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Highlights

- The jump in oil prices over the past several years and concurrent rise in the price of gasoline have refocused attention on oil shale resources in Colorado, Utah, and Wyoming. Past exploration has indicated that oil shale deposits in these three states contain 1.5 trillion barrels of oil, compared to an estimated worldwide resource of conventional crude oil of 2.3 trillion barrels. The majority of these reserves (85 percent) are in Colorado, followed by Utah (10 percent) and Wyoming (5 percent).
- The federal government is encouraging research and development aimed towards producing oil from oil shale. Section 369 of the Energy Policy Act of 2005 provides for "Research, Development, and Demonstration" leases of federal land with oil shale deposits and eventual commercial leases should there be sufficient interest. Four companies are currently involved in the Research, Development, and Demonstration program. These companies are EGL Resources, Chevron Shale Oil Company, Shell Frontier Oil and Gas and Oil Shale Exploration Company. The Bureau of Land Management is also writing a programmatic Environmental Impact Statement for the Research, Development and Demonstration leases.
- Oil shale actually contains kerogen, a solid geologic precursor to oil rather than actual crude oil. This requires drastically different processing technology than conventional crude oil. Heating the kerogen to 200° C to 600° C initiates chemical reactions that convert the kerogen to oil, gases, and coke. It has usually been necessary to subject the resulting product to an upgrading or pre-refining process for it to be accepted by conventional oil refineries. These additional processing steps have usually resulted in oil produced from oil shale being more expensive than conventional crude oil.
- Even with the current interest in oil shale, if a viable industry develops, it will be at least ten years until production of noticeable size occurs. Although there has been much effort toward an oil shale industry in the past, most attempts met with failure and there is not a large body of industrial knowledge based on successful practice. Without this type of knowledge, it is necessary to operate small-scale pilot plants to obtain engineering and cost data for successful scale-up to commercial plants.

Western Oil Shale: Past, Present and Future

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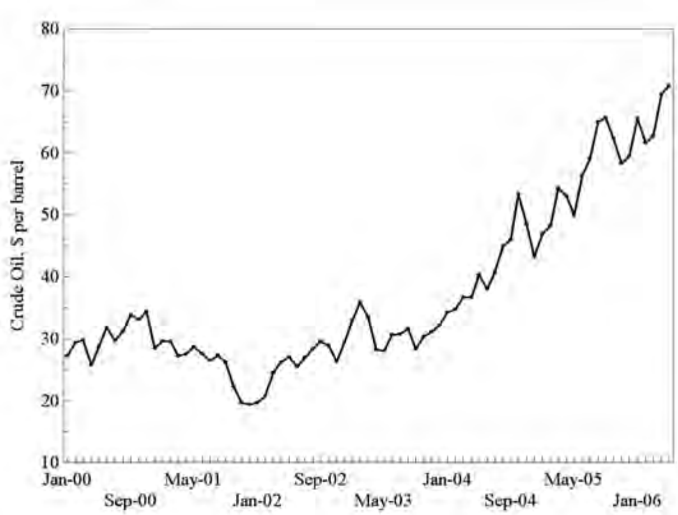
Introduction

The recent price of crude oil and gasoline has focused attention on energy sources other than crude oil and consequently, oil shale has returned to the public's attention as potential source of fuel. Since the beginning of 2000, crude oil has jumped from less than $30 per barrel to a price currently hovering around $70 per barrel (Figure 1). Unlike the oil price shocks of the 1970s and 1980s, the price of oil is being driven by increased demand, primarily in Asia, rather than supply constraints and geopolitical considerations. From 2001 to 2005, demand for petroleum in China increased by 41 percent and China now accounts for 8.3 percent of worldwide petroleum demand, up from 6.3 percent in 2001.

Figure 1
Crude Oil Price, 2000-2006



Source: Energy Information Administration.

In the United States, hurricanes during 2005 and refinery constraints also contributed to the rising cost of petroleum products. Hurricanes Katrina and Rita impacted the Gulf Coast in the fall of 2005 and interfered with refinery activity (42 percent of U.S. refining capacity is located along the Louisiana and Texas Gulf Coasts). Collectively, these events and rising global demand drove the price of gasoline to more than $3 per gallon and there were localized spikes of over $5 per gallon in the South in the aftermath of Hurricane Katrina.

The prospect that the recent price increases may be long-term as a result of global demand has also focused government efforts. In May, 2005, Senator Orrin Hatch introduced the Oil Shale and Tar Sands Development Act of 2005[1] in the U.S. Senate to promote development of domestic tar sand and oil shale energy resources. The major provisions were eventually passed as Section 369 of the Energy Policy Act of 2005. The Bureau of Land Management has initiated a program to lease oil shale properties for research and development purposes.

