Chapter II

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INTRODUCTION

Since 1973, the United States has experienced two major oil supply disruptions and shortfalls which resulted in large and enduring increases in oil prices. Although the Nation has made great strides in reducing oil consumption in response to those price increases, another disruption and shortfall could still have significant negative consequences for the U.S. economy.

Much of the continuing debate on how to deal with another disruption and shortfall has centered around emergency response mechanisms such as oil stockpiling and standby fuel allocation schemes. Little attention has been paid to ways of responding to a shortfall of indefinite duration because it has always been assumed that any oil cutoff would end after a period of 1 or 2 years. An indefinite shortfall is not implausible, however. Indeed, the lasting increases in oil prices that resulted from events in the 1970s are the economic equivalent of lasting supply shortfalls. And as a result of the most recent shortfall, the period 1978-83 saw a 60-percent increase in the real price of oil and an unadjusted decline in oil demand of nearly 4 million barrels per day (MMB/D).

Judging from this historical experience, therefore, an important aspect of the United States' vulnerability to a future oil import curtailment is the Nation's ability to adjust to a lasting or protracted oil supply shortfall and price rise. As demonstrated by the Nation's response to the most recent price shock, a lasting shortfall would require technological and economic adjustments that go well beyond short-term emergency responses, although those responses would also certainly be necessary.

At the request of the Senate Committee on Foreign Relations, OTA addressed the possibility of a lasting shortfall by asking the following questions: how could the United States respond to a large and protracted oil supply shortfall by technical means alone and how do the economic consequences of a shortfall depend on the deployment rate of oil replacement technologies?

As a starting point for its analysis, OTA made a number of assumptions:

1. Acceptance of the International Energy Program[1] IEA agreements results in a 3 MMB/D[2] shortfall in the United States (compared to a preshortfall demand of 16 MMB/D).
2. The shortfall is assumed to be of indefinite duration (i.e., to last at least 5 years) at the outset and to begin in the mid-1980s.
3. The economy would not undergo major structural changes, such as major shifts in output mix or behavior during the 5-year period.
4. The Strategic Petroleum Reserve, as well as private oil ‘stockpiles, would be used to reduce the immediate effects of the shortfall, but they would be depleted within 3 years, dropping from a drawdown rate of 1.5 MMB/D the first year of the shortfall to zero by the end of the third year.

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[1] "Agreement on an International Energy Program (as amended to 19th May, 1980)," International Energy Agency.

[2] Corresponding to a (non-Communist) world oil shortfall of about 9 to 10 MMB/D.

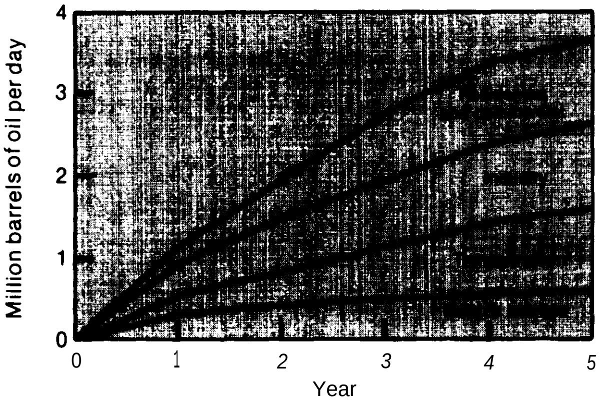
MAJOR FINDINGS

At the onset of an oil supply shortfall, emergency measures such as reductions in private and public oil stocks can cushion the immediate effects of the oil shortfall. After 5 to 10 years, long leadtime technologies such as enhanced oil recovery and synthetic fuels production can begin to provide liquid fuels, which are essentially indistinguishable from the lost oil. In the period of about 1 to 5 years after onset, however, oil consumers will either have to forgo certain energy services or invest in nonoil energy technologies.

OTA has examined each sector in the U.S. economy and identified the technologies that, based on **technical** considerations, are likely to be able to replace the largest quantities of oil, at the least cost, for each sector. The rate that each oil replacement technology (fuel switching and increased efficiency of use) could be deployed was then estimated from existing capacities to produce and install the necessary equipment, historical peak rates of installation and various end-user constraints. Based on this analysis, **OTA has concluded that the United States has the technical and manufacturing capability to replace up to 3.6 MM B/D of oil use within 5 years after the onset of an oil supply shortfall (see** fig. 1 and table 1).

The criteria used to select the most promising technologies for each major end use of oil were: 1) the technology must be commercial now or is likely to be commercial by mid-1985, 2) individual units can be installed or built in less than 2 to 3 years, 3) the technology has sufficiently broad applicability to be capable of replacing a significant fraction of the oil consumed for that end use, and 4) the technology is currently among the lowest cost alternatives to oil for that end use. In other words, OTA selected those technologies that—based on current engineering cost estimates and technical judgments—could replace large quantities of oil in a relatively short time at costs below OTA's estimate of the probable post-shortfall price of oil (*$50* to *$70* per barrel in 1983 dollars).

Figure 1.— Potential Replacement of Oil Through Fuel Switching and Increased Efficiency



SOURCE: Office of Technology Assessment

Inflation following a large oil shortfall will, of course, increase the cost of many of these oil replacement technologies, and it could alter the relative costs among the technologies. These changes will depend on a complex variety of factors and, currently, there is no good way to predict the actual outcome. Nevertheless, the difference between the current costs of the major replacement technologies selected and the probable post-shortfall price of oil is sufficiently large to warrant reasonable confidence that these technologies will be economic alternatives to oil following a large shortfall.

The options satisfying these criteria that can replace the largest amounts of oil within 5 years after the start of a shortfall are:

1. increased efficiency and switching to alternative fuels to reduce oil use for space and water heating in buildings and for steam in industry and electric utilities, and
2. increased average efficiency of automobiles and light trucks on the road.

Smaller, additional amounts of oil can be replaced in transportation and materials uses of oil (e.g., petrochemicals) using a variety of other technologies, but the near- to mid-term opportunities are more limited because of longer lead-times and/or higher costs.

At the end of 5 years, deployment of the major oil replacement technologies would leave transportation fuels and materials production as the predominant remaining uses for oil. Aside from refinery use of oil for fuel (8 to 10 percent of refinery throughputs), less than 5 percent of the remaining oil consumption would be for space and water heating and steam, mostly in residential and commercial buildings in the northeastern United States and in small industrial boilers throughout the country.

This oil replacement would require about 2 trillion cubic feet (TCF) of natural gas (11 percent of 1982 consumption) and 115 million tons of

Table 1.—Major Oil Replacement Options

Sector	Oil replacement potential after 5 years (MMB/D)[a]
Electric Utilities:	
Switching to coal and completion of new powerplants currently under construction	0.5
Increased use of natural gas	0.1
Subtotal	0.6
Industry:	
Switch to natural gas	0.45
Switch to coal	0.2
Increased efficiency	0.15
Reduced refinery throughput	0.2
Subtotal	1.0
Residential and commercial (heat and hot water in buildings)	
Switch to natural gas.. ...,	0.45
Switch to electricity	0.4
Increased efficiency and switch to other fuels.	0.15
Subtotal	1.0
Transportation:	
Increased efficiency of cars and light trucks	0.7
Increased efficiency in other transportation modes	0.1
Increased production and use of ethanol.	0.1
Switch to other alternative transportation fuels	0.1
Subtotal	1.0
Total	3.6

[a]Numbers rounded to nearest 0.05 MMB/D

SOURCE Office of Technology Assessment

solid fuels (coal and wood) peryear (13 percent of 1982 production) as substitutes for oil. Nearly all of the increment of natural gas, however, could be made available through investments in increased efficiency of natural gas use.

End-user investment costs for the major oil replacement technologies can vary from $0 to $5,000 per barrel per day (B/D) of oil replaced (for conversion of an industrial boiler to natural gas) up to $35,000 to $60,000 per B/D of oil replaced (for installation of a central electric heat pump for residential space heating and hot water) (see table 2). However, with residential electricity costing 8 cents per kilowatt hour (kWh) (1983 average was 7.2 cents/kWh), even the cost of installing a heat pump in an average oil-heated residential building could be recovered in 2 to 6 years, depending on the price of oil following the shortfall and on the actual investment cost. The payback period for the other options considered would be shorter, unless there were rapid inflation in equipment costs and/or natural gas prices. (Although some inflation in the price of equipment would be expected, as mentioned above, there is no fundamental reason why these prices should become prohibitively high, Furthermore, natural gas price rises could be moderated by investments in increased efficiency of natural gas use, with investment costs similar to those for increased efficiency of oil use.)

Total investment would amount to $30 billion to $40 billion per year,[3] on average, or about 7 to 9 percent of recent annual investments in producer durables and residential structures.

Although the anticipation of large increases in the price of oil would be a strong incentive to invest in oil replacement technologies, nontechnical constraints could limit the actual rate of investment in these technologies to a level which is considerably lower than the rate at which the technologies could be supplied. For example, in-

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[3] The higher number includes investments to increase the efficiency of natural gas use. The numbers do not, however, include the cost of new car and light truck purchases because this involves an ongoing activity.

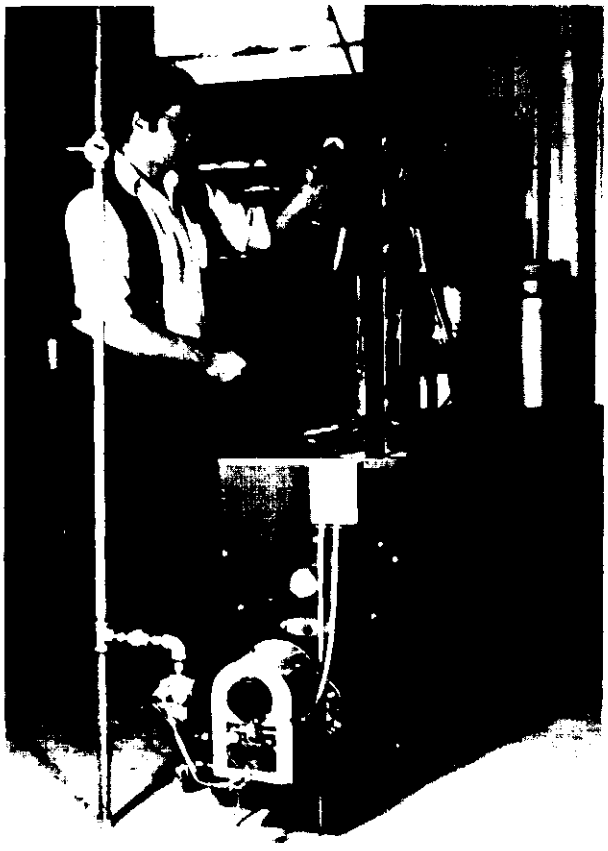


Photo credit: Midco Corp.

Many oil-fired boilers used for home heating and hot water can be converted to natural gas simply by the addition of a gas burner (circled)

Photo credit: Atlantic Research Corp.

A coal-water mixture flows from a pipe at an Atlantic Research Corp. facility. Such mixtures contain up to 70 percent coal in water together with small amounts of stabilizing agents. Because the mixtures are fluid, they can be stored and delivered in systems similar to those used for oil, thereby eliminating the need for a coal yard at the end user's location

dustrial oil users may shut down their plants rather than make large investments in the face of an uncertain future demand for their products. Electric utilities using oil may have difficulties borrowing money in the bond markets particularly if their current financial health does not improve and regulatory climate does not change to facilitate these investments. Further, if electric rates increase after the onset of the shortfall, a drop in demand for electricity could further deteriorate utilities' financial situation. There could also be delays in issuing construction permits for converting industrial and utility boilers to coal and in issuing operating permits and certification for new electric powerplants. States that produce high-sulfur coal may resist the use of low-sulfur coal in these conversions (needed to meet emissions standards[4] while minimizing the investment and construction time). Consumers may defer the purchase of new (more fuel efficient) automobiles.

