Summary

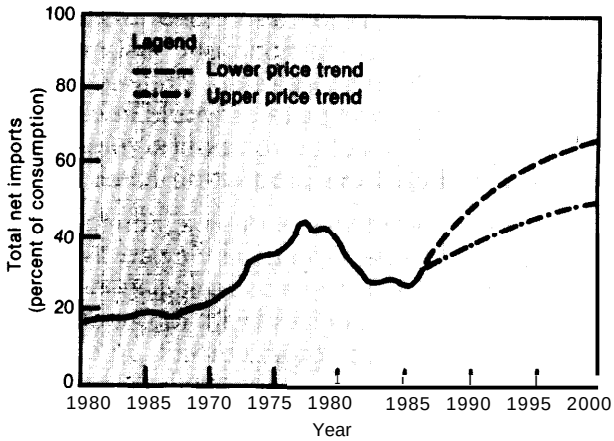
Overview and Findings

The recent precipitous drop in world oil prices from about *$28* per barrel ($28/bbl) in 1985 to between $12 and $18/bbl through much of 1986 dealt the U.S. oil industry a severe blow. In the first year after the price drop, U.S. crude oil production dropped by nearly 700,000 bbl/day, industry capital spending on exploration and production dropped from about $33 billion/year to about $16 billion, drilling activity dropped from over *70,000 well* completions/year to approximately 37,000, and the basic infrastructure of the industry, including its skilled personnel, shrank considerably. There is now a strong consensus that domestic oil production will continue to drop, to between 6 million and a bit over 7 million barrels per day (mmbd) by 1990, down from the 1985 level of 9 mmbd, if oil prices remain in the $12 to $18/bbl range.

A substantial drop in U.S. oil production is only one component of a chain of events . . . resulting from lower world oil prices . . . that could create future problems for the United States' economic stability and national security. First, this Nation's price-sensitive demand for oil will rise as its oil production declines—a combination resulting in a sharp increase in the level of imported oil. Most industry projections of the effects of continued low oil prices envision imports reaching 50 percent of U.S. oil consumption by the early 1990s or before. (Figure 1 shows the National Petroleum Council's import projections for a low and high price track.) At an oil price of $18/bbl, this will amount to a 50 to 60 billion dollar per year drain on the United States' balance of payments.

Simultaneously, similar trends in oil supply and demand will be occurring outside the United States. Lower oil prices are expected to depress oil production outside of the Organization of Petroleum Exporting Countries (OPEC) and the Middle East while increasing the worldwide demand for oil (except where higher taxes maintain prices at previous levels). These changes will increase OPEC's share of the world oil market, with much of the increase going to the Middle Eastern OPEC nations. In time, the Middle Eastern OPEC producers will have returned to the levels of market share and production capacity utilization that in the past allowed them to affect prices or disrupt oil markets. And, thus, they will have regained an ability to upset U.S. economic stability and national security.

Figure 1.—Net U.S. Oil Imports As a Percentage of Oil Consumption, As Projected by the National Petroleum Council



Refiner acquisition cost of crude oil, 1986$	1985	1990	1995	2000
Lower price trend	27	14	17	21
Upper price trend	27	22	28	36

SOURCE: National Petroleum Council, *Factors Affecting U.S. Oil & Gas Outlook*, February 1987.

OTA's evaluation of a set of factors affecting future U.S. oil production lead to the following conclusions:

1. The available evidence points strongly to a continuing, and substantial, decline in U.S. oil

production if oil prices remain in the $12 to $18/bbl range. This evidence includes: a) recent production trends and trends in drilling and other oilfield activity; b) the financial state of the industry; c) industry surveys of future oilfield investment; d) the results of oil supply models; and e) a limited amount of economic analysis.

2. Recent rates of drilling activity are much too low to allow domestic oil production to stabilize close to today's already depressed production levels. Even with quite optimistic assumptions about the productivity of future drilling, a continuation of 1986 drilling rates would lower year *2000* U.S. oil production to about 6 mmbd– a third lower than 1985 production levels.

3. Available estimates of the magnitude of the production decline should be viewed as "best guesses" rather than as precise calculations, even if the uncertainty associated with future oil price levels is disregarded. Most current production forecasts assume implicitly or explicitly that previous trends and relationships established over the past few decades will continue into the future. The severity of the economic dislocations caused by the recent drop in oil prices, coupled with major changes in the industry over the past few years, imply that this assumption deserves to be reexamined. It is probably prudent to assume that the oil industry will adapt in various ways to the new economic environment and, in adapting, will break with many past trends.

4. It is not clear whether a break with past trends would lead to production levels higher or lower than an analysis based on historical behavior would predict. On the optimistic side, the oil industry might be expected to follow an initial period of disrupted operations with movement to more efficient management and positive technological adaptations. On the pessimistic side, any positive effects on oil production levels associated with an adaptive move to higher efficiency might be offset by several factors:

- the industry's higher debt levels caused by the wave of takeovers and mergers during the 1980s, which could depress total exploration and development (E&D) investment;
- the improvement in financial terms offered by several potential overseas producing countries, which might shift E&D investment out of the U. S.;
- the current drop in spending on research and development, which could slow technological innovation; and
- the apparent shift in basic industry E&D investment strategy, downplaying the importance of replacing company reserves and stressing the requirement that E&D investments satisfy rigorous profitability requirements.

There is no ready way to estimate the net effect on production of these diverse factors, Also, further uncertainty is added to estimates of future production levels by the dependence of production on a number of other factors that are not known with any precision, such as the magnitude, geographic distribution, and physical nature of remaining oil resources. Finally, uncertainty is added by the relatively low priority that appears to have been given to publicly ***available*** analysis of the economic attractiveness of new investment in drilling and other production-oriented ventures (the oil industry conducts extensive economic analysis of new investment prospects, but most of the analyses are proprietary and not available to assist in the public policymaking process). The attractiveness of such investment is the key indicator of long-term prospects for adequate U.S. reserve replacement and production.

If oil prices do stay low–perhaps averaging between $14 and $16/bbl for the next several years—what might be the outcome for domestic oil production? With rapid restructuring of the weaker companies, favorable adjustments in E&D strategies, innovation in E&D technology, and favorable potential for continued reserve growth in older oilfields, domestic production might be able to hold above 7 mmbd through 1990 (the upper end of the range of most industry estimates) and drop less steeply than projected thereafter. For the period beyond the early 1990s, the opening of Federal and State lands to exploration and the successful discovery of large oilfields on these lands could be of special importance. On the other hand, if the industry continues to shift to more overseas investment and fails to improve efficiency further, technological change slows be-

cause of reduced R&D spending, and reserve additions from older fields slow because of reduced geologic potential and poor economics, production could sink to the lower end of the consensus range (about 6 mmbd) in 1990 and conceivably even below the expected range in later years.

5. Further economic and technical analysis could be useful to policy makers concerned with falling oil production. With or without such analysis, however, substantial uncertainty will remain about how domestic production will respond to different price levels and policy environments, and policy makers must be prepared to make key decisions without precise knowledge of their outcomes. Some questions that cannot be fully answered with further analysis include:

- How will industry investment behavior adapt to the new price environment and to a changing business environment overseas?
- To what extent will the major industry restructuring of the 1980s eventually lead to higher efficiency and increased interest in new domestic E&D ventures? Will newly merged and restructured companies be able to eliminate their heavy debt burdens within a few years, and will they then act to boost their investment in traditional E&D activities?
- To what extent will technological change act to offset some of the negative effects on profitability of lower oil prices?
- Will relatively low cost drilling in the United States' older oilfields continue to provide large volumes of new reserves, or did the intensive drilling of the past decade essentially "use up" most of these fields' remaining growth potential?
- If large new blocks of Federal and State land are made available for exploration, especially offshore California and in the Arctic, will super giant fields be discovered and developed?
- How long will it take (or what conditions are necessary) to restore enough confidence to potential investors in E&D that they will respond readily to reasonable profitability prospects? To what extent could investment levels rebound without a concurrent rebound in cash flow from the industry's past investments?

6. There are ways to reduce, though certainly not eliminate, uncertainty about the magnitude of a future production decline and the potential effect on production of alternative government policy measures. Of most value would be a comprehensive analysis of the prospective profitability and productivity of new investment in oil exploration and development. Although some valuable economic analyses are available (e. g., the National Petroleum Council's evaluation of Enhanced Oil Recovery) these are too limited in scope and uncoordinated to qualify for the type of comprehensive analysis needed for careful forecasting and policy analysis.

Other potentially useful analyses include:

- A cataloging and analysis of changes in the business environment for oil and gas investment overseas.
- An evaluation of the dissemination and use of new technologies in oil exploration, development, and production during the past decade, and an examination of new technologies just introduced or on the near horizon.
- An economic analysis of existing oil production with high operating costs (especially stripper production), incorporating collection of physical and economic data at the individual well level.
- An examination of the differences in individual companies' E&D strategies and results, to gain further perspective about the potential for industry wide improvements in E&D efficiency.

7. Congress is faced with difficult choices, not only in 'selecting policies to combat trends towards lower domestic oil production and higher imports but also in deciding whether an active government role is wise. Unfortunately, some of the key issues associated with choosing an appropriate government role are ambiguous. For example, earlier concerns about the effect of higher oil imports on U.S. economic stability and national security have been complicated—but not negated–by the significant changes in oil markets and government preparation for market disruptions since the early 1970s. These changes include the construction of the Strategic Petroleum Reserve, the advent of a strong spot

market for crude oil, the beginning of a futures market, and substantial changes in the role of oil in the U.S. economy.

