Secure Fuels from Domestic Resources

The Continuing Evolution of America's Oil Shale and Tar Sands Industries

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Profiles of Companies Engaged in Domestic Oil Shale and Tar Sands Resource and Technology Development

U.S. Department of Energy
Office of Petroleum Reserves
Office of Naval Petroleum and Oil Shale Reserves
June 2007

Oil Shale and Tar Sands Company Profiles

Companies Investing Today to Advance Technology to Provide Clean Secure Fuels for Tomorrow

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Profiled Companies Active in Oil Shale and Tar Sands Development

1. Anadarko Petroleum Corporation
2. Chattanooga Corporation
3. Chevron USA
4. Commonwealth Raw Materials
5. E.G.L. Resources
6. Electro-Petroleum
7. Earth Search Sciences / Petro-Probe, Inc.
8. ExxonMobil Corporation
9. Brent Fryer, Sc.D.
10. Global Resource Corporation
11. Imperial Petroleum Recovery Corp.
12. Independent Energy Partners
13. J. W. Bunger and Associates, Inc.
14. James A. Maguire, Inc.
15. Millennium Synthetic Fuels, Inc.
16. Mountain West Energy Company
17. Natural Soda, Inc.
18. Nevtah Capital Management, Inc.
19. Oil Shale Exploration Corporation
20. Phoenix-Wyoming, Inc.
21. Raytheon Corporation
22. Red Leaf Resources
23. Shell Frontier Oil and Gas, Inc.
24. Syntec, Inc.
25. Temple Mountain Energy, Inc.
26. Western Energy Partners
27. Great Western Energy Corporation

Global Resource Corporation

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COMPANY DESCRIPTION

Global Resource Corporation is a worldwide petroleum research, engineering and development company that is responsible for bringing innovative and new technologies to the petrochemical industry. The company offers proprietary solutions for secondary and tertiary crude oil recovery processes as well as oil shale, resid oil, tar sands, drill cuttings and mud. Based in New Jersey, it operates globally.

INDUSTRY ROLE

GRC's role in unconventional fuel development is that of a technology developer as well as a manufacturer of the equipment necessary to extract such fuels. The firm's technologies could be licensed by end-users to pyrolize oil shale in order to create fuel feed stocks, or to crack bitumen in tar sands or resid oil to enable separation, production and upgrading to synthetic crude oil. GRC has removed all but .01% of the hydrocarbons from drill cuttings.

DESCRIPTION OF TECHNOLOGY

Global Resource Corporation has a patent pending process that allows for removal of oil and alternative petroleum products from various resources including shale deposits, tar sands and waste oil streams with significantly greater yields and lower costs than are currently available utilizing existing technologies. The process uses specific frequencies of microwave radiation to extract oils and alternative petroleum products from secondary raw materials, and is expected to dramatically reduce the cost for oil and gas recovery from a variety of unconventional hydrocarbon resources.

GBR's technology will not only be developed to extract oil from shale, but from depleted oil fields in the U.S. and elsewhere. Many of these fields still contain more than half of their original hydrocarbons because the residual oil is too viscous to extract with conventional technology.

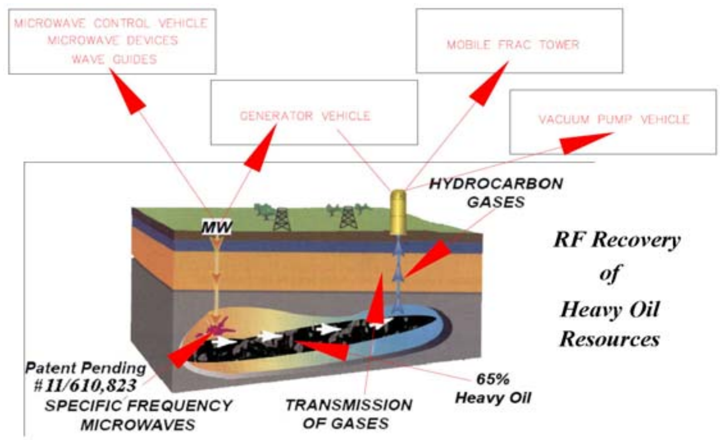
The GRC gasification process uses highly efficient and economical RF energy with a specific microwave frequency along with a vacuum environment to extract hydrocarbons from their original and natural source and crack it into fuels without environmental issues.

- The vacuum creates uniform gasification.
- The process is dry - It requires neither water, nor any type of liquid injections.
- GRC has patents pending for a wide range of frequencies. According to GRC, all current patented microwave solutions use a single common frequency (2.45 GHZ). The GRC process offers Software Controlled Frequencies that are adaptable to the energy source target.

