The Illusive Bonanza: Oil Shale in Colorado
"Pulling the Sword from the Stone"

A History of Hope

Buried beneath the ground, in Colorado and Utah, are a trillion tons of oil shale. Throughout the 20th century, men have tried and tried again to unlock the energy contained in these rocks. To date, all efforts have failed. But every twenty or thirty years, when energy prices spike, a new attempt is mounted. The persistence is understandable: whoever unlocks this resource would capture a trillion dollar prize. But oil shale's track record is not encouraging. The rocks are stubborn, an illusive bonanza, promising much, delivering little. Despite a century of trying and $10 billion in investment, oil shale currently provides an infinitesimal 0.0001 (or one ten-thousandth) of world energy. This paper explains why oil shale is so difficult to unlock, and why the "rock that burns" may never provide more than one percent of U.S. energy.

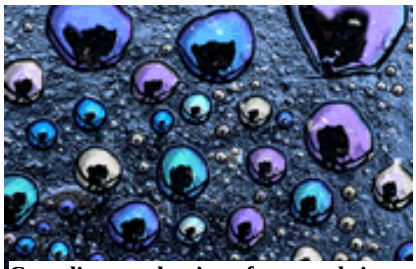
Ancient gar, fossilized in oil shale

Never, Never Land

Recently, after oil prices doubled to $60 per barrel, the U.S. Department of Energy published a new report on oil shale's promise. Sections of the report seem delirious, as if the authors were determined to illustrate that anything is possible on paper. In particular, the study claimed that we could wring "200,000 barrels a day from oil shale by 2011, 2 million barrels a day by 2020, and ultimately 10 million barrels a day." These predictions—both the production targets and their timing—are preposterous, as some industry experts admit. Hyping oil shale is nothing new. As geologist Walter Youngquist once wrote, "Bankers won't invest a dime in 'organic marlstone,' the shale's proper name, but 'oil shale' is another matter." Oil shale's history is one of delusions leading to disappointments. Sometimes the delusions have been motivated by a stock scam, but mostly they seem to have been driven by a belief that wishing can make it so. Peter Pan would have loved the oil shale industry. According to its boosters, to make it fly "all you need is faith and trust and a little bit of pixie dust!"

Hard, Black Gold?

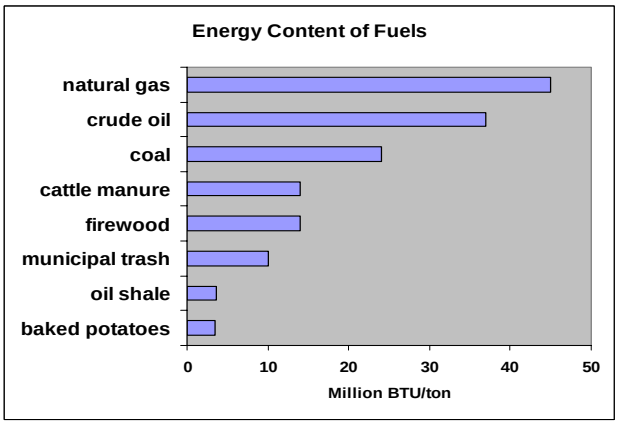
After hearing the bullish projections so often, politicians are perplexed by the lack of progress. "I find it disturbing that Utah imports oil from Canadian tar sands, even though our oil shale resource remains undeveloped," says Utah Senator Orrin Hatch. It's a maddening paradox. If oil shale really is "the richest fossil fuel resource on earth," why has no nation ever produced more than 16,000 barrels a day? And if there really are "one trillion barrels of hard, black gold" in the world's shales, why is global production declining? It's as if we are standing in front of a treasure vault fumbling with the key. Sixty percent of the world's oil shale is in Colorado and Utah, we know exactly where it is, and yet those states produce none. Meanwhile, Alberta is producing one million barrels per day of oil from its tar sands. What's with that? Are we dumber than Canadians?



Canadian production of tar sands is energy intensive—but much less so than wringing oil from rocks.

Oil Shale and Dung Cakes

Oil shale has many apologists. They suggest that technology is lacking. They suggest that cheap oil is to blame. Ever confident, they suggest that "its day will come, just wait." Yet the day never comes. Why has shale failed to deliver? The primary explanation is that oil shale is a very poor fuel. Compared to the coal that launched the Industrial Revolution or the oil that sustains Western Civilization, oil shale is a pathetic pretender, the dregs. When it comes to energy, quality is everything. Quality can be measured in various ways—cost, convenience, and cleanliness all matter—but energy density trumps them all. Coal seams a few feet thick are worth mining, sometimes at depths exceeding 1,000 feet, because coal contains lots of energy. Dense forms of energy like coal and crude oil invented prosperity; they are industrial oxygen. If coal is good, oil is better. Petroleum contains 50% more energy than the best coal, twice that of the hardest oak. There's a lot of "grunt" in a gallon of gasoline, enough to propel a 3,000 pound car thirty miles.