Another complication is that the majority of production forecasts prior to the 1985-86 oil price drop projected domestic oil production to begin falling rapidly in the 199os; in other words, most forecasters expected the production decline and subsequent increase in imports to occur even in the absence of a large price drop, albeit a decade later. At first glance, these predictions would appear to favor a "hands off" policy on oil production since boosting production today would appear to be only delaying the inevitable. Not all forecasters agree with this "conventional wisdom," however; they contend that U.S. production could have been maintained, had prices not tumbled, with continued intensive field growth and innovation in enhanced oil recovery. Further, "buying" an extra decade of moderate import levels could be worthwhile **if** the decade were used to add flexibility and security to the U.S. energy system, rather than to artificially preserve the status quo, so that the Nation would be better prepared to deal with higher import levels when they occurred.

There is also uncertainty about whether allowing U.S. oil production to decline now might yield higher future production rates than would be possible if today's production rates were propped up and the resource base depleted more intensively. Although resource depletion is a valid concept, the remaining U.S. petroleum resource base is less a small resource than it is a low-grade resource whose recovery is amenable to improved technology. Thus, the pace of technology development—likely to be more rapid if production is kept high by tax or other incentives—conceivably may outweigh resource depletion as an influence on future production levels.

If Congress does decide to work to stabilize domestic oil production, it can use a number of policy mechanisms. The following options are discussed briefly in the report:

- oil import fees (either to raise wellhead prices or to establish a price floor);
- tax concessions (including investment tax credits, depletion allowances, cuts in severance and ad valorem taxes, drilling credits, abolishing the Windfall Profits Tax);
- removing the ban on oil exports from the Alaskan North Slope;
- bolstering investment in oil exploration and development R&D; and
- removing leasing restrictions on frontier/offshore areas.

Introduction

The long price slide that took world oil prices from about $40/bbl in 1981 to $28/bbl in December, 1985, and then precipitously downward to the $12 to $15/bbl level throughout much of 1986 has created a depression in the U.S. oil industry. Most indicators of the level of oilfield activity have been slipping since the "peak" year of 1981 and dropped sharply in the early months of 1986:

- The number of rotary drilling rigs working in the United States dropped from over 4,000 in 1981 to about 1,900 in July 1985 to below 700 a year later; they have since rebounded slightly.
- Industry employment dropped from a 1982 high of 708,000 to 585,000 in 1985 and to 422,000 in September 1986, with oilfield service employees bearing the brunt of the drop.
- Total well completions, which had declined moderately from 89,000 in 1981 to 73,000 in 1985, dropped below 40,000 in 1986. Figure 2 illustrates the rise and fall of well completions between 1970 and the present.
- The monthly seismic crew count, that is, the number of teams doing seismic surveys for oil and gas exploration and development, fell from 681 in 1981 to 378 in 1985 and to 195 in 1986.

U.S. oil production has slid from 9.03 million barrels per day (mmbd) at the end of 1985 to 8.35 mmbd a year later, a decline of over 7 percent. Coupled with increased oil demand, the production decline has forced U.S. net imports of crude

[1] That is, crude oil plus "lease condensates," natural gas liquids recovered in the field. Total domestically produced petroleum also includes natural gas liquids recovered from gas processing plants, refinery processing gain, and small amounts of alcohol.

Box A.—Recent Studies by the National Petroleum Council and the Department of Energy

The National Petroleum Council (N PC) and the U.S. Department of Energy (DOE) have recently published reports on U.S. energy supply: Factors *Affecting U.S. Oil & Gas Outlook* and Energy *Security,* respectively. Both reports focus particularly on domestic oil production but also evaluate U.S. and world energy supply and demand.

The DOE report, the more pessimistic of the two regarding oil production prospects, projects U.S. crude oil production to be **6.9 mmbd in 1990 and 5.2 mmbd in 1995 (compared to about 9 mmbd in 1985)** if oil prices* rise from about $14/bbl in 1986 to $16/bbl by 1990 and $22/bbl by 1995. The NPC report projects slightly higher production rates at somewhat lower prices: **7.1 mmbd in 1990** and **5.7 mmbd in 1995** with oil prices at only $12/bbl in 1986 and rising to $14/bbl by 1990 and $17/bbl by 1995. Both of these projections are well within the mainstream of forecasts released within the past year, and are substantially more optimistic than several. For both, net petroleum imports reach the 50 percent level in the early 1990s.

Both reports also examine a higher oil price case. With prices in the low $20s by 1990 and the high $20s by 1995, DOE projects domestic crude oil production to be 7.8 mmbd in 1990 and 6.6 mmbd in 1995; for similar prices, NPC projects production to be 8.0 mmbd in 1990 and 7.0 in 1995. These results imply that an import fee that raised oil prices by $5 to $10/bbl could substantially slow the production decline.

DOE'S projections are based on a detailed computer model of U.S. energy supply, the Energy Information Administration's Intermediate Future Forecasting System. NPC's projections are based on a survey of U.S. and world oil supply and demand forecasts from various sources. Both projections are supplemented by quantitative and qualitative evaluations of oil supply factors. The NPC report plainly acknowledges the substantial uncertainty associated with the projections:

> Even sophisticated statistical analysis of past events is inadequate for predicting the future if the historical data do not contain an event similar to the current or expected future events . . . Energy forecasters have no recent historical events to measure the impact of sharply falling prices of petroleum . . .

Both reports identify the deterioration of industry infrastructure-loss of skilled workers, declining manufacturing capacity of critical oilfield equipment, deterioration of the rig fleet, and so forth-as a critical roadblock to a future drilling recovery. OTA shares these concerns but is somewhat more optimistic about the ability of the industry to increase its rate of additions to oil reserves if incentives improve.

Although both reports evaluate several policy options to increase domestic oil production, only the DOE report presents a quantitative analysis of these options, calculating the net costs and production response for many of them. The uncertainty associated with these estimates is likely to be extremely high, however (in some cases, e.g. lower minimum bids on Outer Continental Shelf acreage, so high that cost/production estimates were not made).

*Measured as the cost of crude oil to U.S. refiners.

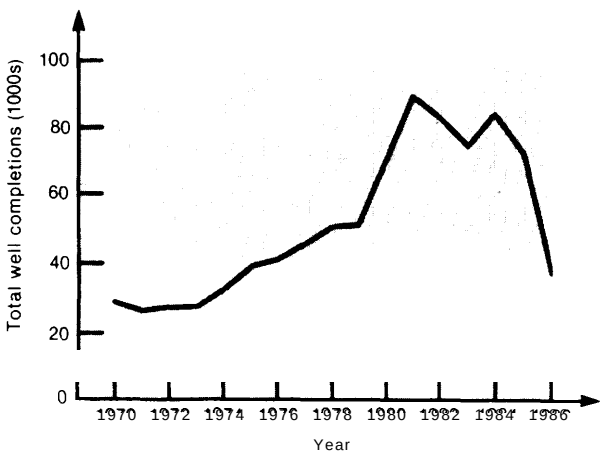
oil and petroleum products up by about 14 percent over a year before, from 4.9 mmbd, or 30 percent of total U.S. petroleum supply, to 5.6 mmbd, or 34 percent of supply.

These trends appear to be pushing U.S. oil supply towards a dependence on imports reminiscent of the situation in the late 1970s, before the production stimulating and demand suppressing effects of the two oil price shocks finally took hold and began weaning the United States from a growing reliance on foreign oil supplies. In fact, a renewed dependence on foreign supplies is precisely what the oil industry and most energy analysts are predicting for the United States—absent either a rapid return to previous price levels or major Federal intervention in the marketplace. Typically, they are projecting a likely decrease (from 1985 production levels) in domestic oil production of 2 to 3 mmbd by 1990, and similar increases in demand, if world oil prices stay at about $15/bbl. Table 1 presents several projections of future U.S. crude oil production assuming continued low oil prices, as well as projections completed before the price drop for comparison.

How and Why Would U.S. Oil Production Decline?

Several mechanisms will drive the expected production decline.

Figure 2.—Oil and Gas Drilling Trends



SOURCE Off Ice of Technology Assessment 1987: based on American Petroleum Institute data

First, production from stripper wells[2] and other marginal wells (wells with high per barrel production costs) will drop because many of these wells cannot be operated profitably at low oil prices and will be shut down. These wells cannot remain out of production for long periods; after a year (or other period depending on State rules) they have to be "plugged" (sealed with concrete) for safety and environmental reasons, and are unlikely to be reopened thereafter. Other shut down wells may be lost because of water encroachment.

Second, fewer new development wells will be drilled, yielding less new production to offset the natural decline in production from older wells,

Third, fewer exploratory wells will be drilled, yielding fewer new fields and thus fewer new opportunities for development drilling,

Fourth, production from enhanced oil recovery (EOR) operations, which seek to capture as much as possible of the estimated two-thirds of original oil-in-place left behind by conventional drilling and waterflooding, will decline because most new projects, and many planned project expansions, will be cancel led as no longer economical.

Fifth, research and development (R&D) will decline, exacerbating the overall problem because R&D traditionally has been an important driver in pushing the industry into new areas and sources of oil production as older sources decline.

In addition, many analysts warn that the industry is losing its ability to recover swiftly in the event of a return to high prices; the infrastructure necessary for such a recovery is rapidly being dismantled as drilling rigs are scrapped, cannibalized for parts, or even sold abroad; manufacturing facilities are retooled; and skilled personnel are laid off, many leaving the industry for good.

Although the reasons given for their predictions may differ, the analysts have tended to focus their arguments on three areas in particular:

[2]Wells producing 10 barrels of oil or less per day, averaged over the lease. Nearly three out of four U.S. oil wells are strippers, and these produce an average of about three bbl/day.