Converting boilers from residual fuel oil to coal will not increase sulfur and particulate emissions if low-sulfur coal is used and particulate control devices are installed. Emissions of some other pollutants, involving impurities found in coal but not in residual oil, ash disposal, and mining-related impacts would increase, however. Furthermore, about one-third of the roughly 100 million ton/yr increase in coal use would be in existing and new electric powerplants and would be used to replace home heating oil. This replacement of oil with coal would lead to net increases in sulfur, particulate, NO_x and other emissions associated with coal. The magnitude of the increase would depend on how much of the coal is burned in new and existing powerplants with efficient emission controls versus the amount burned in existing powerplants with inefficient controls. Presumably most of the marginal electric generation would be in new powerplants meeting new source performance standards.

Table 2.—Estimated Investment Costs for Major Oil Replacement Technologies

Option	Investment cost (thousand 1982 dollars per barrel per day of oil replaced)
• Fuel switching in industrial and utility boilers:	
Conversion to solid fuel (including coal-water mixtures)	10-20
Construction of new solid fuel boiler with coal-handling facility	25-50
Construction of coal-water mixture production plant	2-3
Completion of new powerplants currently under construction	50[a]
Conversion to natural gas	0-5
• Fuel switching in residential and commercial space heating and hot water:	
Natural gas	15-25
Electric heat pumps	35-60[b]
Electric resistance heating	10-20[c]
Solid fuel	5-35[d]
• Residential and commercial energy conservation:	
Building insulation	40-60[e]
• Industrial oil replacement:	
Amalgam of efficiency improvements and product mix shifts	10-70[f]

[a] Assumes $500 per kilowatthour to complete and plant operation at 70 Percent of capacity.

[b] Based on an installation cost ranging from $2,000 to $3,500 for a system used only for space heating to $2,500 to $4,000 for a system for space heat and hot water and on the national average oil use of 676 gal and 1,055 gal per year for homes in which oil provides heat only, and both heat and hot water, respectively.

[c] Assumes $500 per household for electric resistance space heaters and 1,000 for a hot water heater.

[d] Assumes $250 to $750 for wood stove (including installation) for space heating only or $2,500 for new wood-fired central boiler for heat and hot water.

[e] This estimate represents an average over a number of building types and ages. Actual site-specific costs will Vary from less than $1,000 per B/D up to over $200,000 per B/D.

[f] Industrial replacement involves a broad range for investment costs. At the low-cost end, investment is incidental (e.g., for product mix shifts); and at the high-cost end, investments are large because firms are willing to pay an insurance premium in order to Increase the security or price stability of its fuel supplies

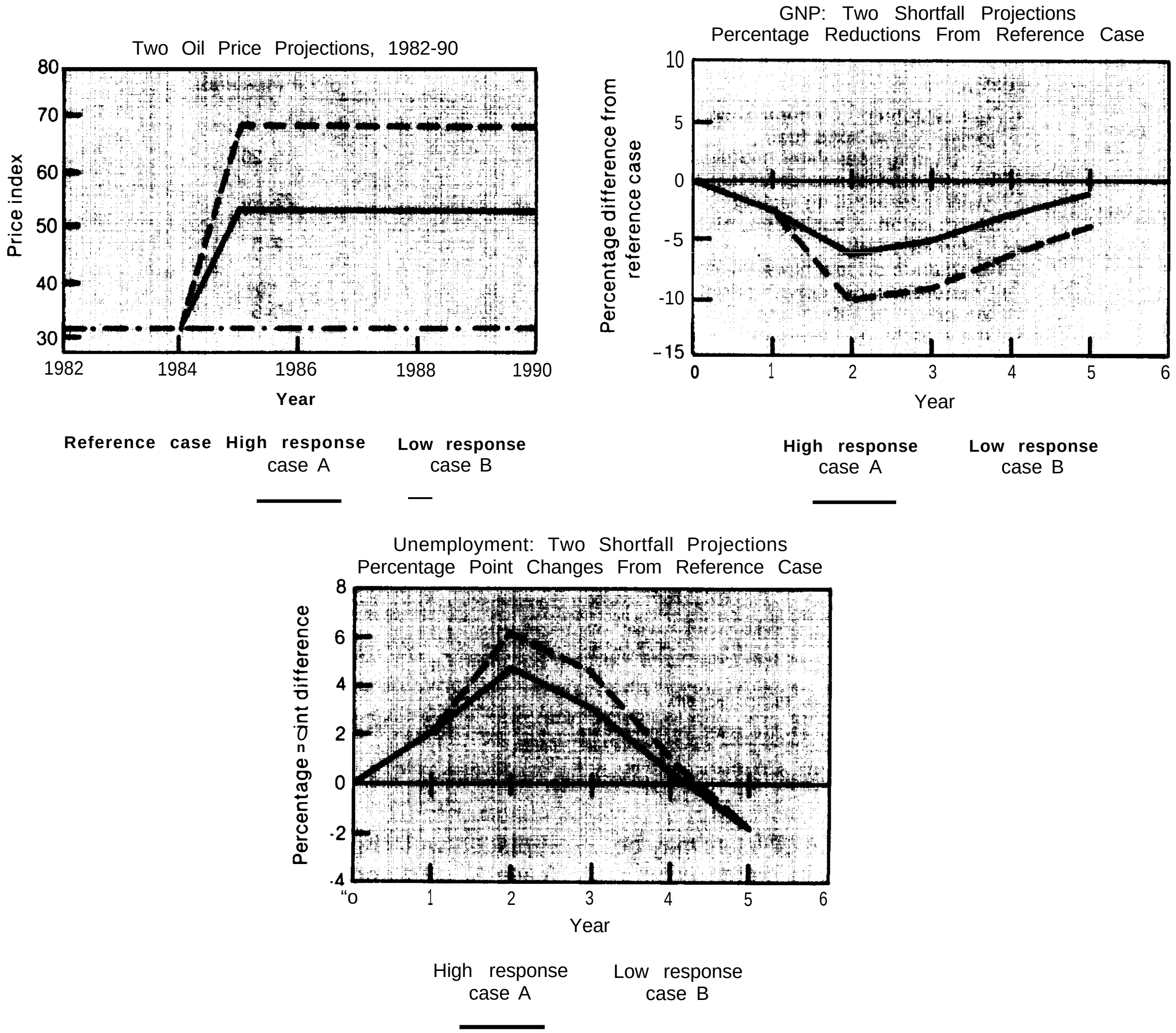
SOURCE: Office of Technology Assessment and Gibbs & Hill, Inc., “Oil Replacement Analysis Phase I—Selection of Technologies:’ contractor report to Office of Technology Assessment, April 1983.

And residential and commercial oil users may be unable or unwilling to invest in increased efficiency and new heating and hot water equipment at a time when their heating bills are putting a strain on their finances; they may simply be ignorant of their options; or, if they are tenants, they may be unable to convince their landlords of the need for the investments. Similar reasons as well as continued price controls on natural gas may inhibit investments by natural gas consumers in measures to increase the efficiency of gas use. As a result, there may be inadequate supplies of natural gas to achieve this level of oil replacement.

Because there is considerable uncertainty about the rate at which oil (and possibly gas) users actually will invest in replacement technologies, OTA derived two plausible replacement scenarios: one, in which the full 3 MM B/D shortfall is replaced with these technologies within 5 years (case A), and another, in which the investment rate is slower and only half this amount is replaced after 5 years (case B).

Although the economic consequences in both response cases would be substantial, the rapid response requires no major changes in the industrial mix of the economy nor permanent curtailments in energy services. Macroeconomic projections indicate that **the rapid response would create significantly less severe economic consequences than a slower, more constrained response.** The average loss in gross national product (GNP) over the 5-year period is significantly less (40 percent) for case A than for case B, employment losses are 30 percent lower for case A than B, and the oil price rise during case A is about half of the case B increase (see fig. 2). Furthermore, although employment is similar after

Figure 2.—Economic Comparison of Two Oil Replacement Scenarios



SOURCE. Office of Technology Assessment.

the 5-year period for the two cases, in case B, the employment level is brought back at the expense of lower labor productivity,

In other words, **to the extent that the lost oil is not replaced through investment in replacement technologies, oil consumption must be lowered through reduced economic activity and personal consumption.** While the total investment cost of the rapid response would be substantial, the investments would result in a lower net cost to the economy than that in the slower, more constrained response.

In addition, there will be a strong interaction between the rate of oil replacement by investment in energy technologies and the state of the economy. The faster rate of oil replacement restrains the growth in oil prices thereby increasing disposable income. This, in turn, improves the investment climate, thereby reinforcing the incentives to make these oil replacement investments. Conversely, investor reticence could lead to a recession which is more severe than that dictated by the magnitude of the shortfall; and this reticence could be self reinforcing leading to a severe recessionary spiral. **Stability** therefore is also a very important concern.

If the low rate of investment occurs, however, two additional factors must be considered before one can conclude that incentives to increase the rate of investment in the replacement technologies will reduce the adverse economic effects. First, oil must be more expensive than the replacement technologies. If it is not, incentives to invest in replacement technologies could still stimulate the economy; but the stimulative effect would be greater if the incentives were directed toward more profitable investments (or towards investment in general). **OTA's analysis indicates, however, that with a real shortage of 3 MMB/D and with market pricing, oil prices would be higher than the cost of the major fuel switching and conservation technologies considered.**

Second, the general level of investment in producer and consumer durables must be below normal levels. **If** it is not, incentives to invest in replacement technologies could increase overall investments somewhat, but they could also stimulate inflation and divert some resources from more profitable investments, which could reduce the overall productivity of the economy in the mid to long term. Historical data, s however, indicate that expenditures for producer and consumer durables dropped following the 1973-74 and 1978-79 oil crises. One would expect a similar behavior following the large oil shortfall considered here; and, in any case, the level of these investments can be followed using existing systems of data collection and analysis.

Considering the uncertainties, the importance of a stable economy, and the significant differences in the economic impacts associated with the rapid versus the slow response, it would be prudent to prepare to stimulate the rapid response, if necessary, and to maintain a stable economic environment. **Although OTA found that the rapid deployment rate could be achieved without government-mandated conversions of production facilities to supply energy technologies, advanced planning by Federal and State governments is needed.**

A system for monitoring directly the rate of investments in oil replacement technologies would have to be established. In some sectors (i.e., new automobile sales and electric utility fuel use), the monitoring apparatus already exists, but care should be taken to ensure that the results are analyzed and published regularly and promptly. In other areas, data collection will have to be modified or expanded. In all cases, the data collection and analysis should be specifically designed to measure the rates of investment in oil replacement technologies and the quantities of oil replaced. And, to be most effective, the monitoring system should be in place and functioning prior to onset of an oil shortfall in order to provide operating experience and a historical data set to aid analysis of the data collected following the onset of a shortfall.

Various levels of contingent incentives, ranging from information and technical assistance to economic incentives and, finally, regulation could also be established to stimulate investment in oil replacement technologies. Removal of those economic regulations that inhibit investments in some of these technologies may also be needed. The details of these incentives and measures, including specific procedures, responsibilities, and implementation plans, should be established before a shortfall so that incentives tailored to individual end uses and energy sectors can be implemented quickly and smoothly if needed.