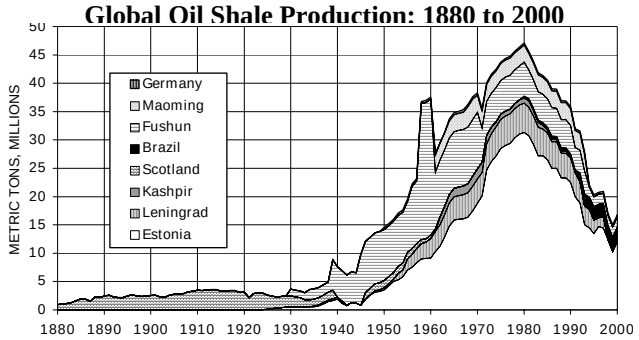
If crude oil is king, oil shale is a pauper. Pound per pound, oil shale contains just one-tenth the energy of crude oil, one-sixth that of coal, and one-fourth that of recycled phone books. Shale outcrops are common in Colorado, but in prehistoric times the Utes did not use it for heat; why bother when you could gather pine or juniper instead? In poor countries, millions of people heat their homes with dried manure. Dung cakes have four times more energy than does oil shale. Oil shale is a fossil fuel—but just barely. Searching for appropriate low-calorie analogues, we turn to foodstuffs, the realm of Weight Watchers. Oil shale is said to be "rich" when it contains 30 gallons of petroleum per ton. An equal weight of granola contains three times more energy. The "vast," "immense," and "unrivaled" deposits of shale buried in Utah and Colorado have the energy density of a baked potato. If someone told you there were a trillion tons of tater tots buried 1,000 feet-deep, would you rush to dig them up? Take a memo, Senator. Oil shale has one-third the energy density of Cap'n Crunch, but no one is counting on Kellogg to become a major energy producer soon. In other words, no one is drilling in the cereal aisle. The mystery is not that we lack an oil shale industry—it's why we've spent billions trying to develop one.

A Ten Million Year Rain

According to the U.S. Geological Survey, half of the planet's oil shale lies within 150 miles of Grand Junction, Colorado. The shale is contained in the Green River Formation, which is famous for its wonderful fossils, imprints of sycamore leaves, dragonflies, extinct birds, crocodiles, and strange fish which lived in ancient lakes. These thick layers of shale were created by a million-year drizzle of fine clay and dying algae. The energy in oil shale is preserved pond scum, algal ooze. The term "oil shale" is a misnomer. The rock is a marlstone, the hydrocarbon a waxy molecule called kerogen. Kerogen is a proto-petroleum, an energy-wannabe. Oil and gas are generated when kerogen is exposed to heat deep in the Earth's oven. If the Green River Formation had been buried deeper, time would have cooked the kerogen into petroleum. But since it wasn't buried deeper, to extract energy from these rocks, you have to put them back in the oven and supply the heat Nature failed to furnish during fifty million years.

The Fuel of the Future?

As a rule, nations don't tap oil shale unless they are destitute. The world's primary producer has been Estonia, a Baltic nation lacking in coal, natural gas, oil, or hydropower. When Russian natural gas and nuclear power became available, Estonia began to phase out its shale oil industry. Elsewhere, small amounts of shale have been mined in China, Brazil, and Russia. Most recently, a well-funded and much-ballyhooed Australian oil shale experiment failed. Tellingly, one partner in that bankrupt project was Suncor, a successful developer of Canadian tar sands. After losing $100 million, Suncor now appreciates the critical distinctions between tar sands and oil shales. There are two ways to produce shale oil. Typically, the rock is mined like coal. After being loaded and trucked to a processing plant, the shale is crushed and fed into an enormous kiln (or "retort"), where it is roasted to 1,000 degrees F. The heat "cracks" the kerogen, whose distilled vapors can be refined into a liquid fuel. Retorting oil shale is capital intensive, messy, inefficient, and polluting. It consumes lots of energy and water. The slag, swollen in volume and contaminated with arsenic, must be safely disposed. The entire process is so costly and laborious that global production has never exceeded 25,000 barrels a day, compared to today's 84,000,000 barrels of total oil production. Retorting a million barrels each day, as some propose, would entail mining and disposing of 700 million tons per year, digging the world's deepest open pit mines, constructing a hundred retorts, and platting new cities to house tens of thousands of workers. In sum, it would be the largest mining operation in the world. In the last ten years, Royal/Dutch Shell has experimented with a new way to produce oil shale, a way that is, at first glance, less destructive and more promising.