Table 1.—Recent Projections of Future U.S. Oil Production

Source	Projected crude oil production (million barrels per day) 1990	1995	2000	Price expectation (dollars/bbl, 1986 dollars)
At low *prices:*				
DRI	7.8	6.3	5.5	$20 by 1995, $30 by 2000
Chevron	5.9-6.9	NA	NA	$10 to $15 thru 1987, $18 to $22 by 2000
API	6.2	NA	NA	Constant $15
CWW	6.1	NA	NA	$15
Unocal	6-6.5	NA	NA	$13.50
Amoco	6.7	NA	4.5	"Low price"
Fisher	6.8	NA	NA	$15
Conoco A	7.0	5.5	3.5	<$12 thru 1995, $20 in 2000
Conoco B	7.8	6.9	6.1	<$20 thru early 1990s, $20 in 1995, $26 in 2000
GRI	7.3	5.4	5.0	$12 in 1986, $14 in 1990, $21 in 2000
NPC	7.1	5.7	4.5	$12 in 1986, $14 in 1990, $21 in 2000
DOE	6.9	5.2	NA	$14 to $16 thru 1990, $21 in 1995
Price outlooks of 1985:				
Chase	8.3	7.0	5.7	Drops to low $20's by 1990, rises 0.9 '\. /year thereafter
DRI B	8.6	NA	6.8	Drops to $21 by 1987, constant to 1994, $32 by 2000
EIA	8.1	6.5	NA	Dips but is $28 by 1990, $31 by 1995
GRI	8.5	8.2	7.8	Dips but is $34 by 1995, >$40 by 2000

[a]Excludes Natural Gas Liquids 1985 Product Ion, 9mmbd
NA = Not available

SOURCES: DRI Data Resources, Inc, *Energy Review*, Summer 1986.
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***Argument One:* The established models of U.S. drilling activity and oil production virtually unanimously predict low rates of drilling and rapid declines in reserve additions and production if low prices continue. Current industry surveys of expected future drilling levels, reserve additions, and production basically support these predictions.**

Available models of U.S. oil supply generally rely on extrapolation from past trends to project future levels of drilling activity, reserve replacement, and production. Under stable conditions, these models can be reliable predictive tools. They are not likely to be as reliable, however, when forced outside the range where past trends provide a good analog.

It is virtually certain that the extrapolative models of oil production are directionally correct in their prediction of a U.S. oil production decline. Under current conditions, however, policymakers should be skeptical of the accuracy of these models. The events of the past year, and of the 1980s in general, in several ways are major departures from past events. The nation has just undergone a period during which oil prices, a key determinant of industry exploration and development activity, have undergone severe dislocation, and in a direction opposite past dislocations. Moreover, during the 1980s, several companies comprising a large segment of the industry's reserve replacement capability underwent significant changes in business strategies, were restructured, or merged with other companies. In addition, the period of the early 1970s to the present has been a period of hyperinflation followed by collapse in industry **costs; the** future path of such costs–a key determinant of the economic attractiveness of new E&D investment—is unlikely to be stable or predictable.

While the results of industry surveys of future drilling rates, reserve additions, and production are very important, policy makers are likely to demand substantial analytical evidence to back up the survey results. For one thing, in recent years the industry (along with just about everybody else) has not been very successful in predicting which way prices and production would turn, and different segments of the industry and different companies often have been at odds about major resource and production projections. Second, the industry participants in these surveys have been the direct recipients of significant financial blows and have seen their friends and colleagues laid off, retired, or even bankrupted. It seems fair to have concerns about whether their expressed views of the future of the U.S. oil industry reflect a cool-headed appraisal or instead reflect their depression about the immediate results of the industry downturn. Third, the industry has a very large financial stake in any policy measures that could alleviate a production decline. Whether or not this stake affects their announced projections of future production, some policy makers and segments of the public believe that it may. These concerns suggest that an analytical verification of industry estimates, capable of being reviewed by independent analysts, would be desirable and probably necessary for public acceptance.

Argument Two: The large drop in oil prices has drastically cut oil industry revenues and placed many of the industry's past investments in jeopardy. After paying off its obligations, the industry's remaining internal cash flow is sharply reduced from earlier levels. At the same time, the industry's traditional sources of outside investment and loan capital, faced with low prices and uncertainty, have backed away from the oil market. These capital sources are particularly important to the independent sector of the industry. Without new sources of investment capital and without a restoration of cash flow from prior investments, the industry will not have enough capital to invest in the major new exploration and development ventures needed to arrest the rapid decline in production.

This argument is most important for projecting oilfield activity levels in the short term, perhaps over a **2-** or 3-year period. Many of the financial entities generally responsible for U.S. drilling and other production activities *have* been hurt badly from the large cut in revenues from their past investments; uncertainty about their survival—especially for many of the small independents—will keep away outside capital, and they have minimal internal resources. Similarly, many banks and other sources of investment capital experienced severe losses and may be reluctant to reenter the oil market. In the short term, new investment will suffer because it will take time for the industry to resolve mismatches between financial resources, drilling capability, and land positions and reserve ownership. After an industry shakeout, however, drilling and other activity, and reserve replacement, could revive *if* adequate incentives, measured by the expected profitability of new E&D investment relative to competing investments, were available. Also, a number of companies, especially those larger integrated companies and independents that had avoided large debt loads, still have substantial internal resources and/or access to external capital sources. The argument that inadequate capital resources will prevent the industry from investing in new production, which attempts to tie the level of new investments to the success of old ones, may explain short term investment behavior of the oil industry (or, at least, some segments of it) but does not adequately explain the industry's *long-term* investment behavior.

Argument Three: **The large drop in oil prices coupled with fears about future price collapses have undermined the expected profitability of new investments in exploration and development. With current price expectations and conservative investment requirements (to account for higher uncertainty), there are too few economically attractive drilling opportunities to spur continuation of the industry's past level of domestic exploration and development activity.**

This argument ties the level of future investments in reserve replacement and production directly to the economic attractiveness of these investments. In OTA's view, the attractiveness,

or expected profitability, of future drilling and other production-oriented ventures is the key indicator of long-term prospects for adequate U.S. reserve replacement and production.

Current industry analyses supporting conclusions about declining U.S. oil production prospects generally stress arguments one and two and pay somewhat less attention to argument three. Models and surveys, the bases of argument one, have been widely used. The second argument about inadequate capital and reduced cash flows is analytically very straightforward and has been advanced with intensity, especially by spokespersons for the independent sector of the industry. In contrast, few in the industry have supported the third, "expected profitability" argument with the careful analysis necessary to establish its credibility.[3] The substantiation of industry projections of declining production that would be provided by a careful analysis of expected profitability must be viewed as very important in light of the high social costs—many billions of dollars—associated with many of the policy measures being considered to arrest the projected decline.

Evaluating the attractiveness of new E&D investment opportunities relative to competing investments is a complex undertaking. It would require a substantial commitment of resources and information from the industry, and much information that would be useful in such an evaluation is proprietary. Although many and perhaps most of the larger oil companies have undertaken extensive analyses of their own investment prospects, these analyses are not likely to be made available to the public. Furthermore, a credible *national* analysis will still have to rely on some form of detailed assumption about that portion of the total remaining oil resource base that is physically available to the industry for exploitation within the time frame of interest. No widely accepted resource model currently exists, although there are a few computer models of oil supply (e.g., the Gas Research Institute's Hydrocarbon Model) that constitute some first attempts at such a model.

[3] We do not doubt that many of the industry's survey responses about future 011 production levels are based on companies' private evaluations of expected profitability of new E&D investments.

An Approach to Understanding Oil Production

Given the concerns about the reliability of current oil supply models under today's radically changed economic conditions, an appropriate means to gauge future oil production is to gain an understanding of both the changes the oil industry has undergone and the forces that will drive future production. The following discussion examines:

- Economic and resource factors affecting production:
  - —changes in the economics of drilling prospects over time;
  - —changes in capital availability and how these changes affect E&D investment levels;
  - –loss of oil production from stripper wells;
  - —the nature of the oil resource base, and in particular, the availability of drilling opportunities that might remain profitable in a low price environment; and
  - —the effects on drilling of the current surplus in natural gas supply.
- Changes in the oil industry affecting production:
  - —the potential effects of industry restructuring on industry investment strategy and capabilities,
  - —the changing business climate for E&D investment overseas and its effect on domestic versus overseas spending,
  - —changes in the efficiency of exploration and development activity and their effects on rates of reserve additions and production,
  - —the potential for technological change to offset some of the drop in profitability caused by low oil prices, and
  - —the effects of a deteriorating industry infrastructure on industry's ability to rebound to higher drilling levels.

The goal of examining these factors is to *determine* whether the preponderance of evidence tends to support or undermine the industry's pessimistic predictions for future oil production, and

to better understand how Congress might best intervene to shore up production *if it chose to do* SO.

Economic and Resource Factors Affecting Production

Changes in the Economics of Drilling Prospects

OTA's interviews with oil industry planners paint a pessimistic picture of remaining domestic exploration and development prospects at low prices. **Essentially all of those interviewed contend that the "inventory" of economic oil and gas prospects has shrunk enormously at mid-1986 prices of$12 to $15/bbl despite the accompanying sharp declines in drilling and other costs.** They assert that the only arena capable of supporting substantial drilling levels at these prices is relatively low-risk, low-to-moderate cost development drilling, primarily for oil objectives, with short lead times; they also assert that exploration drilling is virtually dead at these prices.