In the event of a shortfall, the first level of incentives, involving information dissemination and technical assistance, could be initiated immediately. Economic incentives could be introduced if, after perhaps 6 months to 1 year, investments lag significantly behind the rate that the technologies can be supplied, the general level of investment in consumer and producer durables is depressed, the price of oil has risen at least 50 percent (in real terms), and other economic indicators (e.g., the stability of oil prices, trends in employment and GNP, and speculative investment in oil) suggest the necessity or advisability of further government action. The incentives

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[5] "Statistical Abstracts of the United States 1982 -83," U.S. Department of Commerce, Bureau of Statistics, December 1982.

could then be increased successively until an acceptable rate of investment, as measured by the investment monitoring system, is achieved. In order to avoid the possibility that investors may delay investments in anticipation of future government subsidies, provisions could be included to make any subsidies effective retroactively to the onset of the shortfall.

In the extreme case, government subsidies may eventually have to pay a large part of the $30 billion to $40 billion per year cost of investments needed for the rapid response plus perhaps $10 billion/yr to promote new car sales. It maybe possible to finance these outlays, however, through a windfall profits tax if it were increased so as to collect 50 to 70 percent of the increased domestic oil and natural gas liquids production profits resulting from the price rise.[6]

In any case, **ensuring that the rapid response rate can be achieved clearly requires that a decision be made at the highest level that the government will intervene if the market response is overly cautious. It also** requires advance preparation to establish a functioning system which monitors investments in replacement technologies and to develop specific procedures to be used to stimulate investments, if necessary. The uncertainty would have to be removed from the investment climate, and clear signals about the need for investments would be required. But with the willingness to intervene, the ability to measure the relevant investment behavior, and the mechanism to apply successively stronger incentives, it seems likely that the potential benefits of rapidly deploying the replacement technologies could be realized.

Over time, the vulnerability of the United States to a large oil supply shortfall will gradually change. The long-term trend toward reduced consumption of oil for fuel in stationary applications is likely to continue, Eventually, most buildings, manufacturing (except chemicals), and electricity generation will not be directly dependent on oil, and the vulnerability of these sectors to rapid oil price rises will be reduced. As this occurs, however, most of the technologies considered in detail in this report will become increasingly ineffective as cushions against supply shortfalls because they are directed at replacing stationary uses of oil for fuel. In transportation, materials (e.g., chemicals), and off road agricultural, mining, and construction equipment and vehicles—where the remaining oil consumption will be concentrated—the leadtimes for replacing large quantities of oil is long and is likely to remain so.[7]

The results of these changes are ambiguous and partially contradictory. Although reduced U.S. oil consumption would tend to lower the probability and physical magnitude of an oil shortfall, reduced short-term oil replacement capability would tend to increase the price rise associated with a shortfall of any given magnitude. Furthermore, although expenditures for oil may become a smaller fraction of gross domestic expenditures and manufacturing costs (than they would be without the changes), the economic disruption resulting from a shortfall of a given size could be greater, owing to the larger price rise.

OTA's analysis of increased automobile fuel efficiency indicates that even if this option is pursued vigorously and even if stationary (nonfeedstock) uses of oil are eliminated, the United States would still import large quantities of oil by the year 2000, owing primarily to an expected drop in U.S. oil production in the 1990s.[8] And if world oil markets are tight in the 1990s, the United States could be more vulnerable to a shortfall than it was in the 1970s. If oil consumption (in the United States and elsewhere) remaining after these efficiency and fuel switching objectives are accomplished could be reduced and/or replaced with synfuels at a rate that keeps world oil markets slack, however, sudden reductions in production in any given region of the world would have less of an impact because part of the loss would be made up through increased production from underutilized capacity elsewhere.

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[6] For example, with domestic production of 10 MMB/D, a $23 per barrel increase in oil prices (OTA's lower price rise estimate) would increase domestic oil and natural gas liquids production profits by $73 billion/yr. Sixty-eight percent of this is about $50 billion/yr.

[7] See also *Increased Automobile Fue Efficiency and Synthetic Fuels: Alternatives for Reducing Oil Imports* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-E-1 95, September 1982).

[8] Ibid,; see also World Petroleum *Availability: 1980-2000-A* Tech*nica Memorandum* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-TM-E-5, October 1980).

SPECIFIC FINDINGS

OTA's analysis of oil replacement technologies indicates that the most effective near- to mid-term replacements for the oil lost in a large shortfall are those that increase end-use efficiency and convert oil users to natural gas and solid fuels (coal, wood, and coal-water mixtures), as well as electricity for space heating and hot water (in parts of the country where there is excess nonoil-fired generating capacity). These technologies are primarily directed at replacing the oil used for space heating, hot water, and steam and at reducing gasoline consumption. Replacing large amounts of nongasoline transportation fuels and oil-based materials (e.g., chemicals, asphalt, lubricants), on the other hand, will require longer leadtimes and, in some cases, more extensive replacement of capital equipment.

Replacing Oil Through Energy Technologies

The potential responses to an oil supply shortfall that begins in 1985 are summarized below for each of the major oil-consuming sectors. The results are then collected into estimates of the overall rate that oil could be replaced within a 5-year period.

Rapid Response—Case A

Utility Use

Electric utilities could begin immediately by using natural gas exclusively in the boilers already equipped to use either oil or natural gas. This change could replace up to 0.2 MMB/D or nearly

Photo credit: U.S. Department of Energy

Electricity is generated in this modern coal-fired powerplant. The coal yard is to the left one-third of their projected 1985 oil use. However, because OTA has assumed that incremental natural gas supplies are limited and has allocated[9] most of the gas to the residential, commercial, and industrial sectors, the increment of natural gas allocated to utilities at the end of 5 years is only about one-sixth of their projected 1985 oil use. Consequently, their major options for replacing oil are to convert oil-burning boilers to solid fuels and to complete nonoil-fired powerplants now under construction and scheduled for completion between 1985 and 1990.[10] This is particularly true in the Northeast (New England, New York, and New Jersey), where even if all feasible conversions were carried out and all powerplants were completed and brought on line, utilities would still not be able to replace all of the oil used during times of peak demand. Depending on the growth in demand for electricity, a small amount of oil may also have to be burned in utility boilers in Florida, California, and the Mid-Atlantic States, even after feasible conversions to coal and powerplant completions. Most of this oil, however, could probably be replaced with natural gas. In other regions of the country, completion of all powerplants currently under construction is less important, from the standpoint of replacing oil and providing electricity for residential and commercial space heating and hot water.

The solid fuel options include conversions to coal, wood, and coal-water mixtures.[11] The technical changes to the boiler systems (e.g., heat exchanger tube spacing, ash disposal, particulate control systems) are similar for all of the solid fuels, but coal-water mixtures would probably be favored where space limitations prevent construction of solid fuel yards because the mixtures can be prepared offsite and transported, stored, and delivered to the boilers in facilities that are similar to those used for oil (with appropriate changes to valves, pumps, burners, etc.).

In all, utility conversions and completion of plants currently under construction could replace most of the 1985 utility oil use, or about 0.6 MMB/D.

Residential and Commercial Use

Residential and commercial customers can convert to natural gas and electricity for space heating and hot water. In most regions these conversions could virtually eliminate oil use for these purposes. In New England, the New York/New Jersey region, and Hawaii the oil replacement potential from these conversions is more limited, however, because many oil customers are not located near gas lines and electricity generation is heavily dependent on oil.[12] In these regions, therefore, additional oil could be replaced directly by increasing the end-use efficiency and converting to wood and possibly coal (particularly in the Northeast) and solar collectors. Although the latter options are likely to be pursued throughout the country, in regions other than the Northeast and Hawaii they would serve primarily to reduce the incremental demand for natural gas and electricity rather than increase the total technical potential for oil replacement in these sectors. In all, these changes could replace about 1 MMB/D of oil in the residential and commercial sectors.

Industrial Use

The principal replacements for the 1 MMB/D of oil used in industrial boilers are solid fuels and natural gas. The solid fuel technologies include

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[9] **Priority use for the increment of natural gas was assumed to go to residential and commercial customers. The remaining gas was then divided between the industrial and utility sectors in proportion to the amount of oil remaining after the most likely conversions to solid fuels were completed. In all, it was assumed that 2 TCF/yr of natural gas would be available** for direct replacement of oil. OTA estimates that increased efficiency of natural gas use in the industrial, residential, and commercial sectors could supply nearly all of this gas.

[10] This obviously does **not imply that all powerplants current & under construction can serve as replacements for oil. In many regions, the planned capacity additions greatly exceed the new capacity needed to replace all utility oil use and, at the same time, supply sufficient additional electricity to replace all the oil used for space heat and hot water by residential and commercial customers. In New England, New York, and New Jersey, however, virtually all of the planned capacity additions are needed just to replace most of the oil used by utilities.**

[11] **Coal-water mixtures are fluid mixtures of** pulverized coal and water. These mixtures might typically be 60 percent coal (by weight) and have an energy content of about 3.3 MMBtu per barrel.

[12] Conversions to electricity **for heat and** hot water could actually increase oil consumption in these regions if they are carried out before the utilities eliminate their oil use. And the delay before utilities can accomplish this limits the oil replacement from conversion to electric heating within the 5-year time period.

direct combustion[13] of coal, wood, and coal-water mixtures, as well as the use of onsite gasifiers, which convert solid fuels to a low-energy fuel gas. OTA estimates that about two-thirds of the oil used in industrial boilers could be replaced with solid fuels and natural gas within 5 years, but for a variety of reasons, replacing the remaining third would take longer.

Many industrial facilities have limited space to accommodate ash and solid fuel handling facilities and particulate control systems; and many are too old to justify major investments in only a part of the system, even under the conditions of an extended oil supply shortfall. OTA estimates that these constraints would limit solid fuel substitution to about half of the oil used in the large (greater than *50* MMBtu/hr) industrial boilers. This oil, about 0.2 MMB/D, is consumed in about one-fourth of the 4,000 boilers of this size. Additional oil could be replaced by solid fuels if some of the older facilities were scrapped and replaced with new plants capable of using solid fuels, but decisions to do this would be based on a variety of nontechnical factors, which OTA has not analyzed.

All of the constraints mentioned above, as well as some others, are likely to affect conversions of small (less than 50 MMBtu/hr) boilers to solid fuels. For example, there may be difficulties in obtaining reliable fuel supplies; and diseconomies of scale and often low load factors for small boilers increase the cost per unit of oil saved, relative to that of typical large boilers. Furthermore, the production capacity for small boilers (about 1,000 units per year) prevents replacement of more than a small fraction of the 140,000 small industrial oil-burning boilers. Retrofits to gasifiers could be more numerous, but the total fraction of small boilers converted to solid fuels and the oil replaced from these conversions is still likely to be relatively small.

The remaining industrial boilers not converted to solid fuels and near to existing gas lines could be converted to natural gas.[14] However, since OTA has assumed that only 2 TCF of additional gas would be available and that residential and commercial customers would have priority, only about 60 percent of the remaining oil used in industrial boilers could be replaced with gas, owing to limited supplies of this fuel.

In all, OTA estimates that the solid fuel and gas conversions could replace about 0.65 MMB/D of oil from industrial boilers. In addition, increased efficiency in all uses of oil by the industrial sector and reduced oil refinery throughputs could reduce consumption by another 0.37 MMB/D, bringing the total to a little more than 1 MMB/D in 5 years.

Transportation Use

OTA estimates that about 1 MMB/D of oil could be replaced in the transportation sector in about 5 years, with 80 percent of this coming from increased efficiency of automobiles and light trucks. Substantial savings are likely to occur even in the absence of an oil shortfall.[15] Automobile and light truck manufacturers have been converting their plants to produce more efficient vehicles for a number of years, and as these vehicles replace the ones currently on the road, fuel consumption will drop.