Oil Shale Production History

Historic oil shale production has been identified in 18 different countries. Most past production occurred in the mid- to late-1800s, before the emergence of the worldwide petroleum industry. There were also instances of production during wartime when international trade was stifled. The longest-producing areas were Scotland, where production occurred from the 1860s to 1966 and Australia with production from 1865 to 1955. What most past operations had in common was that they were fairly small and designed to serve a local economy. As the conventional petroleum industry developed and worldwide trade in petroleum became more common, most of the oil shale operations ceased to exist. Currently, oil shale is mined in Estonia, China and Brazil. Estonian production was 11.3 million tons in 2004. The majority of the Estonian production is burned in a thermoelectric power plant and not processed to recover the oil. In China, oil shale has been retorted at Fushun in Manchuria since the 1920s. Current production is about half a million barrels annually after peaking at 7.5 million barrels annually in the 1950s. In Brazil, Petrobras, the state-owned oil company operates two retorts that produce about 3,800 barrels of oil daily. Initial production occurred in Brazil in 1881. Production in Brazil was erratic until the Brazilian government purchased existing oil shale facilities in 1951 and placed them in the charge of Petrobras in 1954.

There have been numerous efforts in the past to develop oil shale resources in the United States. The initial production of shale oil began in the United States about 1850 and by 1860 there were 50 to 60 plants in the United States and Canada distilling oil from shale or coal. These plants were located in Oregon, Massachusetts, Connecticut, Ohio, Virginia, Kentucky, Missouri and Utah. The conventional petroleum industry came into existence in 1859 when Edwin Drake drilled the first well at Titusville, Pennsylvania and it quickly surpassed the oil shale industry due to higher profits. By the 1870s, all of the oil shale plants had either closed or been converted to the use of crude petroleum.

The earliest attempt at shale oil production in Utah occurred at Chris's Creek, about five miles southeast of Levan. The historical record is sketchy, but available information indicates a retort was constructed between 1854 and 1865. Remnants of this retort were

[1]Tar sands, also known as oil sands and bituminous sands, are natural mixtures of sand, clay, water and bitumen. Bitumen is a highly viscous hydrocarbon and unlike the solid kerogen in oil shale is soluble in common solvents. Bitumen is also commonly called heavy oil and is usually to viscous to be recovered through conventional oil wells. The tar sands are usually mined, the bitumen separated from the sand and clay and the upgraded to a synthetic crude oil.

The term "oil shale" refers to the rock that contains kerogen while "shale oil" refers to the oil produced from the rock by prolysis.

photographed in 1961 by Arthur L. Crawford of the Utah Geological and Mineralogical Survey. There was again a boom in oil shale during the 1920s, when the rise of the automobile and diminished production from the Pennsylvania oil fields created concern about the future petroleum supply. This boom included many of the stock promotions common to past natural resources booms. Promoters erected model retorts on street corners in Denver and Chicago and had stock certificates available for investors. The most successful effort during this time was the Catlin Shale Products Company, which operated just south of Elko, Nevada from 1915 to 1924. This plant had total production of about 12,000 barrels.

There was another boom in oil shale activity from the 1940s through the 1960s as a result of the Synthetic Liquid Fuels Act which was passed in 1944 to promote energy self-sufficiency for national security. The 1970s energy crises prompted another round of activity in the oil shale industry. In 1974, the federal government offered six lease sites on federal land for experimental development work and bids for theses tracts exceeded expectations. In addition to the six lease sites offered by the federal government, over a dozen other operations achieved various states of development and there were also numerous proposals that never advanced past the planning stage. In 1982, the federal government established the Synthetic Fuels Corporation to offer loan guarantees. Although Congress dissolved the Synthetic Fuels Corporation in 1986 after crude oil prices collapsed during 1984, the expectation of financial assistance resulted in numerous design studies and proposals for oil shale development that would otherwise not have occurred. The last active oil shale facility from this era was the Union Oil operation at Parachute, Colorado. This operation closed in 1991 and the site has been reclaimed.

