U.S. Energy Strategies:

some Options for Eliminating Oil Imports by the year 2000

The MITRE Corporation

April 1981

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Foreword

In October 1980, the Metrek Division of The MITRE Corporation undertook a study, from an engineering perspective, of options for eliminating or substantially reducing our nation's requirements for imported oil by the year 2000. This study is a part of our ongoing Energy and Resources work program and was supported by corporate Internal Research and Development funds. The major finding of this study is that, if judged desirable, it is possible, using reasonable choices for increases in energy supply and reductions in demand, to eliminate the importing of oil over the next twenty years with an investment outlay less than the cost of the presently projected oil imports over the same period.

Though energy professionals are generally aware of what is possible, we believe a clear, simple statement of such possibilities has not been made to a general audience. We therefore distribute this report believing it to be a basic and useful input to the national energy dialogue. The study will be updated periodically.

In this study we did not consider the effects of oil supply interruptions on the U.S. economy, our treaty obligations to other countries in the event of global scale supply interruptions, the economic equity questions associated with various options or the effects of emerging environmental concerns such as the buildup of carbon dioxide in the atmosphere or acid rain deposition in various parts of the world. Also, the study did not attempt to predict the outcome of major governmental and private research and development activities, but instead, it has relied on presently available supply and energy use options in seeking means of reducing dependence on imported oil. New technical capabilities or difficulties not accounted for in this study could considerably affect the options chosen for import reduction.

To permit options identified in the study to be implemented, a consensus will be necessary among various interest groups: to ensure that environmental laws and regulations emphasize health and safety standards over aesthetic standards; to stabilize the investment climate by removing uncertainty in siting and permit decisions, by limiting the amount of intervention that can take place once projects are underway and by removing uncertainty of financial incentives and energy efficiency regulations; to modify or repeal the Fuel Use Act for industries and utilities to allow the use of natural gas; to accelerate the exploration of all geologically promising areas, including public land; and, to streamline regulations and relieve institutional constraints to ensure the availability of the most cost effective means for the transportation of all energy forms.

This report includes a summary, a description of the approach used in the study, and a concise presentation of the study's major findings. Extensive backup material, which can be used for detailed discussion of the facts, interpretations and options presented in this report, is available at MITRE's Metrek Division, McLean, Virginia.

Study Approach

The study was performed by first developing a baseline energy demand projection for the year 2000. As a conservative frame of reference, the baseline projects a total U.S. energy demand in the year 2000 of 50.5 million barrels per day oil equivalent, including demand for 14.5 million barrels per day of liquid fuels. This scenario is adapted from the "Middle Oil Price" case ($65 per barrel in 1980 dollars) in the 1980 Annual Report to Congress by the Energy Information Administration of the U.S. Department of Energy. The major differences are that our baseline assumes: no synthetic liquid fuels industry; less conservation, particularly in the residential/commercial sectors; and a more conservative estimate of domestic petroleum production capacity in the year 2000. These assumptions lead to a baseline oil import level of 5.8 million barrels per day in the year 2000.

Each domestic energy supply resource was then examined and its probable contribution to energy needs in the year 2000 was estimated based on published information, and interpreted where necessary by the MITRE staff. *For the range of parameters of this study, it was determined that liquid fuels are the only critical domestic energy resource in the year 2000.*

Options to provide increased supplies of domestic liquid fuels were developed. Similarly, options to reduce the demand for liquid fuels below the levels projected in the baseline were generated. These options are characterized as follows.

Technically Feasible
Domestic resources and proven technology are used to produce conventional petroleum and synthetic liquid fuels or reduce demand for liquid fuels at prices competitive with the projected world oil price. We assume a streamlined permitting process and a stable regulatory environment without changes in the existing levels of protection for health and safety.

Reasonable Choices
Significantly less than the technically feasible potential, these levels of supply increase and demand reduction would require industry investments and government support to continue current interest in increasing domestic energy options. No changes in the existing laws to protect health and safety are contemplated. People with perspectives different from the MITRE team could arrive at different reasonable choices.

Business as Usual
The domestic liquid fuels supplies come from the primary conventional sources, conventional oil, natural gas liquids and enhanced oil recovery and there are no reductions in demand in the year 2000 beyond those projected in the baseline energy demand.

All costs and prices throughout this report are expressed as 1980 dollars.

Summary

All Costs in 1980 Dollars

We conclude that with a national consensus that includes the national and local government policy makers, business, industry and the public, the United States can become independent of foreign oil by the year 2000. This may be accomplished while maintaining a real growth in Gross National Product, consistent with U.S. Department of Energy projections, of 2.5 percent per year—from our present (1980) $2.7 trillion to $4.4 trillion in the year 2000.

Elimination of imported oil may be accomplished in a variety of ways. The objective of this study, which was commissioned by the Board of Trustees of The MITRE Corporation, was to review options for reducing oil imports from an engineering perspective. The review has been based on published information, interpreted where necessary by MITRE's energy systems and resources staff.

The magnitude of oil imports in the year 2000 is very sensitive to the real growth in Gross National Product and the cost of energy. Since neither of these factors can be accurately predicted, this study has used values consistent with U.S. Department of Energy projections for a "Mid-Oil Price" scenario.

Although we have not identified a most cost-effective mix of increases in domestic energy supply and reduction in demand, we have identified a set of *reasonable choices* from among known resources, well within technical possibilities, with which the United States can eliminate the need for imported oil by the year 2000.