World oil shale production, dominated by energy-poor Estonia, has fallen by two-thirds since 1980.

Pulling the Sword from the Stone

In 1912, President Taft established the Naval Petroleum and Oil Shale Reserve. In the century since, a dozen attempts to commercialize the resource have failed. The big push came in the 1970s, after the Arab Oil Embargo. Despite federal price supports of $40 per barrel and $10 billion in investment, the mammoth effort failed. In a 13-year period, only five million barrels were produced, as much oil as the U.S. now consumes every six hours. When oil prices collapsed, Exxon, Tosco, and Unocal left. Shell threw in the towel, too, but it held onto the property it had purchased back in the 1950s. By 1990, Shell's scientists had concluded that

blasting, digging, hauling, roasting, disposing and revegetating millions of tons of shale ore would never be economically viable or environmentally acceptable. But it was hard for the company to completely turn its back. In the last 150 years humans have burned about one trillion barrels of conventional oil. The second trillion barrels will be consumed in the next thirty years. Given the burgeoning demand for transportation fuels, Shell wondered if there was another way to "pull the sword from the stone." Instead of bringing the rock to the heat, what if you brought the heat to the rock?

An Underground Toaster Oven

Humor columnist Dave Barry once misted a pair of boxer shorts with hair spray, then used sparks from a roller blade-wearing Barbie doll to set them afire. Another time, Barry demonstrated that if you put a "strawberry Pop-Tart in a toaster for five minutes and 50 seconds, the Pop-Tart will turn into a snack-pastry blowtorch, shooting flames up to 30 inches high. Also, your toaster will be ruined." Putting a chunk of oil shale into your toaster would not offer similar excitement, but in a strange way, Royal Dutch/Shell's fascinating experiment near Rangely, Colorado resembles something Dave Barry might attempt if he had the money to build the world's largest toaster oven.

Genius or Madness?

Although it remains one of the world's great energy companies, and is currently reaping record profits, Shell has been challenged in recent years. An accounting scandal forced it to restate its reserves. Hurricane Katrina hammered one of its deepwater production platforms in the Gulf of Mexico. The company also missed out on western Colorado's lucrative natural gas play, where production is now equivalent to 100,000 barrels of oil per day. With Muslim nations holding most of the world's remaining oil, Shell is finding it difficult to replace its reserves. But if Shell could "pick the lock" on the oil shale vault, an exciting and profitable new chapter of its history would be assured. To this end, the company has spent tens of millions of dollars investigating whether oil shale can be heated underground. Until recently, Shell's employees have been careful not to hype their own research; it's just R&D, they insist. The caution is understandable; most of the techniques are experimental. But the new methods are promising enough that the company recently submitted the largest patent application in the history of the U.S. Patent Office.

Rube Goldberg, Meet Buck Rogers

Although Shell's plan is fresh and bold and audacious, some aspects of it seem inspired by Star Trek. Time will tell whether the company's "in-situ" process is madness or genius. The vision is breathtaking. The company proposes to electrically heat a 1,000 foot-thick section of the Green River Formation to 700 degrees Fahrenheit, then keep it that hot for three years. Beam me up, Scotty, but first share some details. Imagine a ten-acre production plot, 2,000 feet on a side. Inside that area, the company would drill up to 200 closely spaced wells. After those wells are lined with steel casing, 1,000 foot-long electric heaters would be inserted in preparation for the "bake." Before the fire comes the ice. Since it's impractical to heat the rock if it's in contact with groundwater, Shell has to dewater the production area first. To do that, it proposes to construct a "frost wall" to isolate the production zone from the surrounding area. (Frost walls are routinely used in skyscraper foundations, but of course few foundations are 2,000 feet deep.) To build the frost wall, the company will drill a narrowly spaced line of wells, case them, then circulate a frigid coolant until the rock freezes solid. If the frost wall holds, the company will drill dewatering wells inside the production zone. Once the shale is dry, it will be heated, and if all goes well, three years later oil and natural gas will flow. The company hopes to recover up to one million barrels per acre--$60 million worth at today's prices. It's a high-stakes gamble, but if it works a six mile-by-six mile area could produce twenty billion barrels, roughly equal to remaining reserves in the Lower 48.