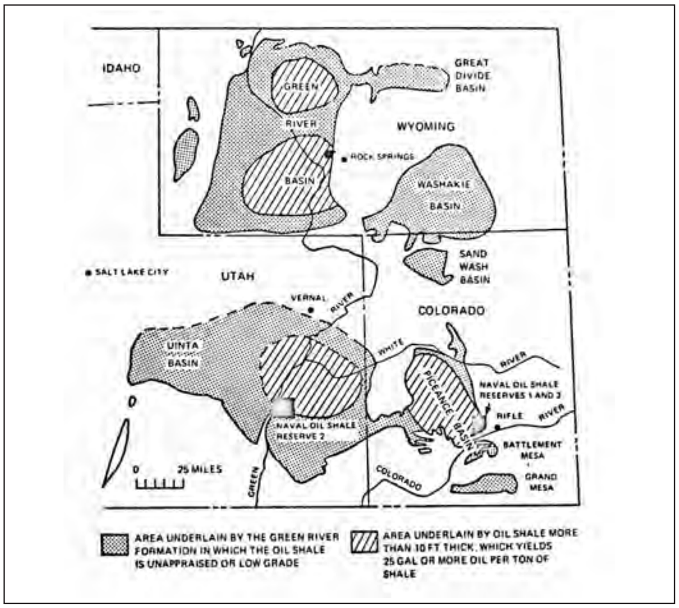
Oil Shale Resources

The term “oil shale” is actually a bit of a misnomer. In the western United States, the rock is usually a marlstone rather than shale, although they appear similar. Rather than containing crude oil, the rock contains kerogen, which is a solid geologic precursor to crude oil. Kerogen results when organic matter is not buried deep enough for the resulting heat and pressure to chemically convert it to crude oil. Heating the rock to approximately 200° C initiates chemical reactions that convert the kerogen to oil, gases and residual coke. This conversion, known as pyrolysis, proceeds at a more rapid rate at 500° to 600° C. The amount of oil recovered from the oil shale varies by deposit and is usually expressed as gallons of oil recovered per ton of shale. It should be noted that when a statement is made that oil shale contains a certain amount of oil, it is the amount of oil obtained through pyrolysis of the contained kerogen.

Worldwide, nearly 100 oil shale deposits containing about 2.9 trillion barrels of oil have been identified in 36 countries. The vast majority of identified oil shale, containing about 2 trillion barrels of oil, is located in the United States. This includes both the western oil shale and deposits in Kentucky, Ohio, Indiana and Tennessee. There are also small deposits in Nevada, Montana, Alaska, Kansas and elsewhere in the United States. The most economically attractive deposits in northwestern Colorado, northeastern Utah, and southwestern Wyoming are estimated to contain 1.5 trillion barrels of oil. By comparison, the latest estimate for worldwide proved petroleum reserves is approximately 1.2 trillion barrels[2].

[2]Proved petroleum reserves refers to known deposits that can be economically exploited. In 2000, the U.S. Geological Survey estimated the total worldwide petroleum resource, including currently uneconomic deposits and estimates for undiscovered fields, at 2.3 trillion barrels. Generally, the term “resource” refers to the overall amount of a mineral present, regardless of associated economic value or likelihood of being extracted. The term “reserve” refers the amount of a mineral that can be economically extracted.

Figure 2
Western United States Oil Shale Deposits



Source: J.D. White, Technical and Environmental Aspects of Oil Shale Processing.

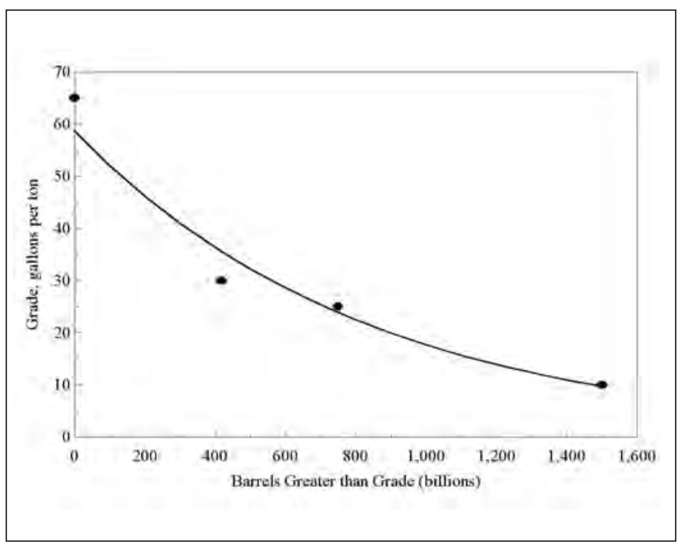
In the western United States, the majority of oil shale reserves (85 percent) are in the Piceance Basin in northwestern Colorado, with Utah's Uinta Basin containing 10 percent of the reserves and the remaining 5 percent located in the Green River and Washakie Basins in Wyoming (Figure 2). The oil shale in the western United States generally contains between about 10 gallons per ton and 50 gallons per ton with some areas containing up to 65 gallons per ton. Of the 1.5 trillion barrels, about 418 billion barrels are in shale that will yield 30 gallons per ton or greater and 750 billion barrels are in shale the will yield 25 gallons per ton or greater (Figure 3).