Domestic Liquid Fuels Are the Critical Energy Resource

Over the next 20 years our nation's total energy demand is projected to grow at an average rate of approximately 1.6 percent per year[1], from the present (1980) 37 to 50.5 million barrels of oil equivalent per day in the year 2000. This estimated year-2000 total United States energy demand is slightly larger than that estimated by Exxon in its recent "World Energy Outlook," issued in December 1980. Demand in the year 2000 for coal, natural gas and electricity is expected to be satisfied with little difficulty. Coal for all uses is in abundant domestic supply. Recent activity in natural gas adds to our confidence that over the next two decades, coal, gas and nuclear power plants should be able to satisfy electricity demand as it grows at a declining rate.

Domestic Liquid Fuel Supplies Can Be Developed

The total year-2000 demand of 50.5 million barrels of oil equivalent per day includes 14.5 million barrels of oil equivalent per day of liquid fuels. *Business as usual* estimates for conventional domestic liquids provide only 8.7 million barrels of oil equivalent per day toward meeting this demand. *Reasonable choices* for increasing

[1]For purposes of this study, energy and gross national product growth rates (1.6 and 2.5 percent per year, respectively) are not analytically coupled. The values were chosen independently on the basis of recent historical data. Significantly different growth rates could lead to significantly different results in terms of the need for energy in general and liquid fuels in particular.

enhanced oil recovery, coupled with development of a coal derived liquids industry, shale oil production and biomass conversion to liquid fuels, could raise the available domestic supply to about 13 million barrels of oil equivalent per day. This is far short of the *technically feasible* and more costly upper limit of domestic liquid production and manufacture of 21.4 million barrels of oil equivalent per day.

Reduction in Demand for Liquid Fuels Is Also Needed

Coupled with these options for increasing domestic liquid fuel supply are *technically feasible* options for fuel switching and improvements in end-use efficiency which could reduce the demand for liquid fuels from 14.5 to 9.5 million barrels of oil equivalent per day in the year 2000. *Reasonable choices* from among these options, primarily in automotive efficiency improvements and fuel switching in the residential and industrial sectors, would result in a liquid fuels demand of 12.7 million barrels of oil equivalent per day in the year 2000.

The Economic Impact Is Manageable

Achieving the *reasonable choices* liquid fuel supply increases and demands reductions will require a capital investment increase of $200 to 320 billion over the *business-as-usual* investment of $390 to 470 billion for liquid fuel supply over the next 20 years. *These total investment requirements are on the order of 26 to 34 percent of the expected cost of $2.3 trillion we would otherwise pay to foreign sources based on the average 1980 rate of oil imports.* National and local government policy makers, business, industry and the public are likely to make the decisions needed to achieve these reasonable choices only if the following prevail: moderate interest rates; stability in the incentive and regulatory climate; greater understanding of our total resource base; expeditious energy facility siting decisions; and freedom from limitations on fuel price or inhibitions to fuel switching. In addition, some relaxation in environmental standards relative to aesthetics, but not health and safety, may be required.

The analysis summarized herein indicates the range of *reasonable choices* to eliminate the need for imported oil while maintaining the health of the nation's economy. These choices do not represent the full range of national strategies. *They demonstrate that we can, at an investment cost of 26 to 34 percent of the potential cost of oil imports over the next 20 years, eliminate or dramatically reduce our dependence on imported oil.* These percentages rise to a range of 39 to 53 percent if the cost of imported oil is assumed to increase during the next twenty years only at the average inflation rate.[1]

These choices are by no means the only or the actual way our energy future may evolve. We intend to follow the nation's progress in developing domestic energy supplies over the next several years and to update this analysis periodically, thus providing a basic and useful input to the national energy dialogue.

[1]The baseline projects a year-2000 price for imported oil of $65 per barrel in 1980 dollars. The price remains at $31.50 if oil prices increase at the average inflation rate.

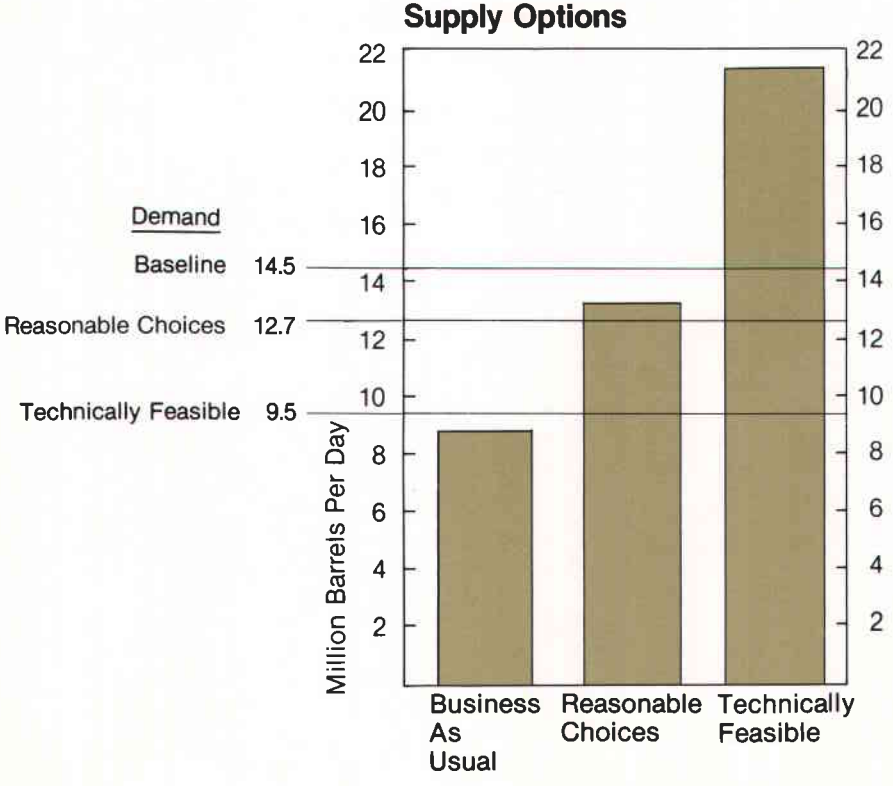
Reasonable Choices Which Eliminate the Need for Oil Imports