Oil Shale and Tar Sands Industry Profiles

GCR's technologies for oil shale, resid oil, tar sands and bypassed oil have been tested at laboratory scale. Since November 2006, Global Resource Corporation has been running microwave tests on oil shale. After exposing the rock to the patent-pending microwave process, Global Resource collects the byproduct gases and heat exchanges them into oil and gases that do not convert back to liquids. The liquids range from C-14 to C-28 and up to 70% of the initial weight of the oil shale (depending on where the sample was mined) is gasified. The energy balance for this gasification is running at approximately $30 per barrel and produces Fractionalized Petroleum Products as opposed to the bitumen that is normal to shale and tar sands after they are liberated from their raw material. Specifically with regard to oil shale, GRC's Gas Chromatograph shows they are producing finished products of diesel fuel and heating oil potentially eliminating additional refining.

For heavy oil and unswept mobile oil in conventional oil reservoirs, the GRC RF technology could be applied to gasify oil resources in-situ. The produced gases would be brought **to** the surface in conventional wells, condensed, and fractionalized on-site into diesel fuel, oil, and combustible gases. Oil wells may be drilled by several methods and multiple well configurations allow multiple points for directional microwave applications.



Coal liquids: Initial testing results have produced large quantities of Hydrogen and Methane gases without CO or CO_2 contaminants making GRC's process one of the first environmentally friendly coal gasification technologies available. The gases are produced within seconds when exposed to the patent pending process.

RESOURCE HOLDINGS

GRC does not currently own or lease hydrocarbon resources. It intends to develop and license its technologies for use by other industry participants.

STATE OF DEVELOPMENT

GRC's next phase is to manufacture a 10-ton per/hour system capable of producing combustible gases and petrochemical fluids.

RELEVANT EXPERIENCE

GBC's technologies were invented by Mr. Frank Pringle who began to identify specific microwave frequencies in 1996. Over the past ten years, Mr. Pringle has specified over 8700 RF microwave frequencies intrinsic to hydrocarbon elements/materials. These frequencies are protected by patent pending filings.

OUTLOOK / FUTURE PLANS

GRC is negotiating with several major companies to form joint ventures for commercializing this technology.

Foreword

A Word From the Office of Petroleum Reserves

Energy Security Is Essential To Preserve America's Economic Strength and National Security.

Reducing our dependence on foreign imports of oil and refined products is essential to achieving the energy security objective.

Import reductions can be achieved in two fundamental ways – reducing our demand for oil through conservation and efficiency and increasing production of fuels from domestic resources, including alternatives, bio-fuels, and unconventional fuels resources.

Two Promising Domestic Unconventional Resources Are Oil Shale and Tar Sands.

America is endowed with more than two trillion barrels of Oil Shale resources, of which more than 1.2 trillion barrels is concentrated in Colorado, Wyoming and Utah.

Our nation is also endowed with more than 50 billion barrels of Tar Sands resources, with the largest deposits in Utah.

If commercially developed, shale oil and bitumen from tar sands could contribute nearly three million barrels per day to reduce oil imports, improve energy security, and fuel economic growth.

This Is Not A New Industry – But Rather An Evolving One...

Public and private investments in research and technology development since the early 1900's have established a solid foundation of science and technology to enable oil shale and tar sands development. The resources and their potential are well understood. When oil shale efforts began to decline in 1982 and were finally curtailed in 1991, numerous technologies approached readiness for demonstration at commercially-representative scale.

... And the Evolution Goes On

Much has happened in the United States and elsewhere in the world since Unocal shut down Parachute Creek in 1991. Early technologies are still viable, but many are being improved and adapted to take advantage of technical advances. New technologies are also emerging that build on the lessons of the past to respond to new technical, economic, and environmental challenges.

Numerous Companies Are Engaged In Technology And Resource Development Activities For Domestic Oil Shale And Tar Sands.

Over 30 private companies are now applying the technologies and lessons learned from prior domestic and foreign oil shale development activity, and ongoing Alberta oil sands development to meet technical, economic, and environmental challenges and evolve a new domestic fuels industry.

This report documents the groundswell of activity of 27 companies that are currently investing private capital and human ingenuity to prove the viability of oil shale and tar sands resources and pilot technologies at commercially representative scale. Additional companies that are engaged in technology and resource development may be included in later editions of this document.

This Report Is Intended To Serve As An Information Resource.

Links and contacts are provided to help readers find more information about companies, projects, and emerging technologies and to facilitate the sharing of information among industry participants.