Oil Shale Processing

Since oil shale actually contains solid kerogen, which must be converted to oil through pyrolysis, the recovery and processing of oil shale is much different from conventional crude oil. Past attempts at recovering shale oil have involved either mining and above-ground retorting or in situ retorting, followed by upgrading the oil produced to yield a product compatible with existing refineries (Figure 4). Numerous retorts, used for heating the oil shale for the pyrolysis reaction, have been designed. Above-ground retorting requires mining the shale and crushing it to a proper size for the retort and disposal of the shale after the retorting process in complete. In situ retorting involves heating the shale in place and avoids the costs of mining, crushing, and disposal of spent shale. In the past, most attempts at in situ retorting have involved rubblizing the shale in place to increase permeability of the rock. A portion of the oil shale underground was burned to produce the heat required to retort the remaining oil shale. Past efforts at in situ retorting encountered problems such as controlling and maintaining the underground combustion process and avoiding subsurface pollution. Past attempts at true in situ retorting, which involves heating rock without rubblization, have generally yielded disappointing results, although some more recent approaches are more encouraging.

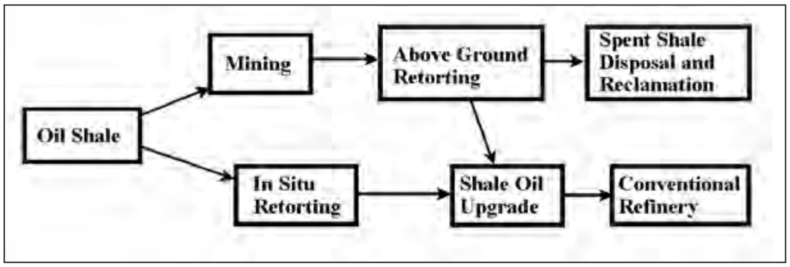
The oil obtained through pyrolysis of kerogen usually has noticeably different chemical and physical properties than conventional crude oil. This requires an upgrade or prerefining step before the shale oil can be

Figure 3
Amount and Grade of Western United States Oil Shale



Source: Office of Naval Petroleum and Oil Shale Reserves.

Figure 4
Oil Shale Processing



sent to an existing refinery for manufacturing petroleum products. Common differences are high pour points which make pipeline transportation difficult, the presence of arsenic, iron and nitrogen, all of which can poison the catalysts used in refineries, and different hydrocarbon compounds which can cause gumming.

Of the three main process steps, mining, retorting, and upgrading, the retorting step has been the most troublesome in past operations. Mining technology is well advanced and techniques used in coal mining are applicable to oil shale while the upgrading step utilizes engineering principles similar to those used in oil refineries. The retorting step involves heating the shale to covert the kerogen to oil. Problems encountered in above-ground retorting include handling fine particles in the retort and preventing agglomeration of the fine particles. Attempts at in situ retorting have generally yielded lower amounts of oil and have been more difficult to control.

In general, technology applicable to recovering oil from oil shale is less mature than that used in convention oil and gas operations. Bringing a new oil field into production involves applying well understood technology whereas processes applicable to oil shale will first have to be tested on a small scale and then scaled up to full production status.

The federal government is taking steps to encourage testing of new technologies applicable to oil shale. Section 369 of the Energy Policy Act of 2005 provided for making federal lands in Colorado, Utah and Wyoming available to industry for research and development projects related to oil shale and tar sands. Under this law, the Bureau of Land Management (BLM) has initiated a programmatic Environmental Impact Statement for commercial leasing of oil shale properties in the three states. Perhaps of more importance, the BLM is in the process of granting Oil Shale Research, Development and Demonstration leases on public land. These leases cover 160 acres each and were initially advertised in the Federal Register in June 2005. Nineteen nominations for leases were originally received from various industry groups (Table 1). A team comprised of personnel from the BLM, the Departments of Energy and Defense and the three state governments selected six of the proposals for further consideration, including three proposals from Shell Oil.

Table 1
Applicants for Oil Shale Research, Development and Demonstration Leases

	Selected for Further Consideration
Colorado	
Natural Soda, Inc.	No
EGL Resources, Inc.	Yes
Kennecott Exploration Co.	No
Independent Energy Partners	No
Phoenix Wyoming	No
Chevron Shale Oil Co.	Yes
Exxon Mobil Corp.	No
Shell Frontier Oil and Gas, Inc.	Yes
Utah	
Brent C. Freyer	No
Oil Shale Exploration Co.	Yes
Great Western Energy	No
Mountain West Energy	No
Syntec Energy	No
Argyll Energy	No
Oil Tech, Inc.	No
Western Energy Partners	No
Wyoming	
Anadarko Petroleum	No

Source: Bureau of Land Management.

Both Oil Shale Exploration Company LLC and Oil Tech, Inc. submitted proposals to use the White River Oil Shale Mine, ensuring one of them would be eliminated. Although it was not selected for the BLM Research, Development and Demonstration project, Oil Tech, Inc., has constructed a retort near Bonanza in Uintah County, Utah. The company has retorted oil from the stockpile of shale at the White River Oil Shale Mine and is continuing efforts to commercialize its technology. Exxon Mobile Corp., was eliminated from the BLM program since the company did not plan to produce oil until the eighth year of a ten-year lease and due to concerns about how to handle nahcolite (a sodium bicarbonate mineral) present at the proposed site. The other companies were eliminated in a preliminary review for not meeting technical, economic or environmental criteria.