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[13] For direct combustion, **large boilers cou ld either be modified or replaced with solid fuel boilers, while small boilers are more likely to be replaced.**

[14] **Obviously, it would be more easily economically justified to extend natural gas lines longer distances to accommodate large boilers and large groups of small boilers than could be justified for isolated small boilers.**

[15] **Maximum savings could reach nearly 1 MM B/D over the 5-year time period, but actual savings will depend on the demand for fuel efficiency in new cars** *and* **the volume of new car sales. In a crisis, new car sales are likely to slump (which would reduce the savings), while demand for fuel efficiency would increase (which would increase savings). These two factors tend to cancel each other out. For example, OTA estimates that with average annual new car sales of 11 million vehicles/yr and a 1990 new car fuel efficiency of 27.5 miles per gallon (mpg), the fuel savings between 1985 and 1990 would be about the same as with annual new car sales of 7 million vehicles and a 1990 new car fuel efficiency of 36 mpg, or about 0.8 MMB/D for cars and light trucks (assuming light truck sales and efficiencies mimic those of cars). In the extreme case, where automobile sales slump to 5 million vehicles annually and 1985 new car efficiency is 25 mpg, rising only to 32 mpg by 1990, savings would still be about 0.5 MMB/D. (See also** *Increased Automobile Fuel Efficiency and Synthetic Fuels: Alternatives for Reducing Oil Imports,* **op. cit.**

In addition, smaller savings are possible through shifts in the modes of freight transport (from planes to trucks, trucks to rail, and rail to water transport), marginal increases in the efficiency of freight and commercial passenger transport, increased production of fuel ethanol (for alcohol blends in gasoline), and conversions to compressed natural gas, liquefied petroleum gas, and (possibly) mobile gasifiers, which convert solid fuels to a fuel gas on board the vehicle.

Total

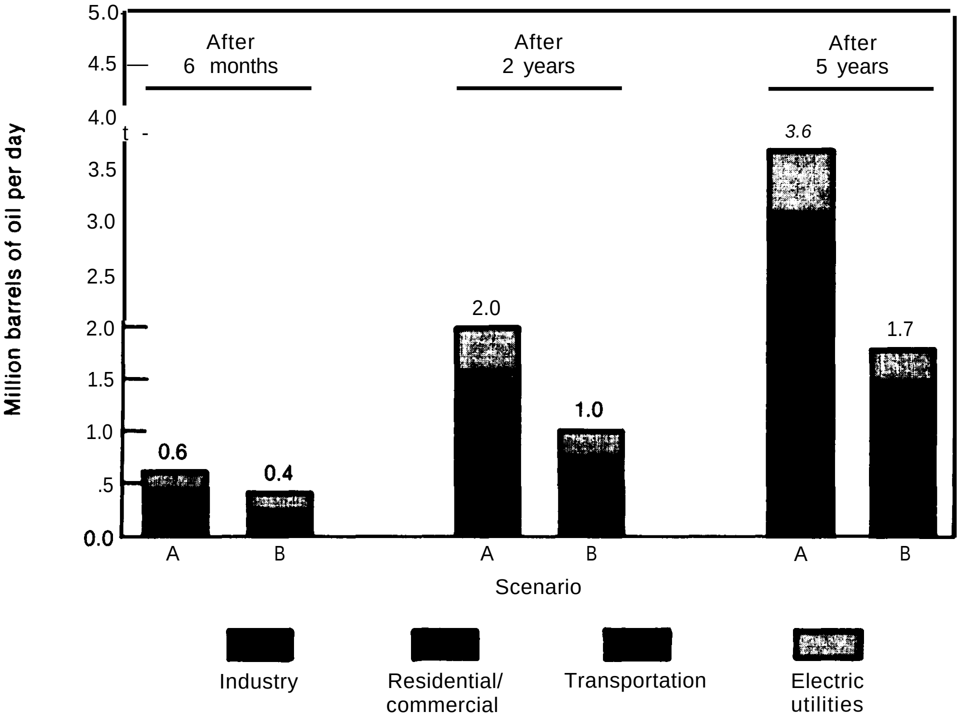
With all of the changes described above, oil replacement could total about 3.6 MMB/D by the end ofs years; and based on current production capacities and historical high rates of conversion, the replacement might proceed something like that shown in figure 1.

Slower Response—Case B

For the slower response case, OTA assumed that new automobile sales would drop to half the level of the late 1970s and that incremental natural gas supplies would be one-third of the 2 TCF per year assumed in the more optimistic scenario. With these alternative assumptions, the oil replacement in the industrial and residential/commercial sectors would drop by about two-thirds. In the utility sector, however, even with the reduced number of coal conversions and new powerplant completions, there would still be sufficient activity to replace about half of utility oil use (provided demand for electricity does not grow rapidly). Similarly, in the transportation sector, there would still be sufficient replacement of older vehicles by newer, more fuel-efficient models to capture almost two-thirds of the oil savings derived in the more optimistic scenario. Taken together, these changes would reduce the oil replacement at the end of 5 years from 3.6 MMB/D to about 1.7 MMB/D.

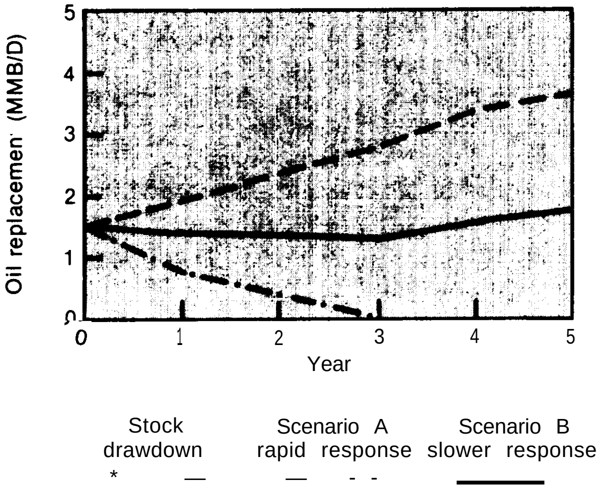
Figure 3 shows the oil replacement by end-use sector for **both** response cases, 6 months, 2 years, and 5 years after the onset of the shortfall. In figure 4, the oil replacement from investment in the replacement technologies is combined with the

Figure 3.—Potential Reductions in Oil Consumption



SOURCE: Office of Technology Assessment,

Figure 4.—Potential Oil Replacement



SOURCE: Office of Technology Assessment

assumed Strategic Petroleum Reserve and private stock drawdown to give two scenarios for the overall potential replacement of oil lost from the short fall, as a function of time.

In all, about 30 percent of the oil that could be replaced in the **rapid response by the end of 5 years could be attributed directly to increased efficiency in space heating, industrial processes, automobiles, and light trucks.** Also, greater efficiency could reduce natural gas use, thereby making more natural gas available to meet the needs of the rapid response case.

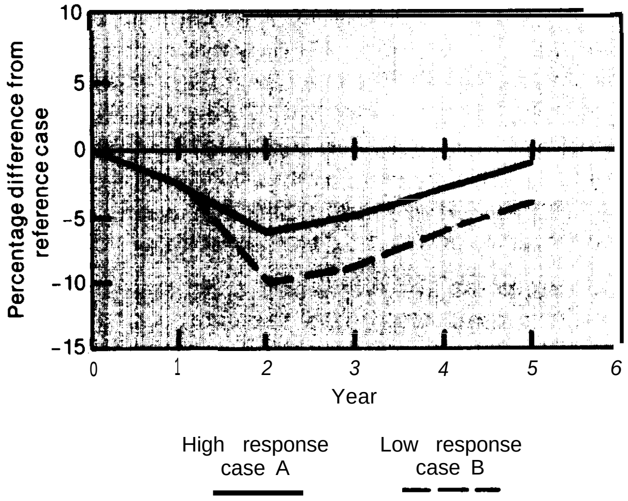
Macroeconomic Impacts

The postulated curtailment of oil imports was simulated using an input/output model of the U.S. economy.[16] While all aspects of such an unprecedented economic shock are difficult to anticipate, the modeling exercise focused primarily on the macroeconomic implications of alternative technological responses. The two 5-year shortfall scenarios, the rapid and the slow response, were simulated in order to bracket the range of technological uncertainties.

Comparisons of the two scenarios suggest that the more rapid rate of investment in oil replacement more effectively limits the losses. The range of possible economic outcomes derived from the model is summarized in figure 5 in terms of GNP behavior.

From the 5-year perspective, the model predicts that the main impact of the shortfall on GNP is a temporary delay in the achievement of long-term output objectives. In the one extreme, case A, the net GNP loss 5 years after the onset of the shortfall (relative to the reference case) could be made up in about a year of normal growth (about 2percent). In the other extreme, case B, making up the loss would take about 2 years. Although there is a severe recession 2 years after the beginning of the oil import curtailment, this recession is only temporary and the economy rapidly regains most of the loss. In other words, the model suggest that if short-term economic problems can be resolved,[17] the loss of oil im-

Figure 5.—GNP: Two Shortfall Projections Percentage Reductions From Reference Case



SOURCE: Office of Technology Assessment.

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[16] Macroeconomic analysis is based on the IN FORUM model (Inter-industry Forecasting Model of the University of Maryland) of the U.S. economy. It permits detailed accounting for oil flows, prices, capital stocks, and technology deployment for 78 producing sectors as well as associated personal income and consumption, exports and imports, and government activities. OTA calibration of the model was limited primarily to activities directly affected by oil markets, and thus the rest of the economy was taken as it was previously incorporated into the IN FORUM model structure. The scope of analysis is also limited to including only a brief treatment of emergency conditions immediately following the disruption shock in order to concentrate on conditions over a 5-year period.

[17] SPR drawdown addresses some of the short-term economic problems, but the economic response also depends on fiscal and monetary policy, speculation, income transfers, and mar-w other factors.

ports should not significantly lower long-term prospects for economic growth.

A second general observation concerns the average loss in the level of GNP over the first 5 years after onset of a shortfall compared to the reference case.[18] **In the rapid response scenario, the permanent loss of oil imports lowers GNP on the average by about** 3.5 **percent. In the slower response scenario, the average loss is about** 6.2 **percent. The GNP rebounds toward the end of the 5-year period because investments in oil replacement have reduced the burden of high energy costs on the economy.**

A third comparison (though less important from a longer term perspective) involves year-to-year change in GNP during the first 2 years following the shortfall's beginning. While comparisons between normal growth rates and average output over 5 years are most interesting, given the model used, this shorter term perspective is probably most important for public perceptions of economic hardship. in the slower response scenario, there is considerably less investment in oil replacement technologies than in the rapid response. This leads to a slower pace of oil replacement and increased bidding for the remaining oil supplies. Consequently, the slower response scenario results in a larger oil price rise and greater economic hardship.

Although GNP actually declines only in the second year after the shortfall begins, the decline in case A is only 1.3 percent from the previous year, while it is 5.2 percent in case B. This difference can be appreciated by noting that in the worst recession since the Great Depression, real GNP declined in 1982 by 1.7 percent from that in 1981. The recession just prior to that, from 1979 to 1980, involved only a 0.2 percent decline in GNP. In other words, case A is within recent historical experience; case B is well outside of it.

Besides this overview of the entire economy, the economic situation 5 years after the shortfall begins can also be described in terms of the market clearing price of oil. Market expectations for oil price inflation provide the rationale for investment in oil replacement at the same time as they cause dislocation in industry and loss of consumer purchasing power. In case A, an oil price increase of about 60 percent above its current level would be sufficient to accommodate oil demand to reduced supply. In case B, oil prices must increase by about twice that amount to balance demand with supply.