The World's Largest Utility Bill

Although Shell's method avoids many of the negative impacts of mining oil shale, it requires a mind-boggling amount of electricity. To produce 100,000 barrels a day would require raising the temperature of 700,000,000,000 pounds of shale by 700 degrees F. How much power would be needed? A gigabunch—in rough numbers, about $500,000,000 per year. The least expensive source for electricity is a coal-fired power plant. How much coal, how many power plants? To produce 100,000 barrels per day, the RAND Corporation recently estimated that Shell will need to construct the largest power plant in Colorado history, large enough to serve a city of 500,000. This power plant, costing about $3 billion, would consume five million tons of coal each year, producing ten million tons of greenhouse gases, some of which would still be in the atmosphere a century from now. To double production, you'd need two power plants. One million barrels a day would require ten new power plants, five new coal mines. How soon will we know whether any of this is

feasible? Shell plans to do more experiments, before making a go/no go decision by 2010. If the company pulls the trigger, it would be at least three or four years before first oil would flow, perhaps at a rate of 10,000 barrels a day. That's less than one-tenth of one percent of current U.S. consumption. In the near term, oil shale is not a silver bullet. It will not delay the imminent peak of world oil production. It will not reduce global oil prices. It will do little to enhance U.S. energy security. By 2020, oil shale *might* yield 100,000 barrels a day, but that remains uncertain. Finally, if it turns out that Shell needs more energy to produce a barrel of oil than a barrel of oil contains, all bets are off. That is a fool's bargain, the equivalent of burning the furniture to keep the house warm. Energy is the original currency, electricity its most valuable form. Using coal-fired electricity to wring oil out of rocks is sort of like feeding steak to the dog and eating his Alpo.

A Vision in Search of Reality

In a ham-and-egg breakfast, the chicken is involved but the pig is committed. Half the world's oil shale resources lie near Grand Junction, Colorado. With respect to oil shale, citizens in this region are committed. The durable myth of this "enormous treasure" ensures that in any energy crisis, oil shale will be proposed as a solution, and that Colorado and Utah will bear the brunt of development. The region has been already been burned once, in the 1980s, when thousands lost jobs overnight. In its report, the RAND Corporation warned that if initial oil shale developers "overstress the environmental carrying capacity of the area, we may never see more than a few hundred thousand barrels per day of production." Amen. Large scale oil shale development of the kind proposed by the U.S. Department of Energy in its report would be a disaster for the region. That report, authored apparently by Dr. Strangelove, casually dedicates all of western Colorado's surplus water to oil shale, proposes enormous open-pit mines 2,000 feet deep, and suggests retorting up to a billion tons of shale each year. This is not a vision, it is a nightmare!

The U.S. Department of Energy suggests that open pit mines, up to 2,000 feet deep, could be used to mine oil shale

Microwaves From the Moon

Americans love panaceas. We want thinner thighs in thirty days, a pill to cure baldness, an ultrasonic carburetor that will double our mileage. For a century, promoters have pitched oil shale as a path to riches and energy independence. A magic wand would indeed be nice, because the nation faces serious energy challenges. Because domestic oil production peaked 30 years ago, the need for energy efficiency, conservation, and renewable energy is both obvious and urgent. Instead, like an addict on a binge, we continue to pursue a policy of "strength through exhaustion." Drilling the Arctic National Wildlife Refuge before improving our woeful vehicle efficiency is a brain-dead approach. As global population and Chinese oil demand grow, new energy sources will be avidly sought. Making intelligent choices about what energy paths to pursue is critical. In the 1970s, during the last energy panic, we failed this IQ test. Yes, there's lots of low-grade oil shale in Colorado and Utah. But there's also enough Helium 3 on the moon to power the world for thousands of years, and enough microscopic gold in the ocean to make everyone rich. It's theoretically possible to microwave solar energy to Earth from outer space, and to transmit wind energy from the Aleutians to Atlanta. Fusion has been just around the corner for fifty years. Grandiose schemes to meet the world's energy needs always find articulate proponents. "Helium 3 could be the cash crop for the moon," says Gerald Kulcinski, Director of the Fusion Technology Institute (FTI). "When the moon becomes an independent country, it will have something to trade." And when pigs have wings, they may fly.

National Energy Security

What contribution can oil shale make to energy security? Producing 100,000 barrels per day of shale oil does not violate the laws of physics, if the price of conventional crude rises high enough it might be economic. But the nation is currently consuming 100,000 barrels of oil every seven minutes. Increasing the efficiency of America's automobiles by two miles per gallon would save ten times as much fuel each year, saving consumers $40 billion at the pump. The National Academy of Sciences has stated that bolder efficiency targets—cars, trucks, and SUVs getting 30, 40 or 50 miles per gallon—are doable and affordable. An aggressive national commitment to fuel efficiency is not optional, it's inevitable. In time, a more efficient fleet could save 20 times as much petroleum as oil shale will ever provide. Dreams and hype aside, oil shale is the poorest of the fossil fuels, containing far less energy than crude oil, much less even than hog manure, peat moss, corn pellets, household garbage, or Cap'n Crunch. A meager amount of energy, tightly bound up in an enormous volume of rock, oil shale seems destined to remain an illusive bonanza, the petroleum equivalent of fool's gold.