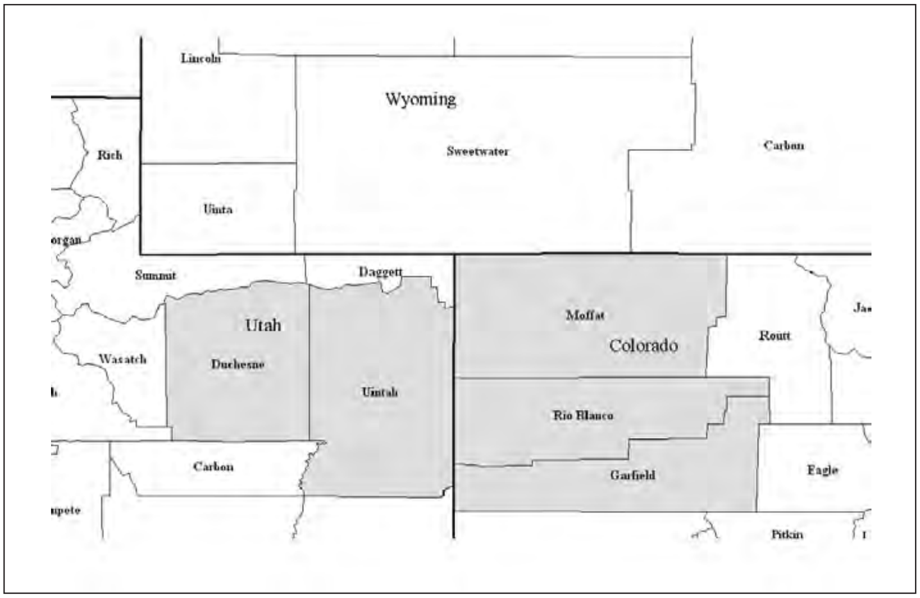
The White River Oil Shale Mine was developed during the energy boom of the 1970s and 1980s by the White River Shale Oil Corporation, a collaboration of Phillips Petroleum Company, Sun Oil Company, and Standard Oil of Ohio, and cost about $80 million to construct. The site was abandoned in the mid 1980s and responsibility reverted to the BLM. The current proposal under the BLM Research, Development and Demonstration program was submitted by Oil Shale Exploration Company, LLC. This Utah-registered company is a partnership of Twin Pines Coal Company of Alabama, Ohio-based L & R Energy, Inc., and Shale Investments, LLC of Utah. The company proposes to use an Alberta Taciuk Processor as a retort. This processor, derived from the rotary kilns used in the cement industry, was originally designed for extracting bitumen from Alberta tar sands and is considered by some to be state of the art in surface retorts. The Alberta Taciuk Processor has also been applied to oil shale in Australia and Estonia.

The proposals submitted by Shell Oil, EGL Resources, and Chevron all involve in situ pyrolysis at oil shale sites in Rio Blanco County, Colorado. The in situ conversion process (ICP) being developed by Shell Oil is perhaps the most innovative technology currently being examined. This process involves drilling vertical holes into the oil shale and gradually heating the shale using electric heaters to covert the contained kerogen to oil and gas. The oil and gas are then recovered through wells similar to conventional oil and gas wells. Between 15 and 25 holes are drilled per acre and the heating takes place over two to three years. As part of the site preparation, the current plan uses ground freezing technology to establish an underground barrier around the production area. Holes would be drilled around the perimeter of the production area and a refrigerated liquid circulated through these holes to freeze the groundwater and prevent hydrocarbons from leaving the production area. Due to the slow heating, the product quality is improved and subsequent pretreatment is less complex as compared to surface retorting or past in situ technologies. Shell Oil has conducted small tests on privately-owned land in Colorado and plans larger tests as part of the BLM Research, Development and Demonstration program. A decision to proceed with large-scale commercial development probably will not be made until 2012. The Shell ICP process is similar to the Ljunstrom process that was developed in Sweden during World War II, when an oil shale industry developed in response to wartime fuel shortages. The Ljunstrom process used electric resistance heaters in holes for in situ pyrolysis and operated in Sweden from 1941 until 1960, when increasing electric costs made it uneconomical.