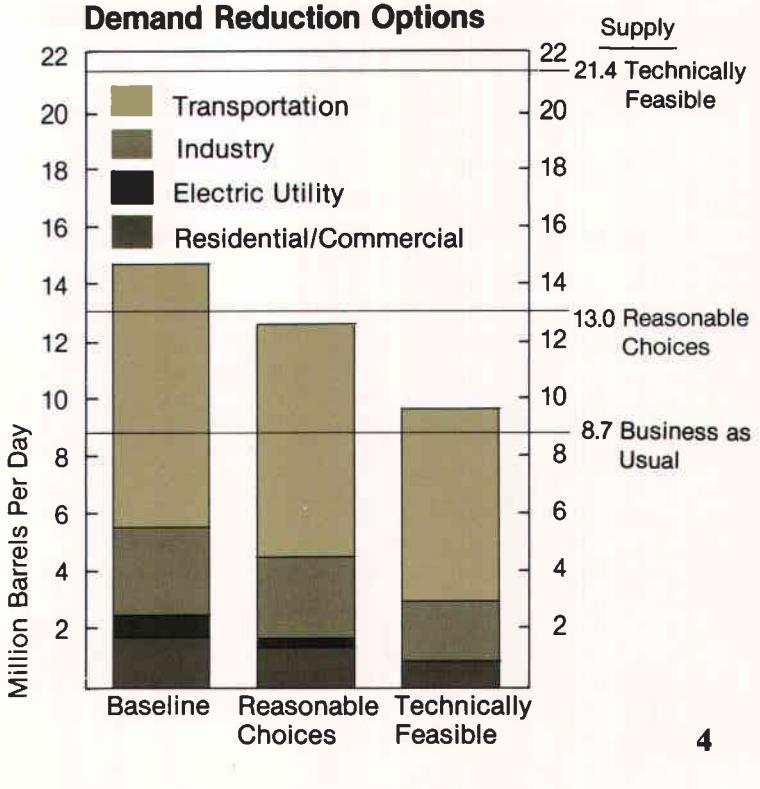
By using reasonable choices for increasing domestic liquid fuel supplies and reducing liquid fuel demand, there are many ways to eliminate the need for imported oil in the year 2000. One set of such choices is presented.

The *reasonable choices* for domestic liquid supply of 13 million barrels of oil equivalent per day (mmboe/day) include:
6.7 mmboe/day conventional petroleum;
2.0 mmboe/day natural gas liquids;
1.4 mmboe/day enhanced oil recovery;
1.2 mmboe/day coal liquids;
1.2 mmboe/day shale liquids; and
0.5 mmboe/day biomass liquids.

The *reasonable choices* for reducing liquid fuels demand by 1.8 million barrels of oil equivalent per day (mmboe/day) beyond the baseline of 14.5 mmboe/day include:
0.82 mmboe/day in Transportation;
0.21 mmboe/day in Residential/ Commercial;
0.48 mmboe/day in Industry; and
0.25 mmboe/day in Utilities.

The options selected may not represent the most cost-effective combination but are representative of what could reasonably be accomplished by the year 2000.



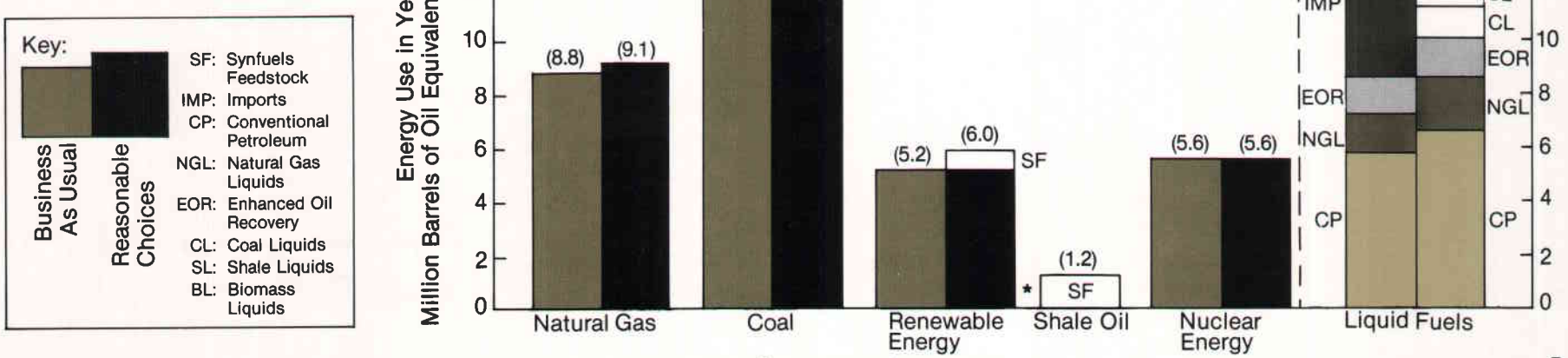


Implementation of reasonable choice supply increase and demand reduction can eliminate the need of oil imports. Primary energy supply must increase to provide feedstock and energy for synthetic liquid fuels production and, in the cases of coal and natural gas, to provide for fuel switching in the residential/commercial, industrial and utility sectors.

To meet total energy needs, the projected demand for natural gas, coal, renewables and nuclear power in the year 2000 are all within the projected supplies of these resources.