As this domestic unconventional fuels industry continues to grow, the Department of Energy will update and supplement these profiles. Other companies and entities interested in being included in this evolving suite of profiles should contact James.Killen@hq.doe.gov.

Anton R. (Tony) Dammer, Director
U.S. Department of Energy
Office of Petroleum Reserves
Office of Naval Petroleum and Oil Shale Reserves

An Historical Perspective

SECURE FUELS FROM DOMESTIC RESOURCES

Oil shale has been recognized as a potentially valuable U.S. energy resource since as early as 1859, the same year Colonel Drake completed his first oil well in Titusville, Pennsylvania. Early products derived from shale oil included kerosene and lamp oil, paraffin, fuel oil, lubricating oil and grease, naphtha, illuminating gas, and ammonium sulfate fertilizer.

In the beginning of the 20th century, the U.S. Navy converted its ships from coal to fuel oil, and the nation's economy was transformed by gasoline fueled automobiles and diesel fueled trucks and trains, raising concerns about assuring adequate long-term supplies of liquid fuels at affordable prices to meet the needs of the nation.

America's abundant resources of oil shale were initially eyed as a major source for these fuels. Commercial entities sought to develop oil shale resources. The Mineral Leasing Act of 1920 made petroleum and oil shale resources on Federal lands available for development. Soon, however, discoveries of more economically producible and refinable liquid crude oil in commercial quantities caused interest in oil shale to plateau.

Interest resumed after World War II, when military fuel demand, fuel rationing and rising fuel prices made the economic and strategic importance of the oil shale resource more apparent. The booming post-war economy drove demand for fuels ever higher.

Public and private research and development efforts were commenced, including the 1946 U.S. Bureau of Mines Anvil Points, Colorado oil shale demonstration project. Significant investments were made to define and develop the resource and develop comercially viable technologies and processes to mine, produce, retort, and upgrade oil shale into viable refinery feedstocks and bi-products.

Once again, major crude oil discoveries in the lower-48 states, offshore, and in Alaska, and in other parts of the world reduced the need for shale oil and industry and government interest and activity again diminished.

Lower-48 U.S. crude oil reserves peaked in 1959 and lower-48 production peaked in 1970. By 1970, oil discoveries were slowing, demand was rising, and crude oil imports, largely from the Middle East, were rising to meet demand. Oil prices, while still relatively low, were also rising reflecting the changing market conditions. Oil shale research was re-energized and new projects were envisioned by energy companies seeking alternative fuel feedstocks.

These efforts were significantly amplified by the impacts of the 1973 *Arab Oil Embargo* which demonstrated the nation's vulnerability to oil import supply disruptions, and were underscored by a new supply disruption during the 1979 Iranian Revolution. Oil prices increased and remained high.

By 1982, technology advances and discoveries of offshore oil resources in the North Sea and elsewhere provided new and diverse sources for U.S. oil imports. The discoveries, surging production from OPEC, and falling demand dampened energy prices.

Global political shifts promised to open restricted provinces to exploration and led economists and experts to again predict a long future of low and stable oil prices.

Despite significant investments by energy companies and numerous advances in mining, retorting, and in-situ processes, the costs of oil shale production relative to expected low crude oil prices, made continuation of most commercial efforts impractical. Several projects failed for technical and design reasons. Federal research and development and leasing activities were curtailed, and most projects were abandoned.

Given today's high oil prices, a decline in global oil production, increasing U.S. and global demand, and resources increasingly controlled by parties unfriendly to the United States, our national attention has returned to the need for secure fuels from domestic resources such as oil shale and tar sands.

Industry is already working to move technologies that can meet our energy and environmental challenges to commercialization as documented in this report.

AMERICA'S OIL SHALE AND TAR SANDS RESOURCES

America's Oil Shale and Tar Sands Resources Have Been Characterized and Assessed - Their Potential is Well Documented

U.S. OIL SHALE RESOURCES

Oil shale is a hydrocarbon bearing rock that occurs in 27 countries around the world. Worldwide, the oil shale resource base is believed to contain about 2.6 trillion barrels, of which the vast majority (2 trillion barrels) is located in the United States.

The most concentrated U.S. oil shale deposits are located in Colorado, Utah, and Wyoming. Of the 1.2 trillion barrels contained in these three western states, the majority (80 percent) are located on Federal land managed by the Department of Interior (DOI). Access to the oil shale resources located on public lands is therefore a critical step in the future commercial development of this resource as discussed in this chapter.

