

# The Energy Crisis

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**Oil Shale: Part of the Solution**

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This report was prepared by  
the staff of Tosco Corporation.

For further information contact:  
Camilla S. Auger  
Senior Vice President  
202-223-9200

EXECUTIVE  
SUMMARY

- The Oil Crisis: The energy crisis is primarily an oil crisis. Roughly half (48%) of the total energy used by the United States is oil and nearly half (43%) of that is now imported--a trebling of the percent of imported oil since 1955. The cost of imported oil is now \$150 million/day, a projected \$56 billion for 1979 alone.
- Need for a Balanced Energy Program: The answer to the energy crisis is a balanced program of conservation, rapid development of solar and the other renewables, and increased domestic production of fossil energy, particularly liquid fossil energy. A strong and effective program of conservation could slow the increase in the overall demand for energy to 50 million B/D equivalent by the year 2000 without sacrifices in lifestyle, while still meeting the needs of a growing population and GNP. An optimum program for solar could yield 10 million B/D equivalent by 2000. To meet the need for the remaining 40 million B/D equivalent an aggressive program to increase domestic fossil energy production is required, if our costly, economically damaging, and hazardous dependence on foreign oil is to be reduced.
- The Contribution of Oil Shale: Since increased exploration and conventional production of oil is anticipated simply to hold constant national production in the face of declining resources, future domestic fossil energy needs must be met through the development of the full range of new sources. Oil shale is one of the most important new sources of domestic fossil energy for a number of reasons:
  1. It is an ideal source of premium quality oil for urgently needed transportation fuels.
  2. The vast resource could yield production at a level roughly half that of Alaskan oil far into the next century.
  3. The technology is ready now for commercial production.

4. At a projected \$25/B selling price, oil shale is the most economic of the new sources and investment per daily barrel is less than that for offshore production.
  5. Oil shale development is compatible with the highest standards of environmental quality.
- Reliability of Cost Estimates: The cost estimates for oil shale noted here are based on a \$12 million program of detailed engineering and are cited by the Rand Report<sup>1</sup> as an example of the type of highly reliable estimates which can be obtained for new technology projects if appropriate engineering design work is carried out.
  - Federal Incentives: Although oil shale is economically competitive today, federal incentives are essential for the first phase of commercialization in order to facilitate capital formation in the face of the massive investment required and the extraordinarily high initial level of uncertainty.

The following factors are the major barriers to investment:

1. The \$1.2 billion capital investment required for a 47,000 B/D commercial oil shale facility with four to five years of outlay on plant construction before the first income from production, assuming no unanticipated problems or delays.
  2. Unpredictable risks and uncertainties due to the fact that the technology has never actually been demonstrated at the commercial scale.
  3. A rapidly shifting and unpredictable regulatory climate which could result in extensive, unanticipated delays, and the potential for extensive post permit litigation.
  4. Lack of a predictable federal energy policy.
  5. Unpredictable levels of national inflation and the potential for reappearances of sudden dramatic inflation of construction costs nationally.
- Jobs: Each 47,000 B/D commercial oil shale facility will generate 2400 construction jobs, 1000 permanent operating

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<sup>1</sup> Edward W. Merrow, Stephen W. Chapel, and Christopher Worthing. A Review of Cost Estimation in New Technologies: Implications for Energy Process Plants (Sante Monica: The Rand Corporation, July, 1979), p.105.

jobs, and roughly 3400 jobs in related areas of employment: a total of 6800 new temporary and permanent jobs. Joint state and industry planning and the establishment of training programs will maximize the employment of state residents in the new industry. A \$1.2 billion investment in oil shale development rather than foreign oil will generate nearly \$5 billion in additional related domestic economic activity for each 47,000 B/D oil shale facility constructed.

- Water Availability: Water rights have been obtained and sufficient water is available for the initial pioneer commercial plants. In addition, a recent study by the Colorado Department of Natural Resources concludes that sufficient water will be available for an industry of 1.5 million B/D without reduction of water for other uses, and projected refinements in oil shale technology based on current research are expected to improve water conservation significantly in the near term. Since the industry is anticipated to reach production levels of 400 thousand B/D by 1990, water availability is not a limiting factor.
- Air Quality: The project closest to commercialization, the Colony Project (Arco 60%/Tosco 40%), has received all required air quality permits for compliance under light industry rather than heavy industry standards. EPA and Friends of the Earth have officially commented on the thoroughness of the review process and EPA noted that Colony demonstrates the compatibility of oil shale development with the highest standards of environmental quality.
- Water Quality: The Colony Project will release no effluents of any kind into rivers, streams or ground water systems. All water used is collected and recycled within the Project, which has been designed as a zero discharge facility.
- Revegetation: Deep underground mining methods will be used; strip mining and open pit mining are generally considered uneconomic for the reserve. The feasibility of successful, long term revegetation of the spent shale to a state fully comparable to the existing vegetation of the area has been extensively researched, tested and demonstrated in pilot plant operations at the Colony Project and others.

- Toxicity: Concern has been expressed by some critics of development that oil shale might be carcinogenic. Extensive, detailed chemical analyses and biological studies by numerous research laboratories have concluded that the carcinogenic properties of shale oil are no greater than those of most conventional petroleum products and less than some industrial fuel oils. Spent shale has the same level of carcinogenicity as ordinary garden soil, charcoal broiled steaks, or oak leaves.

Any toxic wastes produced in the retorting process, such as arsenic, are collected by sophisticated pollution control equipment and prevented from entering the atmosphere, or surface or ground water systems.

- Socioeconomic Impacts: The Colony Project has spent hundreds of thousands of dollars in planning and community development preparation to insure orderly municipal expansion for the new population associated with the project. Joint industry, state and local government planning efforts over the past seven years and special industry/government growth management teams for each new project in Colorado will greatly facilitate orderly community development for the industry as a whole and have begun to prepare the region for future growth associated with oil shale.

A few projects, such as Colony, have been extremely active in collaboration with government to minimize boom town effects through participation in planning and the provision of land, housing, and new municipal facilities and services. However, passage of the Hart/Randolph Inland Energy Impact Assistance Bill is essential to ensure, on a comprehensive basis, that the economic benefits of development will be maximized and the boom town effects minimized as energy development proceeds in rural areas.

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I. THE ENERGY CRISIS AND  
THE NEED FOR SHALE OIL

The Oil Crisis

The term "energy crisis" implies that all forms of energy are involved in the same way, or that a single fix is available through the substitution of one new form of energy or another, or the saving of energy by any form of conservation.

The problem, however, is not a vague difficulty with all forms of energy. While all energy systems are affected, the problem is an oil problem. The dramatic symptoms appeared when oil prices started to increase, led by OPEC decisions in 1972, and local shortages of petroleum became widespread following the embargo of 1973-74 and the trebling of world oil prices. The current round of crises originated in the curtailment of oil production in Iran.

Thus, the problem begins with oil supply. However, it does not end there; it carries through to oil use because of the nature of oil and other energy sources. Oil, of all forms of stored energy, is the most easily substituted for other forms. It is easier to transport, store and burn than coal for stationary uses, and even easier for mobile uses. It is more compact than gas, more versatile than nuclear, and more concentrated than alcohol. Oil and oil products are used for transportation, residential and commercial heating and hot water, industrial power and electric generation.

It is this versatility and prior ease of availability at low cost which has led us, in part, to use oil for so many purposes and to become dependent upon imports of it. Nearly half (48%) of the nation's total current energy consumption is oil.<sup>1</sup> Nearly half of the oil used is imported-- a trebling of the percentage imported since 1955.<sup>2</sup> Imported oil now costs the nation roughly \$150 million/day, a projected \$56 billion for 1979 alone.

The nation's increasing dependence on foreign oil is a tremendous drain on the economy, a threat to the dollar and a problem of national security. Currently, more than 25% of the country's imported oil comes from nations unfriendly to the U.S., whose internal political climates make their future oil export policies unpredictable.

#### The Solution

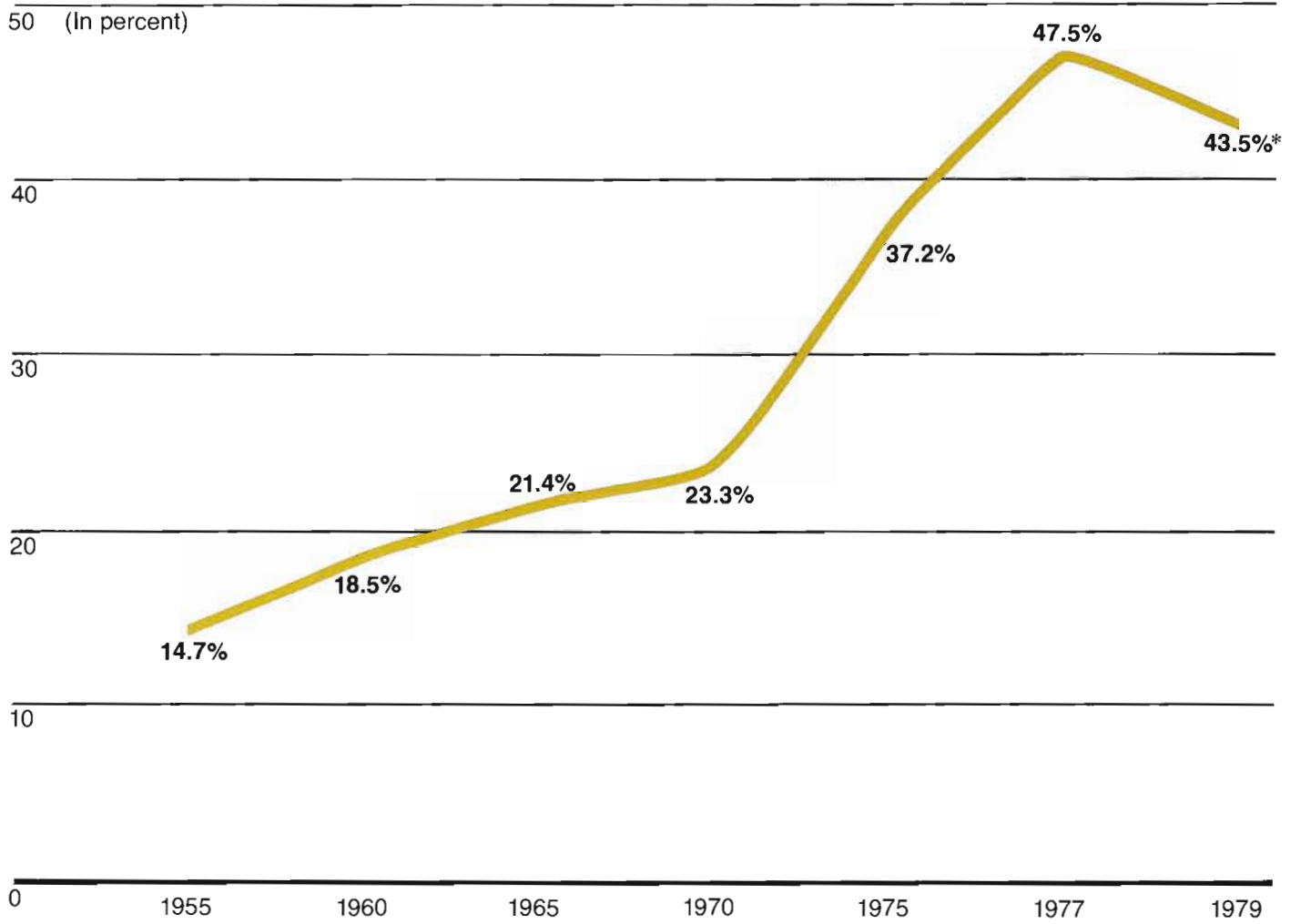
The answer to our dependence on foreign oil is a balanced national energy policy of conservation, increased reliance on solar and the other renewables, and new domestic production of fossil energy from alternative sources.

Conservation and solar can make a major contribution to solving the nation's energy crisis and should be given a high priority in any practical energy strategy for the future. Even using the most optimistic projections for progress in the areas of conservation and solar, however, it is clear that increased domestic production of liquid fossil energy from new sources is also an essential and urgent requirement.

<sup>1</sup>Energy Information Administration, Annual Report To Congress, 1978.

<sup>2</sup>The temporary drop in oil imports in the period from 1977 through 1978 indicated on chart, page 3, was due to the phase in of Alaskan production and decreased Iranian imports. The level of imports has now increased.