Effect of Oil Shale on the Piceance and Uinta Basins

The effect of a developing oil shale industry on the economy of northeastern Utah and northwestern Colorado is dependent on the size of the industry and

Figure 5
Counties Directly Impacted by Future Oil Shale Development

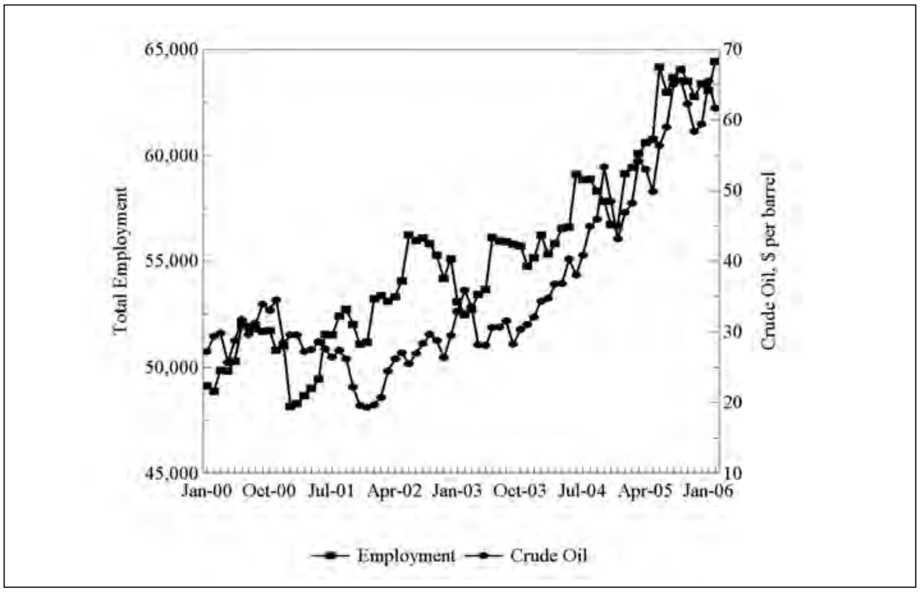


the rate at which it develops. Various studies and planning documents have forecast an industry production level of several million barrels of oil daily. In "America's Oil Shale A Roadmap for Federal Decision Making," the Department of Energy stated a vision of a domestic oil shale industry producing 2 million barrels daily by 2020 and 3 million barrels daily by 2030. Similarly, in its report "Oil Shale Development in the United States Prospects and Policy Issues," the Rand Corporation analyzed an industry producing 3 million barrels per day. To put these production levels in perspective, the United States is currently producing about 5 million barrels of conventional crude oil per day and importing about 10 million barrels per day. At a more local level, Utah is producing 45,000 barrels, Colorado, 60,000 barrels, and Wyoming, 140,000 barrels of crude oil daily. Obviously, the development of an oil shale industry producing several million barrels of oil daily would cause significant changes in the area's economy.

Future oil shale development in the western United States will probably be focused in Colorado and Utah, particularly in Duchesne and Uintah Counties in Utah and Garfield, Moffat and Rio Blanco Counties in Colorado (Figure 5). These counties contain the Uinta Basin deposits in Utah and the Piceance Basin deposits in Colorado. The deposits in Wyoming are thinner and less continuous than those in Colorado and Utah and most industrial interest is focused in these two states. This five-county area is currently a center of oil and gas production, with total employment correlating well with the price of crude oil (Figure 6). The area is rural with a population of slightly over 100,000 and the jobs in the oil and gas industry pay over twice the average annual wage in the area (Table 2). Population projections by the Utah Governor's Office of Planning and Budget and the Colorado State Demography Office indicate that by 2030 the combined population of these five counties will reach 212,000 (Figure 7). Assuming the labor force is 53.5 percent of the population, the average for 2000 through 2005, these five counties will have a labor force of 113,800 in 2030. These projections consider current rates of population increase but do not consider any possible in-migration as a result of a developing oil shale industry.

The best comparison to use to draw insights as to the future of oil shale is the Alberta Tar Sands industry. Approximately 97 percent of the 178 billion barrels of proven oil reserves in Canada are tar sands located in Alberta. Although the processing technology differs from that used for oil shale, there is a similarity in that the majority of the tar sands are mined and sent to processing plants, similar to past efforts at developing oil shale. The first commercial mining of Canadian tar sands started in 1967 and production passed 1 million

Figure 6
Employment and the Price of Crude Oil
Duchesne and Uintah Counties, Utah and Garfield, Moffat and Rio Blanco Counties, Colorado



Source: Bureau of Labor Statistics and Energy Information Administration.

barrels per day in 2004. Based on announced projects, production from Alberta tar sands is expected to be 3.6 million barrels per day by 2020.

