pollutants. A limited number of other standards, including those for drinking water protection, also are in place. On the other hand, new source performance standards–federally set emission standards—have not been determined yet, nor have national emission standards for hazardous air pollutants been set for the variety of fugitive hydrocarbons or vaporized trace elements that might escape from synfuels plants. Likewise, although Occupational Safety and Health Administration (OSHA) exposure standards and workplace safety requirements do apply to several chemicals known or expected to occur in synfuels production, the majority of such chemicals are not regulated at this time.

These regulatory gaps are not surprising, given the limited experience with synfuels plants, and several of the standards–especially the emissions standards—probably could not have been properly set at this stage of industry development even had there been intensive environmental research. However, the difficulties in detecting impacts described above, and some doubts as to the availability of environmental research resources at the Federal level, lead to concern about the adequacy of future regulation.

4. Past History. –Given both the potential for environmental harm and the potential for mitigating measures, the attitude and behavior of both the industries that will build and operate synfuels plants and the agencies that will regulate them are critical determinants of actual environmental risk. Consequently, an understanding of the past environmental record of these entities should be a useful guide in gaging this risk. Unfortunately, there is little in the way of comprehensive research on this behavior. Even the compilation of data on compliance with existing regulations and incidence of deaths and injuries is quite weak.

For example, to our knowledge EPA has sponsored only one major evaluation of compliance with emission regulations; this recent study of nine States showed that 70 percent of all sources failed to comply fully with those regulations. Also, Department of Labor statistics on occupational hazards are compiled in such a way as to overlook health problems that cannot easily be attributed to a specific cause—just the kinds of problems of most concern to an evaluation of potential synfuels problems. Consequently, occupational health and safety statistics that appear favorable to synfuels-related industries are likely to be an inadequate guide to the actual hazard potential.

Anecdotal evidence, although not an adequate basis for evaluating risk, may be useful as a warning signal of future causes of health and safety problems. For example, recent studies have demonstrated that protective gloves used in the chemical industry fail to protect workers from several hazardous, and commonly encountered, chemicals. This points to both an immediate technical problem and an institutional failure in the chemical industry itself and its regulating agencies. On the other hand, the tests, which were sponsored by OSHA, also demonstrate the ability of the regulatory agency to correct past failures.

Another example of anecdotal evidence that may indicate some future problems with industry performance is that some developers have failed to incorporate separate and measurable control systems in synfuels pilot plants. For example, a direct-liquefaction facility in Texas has its effluents mixed with those of a neighboring refinery, rather than having a separate control system whose effectiveness at treating synfuels wastes can be tested and optimized. This might reflect industry's lack of priority or, more likely, its high level of confidence that no unusual control problems will arise that cannot be readily handled at the commercial stage. There is considerable disagreement about the validity of this confidence.

Finally, there is ample evidence that the chemical industry and its regulators have had significant problems in dealing properly with subtle, slow-acting chemical poisons. Chemicals that were unregulated or inadequately regulated for long periods of time, and whose subsequent regulation became major sources of conflict between industry and Government, include benzene, formaldehyde, vinyl chloride, tetraethyl lead, the pesticide 2,4,5-T, and many others. In some cases, controversy persists despite years or even decades of research.

An implication of the above discussion is that adequate environmental management of synfuels is unlikely to occur automatically when development begins in earnest. Although OTA believes that the various waste streams can be adequately controlled, this is going to require a strong industry effort to determine the full range of potential environmental impacts associated with development and to devise and implement measures to mitigate or prevent the important impacts. At present, however, there are indications that most developers are interested primarily in meeting current regulatory requirements, most of which are limited in their coverage of potential impacts. And completing the regulatory record, to provide the incentive necessary to stimulate further environmental efforts, is going to be a difficult and time-consuming job, particularly if ongoing cutbacks in Government research and regulatory budgets are not accompanied by promised improvements in efficiency.

Finally, there are some remaining doubts about the reliability of proposed control systems in meeting current regulatory requirements. These potential problem areas imply that congressional oversight of an emerging synfuels industry will need to be especially vigorous in its coverage of environmental concerns.

WILL WATER SUPPLY CONSTRAIN SYNFUELS DEVELOPMENT?