# Imports as a percentage of U.S. Domestic Petroleum Demand

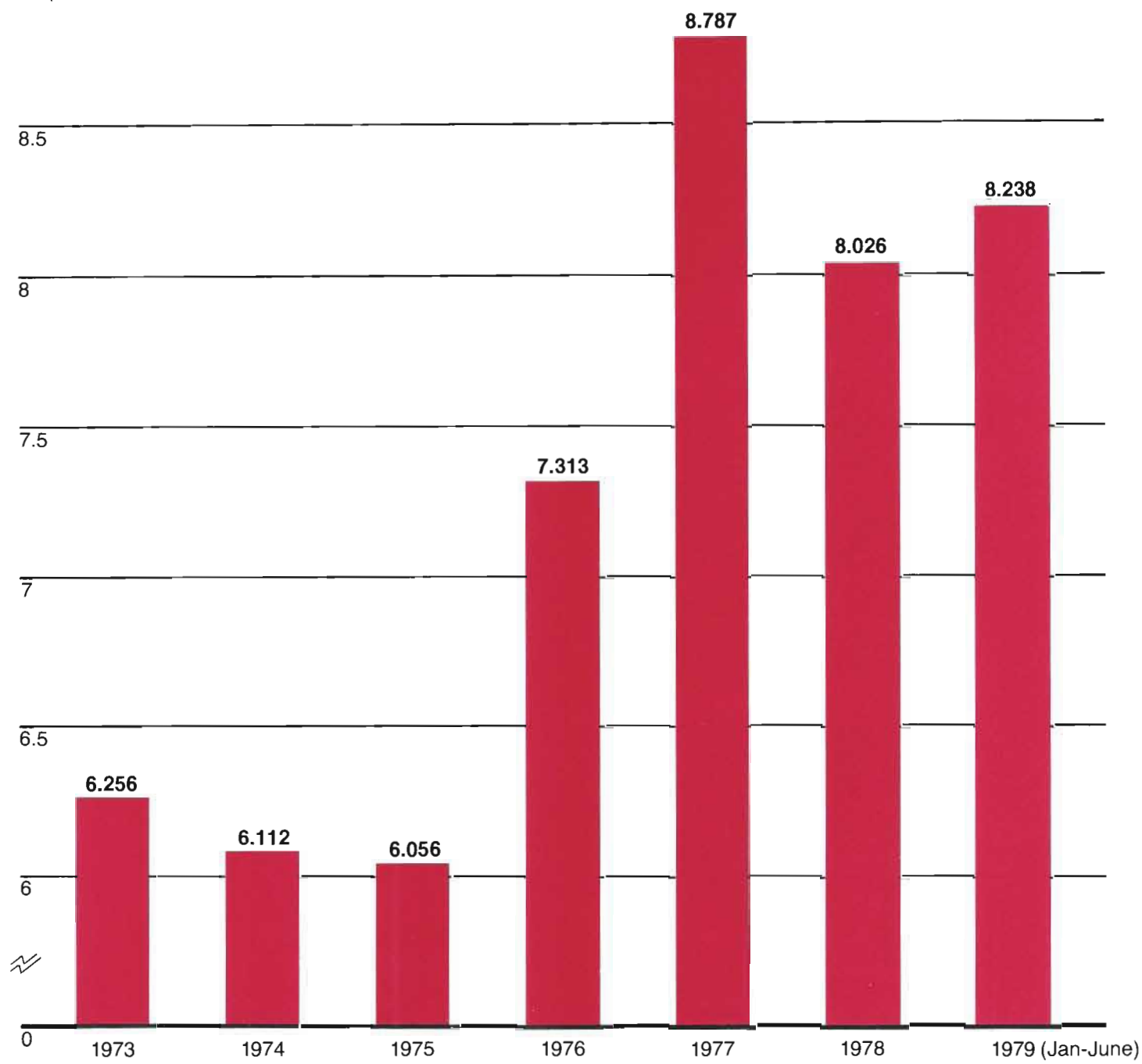


\*January thru July

Source: Energy Information Administration

# U.S. Imports of Crude Oil and Products, 1973-1979

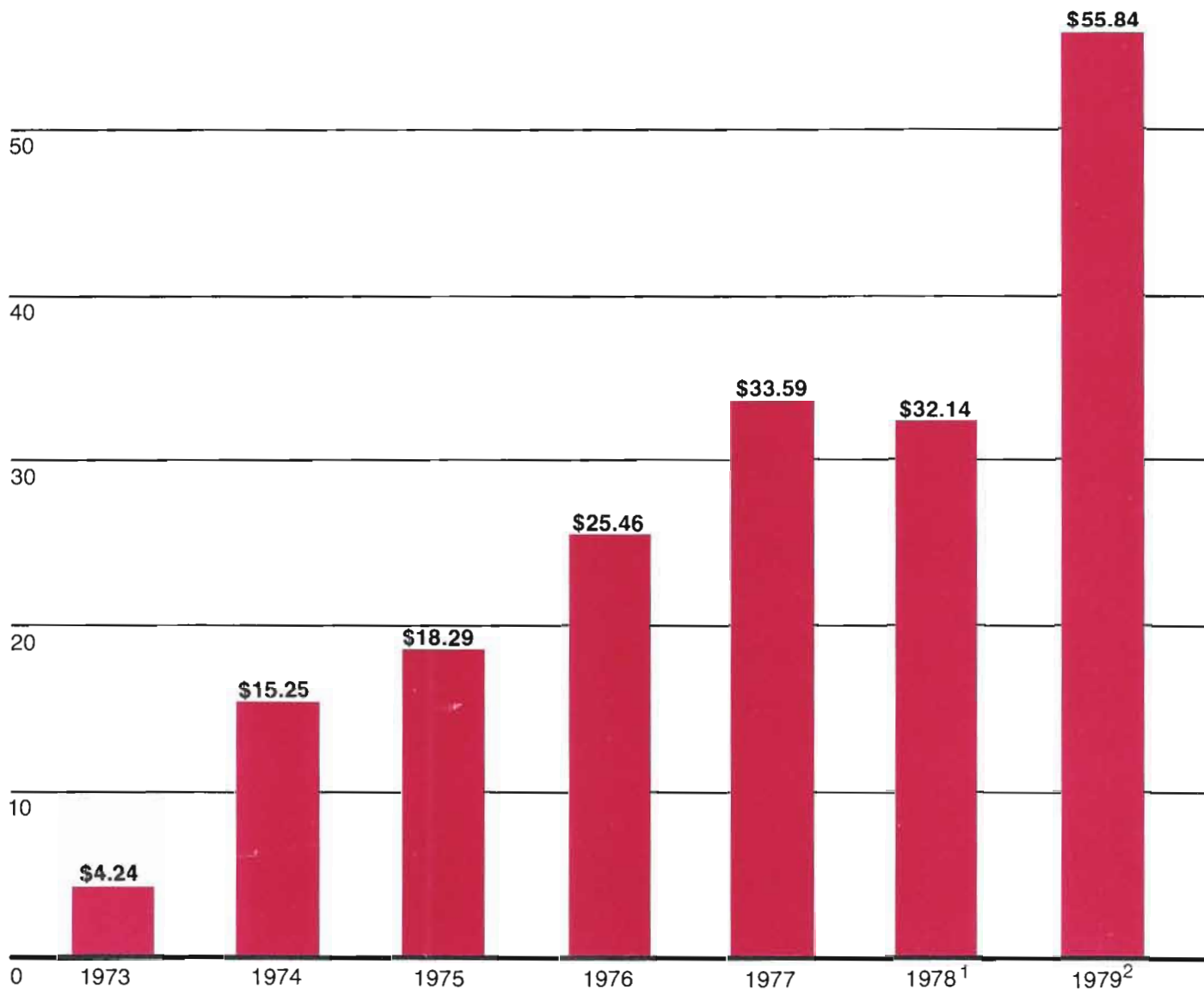
9 (In millions of barrels a day)



Source: Department of Energy, *International Energy Indicators*, August, 1979

# U.S. expenditures for imported crude oil

60 (In billions of dollars)

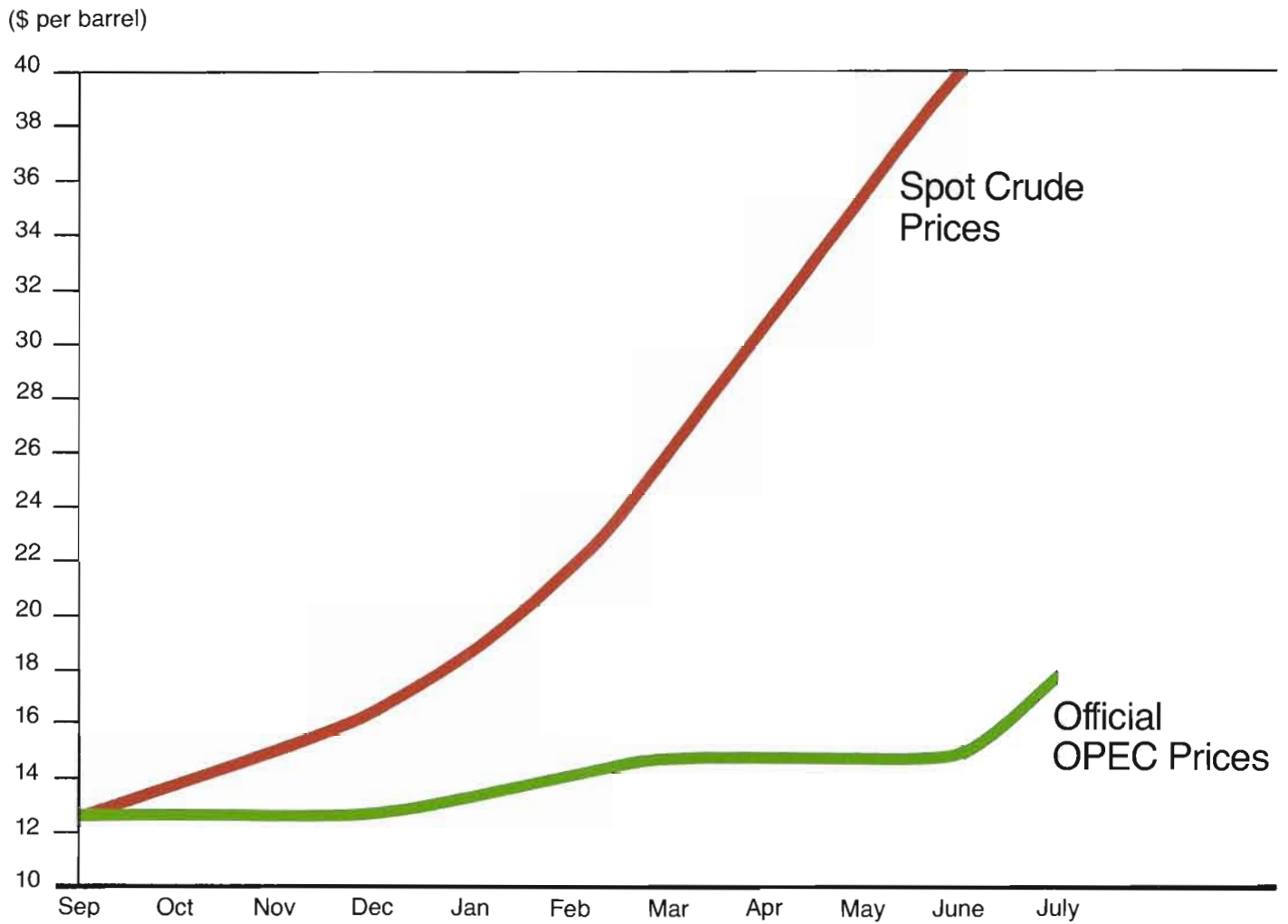


<sup>1</sup>Preliminary data

Source: Energy Information Administration

<sup>2</sup>1979 estimate calculated from DOE's *Monthly Energy Review*, August, 1979. Average crude oil refiner acquisition cost for imported crude (19.00) x yearly average of crude imports (8,052 barrels/day) x 365.

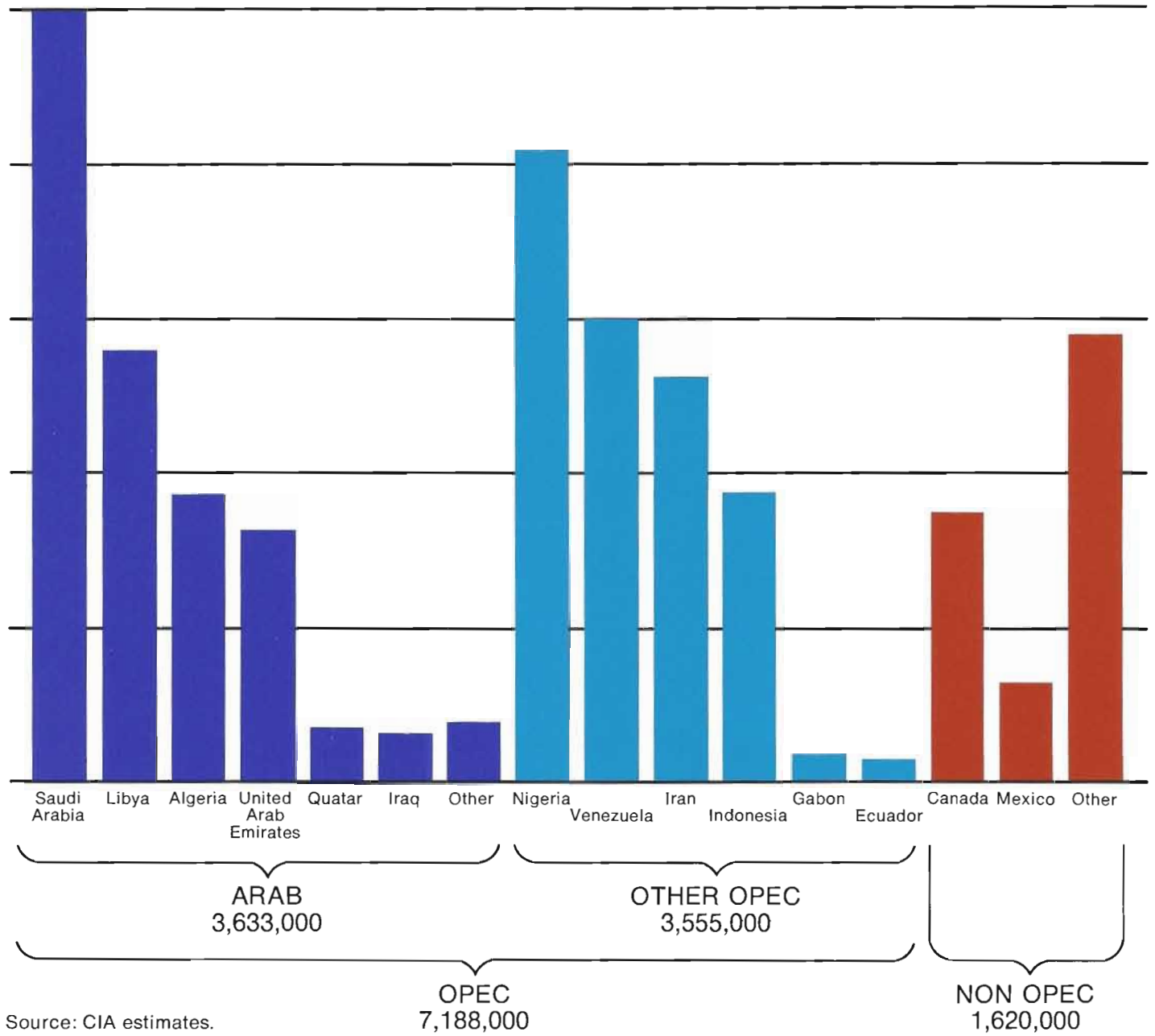
# Recent Crude Oil Prices 1978-1979



Source: Department of Energy

# U. S. estimated imports of crude oil and refined products

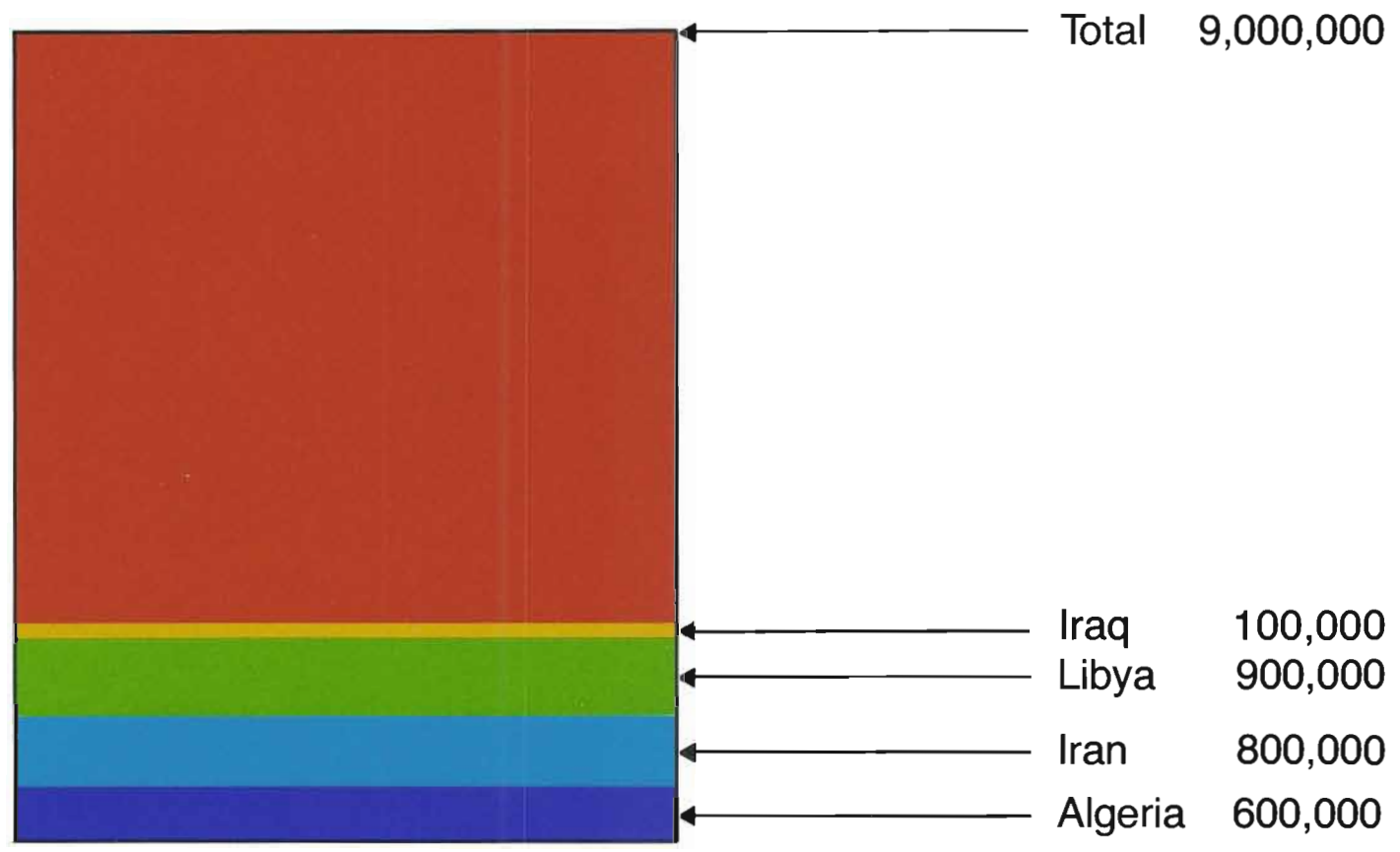
1979





**Over 25% of imported oil comes from nations with which the U.S. has unstable relations.**

Barrels per day imported



Source: API, CIA; (data approximate)

While there is an increasing consensus that solar and conservation are a high priority aspect of the solution, some opponents of increased fossil energy development appear to believe that such a program is unnecessary and that solar and conservation can do the job alone. It is important to examine this point.