Based on the experience of the Alberta tar sands industry, it may take several decades to develop an oil shale industry producing several million barrels per day in the western United States. However, production on a smaller scale may occur as an outgrowth of the BLM Research, Development and Demonstration initiative and other industry efforts. Using current productivity levels for the oil and gas production and refining industries and the coal mining industry as a proxy for oil shale, it is estimated than an oil shale industry producing 100,000 barrels per day would directly employ between 5,000 and 10,000 persons, or from 4 percent to 9 percent of the projected workforce for these five counties in 2030. The development of an industry of this size will result in additional in-migration to the area, with resulting population and workforce growth. While additional jobs and economic growth are desirable, there are also the associated social costs that arise. Rapid in-migration tends to strain local resources and infrastructure such as housing, schools, utilities, sanitation and roads. Some of these impacts can be mitigated through the planning and permitting process, but development of a large-scale oil shale industry will definitely alter the economic and social structure of nearby communities.

The Future of Oil Shale

The history of the oil shale industry in the United States has been periodic booms followed by slumps as the more favorable economics of conventional petroleum eventually dominate. The important question is: Will a sustainable oil shale industry develop or is the current interest another one of the periodic booms to be followed by another bust? The petroleum industry operates in a worldwide commodity market with transparent pricing, so the price received is set by the market and oil derived from shale must be competitive with conventional crude oil. The future of the western United States oil shale industry is strongly linked to the future price of conventional crude oil. The futures markets expect the price to stay over $60 per barrel for the next six years (Figure 8). The 2005 Annual Energy Outlook (AEO), issued in December 2005 by the Energy Information Administration, predicts a gradual decline to $43 per barrel over the next six years. However, the more recent June 2006 Short-term Energy Outlook, also issued by the Energy Information Administration, suggests prices staying over $65 per barrel through the end of 2007.

Based on the experience of the Alberta tar sands industry, it will probably take more than six years for an

Table 2
Baseline Economics
Duchesne, Uintah Counties, Utah and Garfield, Moffat, Rio Blanco Counties, Colorado

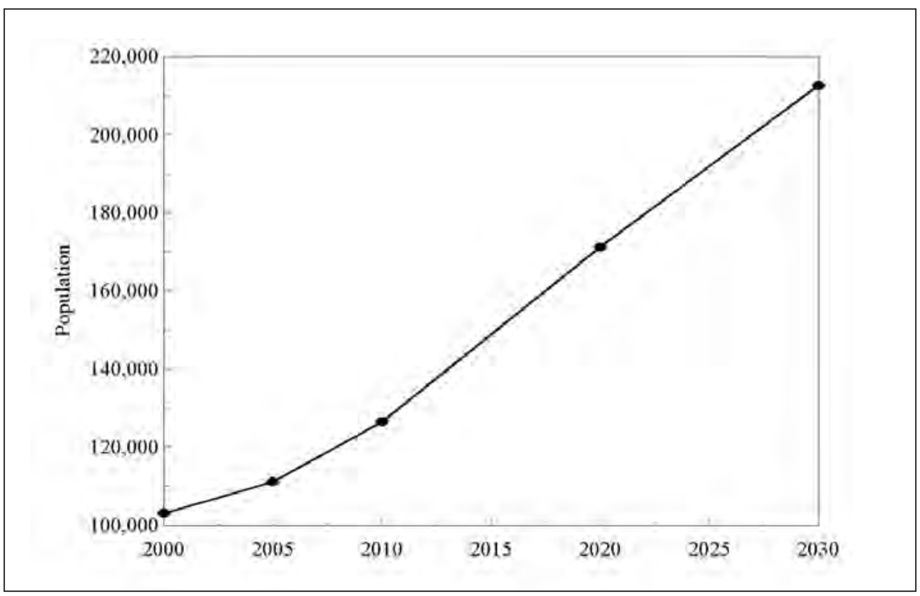
Population (2005)	111,549
Unemployment (2005)	3.9%
Employment (2005)	60,034
Total Wages (2004)	$1.01 billion
Average Annual Wage (2004)	$22,685
Oil and Gas Annual Wage (2004)(e)	$52,200
Oil and Gas–percent of total employment (e)	7.2%
Oil and Gas–percent of total wages (e)	16.5%

(e) estimated by Bureau of Economic and Business Research.
Source: Bureau of the Census, Bureau of Labor Statistics.

oil shale industry of noticeable size to develop. While forecasting prices for such long time periods is tenuous at best, if an oil shale industry does develop, production costs should drop as operators advance the learning curve and new technology is adopted. As an example, the cost of producing oil from Alberta tar sands was over $35 per barrel in the early 1980s. Through increased efficiencies and adopting new technology, the cost dropped to $10 per barrel before rebounding some in recent years due to increased capital and energy costs. Similar decreases in the cost of producing crude oil from oil shale can be expected.