In addition to low risk shallow extension and infield drilling,[4] other prospects still considered to be viable at oil pricesof$12 to $15/bbl include:

- continuation of projects where most front-end capital has been spent (enhanced oil recovery, offshore development drilling, waterfloods[5]);
- drilling to satisfy lease and contract requirements; and
- some exploration drilling where production could not begin for 7 to 8 years or longer, so the current price environment is not relevant (although several major companies have backed away from this type of drilling).

Most of those interviewed were pessimistic that an increase to $18 to $20/bbl would spark a major drilling revival, although all felt that certain additional prospects would become economic, including:

- some deepwater Gulf of Mexico exploratory prospects;
- some onshore wildcat prospects;
- additional enhanced oil recovery, especially $C0_2$ gas injection projects with readily available sources of CO_2, and some projects using the injection of polymers;
- Beaufort Sea exploration and delineation drilling;
- limited offshore California development; and
- many waterflood projects.

There are only scattered published economic analyses that can offer confirmation of these assertions. In an attempt to test at least a few of the assertions, OTA examined how the expected profitability of small-scale exploration and development drilling programs i n the United States has changed over time. OTA compared 1986 profit expectations with expectations for the same physical prospects in: 1985, immediately before the major price drop; 1981, at the height of the drilling boom; and 1972–before the first OPEC price shock. Although only a few physical prospects were examined, we believe that the results are fairly widely applicable to drilling projects of modest scale.

In our analysis, we found that **the profit expectations for the 1986 drilling projects, assuming oil prices would remain in the $14/bbl range during the 1980s, were substantially lower than expectations in 1981 and 1985 in every case;** for example, onshore development well drilling projects with expected real rates of return (before taxes) of 15 percent in 1986 would have been expected to earn 35 to 52 percent in 1985 and 23 to 43 percent in 1981. Although drilling costs dropped substantially from 1981 to 1985 and, to a lesser extent, from 1985 to 1986, the oil price drop has proved to be the more important factor influencing profitability. **This result agrees strongly with the assertions of the industry that**

[4]Extension drilling seeks oil and gas just outside the known boundaries of discovered fields; infield drilling seeks oil and gas inside of these boundaries by drilling in previously undrilled sections or drilling at smaller spacing than previous drilling.

[5]Waterflooding is an oil recover, technique whereby water is injected into the reservoir to maintain or restore reservoir pressure and push additional oil towards the producing wells.

[6]*Expected profitability* is calcu lated by using oil price forecasts typical of the analysis year. *Realized* or *actual profitability* is calculated by using actual price levels up to the present, and forecasted or assumed price levels thereafter.

the price drop has substantially reduced the number of profitable domestic E&D opportunities.

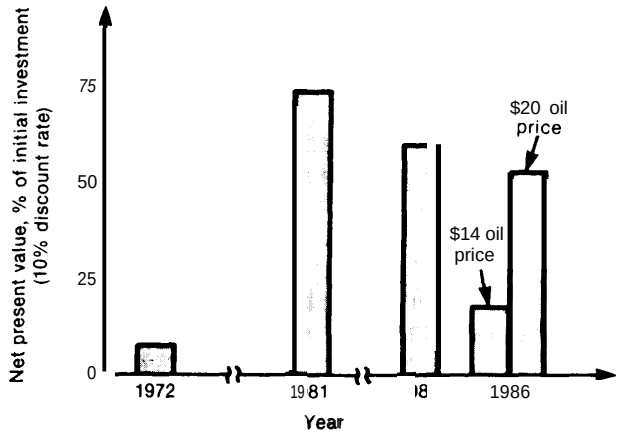
We also found, in every case, that 1986 expected profitability (based on the assumed $14/bbl future oil price) was much better than expectations in 1972, primarily because 1972 oil price expectations were modest. Thus, for the cases examined, today's economic conditions for drilling development wells and exploration wells aimed at small fields would appear to be substantially superior to conditions in 1972, for wells of the same physical promise. At first glance, this appears to indicate that the industry has better economic opportunities today than in 1972. Because so many of the better prospects were drilled in the years between 1972 and 1986, however, today's remaining physical prospects may be considerably poorer than those available in 1972. On the other hand, this effect of "resource depletion" is tempered by the addition of new prospects to the resource "inventory" because of improvements in exploration technologies and in geologic understanding. The net effect of these factors is unclear without further analysis, although an industry consensus would likely be that today's physical drilling prospects are substantially inferior to those available in 1972.

Figure 3 illustrates the change over time in expected profitability for a single exploration prospect in the Permian Basin, Texas.

Another important result of OTA's analysis was that the actual profit performance of the drilling projects was considerably different than the expected performance. **For the wells drilled in *1972,* actual profits were much higher than initially expected; for the 1981 and 1985 wells, actual profits were much lower than expected.**[7] In fact, there is little difference in realized rates of return between the 1986 wells and the 1981 and 1985 wells. The higher drilling costs incurred in 1981 and, to a lesser extent, in 1985 offset the higher average oil revenues obtained with these wells.

[7]Assuming continued $14/bbl oil prices beyond 1986

Figure 3.—How Profit Expectations for the Same Prospect Would Have Changed Over Time: An Oil Exploration Prospect in Texas' Permian Basin



The expected drilling program:
- 20 wells drilled
- 10 producing wells at 8900 ft.
- Initial year production = 222,000 bbl.
- 10 percent depletion rate

SOURCE: Off Ice of Technology Assessment. 1987, based on Congressional Research Service analysis for this study

OTA also examined the effects of assumed $10/bbl and $20/bbl oil prices on 1986 expected profitability. **At** $20/bbl, if drilling costs do not rise, expected profitability for the projects evaluated will be in the same range as 1981 and 1985 profit expectations, implying that a drilling revival **could occur at this price level. However, the strength of any revival would be limited by increases in drilling costs that would occur as the current "surplus" of drilling services is used up. Also, for a revival to occur, producers must be reasonably assured of continued price stability.** Today, many producers say that they are requiring proposed drilling projects to pass a ''low-price hurdle," that is, they must retain profitability at prices that could occur if surplus production drove prices back down again. A hurdleof$10/bbl is frequently mentioned. **At** $l0/bbl, drilling prospects that would yield 15 percent real rates of return at **$14/bbl become either outright losses or yield barely a few percent. Thus, conservative price/cost accounting in approving proposed drilling projects may be playing an important role in stifling drilling activity.**

Our analyses apply only to oil exploration and development aimed at small fields and modest-

sized development wells, and only to physical examples that do not stray far from average conditions. In our view, **the great importance to national policy makers of having an accurate estimate of domestic E&D economics demands a wealth of additional analysis.** This analysis must examine the full range of E&D activity, from the various forms of enhanced oil recovery to exploratory drilling in the Arctic and deep offshore, to extension well and infill drilling in older fields, and so forth. Considerable analysis is already available, for example the National Petroleum Council's report on enhanced oil recovery, but the separate analyses must be collected, intensively reviewed for accuracy, and reworked to fit into a consistent economic framework. Substantial new analyses will be needed to fill in the gaps.

Problems of Capital Availability

As noted previously, the large reductions in cash flow to the oil industry and, to a lesser extent, the withdrawal of outside loan and investment capital are widely viewed as critical factors in driving down levels of investment in oil exploration and development. Total oil and gas wellhead revenues were about $70 billion in 1986, about 43 percent below 1985 levels. Although reliable data for private financing, a major source of funds for independent producers, are not available, many industry analysts are convinced that availability of private funds has declined substantially because of current conditions in the industry. Furthermore, many of the regional banks which had financed the efforts of many small operators during the late 1970s and early 1980s were placed under severe pressure by the bankruptcies of many of their oil service industry borrowers and the reduced values of the oil and gas reserves used as collateral for their loans to independent producers. Poor performance in the agriculture and real estate sectors also played a major detrimental role in the banks' loan portfolios. Many of these banks have pulled back from the oil and gas loan market.

Although capital availability problems are widespread, they are not uniform in their intensity across the industry. The small independent producers have the worst capital problems, with no alternative sources of cash flow and profits and greatly reduced access to the external capital sources they had relied on; the larger integrated companies have been buffered somewhat against the effects of reduced production revenues by increased profits from their downstream (e.g., refining) operations. Those larger integrated companies and independents that previously had avoided large debt loads generally cannot (and do not) claim that their E&D spending is capital limited; they retain substantial internal resources and/or access to outside capital. Although most of these companies have reduced their E&D budgets and activity levels, they presumably have done so because of changed investment priorities.

Although the importance of the drop in cash flow and withdrawal of outside capital to the short-term investment behavior of the industry is not in question, this is not the case with the importance of these factors to the industry's *long-term* behavior. There is disagreement among analysts of the industry as to whether the cash flow from previous investments or the profit prospects for new investments will control the industry's future level of investment. In the past, industry investment levels appeared to be closely tied to levels of cash flow. However, classical economic theory predicts that the volume of new investment should be more closely tied to the characteristics of the new investments. Past industry financial losses and recently reported shifts in the industry's attitude about replacing company reserves—discussed in the section on industry restructuring—reinforce the view that the industry is likely to base its future decisions about the magnitude of E&D investment primarily on a careful evaluation of prospective profits.

Over a period of a few years, companies in a weakened financial condition may go out of business; undeveloped and partially developed properties and equipment will be sold at low prices; companies will merge and be restructured; problem loans will be renegotiated or written off; and new financial entities will enter the industry if good investment opportunities are available. In this manner, the industry would be in position to attract new E&D investment capital if costs are

low enough and E&D efficiency high enough to create attractive E&D investment opportunities.