In the aggregate, the water consumption requirements for synfuels development are small. Achieving a synfuels production capability of 2 million barrels per day oil equivalent would require on the order of 0.3 million acre-feet/year or about 0.2 percent of estimated total current national freshwater consumption, Nevertheless, synfuels plants are individually large water consumers. Depending on both the water supply sources chosen for synfuels development and the size and timing of water demands from other users, synfuels development could create conflicts among users for increasingly scarce water supplies or exacerbate conflicts in areas that are already water-short.

The nature and extent of the impacts of synfuels development on water availability are controversial. The controversy arises in large part because of the many hydrologic as well as institutional, legal, political, and economic uncertainties and constraints which underlie the data, and because of varying assumptions and assessment methodologies used. The importance of the factors influencing water availability will vary in the different river basins where the energy resources are located.

In the major Eastern river basins where energy resources are located (i.e., the Ohio, Tennessee, and the Upper Mississippi), water should generally be adequate on the mainstems and larger tributaries, without new storage, to support likely synfuels development. However, localized water scarcity problems could arise during the inevitable dry periods or due to development on smaller tributaries. The severity of these local problems cannot be ascertained from existing data and they have not yet been examined systematically. With appropriate water planning and management, it should be possible to reduce, if not eliminate, any local problems that might arise.

Competition for water in the West already exists and is expected to intensify with or without synfuels development. In the Missouri River Basin, the magnitude of the institutional, legal, and political uncertainties, together with the need for major new water storage projects to average-out seasonal and yearly streamflow variations, preclude an unqualified conclusion as to the availability of water for synfuels development. The major sources of these uncertainties, which are difficult to quantify because of a lack of supporting information, include Federal reserve water rights (including Indian water rights claims), provisions of existing compacts, and instream flow reservations.

In the Upper Colorado River Basin, water could be made available to support the level of synfuels development expected over the next decade. However, the institutional, political, and legal uncertainties make it difficult to determine which sources would be used and the actual amount of water that would be made available from these sources. The principal uncertainties concern the use of Federal storage, the transfer of water rights, provisions of existing compacts and treaties, and Federal reserve rights. The range of uncertainty surrounding the water availability to the entire basin after 1990 is so broad that it tends to subsume the amount of water that would be needed for expanded synfuels development.

ARE SYNTHETIC FUELS COMPATIBLE WITH EXISTING END USES?

When introducing new fuels into the U.S. liquid fuels system, it is important to determine the compatibility of the new fuels with existing end uses in order to determine what end-use changes, if any, may be necessary. In this section the compatibility of various synfuels with transportation end uses is briefly described.

Alcohols

Neither pure ethanol nor pure methanol can be used in existing automobiles without modifying the fuel delivery system, but cars using them can be readily built and engines optimized for pure alcohol use would probably be 10 to 20 percent more efficient than their gasoline counterparts. New cars currently are being built to be compatible with gasohol (1 O percent ethanol, 90 percent gasoline), so potential problems with this blend are likely to disappear with time.[8] Methanol-gasoline blends have been tested with mixed results. Principal problems include increased evaporative emissions and phase separation of the fuel in the presence of small amounts of water. These problems can be reduced by blending t-butanol (another alcohol) with the methanol, and such a blend is currently being tested.[9] However, due to the corrosive effects of methanol on some plastics, rubbers, and metals in some vehicles, it probably is preferable to use methanol in its pure form in modified vehicles or to require that components in new automobiles be compatible with methanol blends.

Shale Oil

Shale oil has been successfully refined at the pilot plant level to products that meet refinery specifications for petroleum derived gasoline, diesel fuel, and jet fuel.[10] The properties of the diesel and jet fuels are shown in tables 18 and 19, where they are compared with the petroleum counterparts. Current indications are that the major question with respect to compatibility of these fuels with their end uses is what minimum level of refining (and thus refining cost) will be needed to satisfy the needs of end users.

Direct Coal Liquids

One of the direct coal liquids, SRC II, has also been successfully refined to products that meet refinery specifications for gasoline and jet fuel (tables 18 and 19). (The cetane number of the resultant “diesel fuel, ” however, is lower than that normally required for petroleum diesel fuel.) The gasoline, because of its aromatics content,

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[8] *Energy From Biological Processes, Volume II: Technical and Environmental Analyses,* OTA-E-1 28 (Washington, D. C.: U.S. Congress, Office of Technology Assessment, September 1980).

[9] Ibid.

[10] R. A. Sullivan and H. A. Frumkin, “Refining and Upgrading of Synfuels From Coal and Oil Shales by Advanced Catalytic Processes, ” third interim report, prepared for DOE under contract No. EF-76-C-01-2315, Chevron Research Co., Apr. 30, 1980.