Large areas of the United States contain oil shale deposits, but those in Colorado, Utah, and Wyoming contain the greatest promise for shale oil production in the immediate future (Figure 1). The oil shale deposits in these three states occur beneath 25,000 square miles (16 million acres). These deposits contain approximately 1.2 trillion barrels of oil equivalent. Recovery of even a small fraction of this resource would represent a significant contribution to supplement the Nation's oil supply for many decades.

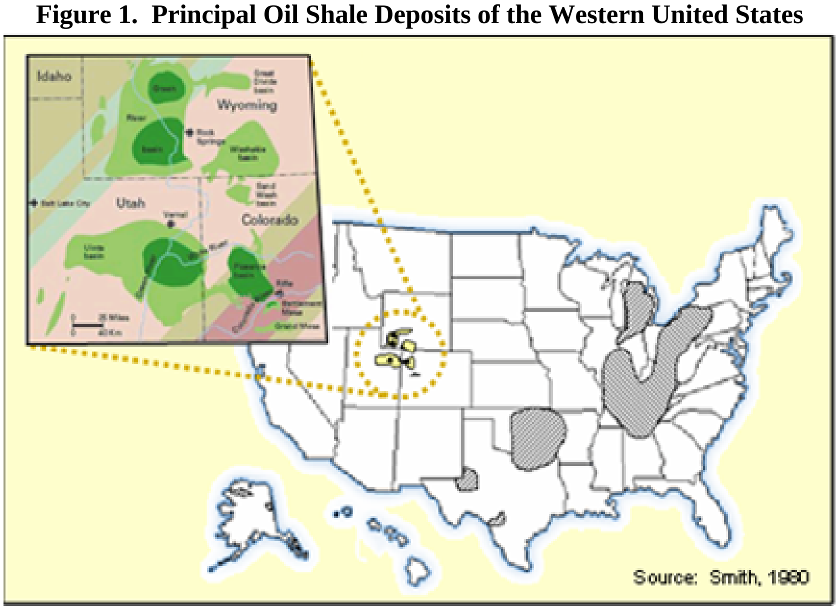
QUALITY AND GRADE

Oil shale resources of the United States have already been identified and been extensively characterized. Yields greater than 25 gallons per ton (gal/ton) are generally viewed as the most economically attractive, and hence, the most favorable for initial development.

With experience, improved understanding, and technology innovation, this cut-off could be reduced, increasing the size of the estimated recoverable resource.

Table 2 from the U.S. Geological Survey[i] displays the richness of various oil shale deposits in three areas of the United States. The oil shale from each region of the United States has unique characteristics as summarized next.

Figure 1. Principal Oil Shale Deposits of the Western United States



WESTERN SHALE: The most economically attractive deposits, containing in excess of 1.2 trillion barrels, are found in the Green River Formation of Colorado (Piceance Creek Basin), Utah (Uinta Basin) and Wyoming (Green River and Washakie Basins).

More than a quarter million assays have been conducted on the Green River oil shale. In the richest zone, known as the Mahogany Zone, oil yields vary from 10 to 50 gal/ton and, for a few feet in the Mahogany zone, up to about 65 gal/ton.

According to Culbertson and Pittman[ii], of the western resource, an estimated 418 billion barrels are in deposits that will yield at least 30 gal/ton and located in zones at least 100 feet thick. Donnell[iii] estimates resources of 750 billion barrels at 25 gal/ton in zones at least 10 feet thick (Figure 2).

EASTERN SHALES: Eastern oil shale deposits have been well characterized as to location, depth, and carbon content. The eastern shale is located among a number of states and is not as concentrated as the western shale.

Ninety-eight percent of these accessible deposits are in Kentucky, Ohio, Tennessee, and Indiana. With processing technology advances, for example the addition of hydrogen to the retorting process, potential oil yields could approach those of the western shale.

Eastern deposits have a different type of organic carbon than the western shale. As a result, conventional retorting of eastern shale yields less shale oil and a higher carbon residue as compared with the western shale.