These price expectations summarize both the technological opportunity set for oil replacement and the behavioral adjustments to higher oil prices which are built into the macroeconomy. Behavioral adjustments include product mix shifts from products with relatively large oil inputs to those with relatively low inputs, adjustments in direct fuel consumption by consumers (mainly by driving less and turning down thermostats), and general restriction of economic activity.

Finally, all of these economic conclusions must be qualified by acknowledging the uncertainties that may not have been treated realistically in the modeling effort. First and most important are emergency responses immediately following the onset of the shortfall. Although the GNP projections shown above included the entire 5-year shortfall period, the actual numbers could be greatly affected by market and political actions that are not closely related to the technological focus of this study. In addition, the oil shortage emergency could trigger inflationary or recessionary spirals that would slow down oil replacement.

On the other hand, the shock of another oil loss could trigger major lifestyle or technological changes that would lower the cost of oil replacement. For example, work and entertainment patterns may be shifted to the home, where rapid advances in communications and computer technologies could significantly reduce the need for auto travel. These were not considered in the economic analysis because primary attention was given to those flexibilities and rigidities in the energy economy that can be predicted from the technology analysis in the assessment and from recent historical experience.

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[18] Please notice that the Model's behavior at the start of the postulated disruption in 1985 is strongly influenced by current expectations that the economy will have considerable growth momentum. If, on the other hand, the United States were mired in recessionary doldrums, the projections could be quite different.

Environmental Impacts

The increased use of solid fuels for the rapid response path (a total of 115 million tons/yr of coal equivalent) will require that coal production be increased by up to 13 percent over 1982 levels, a situation that will entail greater mining-related impacts. About 65 million tons/yr of coal would be used in utility and industrial boilers converted from oil. To avoid increases in sulfur and particulate emissions, these boilers would have to use low-sulfur coal and particulate control systems, for which supplies are adequate for the postulated scenarios. However, there would probably bean increase in nitrogen oxide (NO_x) emissions in some of these boilers; and to the extent that fuels with higher sulfur contents are used in converted boilers (without new scrubbers) sulfur dioxide (SO_2) emissions would also increase.

An additional 35 million tons/yr of coal would be used in new and existing coal-fired utility boilers to replace (mostly distillate) fuel oil used in the residential and commercial sectors. This would also lead to an increase or at least a delay in the reduction (through retiring older boilers) of SO_2 and NO_x emissions. The remaining 15 million tons/yr would be used in new ethanol distilleries. The larger distillery boilers (50 million gal/yr or larger of ethanol production supplied by a single boiler) would be regulated by Federal New Source Performance Standards, but most of the distilleries would probably be regulated primarily by State and local requirements for emission controls.

Production ofs billion gal/yr of ethanol (which is included in the rapid response and is capable of reducing U.S. oil consumption by about 0.1 MMB/D) would require a 15-percent increase in

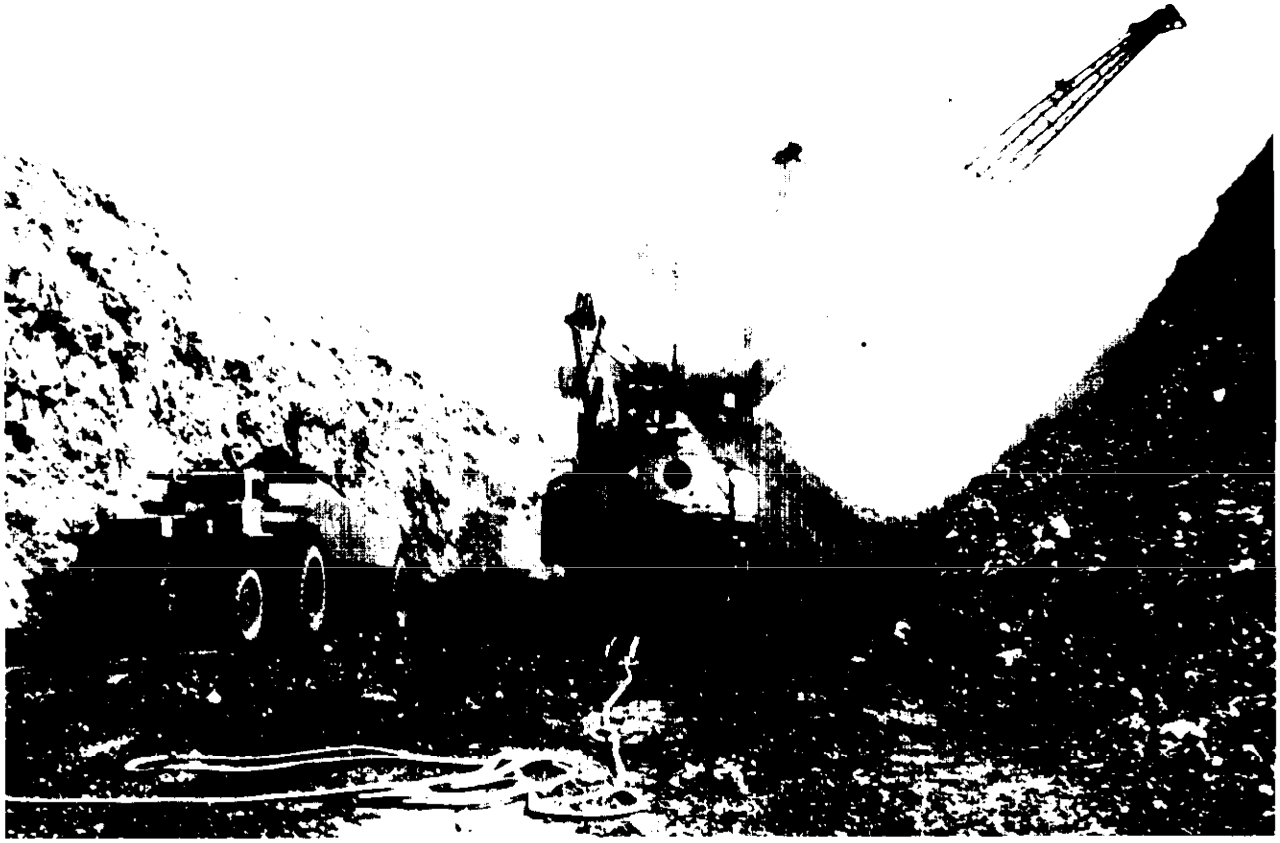

Photo credit: U.S. Department of Energy

Coal is surface mined using drag lines and other large mining equipment grain production. This would probably lead to more than a 15-percent increase in soil erosion and the accompanying pesticide and fertilizer runoff because much of the new cropland would be more erosive and less productive than current average cropland used for grain production.

The increased supplies of wood for fuel could be supplied as part of careful forest management programs without significant adverse environmental impacts; but if the wood is harvested in a haphazard manner, damage to the forest and eventually to forestland productivity could be substantial. Furthermore, burning wood without emissions controls (e.g., for home heating) would likely lead to significant local increases in particulate emissions, including higher levels of polynuclear aromatics (which are generally not a problem with either central electric power generation or natural gas or oil combustion). But sulfur emissions from wood would be insignificant.

Longer Term Effects

In the longer term (greater than 5 years), the principal consequences of the rapid response will be inflationary pressures on natural gas and food. If natural gas production falls sharply in the 1990s, the increased dependence brought about by oil replacement will greatly increase natural gas prices and/or imports. But if production capacity remains at current levels or higher, or a slower drop in production is coupled with feasible increases in the efficiency of natural gas use, price pressures will be lower, and a more orderly, long-term transition to increased use of coal, electricity, and renewable can occur. Supplying the grain feedstocks for 5 billion gal/yr of ethanol production will lead to increases in farmland and food prices, and these increases will persist as long as the feedstocks are supplied. On the other hand, if ethanol production is kept below about 2 billion gal/yr, the impact on food prices probably would be relatively small (i.e., less than a l-percent increase).

Also, the reduction in oil consumption (resulting from the shortfall) and the replacement of oil by nonpetroleum fuels and increased efficiency will accelerate the transition that must occur in the 1990s as domestic oil production drops. And if long leadtime technologies, such as new enhanced oil recovery and synthetic fuel projects, are initiated during the first few years of the shortfall, they would begin to reduce somewhat the liquid fuel shortages in the 1990s. **With the rapid response, the United States could minimize the adverse economic consequences of a large oil shortfall and accelerate many of the changes that will eventually be needed if the United States is not to remain heavily dependent on imported oil. With the slower response, however, the adverse economic effects would be both more severe and longer lasting.**

Finally, **the vulnerability of the U.S. economy to oil supply shortfalls is not likely to decrease in the near-to mid-term future, and it could very well increase.** As domestic oil production declines, U.S. oil imports will increase and/or some of the oil used for space and water heating and steam will be replaced. Increased imports are likely to lead to increased oil production in politically unstable areas of the world, thereby increasing the size of any potential oil shortfall, and reduced use of oil for the most easily substitutable end uses will reduce the quantity of oil that can be replaced quickly. In both cases, U.S. vulnerability will increase.

These trends can be countered somewhat in the mid to long term by relying more heavily on coal and biomass for chemicals production, by increasing transportation fuel efficiency (primarily automobiles and light trucks), and by producing synthetic fuels. The first two actions would reduce the fraction of business costs and personal consumption that is tied to oil prices, thereby reducing the importance of oil prices to the overall functioning of the economy. Domestic synthetic fuels production would reduce the payments for imported oil and together with new sources of conventional oil production in the world, would increase (or at least lower the reduction in) the excess worldwide oil production capacity that can buffer the effect of a sudden drop in world oil supplies. Effecting these changes, however, will require many years. Even if they are pursued vigorously, the United States is likely to remain vulnerable to world oil shortfalls until well after the year 2000.[19]

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[19] See *Increased Automobile Fuel Efficiency and Synthetic Fuels: Alternatives for Reducing Oil Imports,* op. cit.

POLICY

OTA's analysis indicates that the economic damage, such as increased unemployment and lowered GNP, caused by a large oil supply shortfall (or price increase)[20] can be reduced significantly (but not eliminated) by expeditious investment in technologies that replace the lost oil with increased efficiency and alternative domestic fuels. Although a drawdown of the Strategic Petroleum Reserve (SPR) and private oil stocks probably is essential to moderate pressures on the oil markets in the short term, **the effects of investments in oil replacement technologies could easily exceed the importance of stock drawdowns after about 1 year.**[21] And after 2 to 3 years, stocks would most probably be exhausted. Price controls and subsidization of oil imports, such as was done in the mid-1970s, may also be able to moderate the immediate price shock; but the resultant, incorrect price signals, if allowed to persist, could lead to economic inefficiencies that might be more damaging in the long term than those produced by rapid changes in oil prices.

Although OTA has not analyzed the effects of various strategies for oil stock drawdowns or price controls, it is clear that these measures will be most effective if strategies for using them are developed and refined in advance of a supply shortfall. The analysis needed to formulate these strategies may lead to the conclusion that price controls should be rejected; but, at the minimum, a clear plan[22] should be developed for a drawdown of the SPR, in conjunction with deployment of private stocks, if the benefits of the SPR are to be maximized. Furthermore, **any such plans should take into consideration the potential deployment of oil replacement technologies and the effect that various methods of drawdown would have on this deployment.**

Beyond these near-term responses, investments in oil replacement technologies can provide the principal means of easing pressures on oil markets in the mid-term, as well as lowering expectations of future oil price rises (and thus speculation in oil stocks). And these investments (like any other investment in consumer and producer durables) would serve to stimulate the economy and partially counteract the economic downturn resulting from a shortfall. Through these effects, the investments would tend to limit the oil price rise and economic damage.