The capital costs in 1980 dollars for the reasonable choices supply and demand—reduction options are estimated to be $590–790 billion over the next 20 years, with $390–470 billion for conventional domestic liquids, $150–200 billion for alternate domestic liquids and $50–120 billion for demand reduction through fuel switching and efficiency improvements.

Energy Supply for the Year 2000
Business As Usual vs. Reasonable Choices
Including the Effects of Reasonable Choices Demand Reduction



*No Shale oil use under Business as Usual conditions.

Potential Domestic Liquid Fuel Supplies

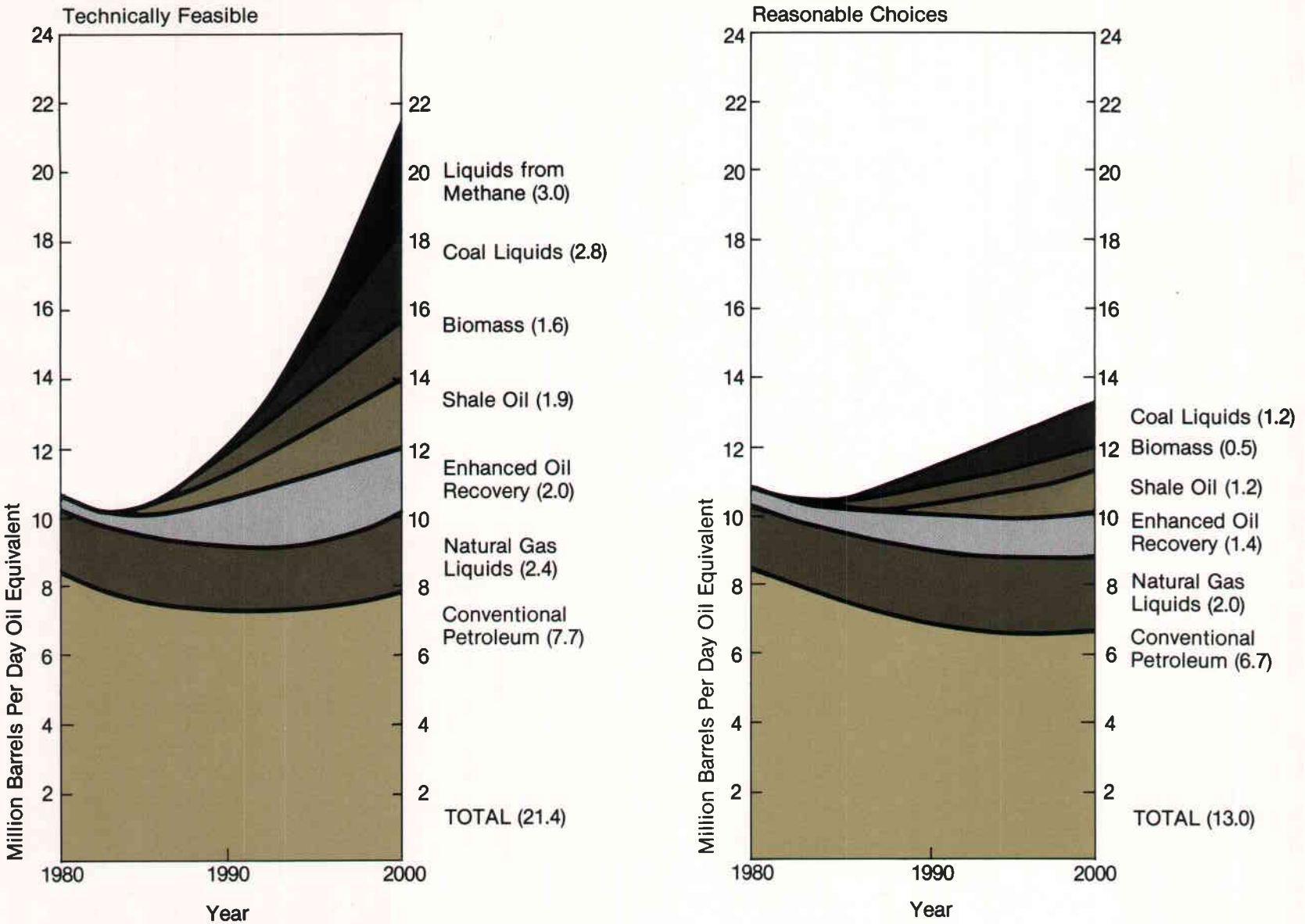
Building on existing national trends, it is reasonable to project conventional and synthetic liquid fuel supplies of 13.0 million barrels of oil equivalent in the year 2000, compared with our baseline demand of 14.5 million barrels of oil equivalent per day.

Conventional petroleum liquid resources, which include conventional oil, natural gas liquids, and enhanced oil recovery are projected to provide between 8.7 *(business as usual)* and 12.1 *(technically feasible)* million barrels per day in the year 2000. The *reasonable choices* projection is 10.1 million barrels per day compared to a projected baseline demand of 14.5 million barrels of oil equivalent per day.

It is technically feasible to provide 21.4 million barrels of oil equivalent per day of synthetic plus conventional liquid fuels in the year 2000, approximately 50 percent more than the projected baseline demand. The *reasonable choices* projection is 13.0 million barrels of oil equivalent per day.

Domestic crude oil supplies are projected to decline even with sharply increasing world oil prices.

Potential Domestic Liquid Fuel Supplies



NOTE: Liquid Fuel Supplies are presented in order of increasing cost.

Capital Requirements for Increased Domestic Liquid Fuels Supplies

All Costs in 1980 Dollars

The incremental capital requirements for the reasonable choices investments appear to be manageable compared to other industrial investments.