Table 2. U.S. Oil Shale Resource in Place (Billion Bbls)

Deposits	Richness (Gallons/ton)		
Location	5 - 10	10 - 25	25 - 100
Colorado, Wyoming & Utah (Green River)	4,000	2,800	1,200
Central & Eastern States	2,000	1,000	NA
Alaska	Large	200	250
Total	6,000+	4,000	2,000+

Source: Duncan, and others (1965)

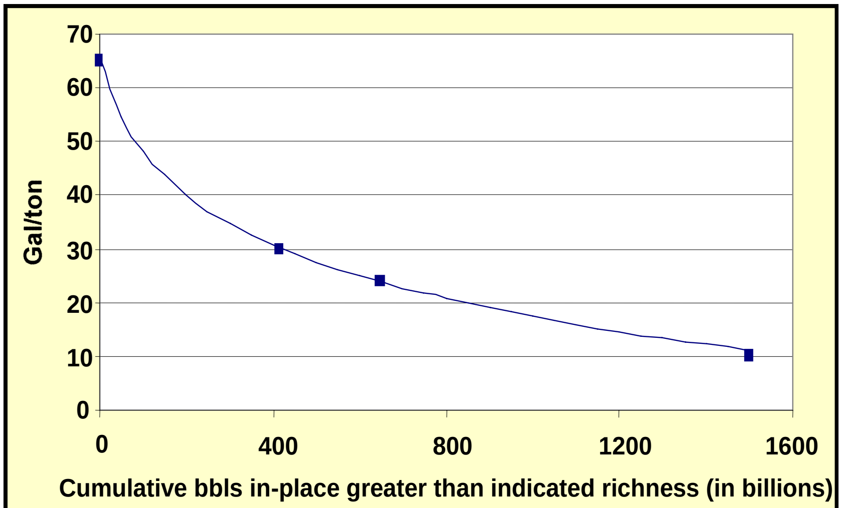
Because of these differences, industry interest in oil shale commercialization has focused on the rich, concentrated oil shale deposits of the western states.

Eastern shale has the potential to become an important addition to the nation's unconventional fuel supplies. The Kentucky Knobs region alone has resources of 16 billion barrels, at a minimum grade of 25 gal/ton. Near-surface mineable resources are estimated at 423 billion barrels[iv].

OTHER OIL SHALES: Numerous deposits of oil shale are found in the United States. The two most important deposits are the western and eastern areas described above.

However, oil shale deposits also occur in Nevada, Montana, Alaska, Kansas, and elsewhere, but these are either too small, too low-grade, or have not yet been well explored to be considered for near-term development.

Figure 2. Cumulative Resource Greater than Indicated Richness



Source: Donnell (1964)

U.S. TAR SANDS RESOURCES

Tar sands (referred to as oil sands in Canada) are a combination of clay, sand, water, and bitumen; a heavy, black, asphalt-like hydrocarbon. Tar sands can be mined and processed to extract the oil-rich bitumen, which is then upgraded and refined into synthetic crude oil.

Unlike oil, the bitumen in tar sands cannot be pumped from the ground in its natural state; instead tar sand deposits are mined, usually using open pit techniques, or produced in-situ by underground heating or other processes.

The U.S. tar sands resource in place is estimated to be 60 to 80 billion barrels of oil. The resource is substantial, but far smaller than Alberta's oil sands or U.S. oil shale resources (Figure 3). About 11 billion barrels of U.S. tar sands resources may ultimately be recoverable[v].

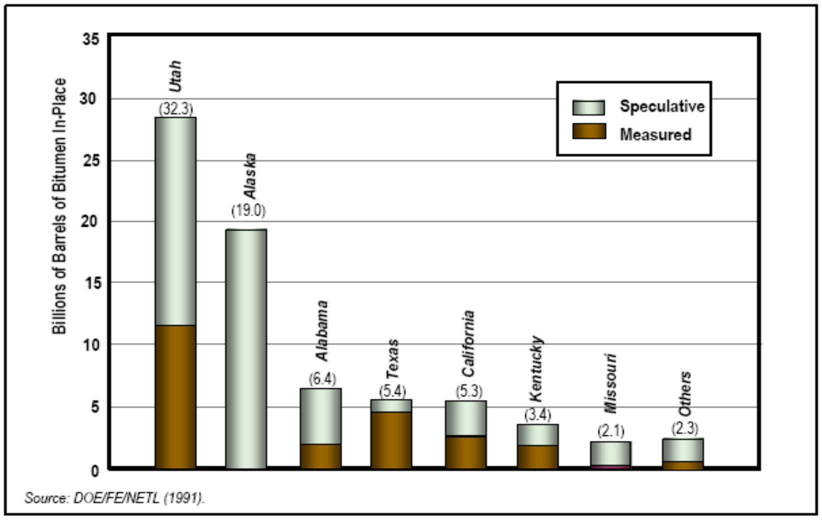
The rate of resource development and the potential volume of production are somewhat dependent on future oil prices. It also depends on industry access to resources on state and Federal lands and the availability of infrastructure for resource development and product upgrading.