In the absence of price controls, the large increase in oil prices accompanying the postulated shortfall would provide a strong incentive for oil users to invest in replacement technologies. Nevertheless, investors may be extremely cautious in making long-term capital investments, owing to the economic uncertainties or high capital costs. In either case, the rate of investment in oil replacement technologies could be well below the rate that they can be manufactured and installed. This, together with lowered rates of investment in other consumer and producer durables, would be indicative of a "market failure" that could lead to a recession more severe than that dictated by the magnitude of the shortfall.

A central problem facing policy makers who wish to minimize the potential economic losses from an oil supply shortfall is therefore to: 1) identify the technologies that can replace large quantities of oil at least cost to various oil users, 2) monitor the performance of energy markets and investment patterns for signs of market failure like

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[20] From an economic perspective a price increase is the same as a reduction in supplies. In this sense, both of the supply shortfalls experienced by the United States in the past 11 years have been permanent, since in each case the price of oil remained permanently higher after the shortfall than it had been before the shortfall. While many circumstances surrounding each shortfall are unique, it is not unreasonable to expect that a future supply shortfall could also be permanent in this sense, even if surplus oil production capacity were to develop later.

[21] After 1 year, investment in oil replacement technologies could replace slightly more than 1 MM B/D (million barrels per day) of oil consumption, However, with oil stocks of 700 million barrels and an initial rate of drawdown equal to 1.5 MMB/D, the rate of oil removal from stocks would have dropped to significantly less than 1 MM B/D after 1 year.

[22] The alternative strategies considered should include: 1) offering unlimited quantities of SPR oil (up to the physical maximum rate that it can be delivered) at a predetermined price, and 2) delivering predetermined amounts of SPR oil (based on the size of the shortfall) at the market price. The former approach would tend to put a lid on oil prices (thereby discouraging speculative, private stock formation beyond a certain level, among other things), while the latter would be directed more toward maintaining physical supplies of oil.

that described above, and 3) where possible and appropriate, apply incentives to modify the investment behavior. Addressing this problem requires advance preparation in order to establish a functioning system to monitor the appropriate investment behavior and in order to develop the specific procedures and incentives to be used to stimulate investments, if necessary.

A decision to intervene will, of course, be made very difficult by the inevitable uncertainty concerning the duration and direction of an oil supply shortfall and by the enormously complicated tasks of choosing appropriate policy levers to affect investment and coordinating the activities of various institutional and governmental entities with different jurisdictions and objectives. These obstacles are formidable; the argument for intervention, however, rests on the real possibility of market failure and on the very high cost to the country of such failure.

The objective of this study was not to analyze in detail the effectiveness of alternative means of shaping investment choices, but rather to specify the most promising technologies for replacing large quantities of oil within 5 years after the onset of a shortfall and to indicate some of the economic costs and benefits, for the country as a whole, associated with investment strategies that rely on these technologies to different degrees. An analysis of this kind can provide useful guidelines for those who find it prudent to consider policies related to these technologies in planning for, or actually responding to, both the immediate emergency and the longer term problems created by an oil supply shortfall.

With these objectives in mind, the policy analysis outlines a general strategy for identifying and responding to the type of market failure described above and summarizes various other policy concerns directly related to implementing this strategy. In the next section, there is a description of a policy strategy designed to ensure that the potential benefits of deploying oil replacement technologies can be realized. Following this are sections on actions that can be taken in advance to prepare for the possibility of an oil supply shortfall, ways of measuring the rate of investment in the replacement technologies, and a brief discussion of selected regional and international considerations.

Several other policy concerns associated with an oil supply shortfall are not addressed in this report. These include the desirability and potential efficacy of military intervention to secure oil supplies. They also include numerous questions of equity associated with large transfers of wealth within the country and the uneven impact of higher oil prices among the regions of the country and energy-using sectors. And there are questions of priority access to or subsidization of oil supplies to various end uses, such as for home heating, which is crucial to the health of millions of households; agriculture, which is essential to the entire population; and transportation, which binds the economy together.

These are all extremely important questions, that will have to be resolved in formulating a comprehensive policy for responding to an oil supply shortfall. In most cases, however, specific decisions regarding these issues would not preclude or obviate the possible need for government intervention to ensure that the potential benefits of deploying technologies to replace the oil lost in a shortfall are actually realized. indeed, realizing these benefits can lessen some of the concerns mentioned in the above paragraph.

Policy Strategy

The basic hypothesis of this assessment is that the United States suffers a 3 MMB/D reduction in its oil supplies beginning in the mid-1980s and lasting for at least 5 years. one of the first actions the government could take under these circumstances is to begin a drawdown of the SPR[23] in

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[23] OTA has not examined what would constitute an optimal drawdown of the SPR. For the purposes of the economic modeling, however, OTA has assumed that private and SPR stocks amount to 700 million barrels and that they are drawn down at a rate beginning with 1.5 MMB/D immediately after the onset of the shortfall, with the rate dropping to 0.75 MMB/D after 1 year and 0.38 MMB/D after 2 years. The stocks would then be depleted by the end of 3 years. For additional information on SPR drawdown, see the following publications:

GAO: Strategic Petroleum Reserve: Substantial Progress Made, But Capacity and Oil Quality Concerns Remain, EMD-82-19, December 1981.

Purchase Price of Strategic Petroleum Reserve Oil Fair But Payment Timing Is Costly, 1980.

order to help stabilize the oil markets as they adjust to the sudden change in supply. This action would reduce the price rise in the short-term; but as the stocks are depleted, the SPR drawdown would diminish in importance.

Another action that could be taken immediately is to expedite, where necessary, the processes of issuing State permits under State implementation plans (of the Clean Air Act) for conversions of industrial and utility boilers to coal (e.g., 10 month permitting process). OTA's analysis indicates, however, that these conversions can be achieved within the existing environmental regulations. if low-sulfur coal is used in the converted boilers, together with particulate control devices, and the boilers are properly adjusted for NO_x emissions, the conversions would not lead to increases in regulated emissions or changes in ambient air quality. Consequently, in most cases there should be little regulatory resistance to issuing the needed permits. Similarly, current permitting procedures need not delay the completion and issuing of operating permits and certification for new electric powerplants.[24]

Unresolved social conflicts, however, could delay coal conversions and new powerplant projects by several years or more. The places where this would have the greatest effect on oil replacement would be in electric utilities in New England and the New York/New Jersey area[25] (which consume about 0.3 MMB/D) and in conversions of industrial boilers to coal (total oil replacement potential of 0.2 MMB/D). While this 0.5 MMB/D of potential oil replacement is an important part of the total, it is not essential. Even if a sizable fraction of these projects were blocked, the Nation still could replace the full 3 MMB/D postulated shortfall within 5 years, although more pressure would obviously be put on other types of oil replacement. Nevertheless, it probably is important to expedite any legal actions and still more important to ensure full and effective public participation during permitting so that citizens' concerns can be addressed and potential benefits of conversion explained.

In addition, a related first step could be to institute changes in electric utility rate regulation since current procedures bias against large capital investments. In particular, elimination of the fuel adjustment clause, allowance of construction work in progress, institution of trended original cost accounting for determining rates on converted plants, and the establishment of rates that allow utilities to capture part of the savings obtained from converting to coal are steps that would probably be necessary if utility boiler conversion is to take place beyond that already in progress. *b These actions would have to take place on the State level but Federal encouragement would help. If the States are unwilling or unable to take action, the Federal Government may have to legislate such changes if they prove necessary. The Public Utility Regulatory Policy Act provides precedent for such Federal action.

Steps to remove remaining price controls on natural gas should also be considered. Such measures would act to stimulate new supplies from old natural gas fields[27] and provide additional incentives for conservation of natural gas. Both would be important in ensuring that the natural gas supplies needed to replace oil lost in the shortfall would be forthcoming, and that they would remain available in the event domestic nat-

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U.S. Strategic Petroleum Reserve at a Turning Point: Management of Cost Oil Supply Problems, and Future Site Development, 1980,
Factors Influencing the Size of the U.S. Strategic Petroleum Reserve, ID-79-8, June 15, 1979.
CBO Financing Options for the Strategic Petroeum Reserve (Barry J. Holt), April 1981.
CRS: Strategic Petroleum Reserve: Implications for U.S. Foreign and Defense Policy, June 15, 1982.
Strategic Petroleum Reserve, IB81096, Feb. 14, 1984.

[24] See Nuclear power in and Age of Uncertainty (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-E-216, February 1984).

[25] Electric utilities in other regions of the country either do not use significant amounts of oil or have sufficient capacity additions planned to eliminate their oil consumption and provide sufficient nonoil-fired electricity for residential and commercial conversions to electric space heating and hot water, even if some of the projects are blocked. In the case of high growth in demand for electricity between 1985 and 1990, however, the Mid-Atlantic region and Florida are marginal cases; and significant resistance to conversion and new powerplant projects could leave these regions consuming a few tens of thousands of barrels per day 5 years after the onset of an 011 shortfall.

[26] For a more complete discussion of the current state of electric utilities in this country and potential regulatory reform proposals see "Promoting Efficiency in the Electric Utility Sector, " Congressional Budget Office, U.S. Congress, Washington, DC, November 1982; and Nuclear Power in an Age of Uncertainty, op. cit.

[27] See "Effects of Decontrol on Old Gas Recovery, " staff memorandum, Office of Technology Assessment.

ural gas production declined significantly over the 5 years after the onset of the shortfall.

In addition to these measures, Congress may also wish to stimulate investments in oil replacement technologies directly. One strategy for doing this would be to establish (where they do not now exist) the data collection and analysis needed to monitor investments in oil replacement technologies. In the event of an oil shortfall, the monitoring apparatus (see below) could be used to measure investment behavior. Various levels of investment incentives could then be implemented, depending on the rate of investments and other economic measures, such as the price of oil, stability of oil markets (as measured by the rate of change of oil prices and stocks), and unemployment and inflation rates.

A first level of government action could involve dissemination of information designed to inform oil users about their options for replacing oil. This could be accompanied by advertising campaigns and statements by political leaders emphasizing the importance of making investments to replace the lost oil and the economic consequences of not doing so. This could also include public participation in a variety of activities designed to increase public awareness of energy issues and create a favorable attitude toward measures designed to replace oil.

In addition to the first level, a second level of action could include economic incentives. Residential and commercial oil customers could be provided with low-interest loans and/or tax credits for qualifying investments. Sales of inefficient automobiles could be taxed, and subsidies could be placed on the sale of more efficient ones.[28] These incentives could be formulated to be a net subsidy on the purchase of new cars if the volume of new car sales dropped significantly.[29] In addition to the regulatory changes discussed above, loan and interest guarantees could be provided for electric utilities in order to facilitate their access to the capital bond markets. Financial incentives, such as tax credits, could also be provided to the industrial sector for investments in oil replacement, although these have proved to be ineffective at the relatively low levels that have been applied historically. JO

In addition to (or in place of) the first two levels, the government could regulate some aspects of oil replacement. The largest utility and industrial boilers could be targeted for conversion to coal; and industrial oil efficiency standards (Btu of oil consumed per unit of output) could be applied to various industries. Fuel use and efficiency standards could also be applied to large commercial and apartment buildings. Application of such standards to small businesses and private homes, on the other hand, could be extremely controversial and difficult to enforce. Similarly, attempts to increase the corporate average fuel economy of automobiles and light trucks without 4 to 5 years advance notice would probably prove to be relatively ineffective because of the long leadtimes for product development and acquisition of new capital equipment.[31]

The investment needed to replace 3 MMB/D of oil and, if necessary, to increase the efficiency of natural gas use would be about $150 billion to $200 billion over a 5-year period, or about $30 billion to $40 billion per year, on average (not including the cost of new cars, which is an ongoing activity). This level of investment is about 7 to 9 percent of recent annual investments in producer durables and residential and nonresidential structures. By comparison, OTA estimates that crude oil prices would rise by $23 to $40 per barrel (above a predisruption level of $30 per barrel), increasing domestic oil and natural gas liquids production revenues by $84 billion to $146 billion per year (with domestic production at 10 MMB/D). Consequently, even in the extreme

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[28] This would, however, encourage the sales of smaller cars, a market where U.S. manufacturers have not been strong competitors in the U.S. market. It would also amount to a net subsidy to auto companies that only sell small cars.