Losses in Oil Production From "Stripper" Wells

There is widespread concern that low oil prices will force many of the nation's "stripper" oil wells, wells whose production averages 10 barrels of oil per day or less (averaged over the lease), to shut down. Once these wells shut down for a year (or other period determined by State rules), they must be "plugged," i.e. sealed with concrete; most will never be returned to production, and their reserves will be lost. This concern is magnified by the importance of stripper wells to U.S. supply. Over *400,000* stripper wells produced approximately 1.3 mmbd, 14 percent of total domestic oil production, in 1985. These wells are concentrated in Texas, Oklahoma, California, and Kansas, which together have three-fourths of the Nation's stripper production.

The probable loss of stripper production at different price levels is highly uncertain because of a scarcity of data about stripper well physical characteristics and production costs. Furthermore, the data that are available reflect historic business practices and costs. Both stripper well operators and the businesses that serve them have been forced to make adjustments in response to the sharp drop in oil prices. Analyses of stripper well production must account for recent declines in the cost of utilities, materials, and services to operators as well as changes in operating practices, such as deferring maintenance, that affect both costs and production levels.

Two quantitative studies of lost stripper well production have been conducted. A study sponsored by the Interstate Oil Compact Commission (IOCC) estimates that, during the first year, 176,000 bbl/day of stripper production, 2 percent of total U.S. crude oil production,[8] would be lost at $18/bbl oil prices, and 277,000 bbl/day or 3.1 percent of U.S. production would be lost at $15/bbl. The Energy Information Administration (EIA) estimates a first-year loss of 85,000 bbl/day, 1 percent of U.S. production, at $18/bbl oil prices, with an additional 4,300 bbl/day loss in later years as major repairs for the still-operating wells become necessary; at $15/bbl, first year losses are estimated at 148,000 bbl/day, with later year losses of 77,500 bbl/day for a total loss of 226,000 bbl/day or 2.5 percent of U.S. production. EIA's estimated first year losses are about half of the IOCC's estimates.

More recently, an IOCC survey of California, Kansas, New Mexico, North Dakota, Oklahoma, Texas, and Wyoming indicates that 110,000 wells in these States, with 307,000 bbl/day of oil production, were shut in during 1986, with 12 percent of the wells permanently abandoned. These values do not break out the production lost solely because of low oil prices (each year, thousands of wells are abandoned even at high oil prices), and thus they are not strictly comparable to the projections above. However, most of the production loss is likely to be attributable to the price drop, and the survey appears to add credibility to the (higher) IOCC projections.

The Nature of the Resource Base

The nature of the remaining U.S. oil resource base will play a vital role in the response of U.S. domestic oil supply to changing oil prices. **There is, however, substantial disagreement in the oil industry about the physical nature of the remaining resources, about where future U.S. reserves will come from, and at what price.**

A central issue in this resource base disagreement is the question of whether the major source of new reserves will be the discovery of large new oilfields, particularly in the frontier areas and deep offshore, or whether it will instead be the aggregation of many thousands of modest increments of reserves gained by drilling new wells in old fields, improving recovery through enhanced oil recovery techniques, and exploring for small fields in familiar producing territories. These different views of the remaining resources in the United States lead to different preferences for policy initiatives (e.g., different degrees of importance attached to expanded leasing of new frontier areas) and to different views of the oil prices necessary for a revival of higher levels of reserve replenishment. Frontier and deep off-

[8] Based on average 1985 production of 8,9 mmbd.

shore oil resources may, in many cases, require prices in excess of $30/bbl for economic development, whereas a considerable portion of the resources available from the smaller scale efforts are viewed as available at prices between $15 and $25/bbl.

The recent history of oil reserve additions generally supports the view that the aggregation of many small reserve additions, especially from the growth of discovered fields through extension well drilling and other mechanisms, plays the weightier role in overall U.S. reserve growth. For example, about 70 percent of total U.S. reserve additions during 1979 to 1984 came from drilling in oilfields discovered before this period, and the percentage of total reserves coming from this source has increased from earlier decades. However, those who view the frontier areas as the critical source of new reserves believe that the intensive drilling of the last decade and a half has already squeezed most of the reserve growth available from our older fields, and that any remaining growth requires much higher prices than before because the easy reserve targets were exploited first. Unfortunately for the advocates of searching for giant fields, however, the record of the past decade of oil exploration has not been very promising, with successes in offshore California and the Gulf of Mexico perhaps more than balanced by grave disappointments in the Gulf of Alaska, Georges Bank, St. Georges Basin, and elsewhere. Clear signs of this disappointment are the very large reductions in recent industry and government estimates of frontier resources,

Resolving the potential roles that continued field growth and giant new fields may play in the future development of the United States' oil resources may not be possible at this time. **Whatever the "correct" view of the resource base turns out to be, however, both the search for giant fields as well as the intensive pursuit of small-scale reserve additions must be pursued if the slide in U.S. production is to stand any chance of being halted.**

The Effects of the Natural Gas Surplus

The state of markets for natural gas is important to oil production. Much exploratory drilling searches for hydrocarbons, not specifically for oil or gas. Added incentives for finding gas will stimulate this type of "nondirectional" drilling and lead to more oil resources being found and developed—and inadequate incentives will do the opposite. Also, because gas is present in nearly all oil wells, the profitability of these wells depends on having a market for the gas at a reasonable price.

Since the early 1980s, a surge in deliverability and declining demand in the electric utility and heavy industry sectors have created a surplus of natural gas deliverability. Low oil prices have added to the gas surplus by promoting gas-to-oil fuel switching. The gas surplus has, in turn, kept gas prices low and kept some producers from having an assured market for their production. Although the reduced incentive for gas drilling has tended to help keep drilling costs low, the net effect on oil drilling is almost certainly negative. **A tightening of gas markets in the next few years, as predicted by many experts, would have a positive effect on drilling in general and would likely lead to increased oil well completions and production capacity. However, uncertainties about the volume of additional gas imports that could be made available from Canada, the actual level of excess deliverability, the volume of gas that could be quickly added to the deliverable base, and future changes in demand for gas have lead to a substantial divergence of opinion about the timing of any end to the current natural gas surplus.**

Changes in the Oil Industry Affecting Production

The Effects of Industry Restructuring

During the 1980s, the oil industry underwent important changes that seem likely to affect the industry's exploration and development strategies and financial capabilities. These changes have included a series of mergers, both voluntary and "hostile," as well as internal restructuring measures such as asset redeployment, stock-enhancement through stock buy backs, spinoff of new companies, asset sales, elimination and consolidation of functions, and other measures. While many of these changes are widely viewed as destructive of the industry's willingness and

capability to replace its reserves, some of the same changes are defended either as strengthening industry's reserve replacement capabilities or simply as being necessary to allow the participating companies to survive.

During earlier debate over the effects of mergers and acquisitions in the oil industry, many of the representatives of acquiring companies, their investment bankers, and their defenders strongly denied that exploration efforts would be reduced. Despite these assurances, mergers and acquisitions have been widely viewed as destructive of the industry's reserve replacement capability. Between 1979 and 1985, over $75 billion was spent on oil industry acquisitions in excess of $1 billion each, adding substantially to long term debt and presumably lowering the capital available for E&D spending. According to OTA's review of a group of companies, merged companies have spent substantially more of their available cash flow on debt repayment and less on oil and gas exploration than other companies. The merged companies typically cut combined capital spending significantly in 1984 to 1985, while other large companies in the group were more often maintaining or increasing their investments. In addition, a number of companies have added substantial debt in the process of fighting off attempted hostile mergers, or simply in preparing defenses against potential takeovers. **Despite potential long-term benefits of mergers such as improved management and improvements in the "fit" of assets and financial and management capabilities, the available evidence strongly suggests that the short-term effect of mergers and attempted mergers on the oil industry's investment in exploration and development has been negative on balance. Initial successes of some merged companies at reducing debt loads may, however, signal that this balance could change.**

A significant apparent change in industry behavior, more a cause of the restructuring than a symptom of it, is **a shift in emphasis among many integrated companies away from maintaining a secure domestic source of reserves to supply their refining and marketing operations, and away from the former high priority they gave to recycling much of their production revenues back into exploration and development.** Companies are now said to be evaluating E&D investment as a separate profit center, requiring each investment to meet stringent financial criteria. These behavioral shifts are said to be the result of both the financial losses incurred by many of these companies in their past E&D investments, and the easy availability of crude oil associated with the expanded role of the spot market. **If this widely perceived behavioral change is real and permanent, a return to previous levels of profit potential in production investments may not cause a return to previous levels of drilling and reserve replacement. This has negative implications for the likelihood of a "rebound" in production following a price increase.**

The Changing Business Climate Overseas

Industry experts consulted by OTA claim that one cause of the current low level of domestic investment in E&D is that the U.S. oil industry has decided to shift its domestic/overseas balance of E&D investments in favor of overseas investment.

In earlier years, many U.S. companies focused on domestic E&D despite the relative "maturity" of the United States' oil resources and the better geologic prospects overseas. They did this partly because of the greater stability and security available within the United States, but also because many oil-bearing countries offered relatively demanding terms for development of their oil resources.

Although problems of stability and security remain, **many countries have eased their terms for oil development. They have removed former caps on the prices paid to foreign developers, eased currency restrictions, lowered taxes and royalty rates, and otherwise improved the potential profitability of private oil and gas development.** At the same time, industry spokesmen have claimed the United States has enacted tax and regulatory changes that worsen the business climate for domestic oil and gas investment.

Evaluating the *relative* business climate for petroleum investments of the United States versus competing foreign nations is complicated, and OTA is not aware of a comprehensive attempt at such an evaluation. Nevertheless, **the attempts**

by many nations to ease investment restrictions and improve potential profitability in developing their oil resources clearly have increased the attractiveness of overseas investment vis-a-vis United States investment. In evaluating the effects of this increase, however, policy makers should keep in mind that most analysts believe that **any increased oil supply outside of the Middle East will tend to enhance market competitiveness and stability whether it occurs inside or outside of the United States—and that, dollar** for dollar, overseas exploration investments will tend to purchase considerably more oil reserves than will U.S. investments.