With current price projections, the near term incremental U.S. tar sands production potential to 2025 will probably not exceed 250,000 Bbl/d. However, should very high oil prices persist, a greater portion of the resource will become economic, and leaner and more fragmented resources may become economically producible.

Quality and Grade

U.S. tar sands differ somewhat in quality and configuration from Canadian oil sands. They are generally leaner in grade, less uniform in quality, and have higher sulfur content.

Figure 3. Known and Speculative U.S. Tar Sand Resources



U.S. tar sands are typically found in layered sandstone and are often consolidated, or cemented. Unlike U.S. sands, Canadian oil sands are less consolidated and mixed with sand and water. While Canadian oil sands are water wet, U.S. tar sands are more typically hydrocarbon wet. New extraction technology approaches may be required.

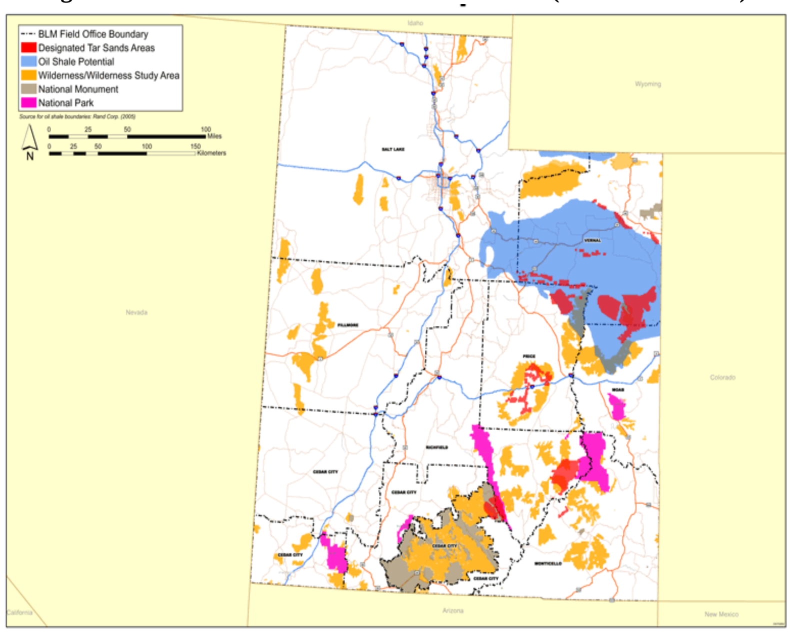
Location and Availability

The United States' largest measured tar sands deposits are found in Utah. The rest is found in deposits in Alabama, Texas, California, Kentucky, and other states. Utah has between 19 and 32 billion barrels of tar sands, about one-third of the domestic resource.

Utah's tar sands resource is concentrated in the eastern portion of the state, predominantly on public land. Approximately 19 billion barrels of speculative resources are thought to exist in Alaska.

Figure 4 displays the location of tar sands deposits in Utah.

Figure 4. Utah Oil Shale and Tar Sand Resources (Source U.S. BLM)



The known (measured) and potential additional (inferred) resource for each of the major Utah deposits are displayed in Table 3 and discussed below. The four largest Utah deposits are:

- ***Sunnyside***: The Sunnyside deposit contains enough recoverable resource to support a 100,000 Bbl/d operation. Thermal or solvent treatment may be required as the ore is consolidated.
- ***Tar Sand Triangle (TST):*** The bitumen is characterized by high sulfur content, similar to Alberta oil sands but, unlike the Uinta Basin deposits described above, which are low in sulfur. TST is located near Canyon Lands National Park, and development is likely to meet with challenges. There appears to be interest in this deposit for in-situ recovery. The product could be transported by truck and rail in bitumen or diluted bitumen state.

Table 3. Major Tar Sands Deposits in Utah

Deposit	Known Resource (MMBbl)	Additional Potential (MMBbl)
Sunnyside	4,400	1,700
Tar Sand Triangle	2,500	13,700
PR Spring	2,140	2,230
Asphalt Ridge	820	310
Circle Cliffs	590	1,140
Other	1,410	1,530
Total:	11,860	20,610

Source: DOE/FE/NETL (1991)

- ***PR Springs:*** This sizeable resource is close to the surface, but is fragmented by erosion and multiple beds. It is in a primitive area, which may slow development. A few rich zones could each support modest size operations on the order of 25 to 50 MBbl/d.
- ***Asphalt Ridge***: Asphalt Ridge was characterized by SOHIO as holding about 1 billion barrels of recoverable oil with the potential to support a 50 MBbl/d facility. Since then, growth of the community of Vernal has encumbered some of the resource. Two rich locations could produce significant yields of bitumen but in more modest quantities than contemplated by SOHIO. Alberta technology could be adaptable for use in the unconsolidated sands of the rich zones.