Table 18.–Properties of Selected Jet Fuels Derived From Shale Oil and SRC-II

	Typical petroleum (Jet A)	350° to 500° F hydrotreated shale oil	300° to 535° F hydrocracked shale oil	300° to 550° F or 250° to 570° F hydrotreated SRC-11
Gravity, 'API	37-51	42	47	33-36
Group type, LV%:				
Paraffins		35	55	3-4
Cycloparaffins		45	40	93-81
Aromatics	<20	20	5	4-15
Smoke points, mm.	> 20	21	35	20-23
Freeze point, °F	–40	–42	–65	–75 to –95
Nitrogen	(a)	2	0.1	0.1

[a] In addition, severe stability requirements mean that heteroatom content must be very low(usually the nitrogen content is less than 10 ppm for petroleum-derived jet fuel).

SOURCE: R. A. Sullivan and H. A. Frumkin, "Refining and Upgrading of Synfuels From Coal and Oil Shales by Advanced Catalytic Processes," third interim report, prepared for DOE under contract No. EF-76-C-01-2315, Chevron Research Co., Apr. 30, 1980.

Table 19.–Propertles of Selected Diesal Fuels Derived From Shale Oil and SRC-II

	Typical petroleum	350° to 650° F hydrotreated shale oil	350° to 600° F hydrotreated shale oil coker distillate	350° F+ hydrotreated SRC-II
Gravity, API	>30	38	41	29
Cetane No.	>40	46[a]	48	39
Pour point, °F.	<+ 15	– 5	–20	–55
Group type, LV%:				
P		37	41	–4-7
N		44	41	70-93
A		19	18	2-23
Nitrogen, ppm[b]	(b)	350	350	0.1-0.5

[a] Estimated.
[b] Heteroatoms must be removed to level required for stability (usually 500 ppm N for petroleum).

SOURCE: R. A. Sullivan and H. A. Frumkin, "Refining and Upgrading of Synfuels From Coal and Oil Shales by Advanced Catalytic Processes, " third interim report, prepared for DOE under contract No. EF-76-C-01-2315, Chevron Research Co., Apr. 30, 1960.

would be used as an octane-enhancing blending agent in conventional gasoline. Aromatics, such as benzene and toluene, are currently used for this purpose in gasoline. Again, a principal question is what minimum level of refining will be needed. other direct coal liquids probably are similar to SRC li liquids.

Indirect Coal Liquids

Other than methanol, which was considered above, the principal indirect coal liquids for ground transportation are gasolines, although the Fischer-Tropsch (FT) processes can be arranged to produce a variety of distillate fuels, as well. There are no indications that these gasolines would not be compatible with the existing automobile fleet, either alone or in blends with conventional gasoline.

Caveat

Despite the apparent compatibility of hydrocarbon synfuels with existing end uses, refinery specifications do not uniquely determine all of the properties of the fuel. The tests used to characterize hydrocarbon fuels were designed for petroleum products and may be inadequate indicators for the synfuels. Some potential problems with the hydrocarbon synfuels that have been mentioned include:

- *Lubrication.* –Hydrotreating of synfuels is necessary to meet refinery specifications. However, the lubricating properties of the synfuels drop with this hydrotreating. This drop in lubricity could lead to possible problems with fuel-injection nozzles and other moving parts that rely on the fuel for lubrication.

- *Emissions.* —The particulate and nitrogen oxide emissions of synthetic diesel fuel could be greater than those from an otherwise comparable petroleum diesel fuel. Automobile manufacturers are having difficulty meeting emissions standards with conventional diesel fuel, and there is some concern that synfuels could aggravate these problems.
- *Variability.* —The direct liquefaction synfuels from coal can vary in composition depending on the coal used.11 Consequently, although the synfuel from one coal may be compatible with an end use, the same process might produce an incompatible synfuel if another coal is used.

In principle, if the exact chemical composition of synfuels were known, synfuels could be blended from petrochemicals and tested extensively for these potential problems before synfuels plants were built. In practice, however, the chemical compositions are so complex, varied, and process-dependent that this option is probably not practical.

The alternative is to wait until sufficient quantities of synfuels are available and to conduct extensive field tests of synfuels processed in various ways and from different coals. Until this is done, statements about the compatibility of hydrocarbon synfuels with current end uses are somewhat speculative.

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[1] Ibid,