#### The Contribution of Conservation and Solar

A recent analysis of the potential for conservation and reliance on solar, Energy Future<sup>1</sup>, suggests that with a vigorous conservation program it would be possible to achieve a minor rate of increase in the level of energy use without sacrifices in the quality of life, while maintaining current levels of growth in population and the GNP. Since, until recently, the consumption of oil was increasing at 1 million B/D/year as a result of population growth, expansion of the GNP, and other factors, a constant level of energy use without sacrifices of lifestyle would require annual increases in the effective level of conservation.

Assuming the successful implementation of such a conservation effort, the authors of Energy Future project a total national energy consumption level of 50 million B/D oil equivalent by the year 2000. This level of consumption would involve a relatively modest increase over the current level of consumption of 40 million B/D oil equivalent, assuming continued population growth, expansion of the GNP and no decline in the quality of life. The conservation effort to achieve such a level of consumption would amount to a savings of between 30% and 50% B/D equivalent.

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<sup>1</sup> Energy Future: A Report of the Energy Project at the Harvard Business School. Robert Stobaugh and Daniel Yergin, eds., (New York: Random House), 1979.

Assuming an equally effective solar program, the authors project that solar energy could supply as much as 10 million B/D energy equivalent<sup>1</sup> of the required 50 million B/D total. This would leave 40 million B/D to be provided by fossil energy and other sources. Roughly half (48%) of the total energy used in the United States is currently supplied by oil and of that, nearly half (44%) is imported. Therefore, assuming no further increases in the percentage of imported oil by the year 2000, 44% of 19.2 million B/D (48% of the 40 million B/D of non-solar energy) of the nation's energy would still need to be imported -- 8.5 million B/D or approximately the situation which exists today. Furthermore, if the rate of increase in oil prices continues, the 8.5 million B/D of imported oil could cost the country twice or three times as much by the year 2000 as it does today.

Therefore, even assuming the most optimistic<sup>2</sup> rate of progress in the areas of conservation and solar, no reduction in foreign imports could be anticipated by the year 2000 without equally dramatic increases in the domestic production of liquid fossil energy from new sources.

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<sup>1</sup>The 10 million B/D energy equivalent figure includes hydro-electric and wood.

<sup>2</sup>These projections for the year 2000 represent a highly optimistic conservation and solar scenario for several reasons. First, these levels of reliance on conservation and solar could be achieved only through substantial improvements in the level of incentives currently in existence or presently being considered by the Congress, as well as the enactment of energy usage ceilings per square foot or other mandatory conservation measures not presently considered politically feasible. While such steps would be highly desirable, the political reality is that they may well be several years away. (continued)

## Fossil Energy Alternative

Among the future domestic sources of fossil energy are increased conventional oil and gas production, coal, oil shale, synthetics from coal, and enhanced oil recovery. Traditional production of oil through exploration and drilling can, at best, only keep pace with declining reserves, so that production in this area might remain constant.

Coal production and all of the promising new sources of fossil energy should be brought on stream as rapidly as possible within the constraints of maintaining orderly, environmentally sound development. There is no single new source available to solve the need for fossil energy

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Second, the amount of solar energy and the savings due to conservation were stated in this example, and are often so stated elsewhere, in B/D energy equivalent which is a misleading concept in the sense that it tends to gloss over the wide diversity in the extent to which the different sectors of energy consumption are amenable to conservation or use of solar energy.

The major sectors of energy consumption are transportation, industrial processing, residential and commercial space heating and cooling, and electricity generation. Among these sectors some are less amenable than others to replacement or conservation of oil. Major progress in the areas of industrial processing, particularly petrochemicals, freight and aircraft transportation, or electricity generation are unlikely without presently unforeseen advances in technology. The major gains would have to be obtained in the areas of automobile transportation through design of more efficient engines and residential and commercial space heating and cooling, which in turn could reduce the demand for electricity. Both areas could yield considerable gains, but only with a program of incentives and mandatory conservation measures not currently planned by Congress. (continued)

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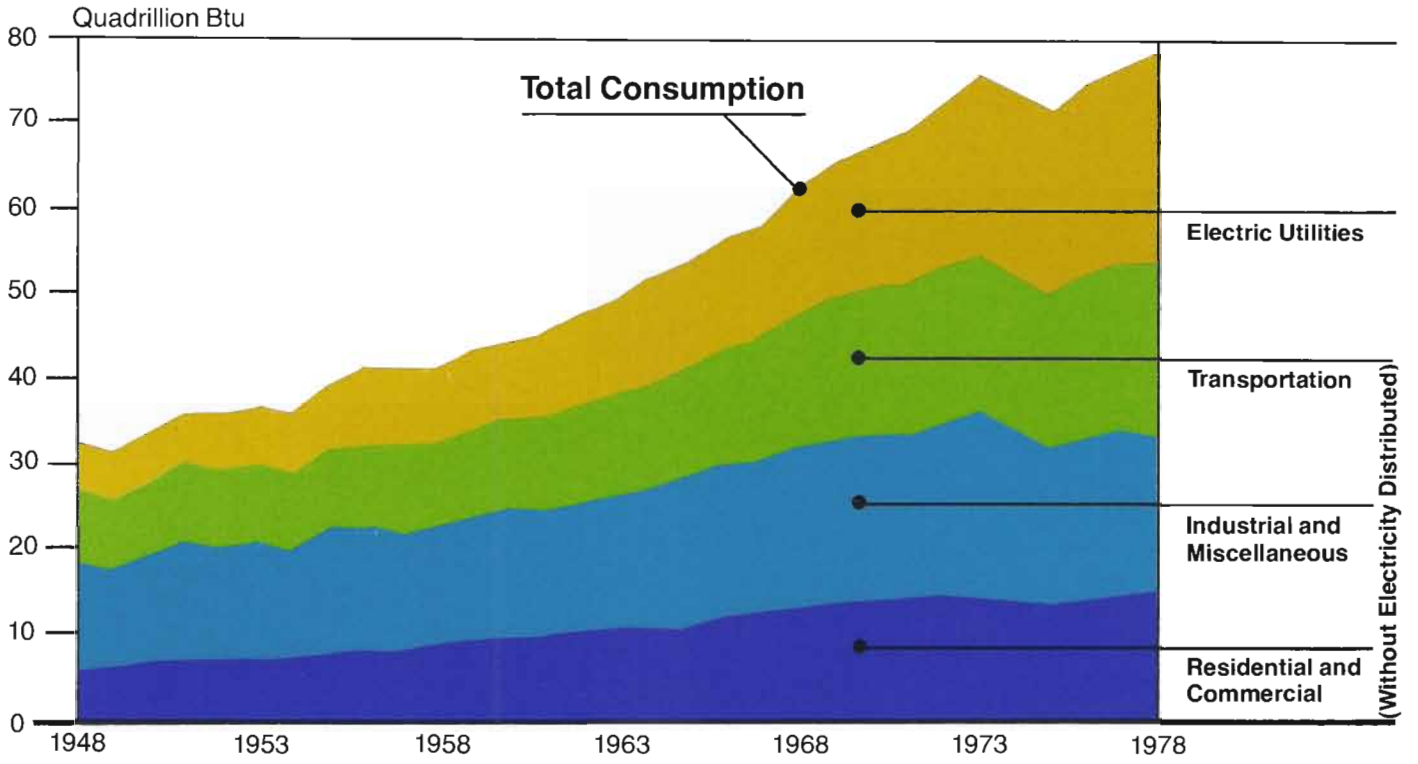
or even supply the major portion of that need. Increased domestic energy production will depend upon successfully bringing on line a multiplicity of new sources, each of which will contribute a modest part of the solution.

Among the new fossil energy sources, however, oil shale is a particularly important near term option. First, it represents a vast domestic oil reserve which could support production well into the next century. Second, shale oil is an ideal source of urgently needed transportation fuels. Third, the technology is ready for commercial production. Finally, the cost of oil shale produced at commercial levels is projected at \$25/barrel, significantly less than the cost projected for coal liquids, coal gas or other synthetic fuels.

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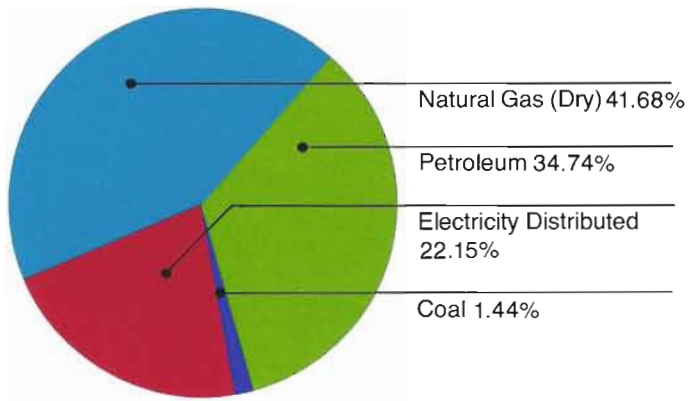
Therefore, even the most optimistic projection for conservation and solar indicates a need for significantly increased domestic fossil energy production. A more modest projection based on the current status of conservation and solar efforts which appear to be politically feasible, amplifies many times the urgency of the need for a broad range of new energy sources in addition to solar, especially in the short term before conservation and solar efforts become fully effective.

# Consumption of Energy by End-Use Sector

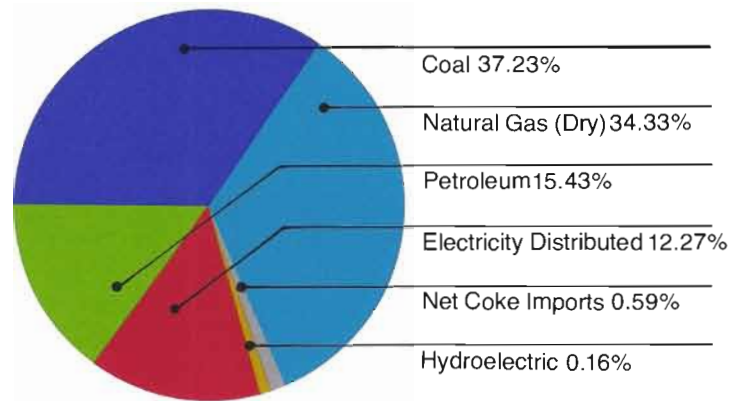


# End Use Sector Energy Consumption by Fuel Category 1978

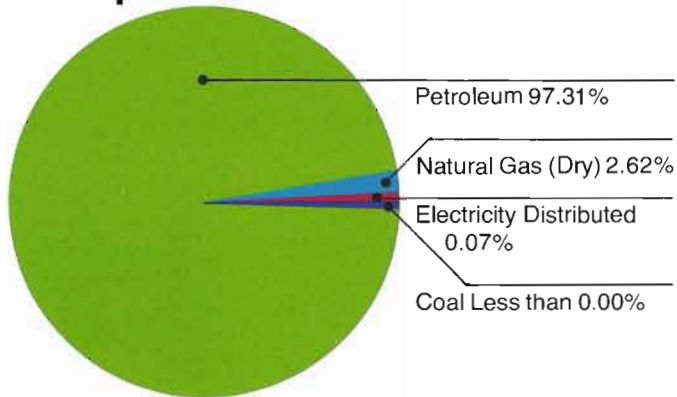
## Residential and Commercial



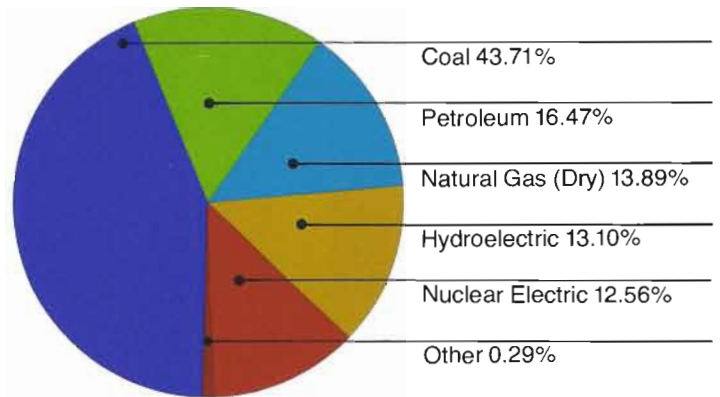
## Industrial



## Transportation



## Electrical Utilities



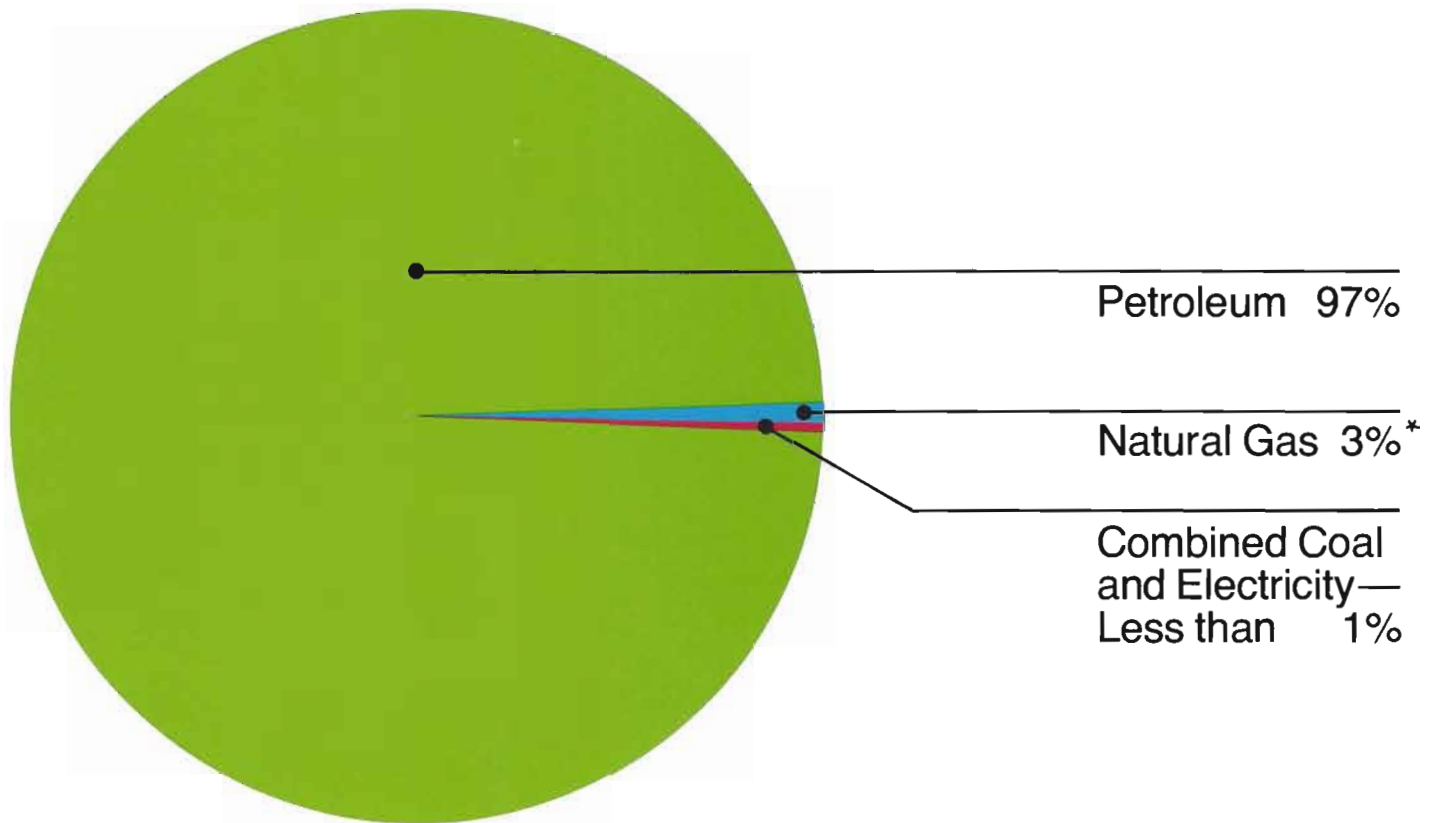
Source: Department of Energy, *Monthly Energy Review*, August, 1979