[29] Keeping new car sales volumes up is nearly as important as encouraging higher new car average fuel efficiency, because even the less efficient new cars are significantly more fuel efficient than the corresponding average car on the road. (For further discussion see *Increased Automobile Fuel Efficiency and Synthetic Fuels: Alternatives for Reducing Oil Imports*, op. cit.

[30] See *Industrial Energy Use* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-E-198, June 1983).

[31] Obviously, new car fuel efficiency would increase following the oil shortfall, but it would primarily be the result of demand shifts to more efficient cars already in production and introduction of new models that were in the development stage prior to the shortfall.

case, where Federal subsidies would pay a large part of these investment costs (and perhaps new cars received subsidies of $1,000 each, on average, or $6 billion to $10 billion per year), these costs could probably be financed through a windfall profits tax, if it were increased to collect 50 to 70 percent of the increased domestic oil production profits.

An overall strategy then might consist of establishing the investment monitoring system and contingent incentives and taxes in advance. In the event of a shortfall, the first level of incentive could be implemented immediately. If, after 6 months to 1 year, investments appeared to be proceeding too slowly and other economic measures appeared to favor market intervention, [32] the second level could be introduced, and the financial incentives could be increased if they proved not to be sufficiently effective. The third level of incentives could then be introduced if the response to the two previous levels were judged to be inadequate.

The advantage of this strategy is that it provides a flexible and well-defined government response that can be adjusted, depending on the market behavior and the response to various levels of incentives. With the monitoring system, which examines each sector individually, there is also the ability to apply different levels (as well as different types) of incentives to different sectors and to identify and correct any significant sector-specific constraints (e.g., certification delays for new powerplants). A possible disadvantage is that investors may delay investments in anticipation of future government subsidies such as occurred in the 1970s with respect to the purchase of home insulation. If this is judged to be a significant problem, however, provisions could be included to make any subsidies effective retroactively to the onset of the shortfall, thereby reducing the speculative value in delaying investments (unless large groups of investors act in concert to trigger a subsidy that might otherwise not have been needed).

Beyond the short- to mid-term oil replacement options, an oil shortfall is likely to renew interests in the longer term options, such as further increases in corporate average fuel economy standards for new cars and synthetic fuels production. Although these options would have little impact on liquid fuel supplies until well over 5 years after the onset of a shortfall, they could contribute to moderating liquid fuel prices in the 1990s when conventional domestic production of both oil and natural gas is likely to decline. To be effective in promoting these options, however, government policies would have to show a stable commitment over a period of a decade or more.

Advance Preparation for an Oil Supply Shortfall

One government response to the threat of a future oil supply shortfall is to promote investments in a wide variety of oil replacement technologies in order to put downward pressure on oil prices and increase worldwide surplus oil production capacity. This reduces the risk of a severe supply shortfall. However, some of these technologies require long leadtimes and therefore are of little use in preparing for the possibility of a shortfall in the near future. Furthermore, this strategy cannot contribute to a quick response if and when a shortfall materializes.

It has been suggested that one way to reduce the response time is to construct and stockpile any oil replacement equipment that might be in short supply following the disruption. Since the time needed to convert an individual facility or building away from oil is less than about 2 years for all of the technologies included in OTA's replacement scenarios, stockpiling could theoretically reduce the time needed to replace the oil significantly.

OTA's analysis, however, indicates that, in most cases, the equipment that would have to be stockpiled represents a sizable fraction of the total investment needed for the complete conversion away from oil. (Conversely, any equipment that is not expensive generally is relatively easy to pro-

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[32] For example, if 1) investment in oil replacement technologies were low, 2) unemployment were rising, and 3) the economy were stagnating, then investment incentives would probably be appropriate. High inflation beyond that caused by rising oil prices, on the other hand, would tend to speak against market stimulation, And if the economy, oil markets, and employment appeared to be stable then, even if investments in oil replacement technologies were low, government intervention to stimulate these investments might not be necessary.

duce, and production capacity for it can be expanded rapidly.) Consequently, it would generally be more cost effective to make the additional investment needed to complete the conversion and then use the equipment to reduce fuel costs, rather than to allow the equipment to stand idle in a stockpile.

In some cases (e.g., conversion of large boilers to coal), a limiting factor could be the number and capacity of experienced architecture and engineering firms capable of designing and carrying out the conversion. Increasing the capacity for these conversions would involve increasing the pool of trained manpower; and, in the absence of immediate job opportunities, this could prove to be difficult and costly.

A number of other actions, however, can be taken in advance to increase the ability to respond to a large oil supply shortfall. But most of these fall into the categories of advance planning and information, rather than hardware acquisition.

A monitoring system needed to measure the rate of investment in oil replacement technologies should be established well in advance of a shortfall to provide operating experience and a historical data set in order to assess better the information collected following onset of a shortfall. The details of the various levels of investment incentives, including specific procedures, responsibilities, and implementation plans, should also be established in advance so that incentives can be implemented quickly and smoothly when needed.

Surveys of boilers where coal conversions are most likely should be kept current; information about potential coal storage sites, coal transportation capabilities, and possible local shortages in skilled labor should be developed; and the information should be made available to assist private and government planning at all levels. Plans for technical assistance could be developed to help large oil users find coal storage sites and transportation for low-sulfur coal and to aid them in the mechanics of obtaining the necessary permits for coal conversions.

Information could also be provided to increase the public's awareness that investments in fuel switching and increased efficiency of energy use, following a large oil supply shortfall, will reduce the adverse economic effects of the shortfall and that these measures can be implemented within the existing environmental regulations. This would encourage investment in the whole range of oil replacement technologies and would increase the public acceptance of, or minimize the resistance to, possible government intervention and other activities needed for oil replacement following a shortfall.

Finally, an important pre-shortfall step might be to undertake the electric utility regulatory and natural gas pricing changes suggested above. Such actions would provide an incentive for utilities to convert existing natural gas boilers to coal at an accelerated rate. Nearly two-thirds of these existing boilers are uneconomic at today's oil and natural gas prices but continue to operate partly because of the current regulatory climate.[33] As discussed previously, the gas pricing changes would bring about additional supplies, and consumers would be able to make decisions about their use of gas based on prices closer to the replacement value. All of these actions would stimulate oil replacement in any event, and, in case of a shortfall, would be in place and operating to help ensure adequate gas supplies for the rapid response.

For these measures to be most effective, there would have to be a commitment, as a matter of government policy, to intervene to promote investment in oil replacement technologies if the market response is overly cautious. However,

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[33] See "Promoting Efficiency in the Electric Utility sector," Congressional Budget Office, op. cit.

with this commitment, the ability to measure the relevant investment behavior, and the mechanisms to apply successively stronger incentives, it seems likely that the potential benefits of rapidly deploying the oil replacement technologies could be realized.

Even in the absence of a supply shortfall in the mid-1980s, the long-term trend is toward reduced use of oil for fuel in stationary applications. As this trend continues, most of the technologies emphasized in this report will become increasingly ineffective as cushions against an oil supply shortfall. The principal remaining uses of oil will be for transportation and materials (e.g., chemicals), and U.S. oil replacement capability will increasingly be determined by the speed with which oil substitutes can be deployed in these sectors.

Although the leadtimes for replacing large quantities of oil in these end uses are likely to remain long, the ability to respond in these areas to an oil supply shortfall could be increased somewhat through research and development (R&D). For example, development and standardization of designs for mobile gasifierss[34] adapted to modern vehicles could provide a device that could be easily and rapidly manufactured in large quantities to replace the fuels used in cars, trucks, buses, and other surface vehicles, although the potential market for these devices is highly uncertain. Development of small (e.g., less than 10 million gal/y r), prefabricated synfuel plants for converting solids, probably solid biomass,[35] into methanol or gasoline,[36] might enable a rapid deployment of these plants to produce gasoline substitutes without the inflationary effect on food prices associated with ethanol production. Continued R&D into chemical feedstocks from plants and solid fuels and more efficient chemical manufacturing processes can also increase the options for reduced oil consumption in the chemical industry. And continued development and manufacturing of increasingly more fuel-efficient vehicles will enable consumers to purchase these vehicles in larger numbers in the first few years following a large oil price rise than would be the case if these efforts stagnate.

Even if successfully developed, the 5-year oil replacement capability of these options is likely to be considerably smaller than that associated with the technologies considered in detail in this report. Nevertheless, continued R&D of oil and natural gas substitutes provides an important means of countering the long-term trends toward increasingly tight supplies of these fuels and therefore provides an important means of reducing the probable magnitude and severity of an oil supply shortfall that may occur further away in time.

Measuring the Rate of Oil Replacement

Owing to the uncertainties about the investment rates in oil replacement technologies that would occur with a free market response and with various levels of market intervention by the government, it is important to have measures of the rates and types of investment that occur to see if intervention is necessary to increase the rate

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[34] Mobi le gasifiers are devices that are carried on board cars, trucks, buses, and other vehicles and that convert solid fuels into fuel gases that can be used to fuel the vehicle. See also the section on technologies in ch. IV.

[35] Solid biomass (wood grasses and crop residues) may be a more economic feedstock for small synfuel plants than coal is, because the former does not require an oxygen plant owing to the higher oxygen and hydrogen content of the biomass. Whether this will prove to be a decisive economic advantage remains to be seen, however.

[36] For a rapid response, gasoline production may be preferred to methanol production because the latter (if used in large quantities) would require retrofitting of vehicles or the manufacture of new vehicles designed for methanol. However, since OTA has not assessed the constraints associated with deploying prefabricated synfuel plants or increasing the availability of methanol-compatible vehicles, it is unclear which of these would be the limiting factor. If the fuel supply were limiting, supplies could be supplemented with the surplus production capacity of methanol from natural gas (perhaps 0.05 MMB/D oil equivalent in the United States). However, unless this methanol is imported, it may be preferable to use the (domestic) natural gas in the vehicles directly, since more miles could be driven per unit of natural gas consumed if it is used directly. On the other hand, future developments that increase the efficiency of methanol-fueled engines could more than overcome the energy loss of converting natural gas to methanol. Current indications are that methanol or gasoline could be produced from solid biomass at lower prices (per unit energy) than ethanol.

of oil replacement and, if so, to help determine the minimum level of intervention needed. As described below, some of the investment rates can be determined from data currently being collected, while the measurement of others will require additional data collection and/or analysis. All rate determinations will require continual and prompts[37] updating and evaluation of the relevant data if they are to be of maximum use in policy decisions. And the data collection and analyses should be carried out in a manner that is designed and intended for determining oil replacement rates through investment in energy technologies.

The rate of increase in the fuel efficiency of cars on the road can be conveniently monitored using the data currently being collected on new car sales, new car average fuel efficiency, and scrappage rates, provided the results are made known in a timely manner. Similarly, considerable data already exists on utility boilers and new powerplants under construction; and the number of these boilers and new powerplants is sufficiently small that they can be monitored on an individual basis.