Tar sands in Alaska, Alabama, Texas, California, and Kentucky are deeper and thinner, so less economic to develop.

Figure 5. The Nevtah/Black Sands Closed-Loop Mobil Extraction Plant (Nevtah Photo)

The Evolution of Oil Shale and Tar Sands Technology

THE PATH TO TECHNOLOGY COMMERCIALIZATION

Energy technology development does not happen overnight. It can take decades, thousands of person-hours of effort, and billions of dollars of investment to advance major energy technologies from the conceptualization to successful demonstration at a commercially representative scale.

Figure 6 depicts the path of energy technology evolution and commercialization. To be deemed successful, a technology must be demonstrated to be effective in producing desired products, energy efficient, economically competitive, scalable, and acceptable to the community.

The development path of a major energy technology from concept to demonstration and commercial scale operation can take as much as 15 to 25 years. This evolution process can be viewed as occurring in three major phases - a Laboratory Phase, a Field Testing Phase, and a Commercialization Phase. While confidence increases at each progressive phase, the level of project risk and required capital investment increases as well.

Failure at any point in the process can require taking a step back, rethinking the approach or the design, or starting over at step one.

By the 1990s, more than 20 technologies for oil shale processing had been conceived. Many had moved beyond basic research and progressed to bench scale plants, field pilots, semi-works scale, or demonstration-scale plants. Of those, at least nine are still considered viable and worthy of consideration for additional effort leading toward demonstration and commercial application.

Figure 6. Evolution of Major Oil Shale Technologies (Lukens, 2004)

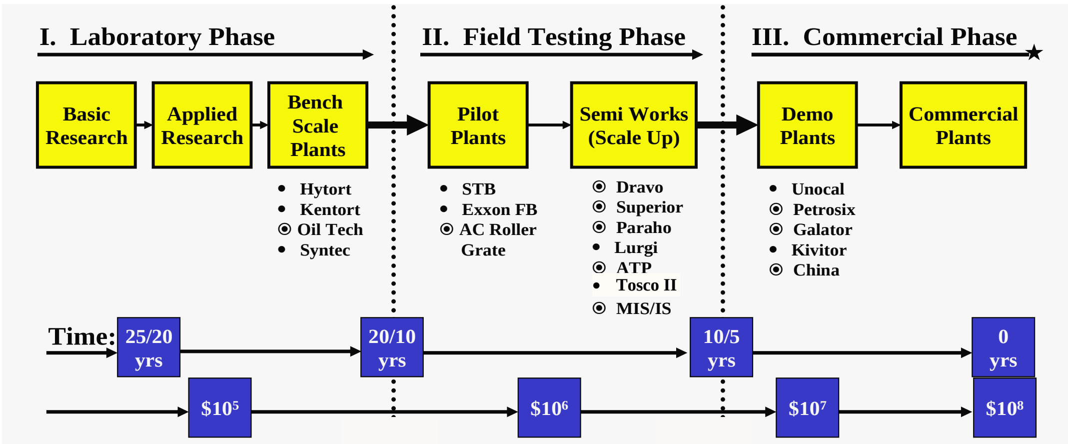


Figure 7. Early Retort, Bonanza, UT (Circa 1900)

THE CONTINUING EVOLUTION OF OIL SHALE AND TAR SANDS TECHNOLOGY

As our understanding of the location, extent, characteristics and potential of oil shale and tar sands resources has improved over time, the technology for accessing and converting these resources to fuels and byproducts has also improved.

Billions of dollars have been invested by private industry and by various governments to research, develop, test, and improve a range of approaches and technologies for oil shale and tar sands development.

The scope of these technology research, development and demonstration (RD&D) efforts embrace the full fuels development lifecycle, including:

- Resource access and extraction,
- Conversion of raw resources to hydrocarbons,
- Environmental protection,
- Upgrading, and
- Fuels manufacturing.

Alberta's Oil Sands Technology

One needs only to look to the Province of Alberta to view the demonstrated success of more than three decades of effort to develop technologies to produce bitumen from Alberta's massive oil sands resources.

Through the evolution of technology, the efficiency and performance of oil sands extraction, separation and bitumen upgrading technology has advanced while operating costs have fallen. In 2006, Alberta produced more than 1 million barrels per day of synthetic oil from oil sands.