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## Use of fuel for transportation

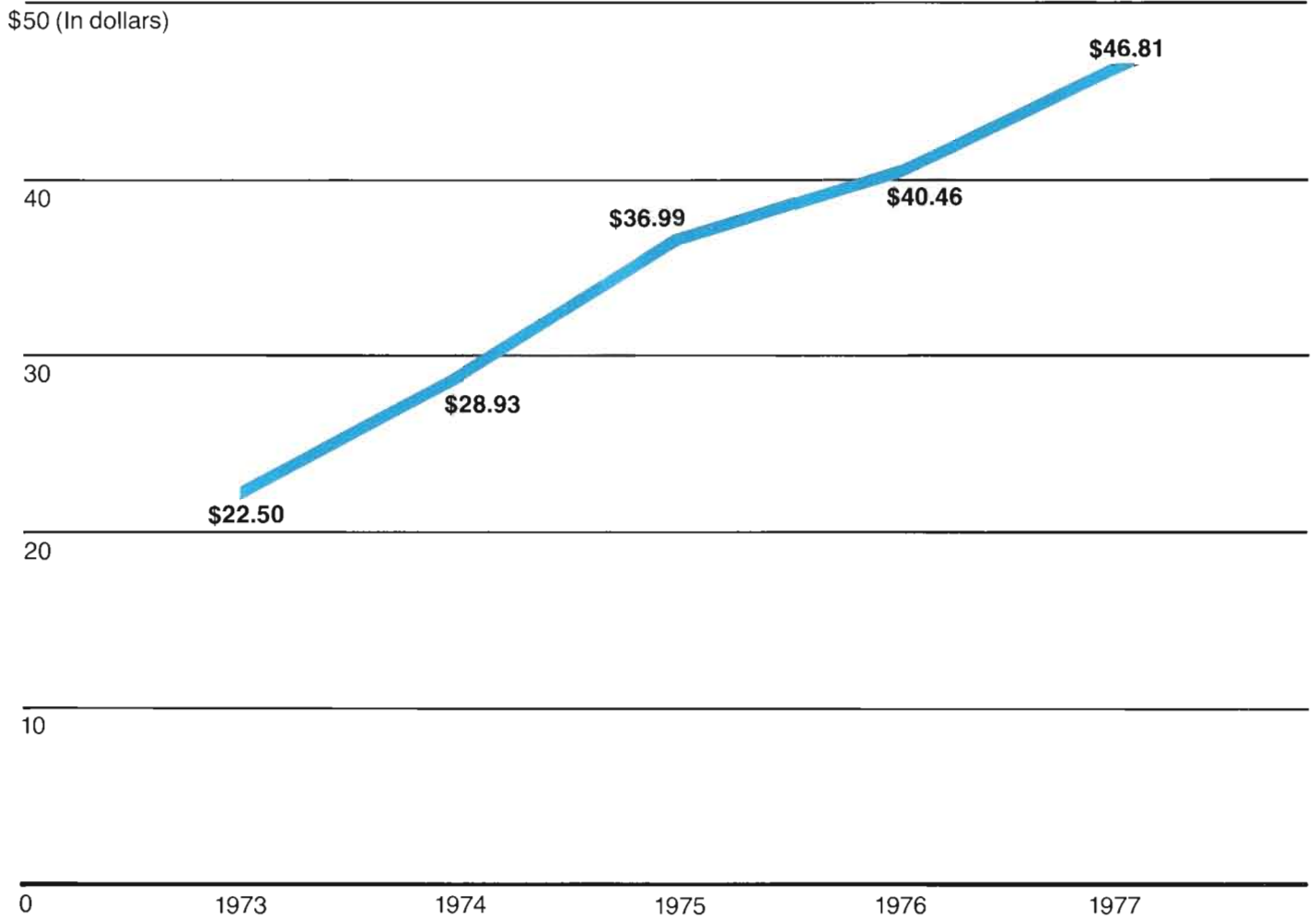
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\*Pipeline transportation use.  
(Based on category of fuel purchased; 1976 data)  
Source: API, U.S. Dept. of the Interior

# Average cost per foot of total oil wells drilled in U.S.



Source: Joint Association Survey

American Petroleum Institute  
Independent Petroleum Association of America  
Midcontinent Oil and Gas Association

II. OIL SHALE: READY, COMMERCIALY COMPETITIVE, ENVIRONMENTALLY SOUND

The Resource

Mineral deposits called "oil shale" appear in many parts of the world, and have been produced on a commercial scale for over 150 years. Scottish shale oil was produced through the late 19th century into the 1920's; Sweden's deposits were worked to economic exhaustion in the period after World War II; Chinese and Estonian oil shale is now in production. A fledgling industry exists in Brazil, and studies are under way in Israel, Morocco and Australia.

Although all these deposits and the Devonian shales of the Eastern United States are all called "oil shale," they vary in their composition, richness, and mineability. Present United States oil shale plans focus on the oil shale of the Green River formation of Colorado, Utah and Wyoming. This deposit, the remains of an ancient, stagnant freshwater lake which gradually filled with organic matter and dust, is especially rich in an area in Northwest Colorado called the Piceance Basin and an area of Utah immediately to the West called the Uinta Basin.

Oil shale is a hard, sedimentary rock, characterized by thin layers resulting from annual patterns of deposition in the prehistoric lake. It does not contain liquid oil, but an organic matter called kerogen. When the oil shale is heated to about 900°F in a process known as pyrolysis, the organic kerogen vaporizes and the vapors may then be condensed into shale oil, except for a non-condensable gas fraction.

The gas fraction, which is small in the Tosco II retorting process, may be used as plant fuel. The remainder of the oil shale is the dust which was deposited in the lake and a small amount of residual carbon. In the Tosco II retorting process the dust is recovered in the form of a fine, black silt-like material called spent shale.

The composition and usability of shale oil is within the range of properties of conventional crude oils, its only unusual properties being a high "pour point" (which is not a problem) and a high nitrogen content. The nitrogen, which would interfere with conventional refinery processes, can be removed by standard hydrogenation processes.

The hydrogenation process produces a synthetic crude oil of premium quality which can be readily converted into transportation fuels in a typical Rocky Mountain refinery. Table I compares the yield from shale oil with that from a premium quality sweet Wyoming crude currently selling for \$28.50 a barrel.

Shale oil is a source of transportation fuels comparable to premium quality domestic crudes. Since it fits easily and readily into the existing complex refining, distribution and consumption system for oil, it is the most straightforward substitute for imported oil.

The available quantities of oil from shale are very large. The entire Green River formation contains an estimated 600 billion recoverable barrels of shale oil in deposits of a richness of 25 gallons per ton of shale

Table I

Percentages of Products from a Typical Rocky Mountain Refinery<sup>1</sup>

	<u>From Wyoming Sweet</u>	<u>From Hydrotreated Shale Oil</u>
Gasoline	52.4%	55.3%
Diesel/Jet	33.5	39.1
High Sulfur Fuel Oil	3.8	-
Low Sulfur Fuel Oil	8.7	3.5
LPG	1.7	2.5
Processing (Loss) Gain	(0.1)	(0.4)
	<u>100.0%</u>	<u>100.0%</u>

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<sup>1</sup>Based on Tosco in-house analysis.

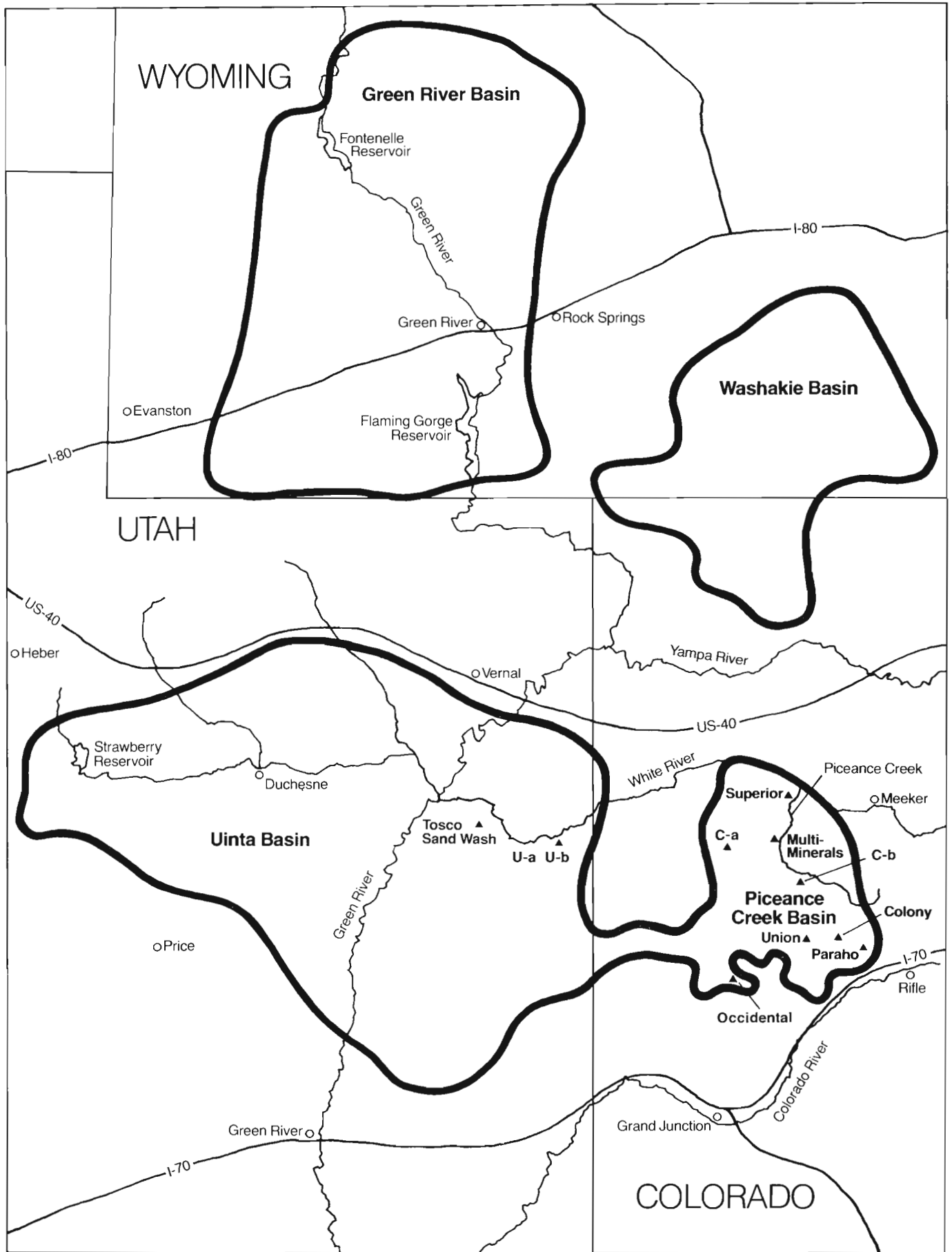
or higher. While recovery of all of this oil will require further refinement of the technology, 130 billion barrels in deposits averaging at least 30 gallons per ton in mining horizons of 30 feet or more can be recovered using existing technology.<sup>1</sup> The currently recoverable oil from shale exceeds by more than four times the current United States proven reserves of crude oil.

Clearly, limits exist on the rate at which these very large reserves may be produced. Using present technology within the bounds of sound environmental practices and water availability without reduction in use by other water users, the maximum production rate is generally thought to be in the neighborhood of one million B/D. While some industry sources think twice that level of production is feasible, most agree that technological advances in the course of a decade following initial commercial production are likely to permit substantially greater future production rates than those now projected.

While one million B/D or even two will not replace all imported oil, currently between eight and nine million B/D, it can make a major difference as part of an effective program of conservation, solar, and increased traditional and new fossil energy production. Oil shale production at the level of one million B/D would represent a new domestic source of premium quality oil equivalent to half of that from Alaska on a continuing basis well into the next century.

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<sup>1</sup>National Petroleum Council estimate.

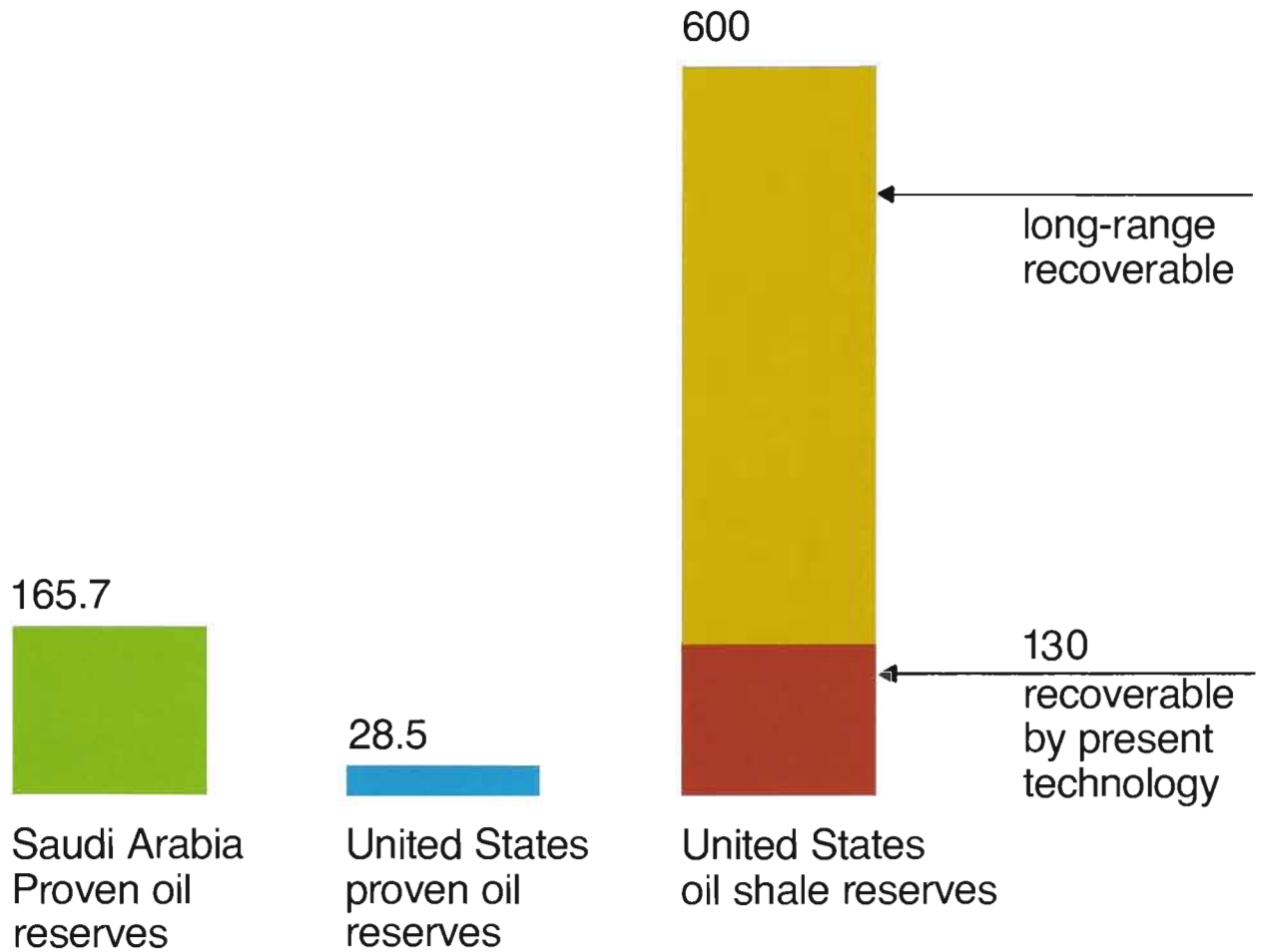


**Proposed Oil Shale Projects**

- C-a — Gulf and Standard of Indiana
- C-b — Occidental and Tenneco
- U-a U-b — Sohio, Phillips and Sun