Monitoring industrial oil use, involving about 4,000 larges[38] boilers, over 140,000 smaller boilers, and numerous varied industrial processes, would require ongoing surveys[39] of manufacturers.[40] Surveys similar to those needed have been conducted in the past by the Department of Commerce, with funds from the Department of Energy.[41] Although these surveys were recently discontinued, they or similar surveys could be reinstated with modifications* to provide the information necessary to monitor oil replacement investments in industry. Some of these data could also be cross-checked with data on deliveries of various types of equipment, new natural gas hookups to existing industrial facilities, and orders received by architecture and engineering firms for conversions of large oil-fired boilers to coal.

A variety of measures can be used to follow the investment in oil replacement technologies by the 18 million residential and commercial oil customers. The companies that deliver fuel oil, kerosene, and liquefied petroleum gas to these customers could report changes in the number of customers (to indicate fuel switching) and changes in the fuel use per heating degree day. (They already collect the latter data so that they know when to refill customers' tanks.) Gas and electric utilities, that have special rates for space heating customers, could report the number of customers in existing buildings switching to these energy sources for space heating (i.e., exclusive of new buildings). Other gas and electric utilities could report the number of existing customers that have shown large increases in their use of these energy sources (indicating fuel switching) and the number that have had new delivery lines installed to increase the capacity. Data could be compiled on changes in the number of gas furnaces and electric heat pumps sold for space heating. And ail of these data could be augmented with surveys of small, statistically representative samples of residential and commercial oil customers. This information could then be combined to give estimates of the rates of investment in oil replacement technologies, and the estimates could be cross checked with data on regional consumption of fuels and electricity by these sectors.

With these types of reporting systems and experience in collecting and analyzing the data, reasonable estimates of the general trends and magnitudes of oil replacement through investment in the major oil replacement technologies could be provided on a continuing basis.

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[37] Quarterly reporting of the data would probably be adequate.

[38] Greater than 50 MMBtu/hr capacity.

[39] Simply monitoring gross industrial energy consumption would not provide sufficient data to distinguish between increased efficiency of oil use and switching to natural gas, on the one hand, and the closing of oil-consuming manufacturing facilities, on the other. For example, increased efficiency of gas use coupled with switching from oil to gas could reduce oil consumption, while leaving gross industrial gas consumption unchanged. These types of ambiguities could not be fully resolved by applying measures of manufacturing output, unless there were detailed information about the fuel use of the manufacturers that are expanding or contracting output. Furthermore, there are seasonal and annual fluctuations in industrial fuel use that could mask the overall trends.

[40] The oil replacement potential in mining (not including oil refining), agriculture, and construction, which are the other parts of the industrial sector, is limited and these subsectors would not need to be surveyed.

Al Under the title "Annual Survey of Manufacturers: Fuels and Electric Energy Consumed."

[42] For example, the surveys should include fuel that is not bought and sold as well as that which is; it should give the production output of various industrial subsectors and the fuel use per unit of product output; and it should provide information on fuel switching capability that is in place.

Selected Regional and International Considerations

As mentioned above, the reduction in oil consumption that is not replaced through investment in oil replacement technologies must be accounted for by reduced economic activity and personal consumption (of oil as well as other commodities and services). The principal market mechanism through which this interaction is effected is the price of oil. And one difference between the slower and faster rates of investment is that, in the former case, the oil price rises to a higher level in order to drive down economic activity and personal consumption to a lower level.

Although there will be some regional and local price differences and temporal fluctuations in these differences, the larger trends and changes in the price of oil should be felt roughly uniformly throughout the country. Consequently decisions to invest or not invest in oil replacement technologies in a given region will not only affect the price of oil locally but also nationally; and these decisions will affect the (local) price of oil less than they would have done if the region were partially isolated from the national oil markets.[43] However, the burden of making the investments (if they prove to be a burden[44]) will not be spread uniformly throughout the country because the total oil replacement potential, the relative replacement potential in the various sectors, and the relative amounts of various types of investments needed all vary from region to region.

For these reasons, a coordinated national policy may be preferred to a series of independent local and regional policies so that some of the burdens can be shared more evenly and the national nature of many of the impacts can be incorporated more easily into policy decisions. Furthermore, in order to maximize oil replacement, it is necessary that every energy sector invest in replacement technologies as rapidly as practicable. National policy bodies may be better able to resist regionally powerful interest groups seeking exemptions, prohibitions, or special treatment that could lead to lower rates of investment.

To a certain extent the United States as a country is in a similar position, relative to the rest of the world, that a region of the country is in, relative to the United States as a whole. Unless the United States is willing to isolate its oil markets partially from world markets, as was done with price controls and entitlements programs in the mid-l970s, the international price of oil will essentially equal U.S. oil prices. Although the United States uses about one-third of the oil consumed by non-Communist countries in the world (and therefore changes in U.S. consumption have considerable influence over the international price of oil), the impacts in the United States of an oil shortfall will still depend partly on actions of other countries. The international price of oil and the health of other countries' economies (and thus their trade with the United States) will be influenced, among other things, by the extent to which they also are willing to invest in oil replacement technologies.

Although OTA has not analyzed the international aspects of this problem in detail, it is clear that actions at the national level will be needed to influence the behavior of other countries in a direction that is consistent with U.S. interests; and the existence and use of a strong national policy for reducing U.S. oil consumption will improve the bargaining position, persuasiveness, and influence of the United States in any such international interactions.

Furthermore, the International Energy Agreement (IEA), to which the United States is a party, states that "Each Participating Country shall at all times have ready a program of contingent oil demand restraint measures enabling it to reduce its rate of final consumption . . . " or it " . . . may substitute for demand restraint measures use of emergency reserves held in excess of its emergency reserve commitment . . . "[45] Currently, the U.S. "emergency reserve commitments" are

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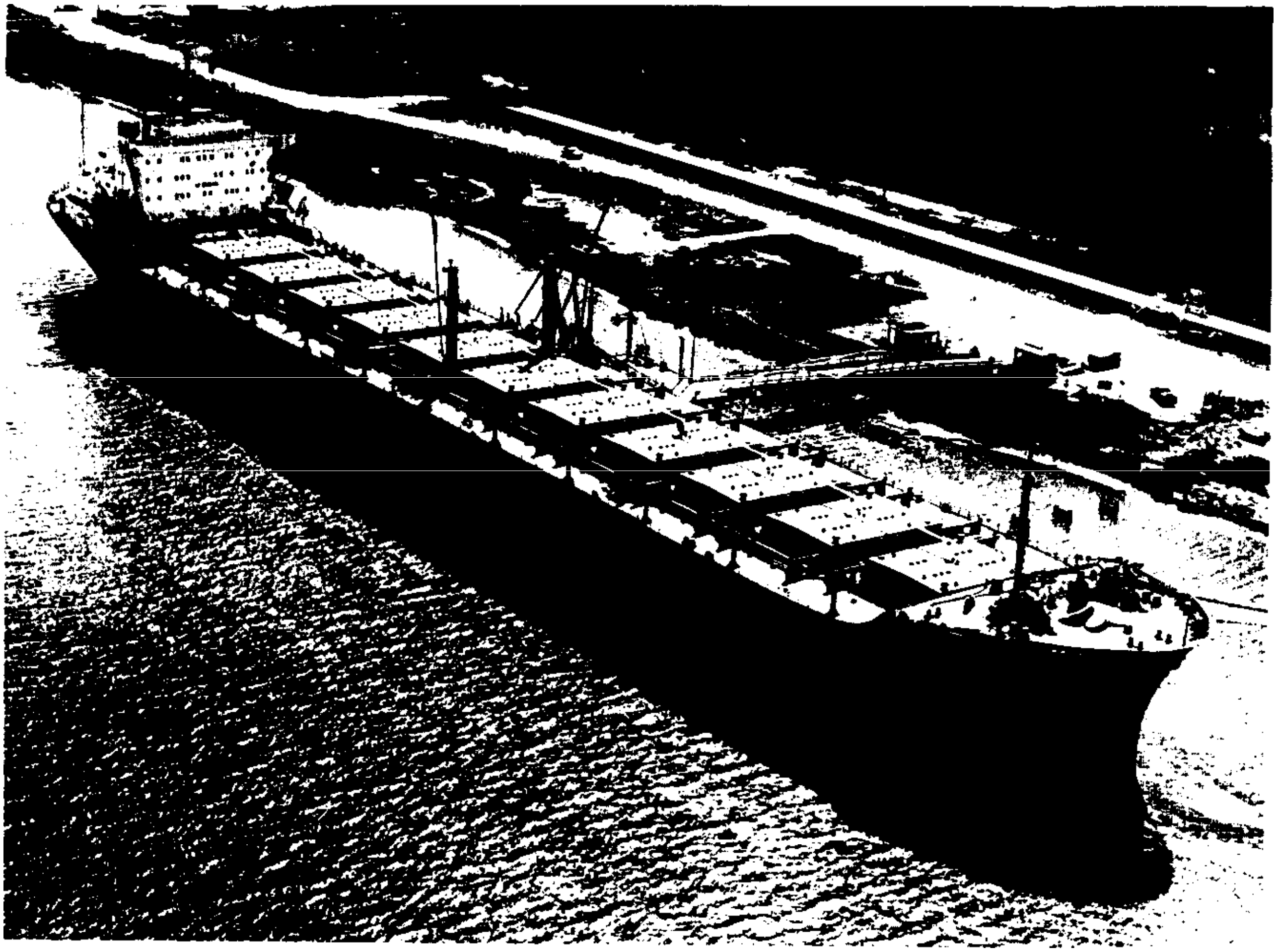
[43] Because the oil replaced by a given investment will be a larger percentage of local oil consumption than of national oil consumption and the investment therefore will have a greater effect on local supplies than on national supplies of oil, unless the two oil markets are strongly coupled.

[44] Obviously, if the investments do not prove to be a burden, incentives to increase the rate of investment will not be needed.

[45] " Agreement on an International Energy Program (as amended to 19th May, 1980)," Articles 5 and 16, International Energy Agency.



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about 400 million to 450 million barrels,[46] which is roughly equal to mid-1984 SPR stocks. Consequently, current "excess" reserves are equal to private oil stocks that can be drawn down. Since the normal market behavior during periods of rising oil prices is to increase private oil stocks, the "excess" reserves may, in effect, be negative for several months after the onset of a shortfall. The tendency to increase private stocks could be countered through a more rapid drawdown of the SPR following a small oil shortfall, but that response would probably be inadequate following the large shortfall considered in this study. And to the extent that the United States appears not to fulfill this part of the IEA, other channels of international cooperation could also be partially compromised.

Finally, the quantity of SPR stocks needed to provide a credible level of "excess" reserves clearly depends on the fraction of the "demand restraint" that relies on these reserves. A national policy designed to ensure that a more rapid rate of oil replacement can be achieved would not only reduce the level (and cost) of reserves needed to ensure compliance with the IEA but

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[46] Emergency reserve commitment is 90 days supply of net imports. In 1983, net U.S. imports were 4.3 MMB/D and they may exceed 5 MMB/D in 1984.

it would also enable the United States to achieve that level at an earlier date. For example, with the supply shortfall and oil replacement scenarios considered in this report, the IEA requirement for demand restrain and "excess" stock use (1.6 MMB/D) would require total "excess" stocks of 980 million barrels for the slow oil replacement scenario and 420 million barrels for the rapid oil replacement scenario. The difference, 560 million barrels, would cost about $17 billion (at $30 per barrel) and take about 3 years to acquire at the early 1984 SPR fill rate.