Changes in the Efficiency of Exploration and Development Activity

An accurate projection of the reserves found and production capability created by the sharply reduced levels of drilling and other oilfield activity caused by low oil prices requires an accurate estimate of the "efficiency" of this activity, as measured by the footage and wells drilled per rig, the reserves found per well, the wildcat success rate, and so forth. These measures have proved to be sensitive to oil prices and oilfield activity levels. For example, rig efficiency (footage and wells drilled per rig per year), reserves added per well or per foot drilled, and many other measures of efficiency declined from the middle 1970s to the early 1980s as oil prices rose and oilfield activity accelerated. Part of this decline was due to the *use* of inexperienced personnel and marginal equipment, made possible by the inability of the supply of services to keep up with the demand. Another element of decline was the spread of drilling activity to more marginal prospects with lower reserves and sometimes under more difficult physical conditions. This was partly a result of the improved economics of these prospects and partly an effect of resource depletion as the best prospects were used up.

The decline in oil prices that began in 1981 forced the industry to become more efficient. For example, drilling became more efficient as the number of inexperienced drilling crews declined, inefficient rigs were dropped from service, footage and turnkey contracts replaced contracts that paid drillers by the day (day rate contracts offered little incentive for efficiency), and drilling technology improved. These factors were important causes of the sharp increase in rig efficiency measured between 1981 and 1985. The industry drilled 89,000 wells in 1981 with nearly 4,000 rotary rigs active; 84,000 wells in 1982 with 3,100 rigs active; and 85,000 in 1984 with 2,400 rigs.

Unfortunately, however, the precise dimensions of the actual increase in efficiency are obscured by other factors that also affect measured rig efficiency. These factors include:

- the proportion of total drilling devoted to exploration, because exploratory drilling is more time-consuming than development drilling;
- possible changes in the number of rigs that are not included in the datag[9]; and
- shifts in the geographic distribution of drilling, because drilling in some areas, such as the Gulf Coast, is more rapid than in others, e.g., the Midcontinent and Rocky Mountain Overthrust Belt, because of different rock conditions and other physical factors.

Similarly, **as the industry cuts budgets and drilling rates and retreats from marginal areas with high costs and low payoffs, measures such as reserves added per well or per dollar invested should improve. Consequently, reserve additions should not drop quite as precipitously as drilling or drilling budgets have. This effect will be tempered, however, by a likely shift in drilling patterns away from deep, high risk exploratory drilling (see the earlier discussion on the Economics of Drilling Prospects), and** also toward shallower and lower risk (but potentially lower yielding) targets. Also, drilling patterns are affected by company lease positions and contractual obligations.

Figure 4 shows the regional variation in oil reserves added per well, illustrating the potential effect of shifting the geographic distribution of drilling.

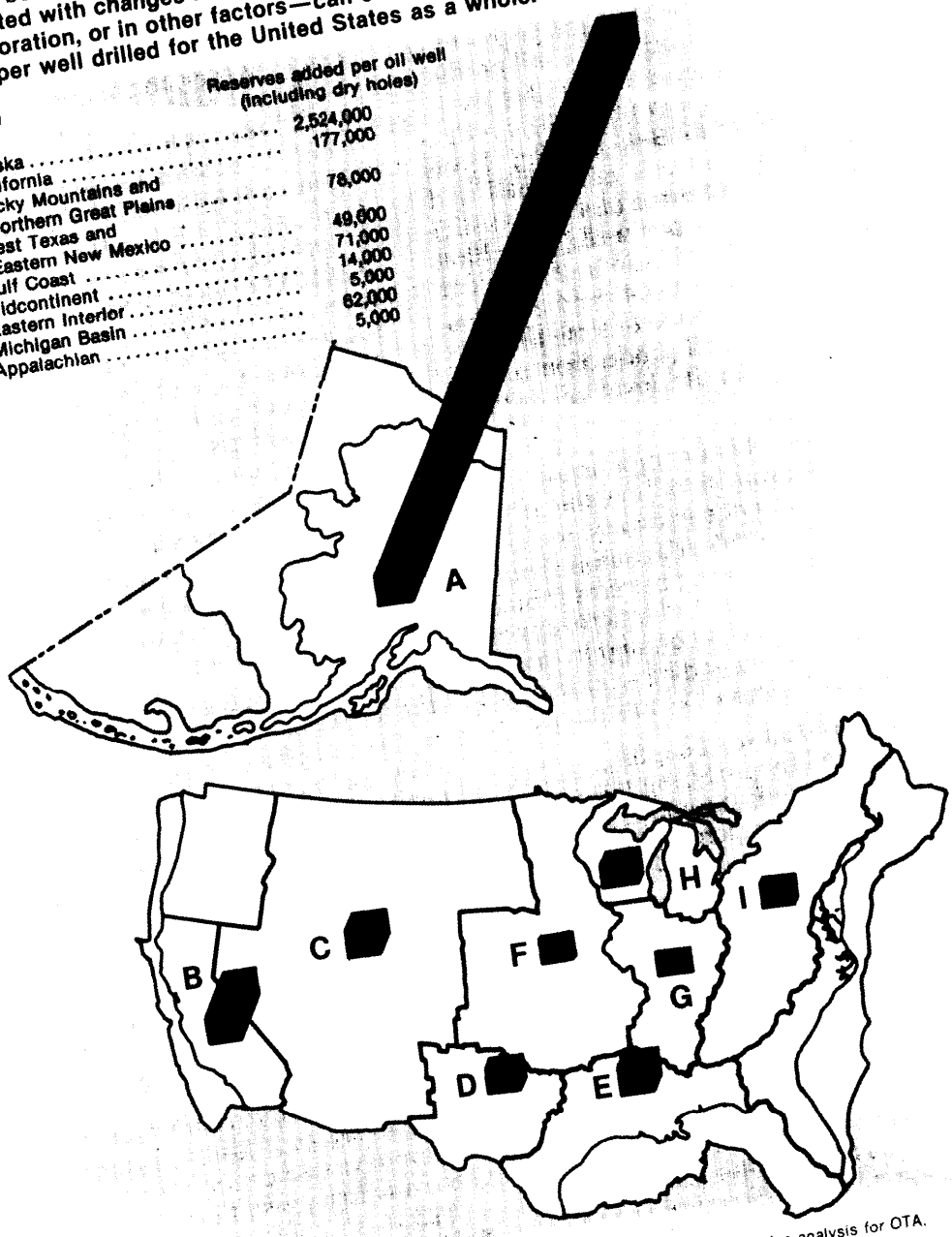
Shifts in drilling during the early part of 1986 seemed to follow the expected pattern of retreating from regions with low average returns. If only

[9]Commonly used rig counts include only so-called rotary drilling rigs, rigs that drill by rotating a drill bit and its attached drilling pipe.

Figure 4.—Regional Differences in Oil Reserves Added Per Well Drilled

The physical reward of drilling, measured in reserves added/well, varies considerably from region to region. Aside from these regional differences, other important factors affecting reserves/well values include the relative markets for oil and gas and the split between development and explanatory drilling. **Shifts in drilling patterns—associated with changes in the geographic distribution of drilling in the emphasis on exploration, or in other factors—can create marked changes in the oil reserves added per well drilled for the United States as a whole.**

Region	Reserves added per oil well (including dry holes)
A Alaska	2,524,000
B California	177,000
C Rocky Mountains and Northern Great Plains	78,000
D West Texas and Eastern New Mexico	49,000
E Gulf Coast	71,000
F Midcontinent	14,000
G Eastern Interior	5,000
H Michigan Basin	62,000
I Appalachian	5,000



SOURCE: Office of Technology Assessment, 1987; based on Congressional Research Service analysis for OTA.

the regional shifts in drilling are considered, the reserves added per average U.S. well in 1986 could be 37 percent higher than the 1981 to 1984 United States average.[10]

Although this estimate could be interpreted as optimistic for U.S. oil supply, in fact it is sobering. Even if these reserve/well values are correct —and they are almost certainly too high—they still imply a substantial drop in U.S. oil production if recent drilling levels continue. For example, estimating Alaskan and stripper well production separately, **if mid-1986 drilling levels continue for the next decade and a half and achieve the regionally adjusted (and optimistic) values of reserves added per well, year** 2000 **United States production will still be 29 percent below 1985 levels, or about** 6.4 **mmbd. Thus, the United States cannot hope to slow the current decline in domestic oil production unless it increases substantially its level of drilling activity.**

A reliable projection of future production rates requires an accurate estimate of how the industry will adapt its investment behavior to the new price environment. Since this adaptation should take a few years, current drilling patterns should not be viewed as permanent. At this time, a projection of likely adaptive behavior, and its likely effect on reserves/well values and other measures of E&D efficiency, will clearly be speculative.

Insight on the potential for adapting to low prices might be gained by analyzing the differences among individual oil companies' historical investment patterns, management styles, and investment outcomes. Some companies, such as Shell Oil, have had consistently low finding costs over the past decade or more. If the more successful companies have simply occupied low cost "niches" in domestic E&D, their success may not offer much room for hope that the rest of the industry could, with appropriate changes in investment behavior, successfully match their cost performance. On the other hand, if their success is owed primarily to behavior that could be copied by the rest of the industry, the long-range outlook for production might look considerably better.

101986 drilling based on July 1986 projections.