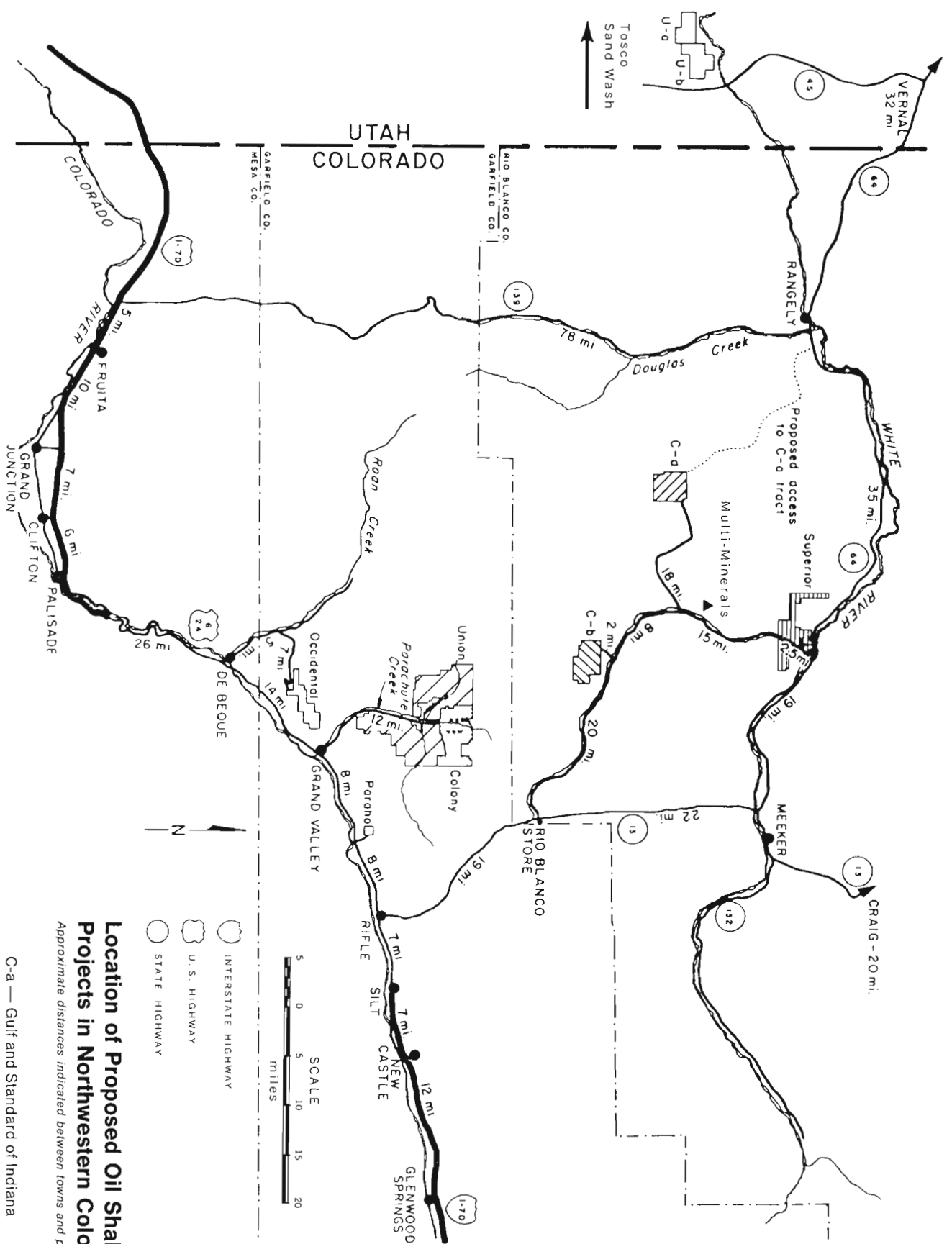
# U.S. Oil reserves and potentially recoverable shale oil compared with Saudi Arabian reserves

(In billions of barrels)



Source: Energy Information Administration, Cameron Engineers





**Location of Proposed Oil Shale Projects in Northwestern Colorado**

Approximate distances indicated between towns and projects

- C-a — Gulf and Standard of Indiana
- C-b — Occidental and Tenneco
- U-a U-b — Sohio, Phillips and Sun

Shale oil would directly replace declining domestic production of crude oil, or if that decline is slowed enough, displace imports. In addition, it would provide a national security "credibility" factor far in excess of actual production rates, because of its stable production cost and very large production potential. Saudi Arabia now exercises an influence in OPEC pricing disproportionate to its production rate because it alone has large unused marginal production capacity. Oil shale can play a similar role for the United States.

#### Status of the Technology

Unlike any other source of unconventional liquid fuels, shale oil production by the TOSCO II process is economically competitive today, field-ready now, and able to move into viable commercial production with no further research and development.

The TOSCO II retorting process entered the pilot stage more than twenty years ago and was scaled up to "semi-works" (semi-commercial) scale nearly fifteen years ago. The TOSCO II process will be used in the commercial development of the Colony Project, a joint venture between Atlantic Richfield (60%) and Tosco (40%).

The Colony Project has its own privately owned shale reserve, detailed engineering plans, and a definitive cost estimate based on these plans, an approved Environmental Impact Statement, and all but one remaining significant permit granted for a commercial scale (47,000 B/D) shale oil project.

Commercial development of oil shale is being pursued by a number of companies. The major technologies for retorting shale oil fall into two categories; surface retorting and modified in situ. The surface retorting process involves three major steps: first, conventional underground mining; second, crushing of the shale rock after it has been mined and brought to the surface; and third, heating of the crushed rock to 900° F. in surface retorts to vaporize and release the hydrocarbons. The vaporized hydrocarbons are then upgraded at the site and, upon completion of the process, are ready for the conventional refining process.

There are several different surface retorting technologies in active development. These differ primarily in terms of the method of feeding the crushed rock into the retorting chamber, the type of retorting chamber used, and the mechanisms for achieving even, rapid distribution of the heat to maximize the efficiency of recovery. The major surface retorting technologies are the TOSCO II process, the Union B process, the Paraho process, and the Superior multi-mineral recovery technology. (see diagrams 1-2 and the diagram in the back pocket).

The pure in situ method, which involves no mining, has been extensively studied and is considered impractical. In the modified in situ process, a working space is mined out in the shale bearing formation and large columns of the rock are rubblized in place by explosion. The rubblized zones are then ignited and the burning shale operates as an underground retort, vaporizing the trapped hydrocarbons. The shale oil vapors are then gathered at the surface where they are further retorted and upgraded. Occidental's process is the best known modified in situ process and the one being most actively developed (see diagram 3).

There are presently a number of oil shale projects in various stages of development in Colorado and Utah using either surface retorting technology, in situ, or a combination of the two, depending on the nature of the resource. The in situ technology is regarded as a promising secondary recovery technique in combination with surface retorting technology.

Roughly 90% of the resource is owned by the federal government. Two federal tracts in Colorado and two in Utah were put up for bid and leased for development under the Federal Prototype Oil Shale Leasing Program. Although two tracts were also offered for bid in Wyoming, due to the leanness of the oil shale there, there were no bidders. In addition to the two federal test lease tracts in Colorado and Utah, there are also a number of developments in progress on privately owned land or state leases.

In Colorado, test lease Tract Cb is being developed by Occidental Petroleum and Tenneco. The lease was by a direct venture of Ashland, Arco, Shell, and Tosco for a bonus bid of \$117.8 million. The original participants withdrew for a variety of reasons after considerable resource analysis and environmental monitoring work. Occidental is now at work on a pilot project on tract Cb using its own proprietary modified in situ technology. Tract Cb is located northwest of Rifle toward the center of the Piceance Basin. The closest town is Meeker (see map). Occidental is also developing a second project on its own privately owned land south of tract Cb.

Tract Ca is being developed by Rio Blanco Oil Shale Company, a joint venture of Gulf Oil and Standard Oil of Indiana. Rio Blanco plans to use both a surface retorting and an in situ recovery technology in combination. Rio

Blanco is under license to use the TOSCO II surface retorting process and is working on the development of its own version of modified in situ technology. Rio Blanco acquired the lease in 1974 for a bonus bid of \$210.3 million. The project is in the resource analysis, environmental monitoring and analysis, and development planning phase. Tract Ca is located northwest of Tract Cb, near the town of Rangeley (see map).

The Colony Project, a joint venture of ARCO and Tosco, is located on a privately owned tract north of Grand Valley and south of both federal test lease tracts (see map). The Colony Project has completed its pilot operation and plans to proceed to a commercial scale 47,000 B/D facility using the TOSCO II process, if effective legislation is enacted by the Congress. The TOSCO II process utilizes hot ceramic balls to heat the crushed shale in a rotating kiln (see diagram in pocket of back cover).

Union Oil Company, which has been involved in the oil shale industry for more than 50 years, is developing its own privately owned tract adjacent to the Colony Project (see map). The Union "B" surface retort uses externally heated gas to heat the shale. A reciprocating rock pump forces crushed shale in from the bottom. Gas and oil leave the bottom of the retort; retorted shale overflows the top. The Union process is widely regarded as practical and commercially ready (see diagram 1).

Paraho Development Corporation is a joint venture participated in by seventeen oil companies for the purpose of further developing a surface retorting technology originally pioneered by the School of Mines. Paraho has operated three retorts on lands leased from the U.S. Naval Oil Shale Reserves

near Rifle, Colorado (see map). The Paraho retort is a continuous vertical kiln. It can be operated by direct combustion within the retort (direct mode) or by external heating of the recycled gases (indirect mode) (see diagram 2).

The Superior Oil Company owns 6,500 acres of oil shale land located on the northern edge of Colorado's Piceance Creek basin (see map). Superior's technology, an indirect hot gas process, is designed for multiple recovery of shale oil, nahcolite, and dawsonite, two minerals which are unusually plentiful on the Superior reserves. Superior believes that its process, which produces four products, is practical and financially flexible.

In Utah, Federal Lease Tracts Ua and Ub are being jointly developed by the White River Shale Project. The lease to Tract Ua was originally awarded to Phillips Petroleum Company and Sun Oil Company (now Sunoco Energy Development Company) in 1974 for a bonus bid of \$76.6 million. The White River Shale Corporation was formed when Sohio Petroleum Company joined the venture and the group was awarded the lease as Tract Ub in 1974 for a bonus bid of \$45.1 million.

White River's two-year Environmental Baseline Monitoring Program included monitoring and analysis of surface water, groundwater, geology and soils, air quality, biological resources, and other studies.

After completing extensive conceptual engineering studies White River filed a Detailed Development Plan with the federal government in 1976 outlining plans for development of the tracts. The lease is currently in suspension at the request of White River pending resolution of problems related to the