Historically, energy industries have typically invested $60 billion per year ($1.2 trillion if projected over the next 20 years) in supply-related plant and equipment.[1]

The *business as usual* investments in conventional domestic liquid fuel supplies are projected to be $390–470 billion over the next 20 years. (Note: This would be a part of the normal total energy industry investment cited above.)

The *reasonable choices* require additional capital investments over the *business as usual* projections of between $150–200 billion over the next 20 years (total of $540–670 billion).

The *technically feasible* options would require additional capital investments over the *business as usual* projections of between $500–900 billion over the next 20 years (total of $890–1370 billion).

As a Frame of Reference—
The cost in 1980 of importing an average of 6.7 million barrels of oil per day at an average cost of $31.50 per barrel was $77 billion.

If oil imports continue at this level over the next 20 years and world oil prices steadily increase to the projected $65 per barrel in the year 2000, the outflow will be over $2.3 trillion. If world oil prices increase only at the general inflation rate, i.e., remain constant at $31.50 per barrel in 1980 dollars, then the 20 year outflow would amount to $1.5 trillion.

(U.S. imports averaged 6.1 million barrels per day of crude oil and petroleum products for the four weeks ending March 20, 1981.)

By way of contrast, utility investment over the 20 years, 1980–2000, is expected to be about $500 billion.[2]

The investment cost of achieving this oil independence amounts to a 2 percent increase in the total national fixed investment (about $10 trillion) expected over the next 20 years.[3]

[1]U.S. Federal Energy Administration. *National Energy Outlook,* Washington, D.C., U.S. Government Printing Office, February 1976. (GPO #041-00097-6)

[2]*Electrical World,* "Forecast," September 15, 1980. Page 69.

[3]Assuming the gross fixed private domestic investment continues to grow at the 3 to 4 percent rate realized over the past 30 years from its expected 1980 value of $212 billion, the total gross fixed private domestic capital invested over the 1980–2000 period will be about $10–11 trillion (in 1980 dollars).

Capital Requirements for Domestic Liquids Supply Options

Supply	Business As Usual		Reasonable Choices		Technically Feasible	
	Production (Million Barrels per Day in 2000)	Capital (Billion Dollars) 1980 Dollars	Production (Million Barrels per Day in 2000)	Additional Capital Over Business As Usual (Billion Dollars) 1980 Dollars	Production (Million Barrels per Day in 2000)	Additional Capital Over Business As Usual (Billion Dollars) 1980 Dollars
Conventional Production[1]	5.9	362-418	6.7	40-47	7.7	121-140
Natural Gas Liquids[3]	1.4	—	2.0	—	2.4[4]	—
Enhanced Oil Recovery[1]	1.4	32-54	1.4	0	2.0	12-20
Coal Liquids	0	0	1.2	72-90	2.8	168-210
Shale Oil	0	0	1.2	24-36	1.9	38-57
Biomass Liquids	0	0	0.5	18-23	1.6	56-72
Gasoline from Natural Gas	0	0	0	0	3.0[4]	100-400[2]
TOTAL (Rounded)	8.7	390-470	13.0	150-200	21.4	500-900
TOTALS (Accumulated)		390-470		540-670		890-1370

[1]The capital costs shown for conventional oil and enhanced oil recovery allow for the costs of replacing depleted wells over the period 1981-2000. Thus, they cannot be directly compared with the capital costs associated with the synthetic fuels options which do not reflect any replacement of worn-out units. Unit capital costs are $32,000 to $37,000 per barrel per day for new conventional crude production capacity and $12,000 to $20,000 per barrel per day for Enhanced Oil Recovery. These costs were based on numbers from data in *The Energy Fact Book* (Congressional Research Service Committee Point 96-FC-GO, 96th Congress, November, 1980).

[2]These figures represent the spread between the optimists' projection and the conventional wisdom (*Wall Street Journal,* "Many Say Natural Gas Can Span Energy Gap But Others Doubt It," March 17, 1981) on capital costs for producing and converting large quantities of natural gas.

[3]Natural gas liquids are a mixture of lease condensate, a byproduct of conventional petroleum production, and natural gas plant liquids, which are high value condensible byproducts of natural gas production.

[4]Achieving these technically feasible levels requires that the more optimistic view of future natural gas production capacity (see page 13) is realized.

Potential for Reducing Liquid Fuels Demand

Using reasonable choices, demand for liquid fuels can be reduced from 14.5 to 12.7 million barrels of oil equivalent per day.

• Major options in the transportation sector are: introducing electric vehicles, improving engine and drive train efficiencies and downsizing or weight reduction.[1]

Technically Feasible:
Efficiency improvements and weight reductions provide a 51.4 miles per gallon total fleet fuel economy in the year 2000 compared to 15.8 miles per gallon in 1980.

— 61 percent improvement in engine and drive train efficiency in 1995 compared to 1985; new car fleet efficiency improved from 25.7 miles per gallon in 1985 to 41.4 miles per gallon in 1995 without weight reduction

— Average new vehicle weight reduced from 2400 pounds to 1800 pounds; new car fleet efficiency in the year 2000 improves to 55.3 miles per gallon

— 38 million electric vehicle fleet in the year 2000 (approximately 20 percent of the total fleet); each multi-car household owns one electric vehicle

Reasonable Choices:
Efficiency improvements and weight reductions provide a 36.3 miles per gallon total fleet fuel economy in the year 2000 compared to 15.8 miles per gallon in 1980.

