The Technological Reality of
Oil Shale Drilling

This memo outlines the technological feasibility of extracting shale oil from the Green River Formation, found in areas of Colorado, Utah, and Wyoming, based upon a 2005 study by the RAND Corporation. While oil shale resources have been recognized for nearly a hundred years, available technology made extraction far too expensive when compared to relatively cheap crude oil prices. However, certain scientific advances show that oil shale could be economically competitive at prices as low as $25 per barrel, with more conservative estimates suggesting the price would need to be $95 per barrel. While RAND projects that large-scale oil shale development is still many years in the future, this memo indicates that current crude oil prices make oil shale a viable alternative.

BASIC OVERVIEW

"Extracting oil from oil shale is more complex than conventional oil recovery. Hydrocarbons in oil shale are present in the form of solid, bituminous materials and hence cannot be pumped directly out of the geologic reservoir. The rock must be heated to a high temperature, and the resultant liquid must be separated and collected. The heating process is called *retorting*. Processes for producing shale oil generally fall into one of two groups: mining, either underground or surface, followed by surface retorting and in-situ retorting."
(James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. x: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

MINING AND SURFACE RETORTING

"In this approach…oil shale is mined with conventional mining methods and transported to a retorting plant. After heating and removal of fine solid particles, the liquid product is upgraded to produce a crude oil substitute that can enter the nation's existing oil pipeline and refinery infrastructure. After retorting, the spent shale is cooled and disposed of, awaiting eventual reclamation."
(James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 11: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

- **Room-and-Pillar Mining Useful for Shallow Recovery.** "Oil shale can be mined using one of two methods: underground mining, most likely using the room-and-pillar method, or surface mining…Room-and-pillar mining can recover about 60 percent of the oil shale in place for seams that are no more than about a hundred feet thick, such as those found in the southern portion of the Piceance Basin and in portions of the Uinta Basin. However, most of the high-grade oil shale resources form more or less continuous deposits anywhere from 500 to more than 2,000 feet thick (Smith, 1980; Pitman, Pierce, and Grundy, 1989). Applying room-and-pillar mining methods to the rich, deep seams in the central Piceance Basin will result in exceptionally low levels of resource recovery—in general, less than 20 percent, and in some cases less than 10 percent (Miller, 1987)."
(James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 12: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

- **Surface Mining Able to Yield More Oil Than Room-and-Pillar Method.** "Surface mining can recover much higher percentages of in-place resources. But the thickness of oil shale deposits, the amount of overburden, and the presence of subsurface water in the Piceance Basin can make surface mining difficult. For example, oil shale sections in the center of the basin underlie more than 1,000 feet of overburden and are 2,000 feet thick. More than 80 percent of the resources within the Piceance Basin are covered by more than 500 feet of overburden. Mining such thick deposits covered by so much overburden would require very large mines, comparable in size to the largest existing open-pit mines in the world…. While mining always involves technical challenges associated with the particular characteristics of the ore body under consideration, the current state of the art in mining—both room-and-pillar and surface techniques—appears able to meet the requirements for the commercial development of oil shale."
  James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 12-13: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

- **Surface Retorting Creates Stable Product.** "Surface retorting involves crushing the mined oil shale and then retorting it at about 900 to 1,000 degrees F... The vessel in which this heating occurs is called a retort. The hot shale oil leaving the retort is not stable and must be sent directly to an upgrading plant for catalytic processing with hydrogen to remove impurities and produce a stable product. This stable shale oil can be used as a refinery feedstock and should compete favorably with sweet, light crude oil."
  (James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 13: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

IN-SITU RETORTING

"In-situ retorting entails heating oil shale in place, extracting the liquid from the ground, and transporting it to an upgrading facility. Various approaches to in-situ retorting were investigated during the 1970s and 1980s. The mainstream methods involved burning a portion of the oil shale underground to produce the heat needed for retorting the remaining oil shale. Much of this prior work was not successful, encountering serious problems in maintaining and controlling the underground combustion process and avoiding subsurface pollution."
(James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 17: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