# Union B Retort

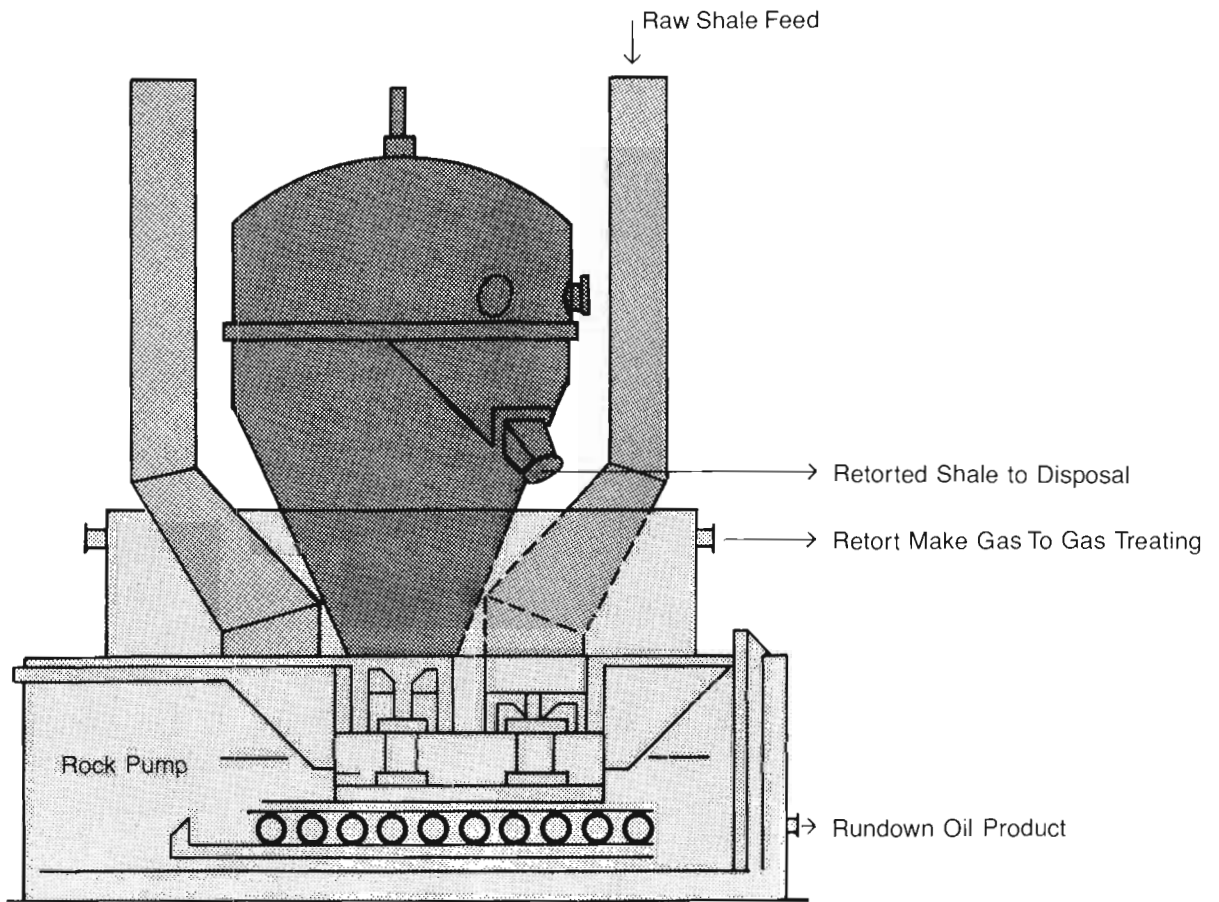


Diagram 1

# Occidental Modified In Situ Process

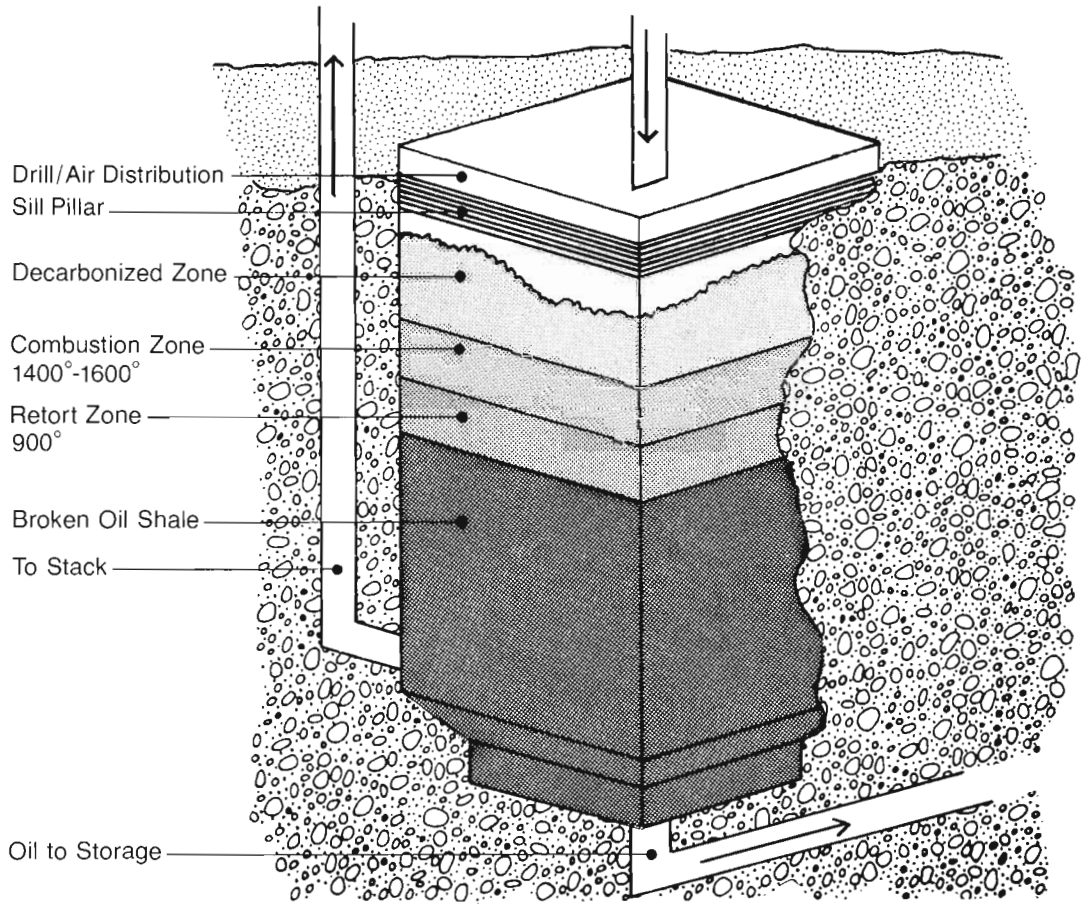


Diagram 3



# Paraho Reactor

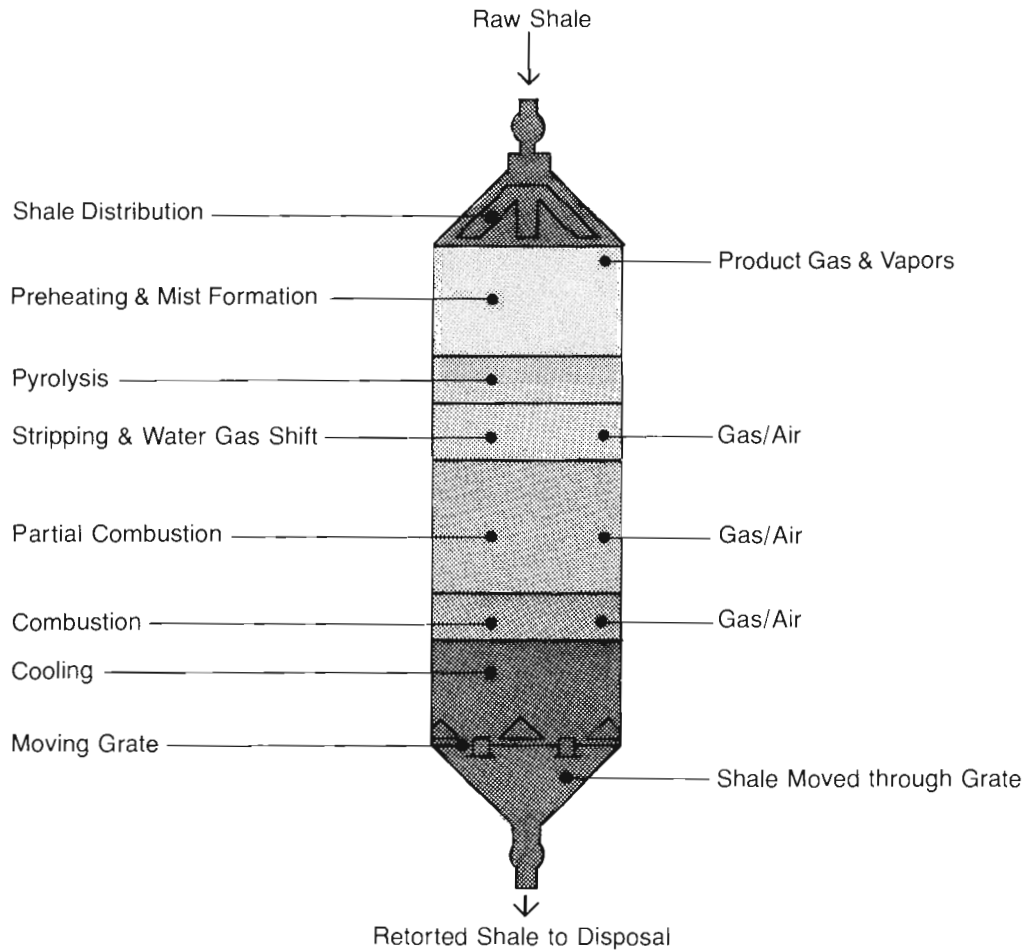


Diagram 2

ultimate disposition of the title to the tracts and other complications.<sup>1</sup>

A state lease, the Sand Wash Project, in northeastern Utah, is being developed by Tosco Corporation. The Sand Wash project is currently completing the resource analysis and environmental monitoring phase and will begin preparation of the EIS and permit applications in 1980. The project will use the TOSCO II technology and much of the plant design, environmental and socioeconomic work carried out for the Colony project.

The first step in the development of an oil shale project is the analysis of the resource to determine the thickness of the shale, the depth and location of the deposit, the extent and location of underground water and other factors. The choice of a technology is based in large part on the characteristics of the reserve. Extensive environmental monitoring is often carried out. After detailed plant design and cost projections for a commercial plant have been carried out, the environmental impact statement (EIS) can be prepared. During the preparation and approval of the EIS, the dozens of other state and federal permit applications can be made for a commercial plant.

All the projects in Colorado and Utah are in various stages of this development process. The test lease tracts are generally in the resource analysis and environmental monitoring phase. Tract Cb is in the pilot plant phase as are several other projects. No projects is in commercial production.

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<sup>1</sup>Cameron Enginners, Inc. Oil Shale Status Report, August, 1979.

The Colony Project is the only project which has completed its pilot plant operation and testing, and has a completed and approved EIS, all but one of its major permits in hand, and its community development and socioeconomic impact mitigation planning completed for a commercial plant. If effective legislation were to pass, the project could move forward to commercial production immediately. Roughly four years would be required for construction of a commercial plant.

The length of time required to prepare for commercial development including resource analysis, environmental monitoring, design work, pilot operations, commercial plant design, permit applications, EIS preparation and approval, and development of the financing package is sufficiently extensive, and the program sufficiently complex and costly that only a few projects are ready for commercialization.

A so-called "crash program" would not occur regardless of the magnitude of the federal incentives enacted. Under a practical and effective incentive program, it is likely that several of the most advanced projects would be able to move forward to commercial production. To the extent that it did not occur naturally, construction of these could be phased to minimize the peaks and valleys of population influx and other impacts.

#### Cost

The detailed plans and definitive estimates for the Colony Project are not rough preliminary estimates, but careful and thorough engineering estimates performed at a cost of \$12 million by two world-scale contractors.

This estimate is used in the recent Rand Corporation study of cost estimate escalation in "synfuel" projects as an example of a mature and reliable estimate, in contrast with less reliable and probably understated numbers for untried and less developed processes. The estimate was completed in 1974 and is now in the process of being updated to take normal inflation into account.

Using the currently projected, updated costs, the investment cost for the Colony Project is about \$25,000 per "daily barrel" of shale oil production capacity. Based on published oil industry statistics, the 1978 cost of finding and developing conventional oil and gas was about \$27,000 per daily barrel, significantly more than the current estimated cost of oil shale production from the Colony Project.<sup>1</sup>

Subject to the updating now in progress, it appears that upgraded shale oil from this proposed plant can sell at around \$25/B, returning all capital, operating and financial costs, and yielding about a 15% discounted cash flow rate of return on an all equity basis. This is well within current prices, since comparable quality Wyoming sweet crudes are now selling at \$28.50/B.

While conventional oil and gas exploration should continue to be affected by general inflation, it is likely that such inflation will be offset or more than offset in second-generation shale oil plants by efficiencies resulting from technological advance. Thus shale oil can play a stabilizing role in energy pricing.

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<sup>1</sup>Tosco in-house analysis based on industry and Department of Energy data published in Oil Daily, June 11, 1979.

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<sup>1</sup>Tosco in-house analysis based on industry and Department of Energy data published in Oil Daily, June 11, 1979.

Other sources of liquid fuels, such as coal liquefaction, should also be pursued. Gasoline and other fuels from coal are now being produced in South Africa's SASOL plant. Expanded production levels are projected both from SASOL II, now under construction, and the proposed SASOL III. While there is no doubt of the workability of the process, costs are high. The U.S. contractor now building SASOL II estimates that gasoline from a comparable plant in the U.S. West would require a price of over \$60/B. Nevertheless, even this cost may well seem cheap by the time such a plant is built. Other coal liquefaction processes are in pilot or pre-prototype stages, and work on these should be pursued.

These facts demonstrate that we cannot afford not to pursue commercial-scale development of shale oil. It is commercially ready and competitive with conventional sources, and highly competitive with other unconventional sources. It is a secure domestic supply. It is a source of urgently needed transportation fuels which are the least amenable to conservation or replacement by solar, and it is the most direct replacement for imported foreign oil.

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## **Estimated cost of shale oil compared with estimated cost of coal liquefaction and coal gasification.**

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SHALE OIL <sup>1</sup>	\$25 per barrel
COAL LIQUIDS (DIRECT) <sup>2</sup>	\$36 per barrel
COAL LIQUIDS (INDIRECT) <sup>2</sup>	\$37 per barrel
OIL SANDS <sup>2</sup>	\$31 per barrel
COAL GAS <sup>2</sup>	\$40 per barrel

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<sup>1</sup>TOSCO estimate.

<sup>2</sup>Cameron Engineers, Testimony to the Senate Budget Committee Task Force on Synthetic Fuels, September 5, 1979.

### III. THE ROLE OF GOVERNMENT

First generation oil shale recovery technology is ready for commercialization, and private industry has invested hundreds of millions of dollars to acquire shale reserves, to prepare project sites, and to demonstrate mining and retorting techniques. Several advanced projects could move forward promptly with construction of commercial scale facilities, but a combination of normal risks and unusual obstacles has thus far prevented any industrial firm or venture from making the substantial investment required for a commercial oil shale plant.

The fundamental deterrent to commercial oil shale production is a combination of the major frontend capital investment and the unusually high level of unpredictable risks involved. A full-scale commercial plant producing 47,000 B/D of shale oil will cost roughly \$1.2 billion. Furthermore, the capital investment must typically be made over a three to four year construction period, during which there is no project revenue.

In addition to the magnitude of investment, the risk of loss is particularly difficult to assess in the case of pioneer commercial projects using technology which has not been demonstrated at the commercial level. The risks include scale-up difficulties, unexpected design changes, and the possibility that inflation rates for the economy as a whole could significantly exceed current estimates.

Finally, the shifting and uncertain regulatory climate provides another level of risk beyond the control of project developers. This contingency includes unforeseen delays in



the permitting process, unanticipated changes in permitting and regulatory standards, and the possibility of obstructionist post-permit litigation.

If the nation is to have any significant commercial oil shale production by the mid-1980's, these investment obstacles must be overcome by a federal program to provide financial incentives for the first generation pioneer plants. After the first commercial plants have demonstrated the viability of the technology and the economics, the risk should be reduced sufficiently to attract private investment without special federal incentives.

The program should include a broad and flexible range of financing mechanisms so that assistance can be tailored to meet the differing needs of individual projects and firms. The following forms of financial assistance would be most effective.

- Federal Loan Guarantees. Federal guarantees of project loans would go to the heart of the problem in launching a commercial oil shale venture by facilitating the acquisition of sufficient capital at an acceptable cost of capital. If 75% of project costs could be obtained through federally guaranteed loans, private investors should be expected to contribute equity funds to cover the remaining 25% of costs.

The security of a government guarantee is needed because the assets of a project using unproven technology are not normally considered adequate collateral for private construction loans of the magnitude required. Furthermore, the favorable interest rate which could be

obtained on a federally guaranteed loan would reduce project interest costs substantially. Since interest is a major portion of the total product cost, that is a significant advantage.

- Production Tax Credit. For some advanced projects involving large companies with access to capital, the \$3/B production tax credit would tip the economic analysis of shale oil production in favor of early investment. This incentive approach is most effective where project sponsors have a high level of confidence that their project will operate successfully and can be built within the estimated time and cost of construction.
- Federal Procurement or Price Guarantees. Procurement or price guarantees would be helpful to very large companies with access to adequate investment capital but which are deterred from investing because of uncertainty over future market prices. Since these large companies typically use internally generated capital, they tend to evaluate project investments on an all-equity basis, which normally calls for a higher rate of return on investment (ROI) than a leverage basis with 25-30% equity and 70-75% debt. This higher necessary ROI can cause the required selling price for shale oil to be higher, thus making price protection at a premium level an attractive form of federal assistance.

In addition to financial incentives, a truly effective program to stimulate oil shale development should include a method of expediting the permit review process and improving

the predictability of regulation, a specialized separate entity to implement the financing mechanism, and a comprehensive federal impact assistance program to insure that state and local governments have sufficient frontend financing to meet the need for orderly community development without negative boom town impacts. The elements of such a program can be summarized as follows:

1. Financial Incentives

1.1 Range of Financial Incentives: Reliance on a broad range of incentives is the most effective approach for several reasons:

- Since each project will have significantly different needs depending on the corporate position of the developer and the nature of the project, a flexible range of different incentives at the same cost to the government can provide the most cost effective financing for the widest range of participants.
- A range of incentives will insure diversification of the industry and prevent domination of the technology by a few major companies. Loan guarantees in particular are important to independent and smaller companies who must borrow the capital for an oil shale project.
- A range of incentives will facilitate a flexible and responsive approach to commercialization by permitting government to emphasize

whichever incentives prove most workable in practice.

## 1.2 Safeguards

- Project developers should be required to put up a minimum of 25% of the project cost under all incentives to demonstrate a strong commitment to the project's commercial viability.
- Each partner in a development project should be permitted to use whatever incentive or combination of incentives he judges to be most helpful, but no developer should be permitted to receive incentives totaling in excess of 75% of his share of the total project cost. For example, Tosco anticipates that it will elect to use a loan guarantee for its portion of the Colony Project, while ARCO might elect the tax credit for its portion of the project.
- The program of incentives should be limited to pioneer plants. Additional incentives for second generation plants using the same technology should be reviewed by Congress later as a separate issue if necessary.

1.3 Shale Oil Exchanges: Since it is considered an alternate fuel under the Fuel Use Act, shale oil entering the national marketing system on exchange in the West should be permitted to fulfill the requirements for use of an alternate fuel by the end user in any part of the country. This approach would broaden the market for shale oil and make possible user financing and participation in oil shale development projects. User participation could assure a long term secure oil supply for utilities and industrial users in the Northeast, for example, while opening up the oil shale industry to a broader diversity of non-oil-company participants.

## 2. Energy Mobilization Board

Expediting and greater certainty in the permitting process are extremely important aspects of the program which augment the financial incentives in that they reduce the risk. The Board should:

- Designate high priority energy projects.
- Establish with the states a binding schedule for the permit review process and monitor implementation.
- Assign a staff member responsible for expediting each high priority project.
- Conciliate and mediate between state and federal agencies and the developer.

- Submit a report to Congress at the end of twelve months identifying repeated problem areas in the permit review process, recommending improvements in the system, and identifying any additional powers the Board may require to carry out its responsibilities more effectively.

The Board should not at this point be authorized to:

- Preempt state requirements.
- Override or waive substantive environmental standards.

The Board could be granted such powers in selected areas in the future, if necessary, after further Congressional review of any specific problems cited in the Board's report which may require such action.

### 3. Separate Entity

A separate entity created exclusively to administer the financial package is critical to insure rapid commercialization of the industry. The existing institutional inertia, the responsibility of ongoing programs, and numerous legal restrictions which would require specific detailed modification by Congressional action, make DOE an ineffective vehicle to facilitate a specific new high priority commercialization program. DOE should continue to manage R&D and make technical

judgments. The separate entity, which could have a legally limited life, should be kept small, and should be restricted to the role of a financing vehicle for the commercialization program. The usefulness of such an entity would depend, of course, on prompt staffing and immediate activation.