— 20 percent improvement in efficiency in 1995 compared to 1985; new car fleet efficiency improved from 25.7 miles per gallon in 1985 to 30.8 miles per gallon in 1995

— Average new vehicle weight reduced from 2400 pounds to 1975 pounds; new car fleet efficiency in the year 2000 improves to 37.5 miles per gallon

— 12 million electric vehicle fleet in the year 2000 (7 percent of the total automobile fleet)

• The major option in the residential/ commercial sector is for conversion of existing buildings to gas or electricity.

Technically Feasible:
— On a base of 16 million oil heated homes, convert 4.5 million to gas and 3.5 million to electricity

Reasonable Choices:
— On a base of 16 million oil heated homes, convert 1.3 million to gas and 0.7 million to electricity

[1]Our baseline assumes that 10 percent of the 1985 new car fleet will be diesel and 34 percent of the total automobile fleet will be diesel in the year 2000.

[2]This and all other fuel economy values presented are estimated, on-road performance values as opposed to test-stand data. The Corporate-Average Fuel Economy (CAFE) standard, as measured by EPA test procedures, is 27.5 miles per gallon for the 1985 fleet, a test value which U.S. automakers expect to exceed by several miles per gallon.

• In the industrial sector, major options include conversion of boilers to coal or natural gas, coal-fired or gas-fired cogeneration and improved thermal process efficiencies.

Technically Feasible:

— Retrofit 600 oil-fired boilers (> 50,000 pounds steam per hour) to coal or gas. This is 10 percent of the total oil-fired boilers and is approximately equal to the number originally built to burn coal

— Use coal- or gas-fired congeneration to replace 0.22 million barrels per day of oil-fired congeneration. This savings is approximately 25 percent of projected cogeneration activity targeted for six industrial sectors

— Retrofit 50 percent of oil refinery capacity to use coal or gas for process heat

Reasonable Choices:

— Retrofit 240 oil-fired boilers, 40 percent of the technically feasible retrofits, to burn coal or gas

— Use 20 percent of technically feasible coal- or gas-fired cogeneration, targeted for the chemical, pulp and paper industries

— Achieve 27 percent of the technically feasible oil savings by using coal or gas in the 40 refineries that are most attractive for future investment

• Utility oil use could be negligible by the year 2000 because of market forces and plant retirements.

Capital Requirements for Reducing Liquid Fuels Demand

Sector	Reasonable Choices		Technically Feasible	
	1980 Dollars Capital ($ Billion)	Oil Savings Over Baseline (mmb/day)	1980 Dollars Capital ($ Billion)	Oil Savings Over Baseline (mmb/day)
Transportation	26- 72	0.82	69-184	2.28
Residential/Commercial	5- 10	0.21	17- 30	0.55
Industrial	23- 35	0.48	80-160	1.77
Utility	—	0.25	—	0.35
Total (Rounded)	50-120	1.8	170-370	5.0

[1]No significant capital investment beyond *business as usual* is required to effect these savings.

Domestic Natural Gas

Conventional wisdom on domestic natural gas supply potential may be wrong.

Natural gas supplied approximately 10 million barrels of oil equivalent per day in 1980 and has significant potential as an energy resource over the next 20 years. Current data from the Department of Energy and the American Gas Association project domestic supplies of 8.8 to 12.5 million barrels of oil equivalent per day in the year 2000. Recent finds of natural gas in the Western and Eastern Overthrust Belts have caused some analyses to project supplies of natural gas between 14 and 18 million barrels of oil equivalent per day in the year 2000.

Proven reserves are defined as identified deposits which can be extracted profitably with existing technology under present economic conditions. Thus, reserves are not estimates of what is in place or of the amount of natural gas that will ultimately be recovered.

Recent reserves estimates are relatively stable at approximately 10 times annual production.

Estimates of total domestic supply (proven reserves, potential conventional supply and unconventional supply) are 70 times current annual consumption.[1]

In 1980, approximately 16,000 new gas wells were drilled, a rate which is more than double that of five years ago. An analysis of two months data (June 1980 and January 1981) for wildcat wells, as reported in *Exploration Daily*, and development wells, as reported in *Oil and Gas Journal*, reveals an average new well flow capacity of 4 million cubic feet per day.

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[1]Lewin and Associates, Inc. Enhanced Recovery of Unconventional Gas (Vols. I-III). Prepared for U.S. Department of Energy. Washington, D.C., U.S. Government Printing Office, February 1979. (Pub. No. HCP/T2705-03)

American Gas Association and American Petroleum Institute. *Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada as of December 31, 1979.* Washington, D.C., American Petroleum Institute, June 1980.

Potential Gas Committee. *Potential Supply of Natural Gas in the United States (as of December 31, 1978).* Golden, Colorado, Colorado School of Mines/ Potential Gas Committee, April 1979.

The quantities of gas estimated from recent findings reflect, among other factors, the history of production in some fields at several depths, the existence of deep, undeveloped sedimentary basins and the fact that less than 2 percent of the U.S. has been explored for natural gas and only to an average depth of less than 6000 feet.