The Effects of Technological Change

The continuing evolution of oilfield technology, particularly as it may facilitate the exploitation of existing resources at lower cost, clearly is an important factor in the ability of the industry to keep reserve replacement and production close to historic levels in the face of low oil prices. In general, however, **the majority of the operators and analysts we talked with were skeptical of the potential for both new technology and improvements in existing technology to allow access to significant volumes of oil that currently are uneconomical at prices below $20/bbl. In support of this view, statistics of important measures of exploration and development efficiency-such as reserves added** per well drilled and exploration success rates—have either held steady or deteriorated over the past decade despite the introduction of such technologies as three dimensional seismic analysis, seismic interpretation with personal computers, advanced reservoir modeling, and an array of others. **If technology development has made a difference during the past decade, especially in the onshore lower** 48 **States, it appears to have been primarily one of counterbalancing the negative effects of continuing resource depletion.**

Nevertheless, **there is a significant minority in the industry who have a far more positive view of the potential of improved oilfield technology.** They can point to a number of new technologies just being deployed, or on the immediate horizon, that have promise for lowering industry costs enough to either allow development of additional resources at current low prices, or at least to allow added resource recovery at prices significantly lower than previously thought possible, often in the lower $20/bbl range. These technologies include:

- important improvements in the resolution capability and cost of seismic imagery;
- new developments in chemical enhanced recovery that lower the price threshold from $25 to $30/bbl to about $20/bbl; and
- improvements in horizontal drilling that offer the potential of expanding a field's recoverable reserves by allowing operators to exploit thinner pay zones.

Even if industry optimists are correct, the potential of new technology will not be realized without a significant R&D effort on the part of the industry. Although precise figures are not available, industry observers agree that industry R&D expenditures are down by at least ***30*** or ***40*** percent over the past 3 years. Although some cutbacks clearly are appropriate (e.g., for efforts aimed at accessing very high-cost resources in difficult environments that are not now technically recoverable) the overall size of the cutbacks and a general shift away from long term research targets are of substantial concern.

Effects of a Deteriorating Industry Infrastructure

The large drop in industry activity levels accompanying the price drop has meant a shrinking of the industry's "in frastructure," that is, the inventory of rigs and other equipment used in exploration and development activity, the manufacturing capacity to produce the equipment, and the people to man the equipment and plan and supervise its use. The industry has expressed the concern that, in the event of an oil price rise or other incentive for a "rebound" in activity levels, the lack of infrastructure would mean severe delays, inefficiency, and cost inflation as too much demand for oilfield goods and services chases too little supply–a repeat of the hyperinflation in these goods and services that marked the middle to late 1970s and early 1980s.

Any rapid improvement in E&D investment prospects, fueling increased demand for oilfield goods and services, will create delays and inflationary pressure, but increasing effective oilfield activity should be less difficult and inflationary than it was in the 1970s. One reason for this conclusion is that the level of activity of the earlier drilling "boom" was much higher than was justified by the results, primarily because drilling rigs were operated inefficiently, inadequate equipment was used, and many wells were drilled with minimal prospects for success. Thus, **it is not necessary to return to 1981** *levels* **of active rigs or employment to achieve 1981 levels of reserve additions and added production capacity.** Another reason is that most oilfield equipment is relatively sturdy and will not deteriorate excessively if moderate precautions are taken i n storage. Finally, in recent years there has been an oversupply of trained workers and professionals in the industry, and there is little reason to believe that most of these have been irrevocably lost to other fields. **A *2,500* rig fleet, operating efficiently, probably can achieve the same results as a 4,000 rig fleet did in 1981. For now and for at least another few years, there should be adequate equipment and personnel to assemble and operate such a fleet relatively quickly —perhaps within 6 months to a year. However, this conclusion presupposes that a rebound in oilfield activity levels will be accompanied by investor and industry confidence that the rebound will not be short-lived, so that contractors will be willing to invest in refurbishing rigs, laid off workers will be willing to return, etc. This is not necessarily a foregone conclusion given the "lesson" administered by the recent price drop. Also, the capability for a rebound will decline over time.**

Policy makers should recognize that OTA's guarded optimism about the ability of industry infrastructure to support a rebound in activity is not shared either by the National Petroleum Council or the Department of Energy. Their respective reports, *Factors Affecting U.S. Oil and Gas Outlook* and *Energy Security,* both identify the destruction of the industry's infrastructure as a key roadblock to a drilling recovery.

Resisting a Decline in U.S. Oil Production: Should Government Play an Active Role?

For reasons encompassing both national security and U.S. economic competitiveness, many energy analysts and significant segments of the oil industry (especially the independent producers) are arguing that the Federal Government should intervene to halt or ameliorate the expected decline in U.S. oil production.

The policy preferences of Federal policy makers are likely to depend on how they would answer the following two questions:

1. Will declining domestic oil production seriously damage U.S. economic and national security interests? and

2. Can Federal intervention succeed at stabilizing domestic crude oil production without incurring unacceptably high costs (in terms of direct consumer spending, Federal budget impacts, or market distortions)?

Properly addressing both of these questions requires a comprehensive examination of U.S. and world energy supply and demand, not merely an examination of domestic oil production. For example, the shift in oil trade away from long term contracts to the spot market has served to make the world oil market more unified. With the present market structure, new discoveries and production capabilities anywhere in the world–and especially outside of the Middle Eastern OPEC nations–contribute to market stability and thus to U.S. economic and national security interests, Similarly, the ability of energy consumers to switch to other fuels, improve their efficiency of energy use, or even shift the basic structure of their economies will affect their reliance on oil. Consequently, an evaluation of United States crude oil production can provide only a piece of a larger puzzle, albeit an important piece. In the following discussion, we address the above questions in the limited fashion allowed by the bounds of our analysis.

Will Declining Domestic Oil Production Seriously Damage U.S. Economic and National Security Interests?

If imports provide the least expensive source of oil, should we care if U.S. domestic oil production decreases and import dependence rises? Are the potential damages from rising import dependence large enough to justify the costs to the U.S. economy of subsidizing domestic oil production or taking other measures to restrain import levels? This question forms the core of a serious policy dispute. Unfortunately for policy makers, there are a number of substantive opposing arguments as well as significant uncertainties about this issue.

Advocates of oil import fees and other measures designed to forestall added U.S. dependence on oil imports believe that both economic and national security interests justify the costs of such measures. They note that the drop in oil industry investment has hurt significant sectors of the national economy as well as the economies of oil-producing States such as Texas, Oklahoma, and Louisiana, and that expanded imports hurt the U.S. trade balance. Perhaps most important from an economic standpoint, they believe that expected increases in oil demand and decreases in non-OPEC oil production capacity will soon return market control to OPEC and thus restore the potential for future price shocks and accompanying economic disruption. As for national security, the industry points to the strategic importance of oil to the United States, both for itself and even more for its allies, and the likelihood that increased import dependence will translate into an increased vulnerability to future oil disruptions.

These arguments must be balanced against the potential negative impacts an import fee or the like would have on the U.S. economy, as well as arguments that the national security implications of rising oil imports have been tempered substantially by economic and physical changes that have occurred since the earlier price shocks.

The negative economic effects of an import fee are viewed as including an increase in the rate of inflation, a decline in gross national product resulting from reduced discretionary income, and a decline in trade competitiveness among the United States' energy-intensive industries (e.g., chemical products). Balancing negative and positive impacts requires extensive, sophisticated economic analysis, with the best analyses yielding results that will still be highly sensitive to arguable input assumptions.

Changes in oil markets and the U.S. economic structure that have occurred since the early 1970s, combined with certain insurance measures such as the Strategic Petroleum Reserve, have likely made the United States less vulnerable than previously to future oil price shocks and supply disruptions. For example, the growth of a large spot market in crude oil has made embargoes extremely difficult to enforce and should act to curb the "inventory panic" that in the past served to escalate prices rapidly at the first signs of a shortage. Other positive changes include:

- the U.S. decontrol of oil prices, which allows a more rapid market adjustment to changes in oil supply and prices;

- the increase in diversification of producing countries, which adds stability to world supply;
- the increase in oil stocks held by Japan, West Germany, and other U.S. allies; and
- the growth of natural gas supplies throughout the world, which allows for substantial fuel-switching capability in industrial and electric utility markets.

Although these improvements in the U.S. strategic situation do not imply that growing oil import levels represent no threat, they do imply that comparisons with earlier years must be viewed cautiously.

To keep these arguments in perspective, it is important to understand where U.S. oil production was heading before prices dropped so precipitously. **Even before the sharp 1986 declines in world oil prices, most energy analysts were predicting a future of declining domestic oil production and increasing imports.** For example, one so-called "consensus view" of future U.S. production under previous price expectations (prices in the mid to low $20s/bbl for a few years and a gradual increase thereafter) had U.S. production declining from about 8.9 mmbd in 1985 to below 7 mmbd by 1995 and below 6 mmbd by 2000. Therefore, **the recent price drop might be said to have advanced by 5 or 10 years a process of declining U.S. production that most industry analysts believe would have occurred anyway because of the maturity, and thus declining prospects, of the U.S. resource base.**

Not all analysts would agree with this view. A minority of oil analysts believe that U.S. production could have been maintained at stable levels for another few decades had oil prices held up and had the industry expanded its efforts to attain increased recovery from its older fields. This more positive view is based on an optimistic assessment of the remaining oil resources that can be recovered by more intensive drilling as well as by enhanced recovery. If correct, this view implies that the "cost" of the price drop to the United States, in terms of lost domestic production capacity, could be considerably greater than implied by the more pessimistic pre-price drop production forecasts.

Policies To Bolster U.S. Oil Production

Advocates of government action to slow the decline in U.S. oil production have suggested a variety of potential solutions, Most involve substantial present or future costs; all of these are opposed by powerful constituencies.