While it has been argued that the creation of a separate entity might represent the first step toward establishment of a national oil corporation, the consequences, including nationalization as the energy crisis deepens, are likely to be far more serious as a result of the delays in development resulting from the failure to establish an effective vehicle to carry out an aggressive domestic development program for new energy sources.

#### 4. Impact Assistance

Passage of the Hart/Randolph Inland Energy Impact Assistance Bill is essential to insure orderly community development, minimize boom town impacts, safeguard the quality of life, reduce inflation in the development areas, reduce potential construction delays, and reduce the cost of the energy produced. Tosco, in collaboration with local, state and federal offices, has already carried out extensive planning and has spent millions of dollars with ARCO to insure orderly community development for the Colony Project. However, a national federal impact assistance program is critical to provide sufficient frontend financing for state and local governments to handle the impacts of energy development in a comprehensive fashion.

#### IV. THE ENVIRONMENT

##### Overview

The Colony Project has taken a careful and thorough approach to environmental issues and is committed to environmentally sound development. Colony is the only planned oil shale project which has an approved environmental impact statement and has received all but one of the major permits required. The EIS process required five years and was one of the most detailed and extensive ever received by the BLM. In addition to the EIS work for Colony, Tosco helped initiate and participated in several federal, state, local, environmental, and industry planning commissions for oil shale development and has collaborated actively with state and local governments on impact assessment and socioeconomic planning.

The venture partners, Tosco and ARCO, have spent approximately \$8.3 million for environmental studies, socioeconomic planning and community development for the Colony Project to date. It is projected that more than \$80 million of the total capital cost of a 47,000 B/D commercial oil shale facility will be directly related to systems designed to mitigate environmental impacts of the Project.

On July 11, 1979, Alan Merson, Regional Administrator of the United States Environmental Protection Agency, made the following statement to Colony in approving its application for a PSD permit:<sup>1</sup>

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<sup>1</sup>Letter of July 11, 1979, from Alan Merson to Dr. Legatski transmitting EPA's conditional permit to commence construction and operate the Colony Development Operation.



We have appreciated your cooperative attitude throughout this process. Your clearly evidenced corporate policy of being a "good environmental citizen" will be of inestimable mutual benefit during the construction and operation of your project.

This section summarizes the major environmental and socioeconomic issues identified with proposed commercial oil shale development and the steps taken by Colony to eliminate or mitigate adverse environmental impacts.

#### Water Availability

The estimated requirements of the 47,000 B/D Colony Project is 9,000 acre feet/year. 1,715.5 barrels of oil can be produced per acre foot of water consumed, or .00058 acre feet of water is utilized to produce one barrel of oil. Colony has acquired Colorado River water rights, has contracted with the United States Bureau of Reclamation for additional water, and plans to drill various ground water wells on the project site to supply water needed for the initial developments. Over the past ten years, Colony has acquired sufficient senior water rights for the Project.

Recent research by Tosco suggests that with further improvements in project design and technology, water consumption could be reduced by as much as 20% in the near term. Additional refinements in technology as commercialization proceeds are expected to yield substantially greater gains in water conservation over the next decade.

While it is generally agreed that adequate water is available to support initial levels of commercial oil shale

production, questions have been raised concerning the availability of water to support an expanded oil shale industry. In response to this issue, the Colorado Department of Natural Resources (DNR) recently completed an assessment of water availability for oil shale and coal gasification developments in the Upper Colorado River Region.<sup>1</sup> The initial draft report is based on research and analysis performed over a twenty month period.

The draft report concludes<sup>2</sup> that the water needs of a 1.5 million B/D synthetic fuel industry (i.e., oil shale and coal gasification) could be satisfied from surface supplies without significant, if any, reduction in the other projected consumptive water uses in the Upper Colorado River Region.<sup>3</sup> The report suggests that in addition to surface water, ground water may provide a significant source of water supply for oil shale development.<sup>4</sup> The report also suggests that utilization of available conservation techniques by municipal and agricultural users could substantially increase the supply of surface water for the synthetic fuels industry and other users.<sup>5</sup>

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<sup>1</sup>The study was funded by the U.S. Water Resource Council pursuant to Section 13(a) of the Federal Non-Nuclear Energy Research and Development Act of 1974.

<sup>2</sup>The report's conclusions are subject to certain assumptions, including project siting, water delivery systems, projection of other consumptive uses, projected requirements of the oil shale industry, and similar facts.

<sup>3</sup>Ibid. at ci.

<sup>4</sup>Ibid. at cix.

<sup>5</sup>Ibid. at cvx.

## Water Quality

The Colony Project's water quality preservation plan is designed to prevent any effluents from entering either surface or ground water systems. The total Project is designed to be a zero discharge system. The only water quality impacts anticipated at the Project will result from temporarily increased surface water sediment due to the disruption of the surface during construction and a minor increase in salinity due to the slight decrease in flow which necessarily result from any additional water use.

The essence of the water quality plan at Colony is to permit no effluents. All water from the mine, the retorting process, and the spent shale disposal site will be collected, purified and recirculated to be used as a wetting and compacting agent at the spent shale disposal site.<sup>1</sup> The mine is designed to prevent any run-off of river water into the underground water system, the plant is a zero discharge facility, and catchment dams are placed above and below the project site to collect and recirculate any precipitation run-off which may have come in contact with spent shale.

The Colony Project involves two major uses of water. Steam and water are used in the retorting process. Water is used for cooling and in the revegetation process. The Colony processing plant is designed to recycle all used water to minimize water consumption. Prior to re-use for process cooling and human use, used water is treated and upgraded at the water treatment plant.

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<sup>1</sup>Colony Development Operations, EIS, Vol. I, "Retorting and Upgrading," and "Solid Waste Disposal," pp. II-24 to II-76.

**Water quality is frequently tested**



Water used in wetting the spent shale to facilitate compaction and reduce dust during transportation and placement which does not evaporate is permanently entrapped in the spent shale pile by compaction and capillary action. Precipitation run-off is caught in a sealed catchment below the processed shale pile and recirculated.

### Air Quality

On January 10, 1979, the Air Pollution Control Division of the Colorado Department of Health gave its initial approval to 53 emission permits for the Colony Project. On July 11, 1979, the U.S. Environmental Protection Agency (EPA) issued a Prevention of Significant Deterioration of Air Quality (PSD) Permit for the Colony Project.<sup>1</sup> In issuing the PSD permit and later in the press, Alan Merson, Regional Administrator of the EPA, praised Colony as a "good environmental citizen" and for its cooperative attitude throughout the application process.

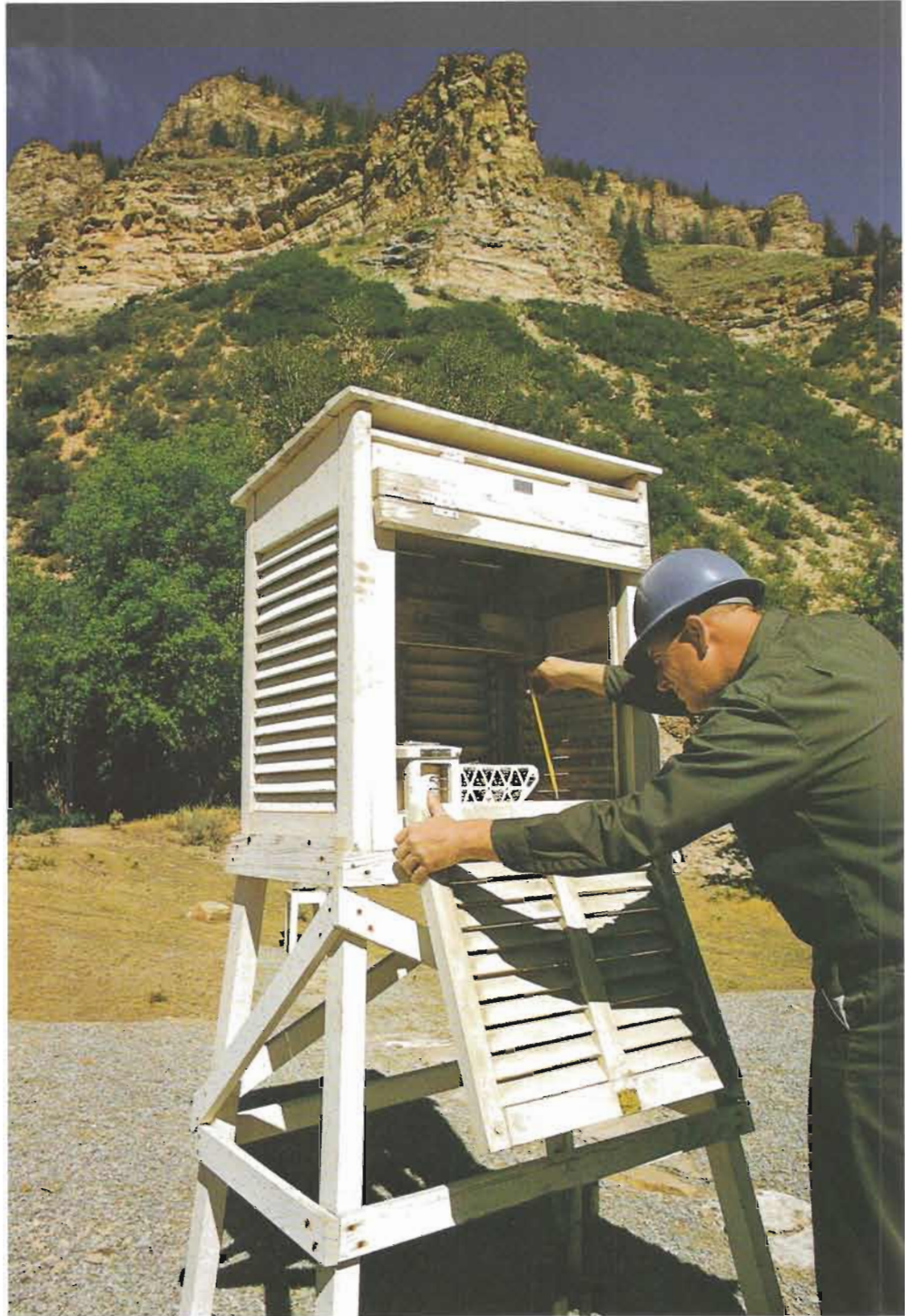
Air quality at the Colony Project will be affected in two ways. First, dust will be generated by construction, transportation, and process activities, adding to the suspended particulate matter in the air. Second, gaseous emissions will be released from the plant, mining and reclamation equipment, and employee vehicles.

The process plant employs the best available control equipment to minimize air pollutants. Venturi water scrubbers are used on all stacks to remove particulate matter. The

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<sup>1</sup>Colony Development Operation PSD Permit, approved by EPA on 7/-1/79.

**Baseline environmental monitoring**



ammonia and sulfur recovery and coking units are primarily used to reduce emissions of  $\text{NO}_x$ ,  $\text{SO}_2$  and hydrocarbons, but will also produce valuable by-products for sale. Contained arsenic is also removed and disposed of as a solid waste.<sup>1</sup>

The crushing and conveying facilities use bag dust collection units to remove dust. All crushing and conveying equipment is enclosed to the extent possible to prevent windblown dust during the movement of the crushed shale. The stacker/reclaimer on the spent shale pile will use a water spray dust suppression system. The dust prevention technique for the spent shale disposal area and reclamation of the spent shale are discussed in the section on Mining and Revegetation.

The Colony Project will not generate emissions that will cause or contribute to violations of any state or federal ambient air quality standards. The EPA, in issuing the PSD permit, expressly found that Colony proposes to apply the "best available control technology" at the project, and further, that Colony's proposed emissions monitoring program will adequately assess the air quality impacts and assure continued compliance with the conditions of the PSD permit.

Not only has Colony met all the applicable state and federal air quality standards, the particular standards with which the project has complied are those applicable to light rather than heavy industry, since Colorado chose to apply the light industry category to the oil shale region.

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<sup>1</sup>Colony Development Operations EIS, Vol. I. "Retorting and Upgrading," 1975, pp. II-24 to II-48.

## Mining and Revegetation

Oil shale will be mined using conventional room and pillar underground mining techniques. Strip mining and open pit mining are generally considered uneconomic and impractical for the resource. The mine mouth will represent a relatively minor disturbance of the mountainside, no more visible than the entry of an underground coal mine.

A fully environmentally acceptable method of disposing of the spent shale from retorting has been developed, extensively tested, and demonstrated by Colony over several years at the pilot facility. The Colony method addresses the multiple issues of potential dust and water pollution and results in a stable, fully revegetated land mass.

After the oil shale is brought to the surface, crushed, and retorted to remove the oil, the retorted shale is cooled and water added to bring its moisture content to approximately 13%. Immediately after retorting, the processed shale has the consistency of fluffy black dust, and the addition of water makes it dense, impervious to wind, and more easily transported and compacted. The processed shale is then transported by covered conveyor to a deep canyon where it is spread on the disposal pile and compacted.

The compacting stabilizes the pile and effectively prevents any surface water percolation deeper than the first 13 inches. Any water which does not evaporate is trapped within the pile by capillary action and compaction. Should rain water flow over the pile, it is caught in a catchment dam below the disposal pile and is recirculated through the project's water cycle.



## Colony Development Operation's semi-works plant and pilot mine



- A — Mine Mouth
- B — Crusher
- C — Crushed Shale Storage
- D — Retort

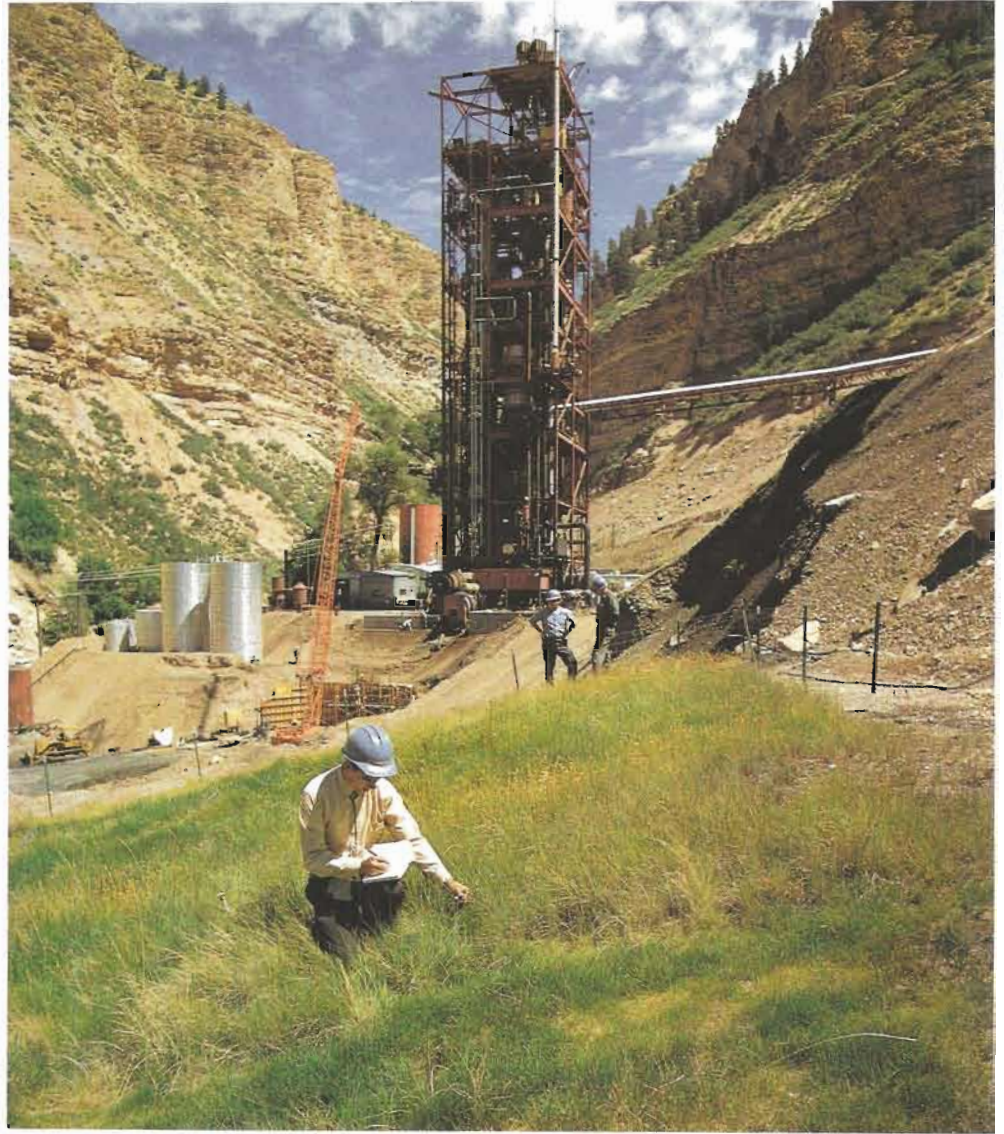
**Underground room-and-pillar mining**



**Tosco II Retort**



**Processed shale is successfully revegetated**



The reclamation process begins with recontouring to develop a 4:1 slope with terracing every 25 vertical feet to further stabilize the pile and control drainage. A sprinkler system is used to leach down the surface salts to provide a clean rooting zone for surface vegetation. The leached salts remain trapped in the pile below the planting zone and any surface run-off during the leaching process is collected at the catchment dam below the pile and recirculated.