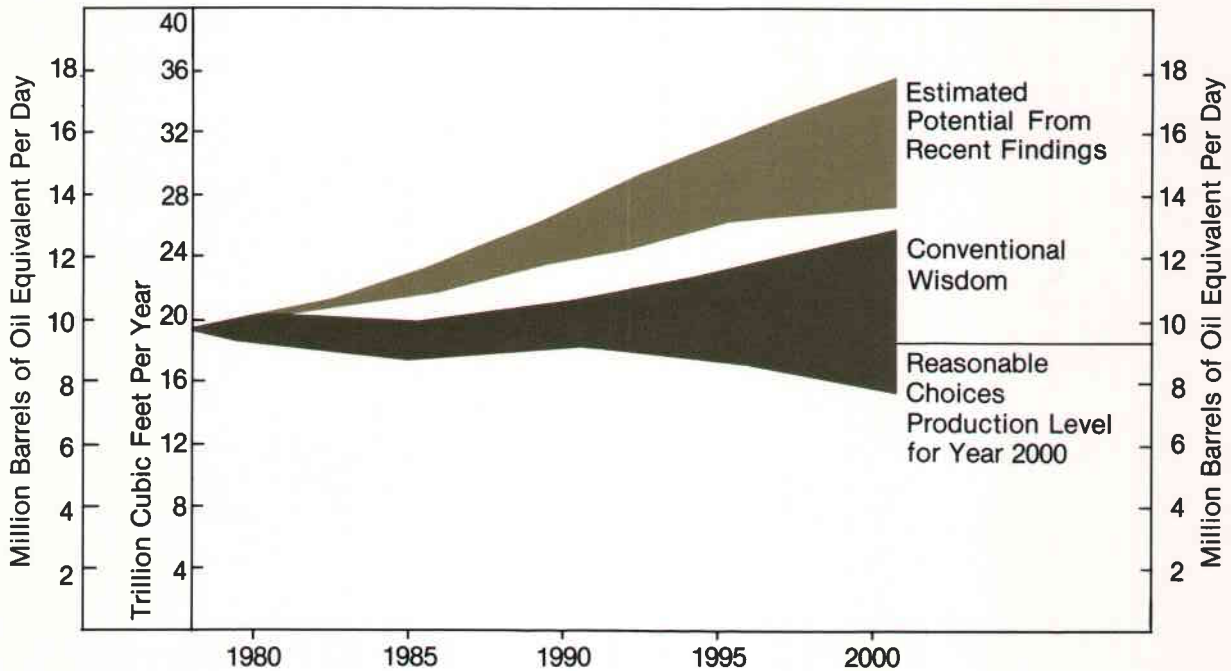
As examples, we cite the following:

— A gas field in Freestone County, Texas, produced in the 1920s at 2,000 to 2,400 feet and was then abandoned. In the 1950s the field produced from 8,500 feet and was again abandoned. In the 1970s it started producing at 13,500 feet.

— Recently it was discovered that the Michigan sedimentary basin is 30,000 feet deep, not a few thousand feet, as previously believed.

— Deep sedimentary basins under 13,000 feet of gneiss (granite) in West Virginia and under 18,000 feet of gneiss and lava in Arizona and New Mexico have potential for vast amounts of natural gas.

Projections for Domestic Natural Gas Supply



Sources:

American Gas Association. *Potential U.S. Gas Supplies through 2000.* Arlington, Virginia, American Gas Association, Gas Supply Committee, 1979.

U.S. Department of Energy, Energy Information Administration. *Preliminary 1980 Annual Report to Congress.* Washington, D.C., September 1980.

National Petroleum Council. *Unconventional Gas Sources:* Vols. 1-4. Washington, D.C., National Petroleum Council, 1980.

Lewin and Associates, Inc. *Enhanced Recovery of Unconventional Gas:* Volume II - Main Report. Prepared for U.S. Department of Energy, Washington, D.C., U.S. Government Printing Office, 1978.

Oil and Gas Journal. "No Let Up in Sight for Big Surge of Drilling in U.S.", October 20, 1980, p. 37.

Phillip F. Anschutz. "Overthrust Belt Presents Great Gas Opportunities." *The Oil Daily.* November 9, 1979.

Gordon J. MacDonald, Internal MITRE Memorandum. April 1981.

Other Domestic Energy Resources

There are sufficient domestic coal, nuclear and renewable resources and, possibly, enough domestic natural gas both to satisfy the projected demand in the year 2000 and to accommodate substitution for liquid fuels in stationary applications. Liquids are the only fuels that could be in short supply.

Please Note

On page 14 the oil equivalent presented for the nuclear power capacity is equal to the electric energy output of the nuclear plant assuming a 0.43 capacity factor. The oil equivalent of the thermal energy input to the power plant would be greater by a factor of approximately three.

Coal

The United States has sufficient recoverable coal reserves to last over 300 years at our current production rate of 830 million tons per year. Coal production is currently demand limited and could easily increase to one billion tons per year if required. There are no significant physical or technical barriers in doubling coal production by the year 2000.[1]

Nuclear Power

Over the past 20 years, the nuclear power industry has grown from 2 plants to 75 plants in operation and 82 plants under construction for a combined capacity of 146 gigawatts (895,000 barrels of oil equivalent per day) of which about one-third is on-line today. There are no technical barriers to doubling nuclear power capacity to 300 gigawatts (1.8 million barrels of oil equivalent per day) by the year 2000.[2]

Renewables

Renewable energy resources, including hydroelectric power, now provide approximately 2.5 million barrels per day of oil equivalent. They could provide 4.9 million barrels of oil equivalent in the year 2000, not including the potential contribution of 1.6 million barrels per day of oil equivalent from biomass liquids.[3]

Natural Gas

Considered in the previous section.

[1]President's Commission on Coal. *Coal Data Book* and *Staff Findings.* Washington, D.C., U.S. Government Printing Office, March 1980. U.S. Department of Energy. Energy Information Administration. *Preliminary 1980 Annual Report to Congress.* Washington, D.C., September 1980.

[2]U.S. National Academy of Sciences. *Energy in Transition 1985–2000: Final Report of the Committee on Nuclear and Alternative Energy Systems.* Washington, D.C., National Research Council, 1979.

[3]U.S. Department of Energy. Office of Policy and Evaluation. *Preliminary Base Case 1985 and 1990 U.S. Energy Projections* (NEP III). Washington, D.C., August 1980. U.S. Department of Energy, Energy Information Administration. *Preliminary 1980 Annual Report to Congress.* Washington, D.C., September 1980.