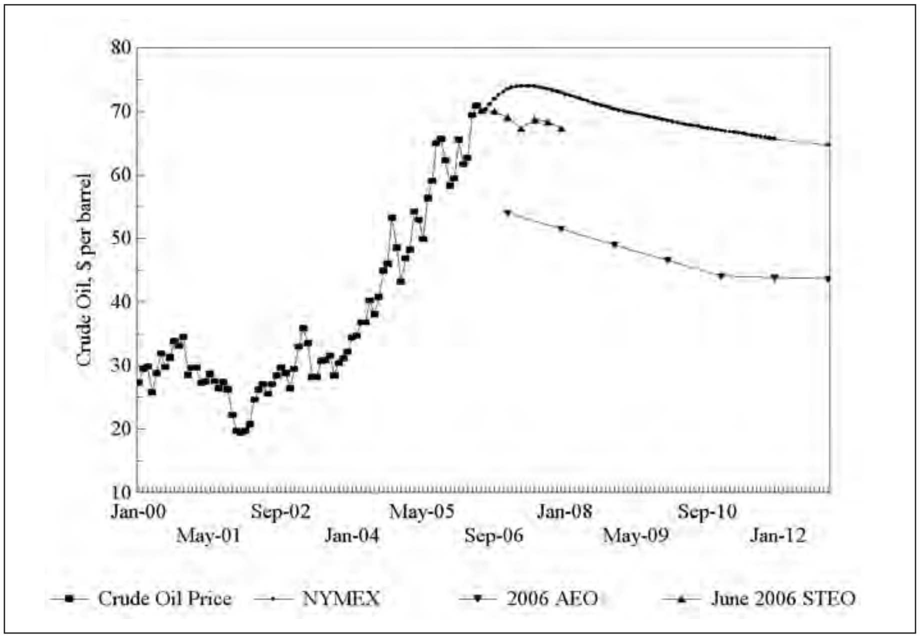
Most current estimates of the cost of producing crude oil from oil shale are based either on dated engineering data or unproven designs with little testing. Published figures range from $10 per barrel to $95 per barrel. Part of the reason for this large range is that although there is a long history of activity in the oil shale industry, there is not a large body of industrial knowledge based on successful operations from which to draw. The available cost estimates are generated either by companies involved in developing oil shale resources, so the cost estimates are based on engineering calculations but not actual operating costs, or analysts employed by various government agencies and think tanks. Actual operating costs will be determined through engineering pilot plants and small demonstration units. Once firmer numbers for operating costs are determined and technology proven, larger-scale commercial plants can be constructed. This type of process can take several years. For instance, the Oil Shale Exploration Company has outlined a plan to initially process 1,000 tons of shale from the existing stockpile at the White River Oil Shale Mine at a pilot-plant sized Alberta Taciuk Process retort in Calgary,

Figure 7
Population Projections, 2000-2030
Duchesne and Uintah Counties, Utah and Garfield, Moffat and Rio Blanco Counties, Colorado



Source: Utah Governor's Office of Planning and Budget and Colorado State Demography Office.

Figure 8
Forecast Price of Crude Oil
Source: Energy Information Administration and NYMEX.



Alberta, which will take about 11 months. The pilot-plant retort will then be transported to the mine site and operated for another 11 months, after a three-month setup period. If these two phases are successful, a larger demonstration-size Alberta Taciuk Process reactor, sized to handle 250 tons per day, will be constructed at the mine site. Permitting, engineering and construction of the demonstration plant is expected to take two years, and it will be operated an additional two years. The combined time for this entire process is in excess of six years. Only if the demonstration plant is successful and indicates a full-size plant will be profitable will the decision then be made to proceed with a commercial operation. This plan indicates that development of commercial oil shale industry in the Uinta and Piceance Basins is probably in excess of 10 years in the future.

During the next 10 to 20 years there is the possibility of many developments that can affect the future of an oil shale industry. Many geologists and other observers of the petroleum industry are predicting that worldwide petroleum production will peak by 2020. These predictions are based on theories advanced by Dr. M. King Hubbert, a geophysicist who in 1956 published a research paper that correctly predicted United States oil production would peak in 1970, based on geologic constraints and a limited amount of resource. Should global oil production peak in the next 20 years, the lower supply would result in continued high prices for petroleum and bode well for the future of nonconventional fuel sources such as oil shale. The theory of peak oil production is by no means universally accepted among energy analysts. Detractors cite incomplete knowledge of geology and amount of total resource, especially outside of the United States, in addition to changes in economics as prices fluctuate and technology advances as reasons peak oil theory is not valid.

Technology also continues to advance, which in turn affects the economics of production. Over the past several decades, process control and monitoring has become much more effective due to improved electronics. Similarly, process design and computer modeling are much easier to accomplish due to increases in computer power. Aside from these advances, which are applicable to any processing industry, research specific to oil shale continues. Engineers continue to optimize mining methods to reduce costs and new retorting methods such as the Alberta Taciuk Processor and the Shell In Situ Conversion process show promise. These types of technology improvements may result in a viable oil shale industry even if the price of crude oil declines. It may be a new technology, yet to be discovered, that allows a viable oil shale industry to develop.

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