The recontoured area is covered with a layer of topsoil saved from the area under the spent shale pile in order to promote a vigorous vegetation cover. Fertilizers are then added and seeding takes place. An irrigation sprinkler system waters the seedlings and prevents windblown dust for the first season, after which no further irrigation is required.

Colony has conducted extensive research to determine suitable growing media, soil additives and plant species.<sup>1</sup> Numerous research projects and plots at the pilot facility have demonstrated that the spent shale can be permanently and successfully revegetated to a state comparable to the surrounding terrain.

## Toxicity

### Carcinogenicity

Concern has been expressed by some critics of oil shale development that the rock itself, the oil made from it, air

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<sup>1</sup>Colony Development Operation, EIS, Vol. I, "Reclamation 1975.

emissions from the processing, and the spent shale might be carcinogenic. To examine that possibility, Tosco commissioned extensive research and analyses of oil shale by several respected research laboratories.

These analyses relied on the two major methods for evaluating carcinogenic properties. The first method is chemical analysis for substances generally found in carcinogenic materials. The substance tested for is benzo [a] pyrene (BaP), a PAH compound formed during combustion of all organic material. BaP, while not a known carcinogen to humans,<sup>1</sup> is generally indicative of the presence of other associated carcinogens.<sup>2</sup> The second major procedure is bioassay, which generally involves extended contact of test animals such as mice and hamsters with suspected carcinogenic materials. Since 1964 more than 1,000 detailed chemical analyses have been carried out to measure the presence of cancer-causing substances in oil shale. Lifetime experiments were conducted with 2,800 mice and hamsters to determine if concentrations of the materials or extracts made from them are hazardous.

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<sup>1</sup>Selikoff, I.J. et al., "Inhalation of Benzo [a] pyrene and Cancer in Man," a paper presented at the 1st Fall Assembly of the American College of Chest Physicians, Chicago, Illinois, October 30, 1969.

<sup>2</sup>Sawicki, E. Arch. Environ. Health 14, 46 (1967), "Airborne Carcinogens and Allied Compounds."

Chemical Analysis: Tests conducted by the Kettering Institute of the University of Cincinnati indicate that shale oil, like all other petroleum products, contains small amounts of polycyclic aromatic hydrocarbons (PAH), some of which are known to cause tumors in animals under laboratory conditions. The potential carcinogenicity of PAH materials, or any compound, varies significantly in relation to context, concentration, and length of exposure. PAH's are formed by all combustion and pyrolysis processes and are normally biosynthesized by bacteria and plants and metabolized by animals. Soils, plants, petroleum and foods all contain PAH. The PAH most frequently discussed is benzo [a] pyrene (BaP), a mouse-skin carcinogen. The BaP content of shale oil is comparable to or less than that of many presently used petroleum materials, and is dramatically reduced when the crude oil is upgraded by hydrotreating.

Various types of spent shale processed by the TOSCO II process have been analyzed by the Kettering Institute,<sup>1</sup> the Denver Research Institute,<sup>2</sup> the Eppley Institute

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<sup>1</sup>National Science Foundation, First Annual Report, "The Disposal and Environmental Effects of Carbinaceous Solid Wastes from Commercial Oil Shale Operations," NSF GI 3428X1 by Josef J. Schmidt-Collerus, Denver Research Institute January, 1974.

<sup>2</sup>Wallcave, L., et al., "Skin Tumorigensis in Mice by Petroleum Asphalt and Coal Tar Pitches of Known Polynuclear Aromatic Hydrocarbon Content, "Toxicology and Applied Pharmacology, 18 41 (1971).

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<sup>2</sup>Wallcave, L., et al., "Skin Tumorigensis in Mice by Petroleum Asphalt and Coal Tar Pitches of Known Polynuclear Aromatic Hydrocarbon Content, "Toxicology and Applied Pharmacology, 18 41 (1971).



Institute for Research in Cancer,<sup>1</sup> and the Battelle Institute at Columbus, Ohio. These analyses place the BaP content of processed shale at less than 40 parts per billion -- about one-tenth that of oak leaves, and less than or equal to that found in charcoal-broiled steaks, smoked fish, coconut oil and forest or garden soil.

Biological Testing: Biological testing to determine the potential carcinogenicity of oil-shale-related materials has been undertaken by the Eppley Institute for Research in Cancer in Omaha, Nebraska, and by Bio-Research Consultants, Inc., Cambridge, Massachusetts. In the Bio-Research experiment, a group of hairless mice lived their entire lifetimes on bedding materials which included various concentrations of spent shale produced by the TOSCO II process. In every case, the skin areas were found to be totally free of lesions or cancers.<sup>2</sup>

Experiments by the Eppley Institute carried out by the classical skin painting method indicate that oil shale solids demonstrate carcinogenicity equivalent to similarly prepared materials in everyday use. Intra-tracheal inhalation of raw oil shale rock particles, TOSCO II spent shale, TOSCO II atmospheric effluent, or shale oil coke in hamsters did not cause lung cancer.

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<sup>1</sup>Eppley Research Institute.

<sup>2</sup>Ibid.

Positive control test groups treated with BaP developed lung cancers, proving the validity of this animal test model.

Summary: Chemical analyses at various laboratories have shown conclusively that crude shale oil produced by the TOSCO II process contains quantities of BaP similar to those found in most conventional petroleum or refinery products and less than some industrial fuel oils. Upgraded shale oil, which is the final product, has significantly reduced levels of BaP.

Biological testing has also proven that the carcinogenic potential of crude shale oil is of the same magnitude as other conventional petroleum products, and that hydrotreating or upgrading the shale oil reduces the carcinogenic properties. Numerous studies have established that spent (processed) shale contains substantially fewer carcinogenic properties than many common materials, including a variety of cooked foods. In summary, none of the oil shale solids, liquids or processing emissions present a cancer hazard to either the work force or the general population.

#### Disposal of Toxic Wastes

Some toxic wastes, including arsenic, are produced as by-products of the retorting and upgrading of shale oil. Such wastes are collected by air pollution control equipment and will be disposed of by burial in the spent shale disposal pile. This method of disposal has gained wide acceptance

in eastern coal fields for disposal of acid bearing coal wastes. Because of the impermeability of the compacted spent shale, and the catchment dam below the disposal pile, none of the arsenic or other solid wastes will migrate into the surface or ground water systems.<sup>1</sup>

### The Greenhouse Effect

Concern has been expressed recently about the long term effects on the earth's climate of the increasing amounts of carbon dioxide being released into the atmosphere. Since carbon dioxide absorbs infra-red radiation, it is speculated that higher concentrations of it might begin to reduce the rate at which heat escapes from the earth's surface, leading to a two to three degree rise in the average temperature of the atmosphere. It has been hypothesized that this process, known as the "greenhouse effect", could affect the earth's climate, lead to melting of the polar ice caps and ultimately inundation of the coasts.

Carbon dioxide escapes into the air by a variety of natural processes, including the decay of animal and vegetable matter. It is removed by photosynthesis and other natural

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<sup>1</sup>Colony Development Operations, EIS, Vol. 1, "Solid Waste Disposal," 1975, pp. II-60 to II-77. Also Heley, William, "Processed Shale Disposal for a Commercial Oil Shale Operation" from Mining Congress Journal, 5/74, and other internal Colony research.

processes which maintain the concentration of carbon dioxide in the air at relatively static levels. Fossil fuels such as coal, oil and natural gas, also produce carbon dioxide when burned, and in recent years some researchers have expressed concern that the world may be consuming fossil fuels at such a high rate that at some point in the future the incremental carbon dioxide from this additional source could result in a significant worldwide greenhouse effect.

The greenhouse effect theory has been mentioned as an argument against the development of oil shale on the grounds that shale oil production and utilization might accelerate the greenhouse effect. In considering this view, two points should be noted. First, the hypothesis that fossil energy production and utilization will result in increasing concentrations of carbon dioxide, which in turn will result in climatic changes, is highly speculative and controversial. Several recent studies conclude that the release of more CO<sub>2</sub> into the atmosphere might actually stimulate greater agricultural production and increase natural vegetation, which in turn would increase the earth's capacity to absorb CO<sub>2</sub> and hold constant the CO<sub>2</sub> level in the atmosphere. Other studies indicate that the amount of incoming infra-red radiation absorbed by the CO<sub>2</sub> in the atmosphere may actually lower the amount that reaches the earth's surface, and that the heat in the atmosphere will be radiated into space, thus calling into question the existence of a greenhouse effect. Data showing a 1% decrease in the temperature of the Northern Hemisphere between 1940 and 1970 cast further doubt on the existence of the greenhouse effect.

Second, if it should be demonstrated in the future that the so-called greenhouse effect does exist and that fossil energy does contribute to it, the problem would require a

broad international solution. Since the nation will need liquid fossil fuels well into the next century, the failure to develop domestic oil shale will simply result in greater dependence on imports without, however, reducing the greenhouse effect.

Third, EPA projects that the additional CO<sub>2</sub> released by an oil shale industry will be negligible.<sup>1</sup> They estimate that a five million B/D oil shale industry by the year 2030 -- a rate of development far in excess of anything currently planned or considered feasible -- would result in a 1% increase in the worldwide total of CO<sub>2</sub> emissions. According to the National Academy of Sciences<sup>2</sup>, oil shale is the best of all the synthetic fuels from the standpoint of CO<sub>2</sub> emissions. Natural gas is the lowest in terms of CO<sub>2</sub> emissions, conventional petroleum and oil shale rank second, some types of enhanced oil recovery rank third, coal ranks fourth, and coal liquids rank fifth.

#### Socioeconomic Impacts

Most of the energy development which will take place in the next decade will occur in rural areas of the country. Oil shale development will take place in Northwestern Colorado and rural areas of Utah. Advance planning and adequate frontend financing are essential to insure orderly

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<sup>1</sup>Discussion with Robert Statnik of EPA.

<sup>2</sup>National Academy of Sciences, Congressional Record (Senate 10654).

municipal expansion in response to the rapid influx of new residents into these rural areas.

One 47,000 B/D commercial oil shale facility will triple the tax base of the county in which it is located and provide thousands of new jobs. However, new housing, roads, schools, sewer and water systems, and other municipal facilities and services must be planned, developed, and ready for the construction force during the first years of plant construction, while the necessary level of tax reserves will not be generated until the oil shale facility is in full operation five years later.

This cash flow or "tax lead time" problem makes it impossible for small rural communities to expand rapidly to meet the need. Bonds, the only alternative for raising the funds, are generally considered unfeasible, since the timing of the development is often uncertain, the risk of unpredictable, sudden and extensive delays is high, the response time required is extremely short due to the rapid population growth, and the investment required is far in excess of anything within the experience of these communities. Rural areas must double the size of their communities within two to three years or less on the expectation that energy development will in fact proceed as projected.

The failure to develop housing and services in a timely fashion results in the "boom town syndrome". The work force, unable to find housing, is forced to live under squalid conditions. The lack of housing, services and basic goods results in spiraling inflation, and the unplanned growth

results in strip development, wasteful use of prime agricultural land, energy and water. The living conditions lead to depression, alcoholism, family problems, high employee turnover and finally, plant construction delays. The transience, in turn, encourages crime, which further encourages turnover. This negative syndrome, which is extremely difficult to control once it has begun, is avoidable through adequate planning and frontend financing.

Communities anticipating major energy development require a minimum of two years lead time for planning prior to the start of plant construction. The planning process involves the development and approval of a comprehensive master plan and zoning, construction feasibility studies, the purchase of land for schools and other major facilities, facility design, and the simultaneous construction of roads, schools, water and sewer systems, and other facilities -- in short, a major new community development program within existing towns.

Tosco has initiated and collaborated with local, state, and federal officials in the planning for orderly community development in Colorado for more than six years. Since company towns, which were once the typical industry response to the problem, are now considered undesirable by both government and industry, a range of innovative new methods for facilitating orderly community development was developed for Colony.

Colony purchased land early in the development cycle, before inflation of prices, which will be made available at

cost for housing in an area local officials consider desirable for residential development. Hundreds of thousands of dollars were invested by Colony for detailed master planning for the residential area and for architectural design for schools in accord with the specifications of local government.

Grants were made to local government to carry out more comprehensive planning of their own. Tosco has collaborated with federal, state, and local officials to obtain joint industry/government funding and participation in statewide socioeconomic impact analyses for the oil shale industry as a whole, in the development of a regional growth monitoring and projection system, and in the preparation of a detailed analysis of municipal financing options and the need for new legislation to provide greater flexibility for local government in the area of financing for municipal expansion.

In addition, the state of Colorado has been extremely active in socioeconomic planning. The state has established a state impact assistance coordinator's office and industry, state, and local government impact teams to set municipal expansion priorities and develop fiscal strategies to implement community development plans. Local government has carried out much of the master planning and zoning process, and in some cases, purchased land for schools and begun construction feasibility studies.

State and local government have laid a strong foundation for orderly community development and Colony, in collaboration



with government, has carried out the necessary planning and made the early investments to manage the socioeconomic impacts associated with the Colony Project. However, there is an urgent need for additional frontend financing for comprehensive and continuing planning and management by local and state government and for implementation of community development, specifically the construction of roads, schools, and other major municipal facilities. It is essential, therefore, that the Hart/Randolph Inland Energy Impact Assistance Bill be enacted to provide state and local governments in both the East and West with sufficient resources to ensure that energy development proceeds in an orderly manner and without sacrifice to the quality of life.

V. CONCLUSION: THE NEED FOR ENERGY ACTION

The gasoline lines of 1979, the rapid OPEC-led increase in crude oil prices, and the steadily worsening threat of catastrophic effects on the national economy in the event of another disruption in Middle East production are facts that require decisive and effective action. Few people now argue, as some did even after the events of 1973-74, that there is no problem or that it is contrived and can be eliminated merely by legislative fiat.

Yet there remains a risk that effective action will not be taken, as a result of misinformation, polarization of opinion beyond the power of reason or compromise, and an inability to look beyond immediate national special interests to the long term needs of the country.

Much of the public debate has taken the form of argument for this instead of that, one course of action rather than another, conservation instead of production, solar instead of coal, and so on. All have occupied the time and energy of the press, the Congress and Administration, and many business and interest groups. These arguments over supposed alternatives are, by and large, dangerous distractions from the single real choice -- we can continue our reckless drift to helpless dependence on imports of oil from unstable and unreliable sources, or we can take every reasonable and feasible action to regain control over our economy and our lives, including conservation, development of solar energy, increased production of conventional fossil energy, and development of new domestic fossil energy sources.

This is the only fundamental decision we must make. The other important matters which need determination are derivatives from this basic choice and cannot be permitted to distract from it.

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