- **Shell Oil Develops Cost-Effective Extraction Technique.** "In the early 1980s, researchers at the Houston R&D center of Shell Oil envisaged an entirely different type of in-situ retorting, which they named the In-Situ Conversion Process. In Shell's approach (Figure 3.2), a volume of shale is heated by electric heaters placed in vertical holes drilled through the entire thickness (more than a thousand feet) of a section of oil shale. To obtain even heating over a reasonable time frame, between 15 and 25 heating holes will be drilled per acre. After heating for two to three years, the targeted volume of the deposit will reach a temperature of between 650 and 700 degrees F. This very slow heating to a relatively low temperature (compared with the plus-900 degrees F temperatures common in surface retorting) is sufficient to cause the chemical and

physical changes required to release oil from the shale. On an energy basis, about two-thirds of the released product is liquid and one-third is a gas similar in composition to natural gas. The released product is gathered in collection wells positioned within the heated zone."
(James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 17: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

- **Shell's Technique Minimizes Environmental Damage.** "This approach requires no subsurface mining and thus may be capable of achieving high resource recovery in the deepest and thickest portions of the U.S. oil shale resource. Most important, the Shell in-situ process can be implemented without the massive disturbance to land that would be caused by the only other method capable of high energy/resource recovery—namely, deep surface mining combined with surface retorting. The footprint of this approach is exceptionally small. When applied to the thickest oil shale deposits of the Piceance Basin, drilling in about 150 acres per year could support sustained production of a half-million barrels of oil per day and 500 billion cubic feet per year of natural gas."
(James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 19: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

- **U.S. Government Impressed by Shell's In-Situ Method.** "Scientists from the DOE have reviewed the Shell in-situ process and report that the technology is very promising."
(James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 19: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

TIMELINE AND COST

- **Producing One Million Barrels of Shale Oil Per Day Is Estimated to Be More Than 20 Years Away.** "Currently, oil shale commercialization is in the first phase, namely, *research and development.* A few firms might be prepared to enter the *scale-up and confirmation* phase. We estimate the duration of this phase to be at least six years, considering the time required to obtain permits, design and construct a demonstration capable of producing 1,000 to 5,000 barrels per day, and obtain technical and environmental data required for the design and permitting of a first-of-a-kind commercial operation. Even if a few firms decide to immediately move forward with a single-module commercial plant (as did Union Oil in the early 1980s) or a small-scale commercial facility, the decision to invest in a full-scale commercial facility is at least six to eight years in the future, especially considering the additional requirements likely to be associated with permitting a longer-term operation…. Given that industry is unlikely to reach the production growth phase until 12 to 16 years after the decision to pursue process scale-up and confirmation and that this initial decision has not yet occurred, an oil shale production level of 1 million barrels per day is probably more than 20 years in the future, and 3 million barrels per day is probably more than 30 years in the future."

(James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 22-23: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)

- **A Barrel of Oil Must Be Over $70 for Shale to Be Profitable.** "Considering mine development, upgrading, and modest infrastructure expenditures, a 50,000 barrel per day first-of-a-kind surface retorting complex will incur capital expenditures of between $5 billion and $7 billion (2005 dollars) and possibly higher than that. We assume operating and maintenance costs for first-of-a-kind plants to be between $17 and $23 (2005 dollars) per barrel (OTA, Volume I, 1980; Albulescu and Mazzella, 1987).10 Given these capital and operating cost estimates, we project that the price of low-sulfur, light crude oil, such as West Texas Intermediate, will need to be at least $70 to $95 per barrel for a first-of-a-kind oil shale operation to be profitable…. Several earlier RAND studies have examined cost improvement expectations for oil shale mining and surface retorting (Merrow, 1989; Hess, 1985). This work indicates that after 500 million barrels have been produced with this technology, production costs could drop to about 50 percent of the costs for initial commercial plants. For initial production costs between $70 and $95 per barrel, experienced-based learning could drop those costs to between $35 and $48 per barrel within 12 years of the start of commercial oil shale operations."
  (James T. Bartis, et. al., *Oil Shale Development in the United States: Prospects and Policy Issues* (Santa Monica, CA: RAND Corporation, 2005), p. 15-16: http://rand.org/pubs/monographs/2005/RAND_MG414.pdf)