Future Domestic Energy Demands

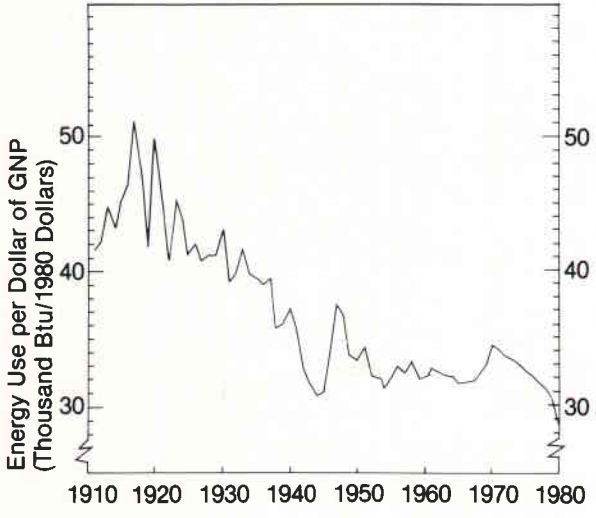
The baseline energy demand of 50.5 million barrels of oil equivalent per day in the year 2000 is probably a high estimate.

Historically, U.S. energy consumption per unit GNP has been declining.

Forecasts of energy demand in the year 2000 have also been steadily declining since 1972. Forecasts which were among the lowest when made in 1972 are comparable to the highest forecasts made as recently as 1978.

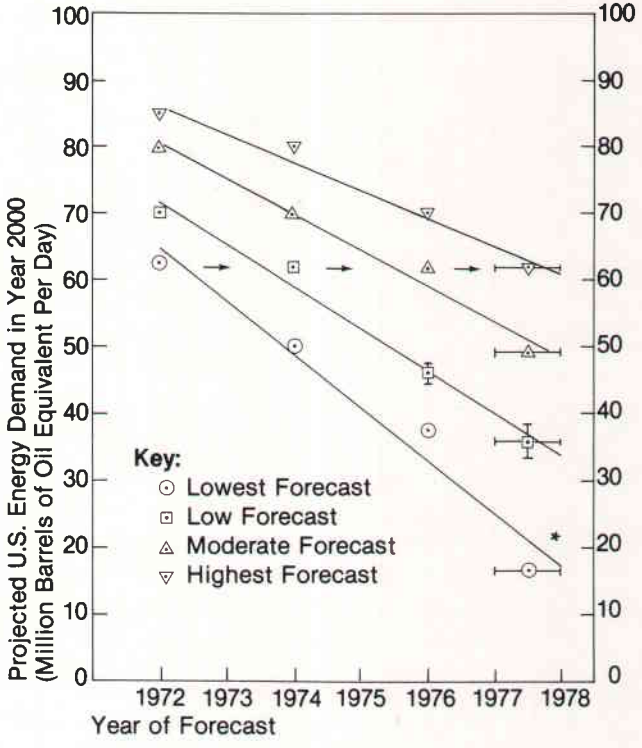
With continued price increases, actual energy demand in the year 2000 could be less than our baseline, requiring somewhat less in increased domestic liquid fuel supply increases or demand reduction than projected by this study.

Energy Consumption per Unit of GNP in the U.S., 1910-1980



U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, February 1981.
U.S. Department of Commerce, Telecon, March 1981.

Projections of U.S. Energy Demand in Year 2000 According to Various Forecasters and Year of Forecast



Reconstructed from data assembled by Amory Lovins, and presented in *Science*, Vol. 208, June 20, 1980, p. 1353.

* These linear correlations are meant only to highlight forecasting trends over the past decade and should not be extrapolated beyond their 1978 values.

MITRE Background

The MITRE Corporation was formed in 1958 as a spinoff from MIT's Lincoln Laboratories at the request of the United States government in response to the demands of rapidly advancing technology and the high costs associated with developing modern defense systems. The problems involved in such development required a conflict-free institution with MITRE's capabilities to perform design, analysis and evaluation and provide technical integration of complex systems.

In keeping with its purpose, MITRE was expected to serve the government in a systems engineering capacity with objectivity as well as with technical competence. To foster such objectivity, MITRE was chartered as a nonprofit corporation under control of a board of trustees. The company does not engage in manufacturing and is restricted from either competing with or working for private industry. In the event of its dissolution, the company is required to turn any assets over to the federal government.

In 1967, MITRE expanded its support to civilian agencies. Surface transportation, advanced information systems, and energy and environmental engineering were added to an already existing air traffic control work program. The Metrek Division was formed in 1976 to consolidate this support to civilian agencies.

In 1971 MITRE authorized Independent Research and Development funds for a series of planning conferences to identify energy, resource and environmental issues and their interrelationships. Leaders from industry, government and the research and development community were invited to participate. The scope of these deliberations broadened with a series of four international symposia during 1972: one in Washington, D.C., the second in Canada, the third in France and the fourth in Japan. As an outgrowth of these conferences, MITRE co-sponsored an energy policy workshop which resulted, in 1973, in a proposed outline for U.S. energy policy.

Early sponsored work included assistance to the National Science Foundation in developing an agenda for research in the field of energy conservation and renewable energy and support for the Department of Interior in investigating methods for dramatically increasing U.S. coal production as well as defining research and development programs for advanced coal-fueled power conversion systems. The current work program of the Energy and Resources Division includes activities in support of government programs in fossil energy extraction and utilization; synthethic fuels; renewable energy systems; energy, economic, and environmental policy analysis; and resource recovery systems engineering.

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