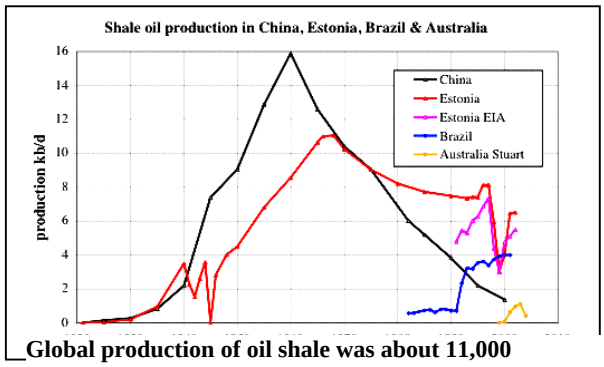
The Illusive Bonanza: Oil Shale in Colorado: Notes, References, Further Reading

Further Reading

The U.S. Department of Energy's report, "Strategic Significance of America's Oil Shale Resource," is catalogued at http://www.evworld.com/library/Oil_Shale_Stategic_Significant.pdf The report was issued by the Office of Naval Petroleum and Oil Shale Reserves, which has been touting oil shale for nearly a century. Since no nation has ever produced more than 16,000 barrels/day, and global production is currently about 10,000 barrels/day, it is absurd to contend, as this report does, that the U.S. will soon be producing 1,000,000 barrels per day. Of course, anything is possible on paper.

The RAND Corporation report, "Oil Shale Development in the United States," is somewhat more balanced. It is at http://www.rand.org/pubs/monographs/2005/RAND_MG414.pdf

Petroleum geologist Jean Laherrere recently published an Oil Shale Review at http://www.hubbertpeak.com/laherrere/OilShaleReview.pdf The graph at right is also from Laherrere.



Global production of oil shale was about 11,000 barrels/day in 2000. This represents less than 0.0001 or one ten-thousandth of global energy.

"Shale Oil—The Elusive Energy," by noted petroleum geologist Walter Youngquist, is a short but comprehensive introduction. Find it at http://hubbert.mines.edu/news/Youngquist_98-4.pdf

Boomtown Blues, Colorado Oil Shale, by Andrew Gulliford, examines the remarkable 100-year history of oil shale development and chronicles the social, environmental, and financial havoc created by the industry's continual cycles of boom and bust. The book is available at http://www.upcolorado.com/bookdetail.asp?isbn=0-87081-720-5

Shell's In-Situ Approach & Electricity Demand

Shell's Mahogany Research Facility is near Rangely, Colorado. As of 2005, the company has produced some 2,000 barrels of oil shale from a test plot the size of a three-car garage. Shell now plans to test key aspects of its method, including the frost wall and downhole heaters, at larger scale. Results will be available in 2009. Spokesmen say they expect to harvest about 65% of the oil in place, two-thirds as a liquid, the remainder natural gas. According to the RAND Corporation, "An operation producing 100,000 barrels per day requires approximately 1.2 gigawatts of dedicated generating capacity." This is a very large power plant, equivalent to the combined capacity of Colorado's largest power plant at Craig, Colorado, shown above. Production of a million barrels a day would then require ten such power plants, plus five new coal mines to feed them. Shell believes it can harvest 3.5 units of energy for every unit of fuel consumed at the power plant. But this calculation presumes the electricity is produced by an advanced, 60% efficient, combined cycle gas plant. A standard new coal plant has an efficiency in the 35% range, reducing the energy balance to 2:1. Shell has not released detailed studies of this critical issue, but we suspect the real energy return may be even lower. At this early stage, one can only guess at Shell's initial capital cost for producing 100,000 barrels per day. Including the necessary power plant, our guess is that it would be in the $7 billion to $10 billion range.

Energy Density

The energy density of various fuels can be found online. Caloric content of foodstuffs is at http://www.nutritiondata.com/ Typical carbohydrates would have about 4 Calories per gram. This is equivalent to approximately 7,000 BTU per pound, or 14,000,000 BTU/ton. A useful online energy conversion calculator is at http://www.onlineconversion.com/energy.htm

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