OTA has not undertaken the kind of comprehensive evaluation that policy makers must have before deciding on a specific course of action. Although the results of OTA's study offer a number of insights about the effectiveness of specific policies, we were not able to measure the actual effects on oil production of the policies nor their net social costs.

1. **Oil Import Fees.–Oil import fees may be structured** either as a constant dollar addition to the prevailing price of imports or as a sliding fee designed to raise import prices to a predetermined value (e.g. $25/bbl). An interesting alternative is a price floor, deliberately set below prices prevailing at the time of enaction, designed to guard against future price drops and thus to ease the downside risk of new production investments.

To the extent that an import fee raises domestic oil prices higher than prices that would have occurred without it,[11] it will raise industry revenues and improve the prospective profitability of new production investments. This in turn will ensure that oil investment and production will also be higher than without the fee, at least for a considerable period. For example, **OTA's economic analyses show that for the small scale development and exploratory drilling prospects examined, increasing oil prices from $1s to $20/bbl raised expected rates of return to the levels expected in 1981,[12] when oilfield activity was at a peak. Such an increase in expected profitability would be bound to stimulate new oil investment.** However, policy makers must be con-

[11] Over the long term, an import fee might help to hold down world oil prices by reducing the demand for imports and thus reducing OPEC market dominance. It is therefore quite conceivable that the net domestic oil price could eventually be lower than it would have been in the absence of the fee.

[12] Assuming drilling costs would not rise. This assumption will be reasonable only if any increase in drilling activity stimulated by the price rise was not so large as to use up much of the current surplus of drilling capacity.

cerned about the cost to consumers of higher oil prices, both directly and as a result of higher manufacturing costs, and the effects of such higher costs on the U.S. balance of trade. In addition, because of uncertainties about the resource base, the effects of structural changes in the industry, and other factors affecting production, policymakers cannot predict with a high **degree of confidence how much additional production will be "purchased" with an import fee. There is little agreement in the industry as to what oil price would be necessary to stabilize production—or whether it is even possible to do so.**

Based on OTA's conversations with industry planners, the sharply perceived threat of future plunges in oil prices plays an important role in industry reluctance to invest, especially for longer term projects. If this is so, the institution of a provisional tax designed to establish a price **floor below current price levels–possibly at $15/bbl —could also boost investment at no immediate cost to consumers. OTA's** economic analyses reveal some of the potential of such a price floor. For small-scale development and exploratory drilling, **using a $10/bbl "hurdle price" to guard against future price risk transforms an attractive prospect at $15/bbl—with a projected real (before tax) rate of return of over 15 percent—into an outright loser. Thus, for investors who feared future price drops, a price floor could provide the assurance necessary to proceed with drilling.**

The perceived attractiveness of a price floor depends in large measure on the policy maker's expectations for future oil prices. If he expects prices to stay above $15/bbl at most times, with occasional brief declines below this price, a $15 price floor looks particularly attractive because it reduces risk at a low cost. On the other hand, if he envisions prices plunging below the floor price for extended periods, the consumer cost and balance of trade questions may become paramount.

2. **Tax Concessions.—OTA** examined the effects of several tax changes on the expected profitability of small-scale drilling. These changes included reinstituting investment tax credits (of 20 percent), allowing a 27.5-percent depletion allowance for all producers, cutting severance and ad valorem taxes in half and to zero, and instituting a 20-percent drilling credit. **For the small-scale drilling examined, lower State taxes and additional tax credits for Federal income taxes improved the prospective profitability of new investments, with a 20-percent drilling credit and a higher depletion allowance having the greatest effect. However, none of these measures achieved nearly as much of an increase in profitability as a $6/bbl increase in oil prices.[13] For example, for the development wells examined, cutting severance taxes in half added about 2 percentage points to the real after tax rate of return, whereas adding $6/bbl to the oil price increased the return by between 12 and 17 percentage points.**

Industry spokespersons have claimed that the new tax code will hurt the industry's investment capability. An examination of this claim is beyond the scope of this study. However, OTA did examine the effect of the new code on the profit expectations for a series of small scale exploration programs. **Contrary to OTA's expectations, the calculated after tax return on investment from a number of small exploratory drilling programs was slightly higher under the new tax code than under the old.** For these cases, the benefits of the lower tax rates in the new code outweighed the loss of the investment tax credit. Were company profits low or nonexistent, however, the lower tax rates would have little value and the loss of the investment credit would have been the primary factor. The alternative minimum tax in the new code, not accounted for here, may also affect the balance of the old and new codes.

The industry has been united in its advocacy of repeal of the Windfall Profits Tax (WPT), which was originally enacted to prevent domestic producers from obtaining a financial windfall from the decontrol of domestic oil prices. Although the tax is not collected at today's lower oil prices, it represents both an administrative burden to the industry and a disincentive to **E&D** investment, especially for projects with delayed production starts and for investors who expect oil prices to rise significantly during the production lifetime

[13] The reader is reminded that a fair comparison of alternative policy measures requires an estimate of costs as well as results. Ideally, policies should be judged based on a measure of (production gained) /(cost).

of the project. The magnitude of the investment incentive represented by WPT repeal depends on the price expectations of the oil companies; given the wide range of announced price forecasts and the current turmoil in the market, estimates of the oil production potentially added by repeal will be especially uncertain,

3. **Removing the Ban on Oil Exports From the United** States.– Federal law currently prohibits the export of Alaskan North Slope crude oil from the United States. The effect is primarily to force the shipment of Alaskan crude oil via high-cost domestic tankers to a saturated west coast market or all the way to gulf coast or east coast markets. Were Alaskan oil to be shipped via lowest cost tankers to Pacific markets, the reduced shipping costs would yield a significantly higher net back price to the producer; additionally, reduced pressure on west coast markets would likely raise producer prices there as well. **The Minerals Management Service has estimated the prospective increase in Alaskan wellhead prices resulting from an end to the export ban to be** $2 **to** *$3/* **bbl;** others have estimated the increase to be as high as $4 or $5/bbl. Even at the lower end of the range, **the price differential represents a significant percentage of current well head prices,** because these are kept well below world oil price levels by the Trans-Alaskan pipeline fee (about $6/bbl) and other shipping and tax costs.

4. **Bolstering Investment in** R&D.—Improving the technology of exploration, development, and production is an important means by which the oil industry can minimize the negative effects on oil production associated with continuing low prices. As noted earlier, however, the industry has been cutting back on R&D in line with its decreasing oil and gas revenues. In particular, the oilfield service sector has played a major role in previous industry R&D, yet has absorbed the brunt of financial damage associated with the price drop.

Research and technology development that could help the industry stem the production slide at low prices include:

. improved understanding of the potential for adding new reserves in older fields from conventional drilling;
- improvement in enhanced oil recovery technologies, and better understanding of how to apply them to a wide variety of geologic situations;
- improvement in the resolution and cost of seismic analyses, to allow the wider use of pre-drilling geologic analysis, to reduce dry hole risk, and to allow better placement for development wells; and
- further development of offshore production technologies that negate or moderate the requirement for giant production platforms.

The first three research areas might be included in a more general program aimed at improving the state-of-the-art in petroleum geosciences (i.e., improving our understanding of where the oil is in a reservoir, how it moves, and how it can be recovered).

Policies to bolster R&D appear especially attractive because they are an order-of-magnitude less expensive than direct economic incentives for increased production. However, policy makers must recognize that most industry planners believe that technological change can play only a modest role in stopping a production slide in the face of continuing low prices. Also, designing a policy measure that will provide an efficient incentive to promote *effective* R&D is not likely to be easy, with particular problems being industry fears about losing proprietary advantages, the potential for government direction to be out of touch with industry requirements, and the difficulty of restricting the benefits of incentive programs to the primary R&D objectives.

Suggested policies for bolstering R&D include:

- government sponsorship of industry/university cooperative projects,
- allowing intra-industry cooperative projects by granting anti-trust exemptions,
- direct government assistance in the form of grants and contract awards,
- government-directed research projects, and
- tax incentives.

5. Removing Leasing Restrictions on Frontier/ Offshore Areas.–Industry groups have long urged the Federal Government to open up a variety of publicly owned properties to oil explora-

tion and development as a means of bolstering domestic oil reserves and production capacity. This recommendation has become more urgent in light of the recent oil price drop and its projected negative impact on domestic production. Two of the primary target areas are the California offshore basins and the Arctic National Wildlife Refuge (ANWR); both have potential recoverable oil resources of a few billion barrels. Both of these areas have been held from leasing because of environmental objections. For California, the primary objections involve the potential effects of spills on vulnerable ecosystems and high-value recreational areas and the air quality problems associated with production, transportation, and other ancillary facilities associated with development. For ANWR, the primary objection is the potential danger to the Porcupine Caribou herd and to other important species, and the loss of the area's wilderness character.

Arguments about opening these areas to oil exploration and development center about three types of questions:

1. Are the estimates of environmental impacts accurate?
2. Will development of the areas really make a difference in the United States' long-term strategic position vis-a-vis energy supply?
3. Which are more important, the environmental values that would be preserved by foregoing development or the energy supplies that would be made available? Is it possible to have development while protecting *most* of the environmental values.

These questions have been extensively aired in the media and in reports and congressional testimony, and there is little OTA can add at this time. One point worth making, however, is that volumes of oil obtained from these areas should be compared to rates of domestic oil production, and *not* to total U.S. energy consumption, as is sometimes done to illustrate the supposed insignificance of the resource. By the time areas such as ANWR could be developed—not much before 2000–oil will be even less interchangeable with alternative fuels than it is now, assuming the share of oil used for transportation fuel or chemical feedstocks continues to grow.