Although U.S. tar sands resources are significantly smaller than the massive Alberta oil sands, and compositionally different in important ways. The evolution of Alberta's oil sands industry and technologies contributes both technology and lessons learned to guide development of U.S. tar sands resources.

Several U.S. companies have been active in the Alberta Oil Sands effort. Many are now applying knowledge and technology developed in Alberta and in other oil and energy resource development efforts to overcome challenges posed by America's own tar sands resources. The companies and technologies, described in a series of profiles that follow this discussion, demonstrate that much oil sands technology has moved from the lab, to the field, and on toward commercial stage demonstration that could result in commercial-scale application within a decade.

U.S. Oil Shale Technology

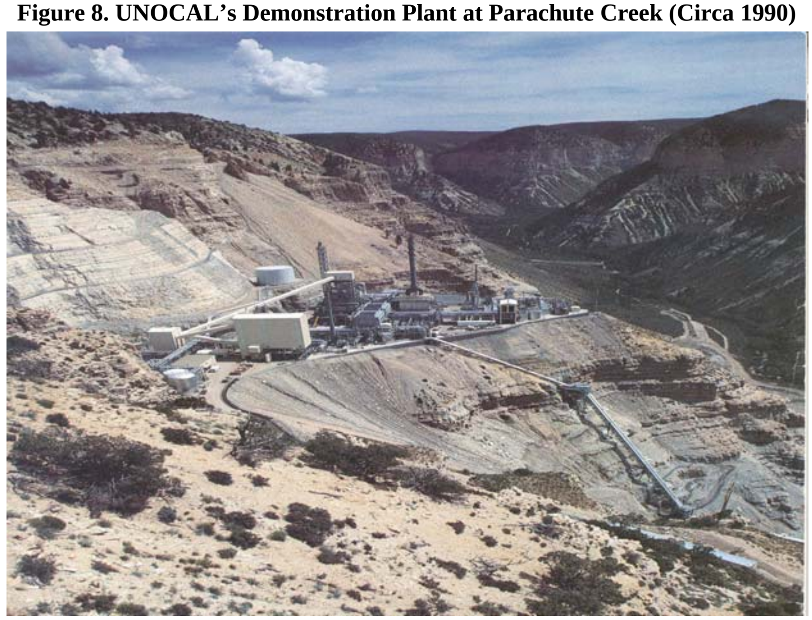
Because of the abundance and geographic concentration of the nation's known resources, oil shale has been recognized as a valuable U.S. energy resource since as early as 1859, the same year Colonel Drake completed his first oil well in Titusville, Pennsylvania.

Early products derived from shale oil included kerosene and lamp oil, paraffin, fuel oil, lubricating oil and grease, naphtha, illuminating gas, and ammonium sulfate fertilizer.

Since then, energy companies and petroleum researchers have developed, tested, enhanced, and in many cases, demonstrated a variety of technologies for recovering oil and gas from oil shale and upgrading it to produce fuels and byproducts.

Both surface processing and in-situ technologies have been conceived, developed and tested in the laboratory, field tested at pilot and semi-works scale, or demonstrated at commercially representative scale in demonstration plants.

Figure 8. UNOCAL's Demonstration Plant at Parachute Creek (Circa 1990)



Generally, surface processing consists of three major steps: (1) oil shale mining and ore preparation (2) pyrolysis of oil shale to produce kerogen oil, and (3) processing kerogen oil to produce refinery feedstock and high-value chemicals

For deeper, thicker deposits, not as amenable to surface- or deep-mining methods, the kerogen oil can be produced by in-situ technology. In-situ processes minimize, or in the case of true in-situ, eliminate the need for mining and surface pyrolysis, by heating the resource in its natural depositional setting.

By as early as 1978, the U.S. Department of Energy had concluded that the development of a domestic oil shale industry was technically feasible and was ready for the next steps toward aggressive commercialization (Ref. 12).

- Surface and sub-surface mining technologies were deemed commercially proven and economic.
- Numerous surface retorting technologies were largely demonstrated, although additional process design improvements were deemed desirable to improve reliability and to reduce costs.
- In-situ technologies, although less costly than surface retorts, had been demonstrated to a more limited degree, but warranted additional public and private R&D investment and testing.
- Environmental impacts, though significant at the time, appeared to be controllable to meet existing and anticipated regulatory standards with available technologies. A programmatic environmental impact statement was prepared in 1973 to support the Department of Interior's Prototype Oil Shale Leasing Program.
- Upgrading and processing technologies to convert kerogen oil to quality fuels and chemical byproducts were also considered proven, although on-site processing and new commercial refineries would be required to support a full-scale industry.
- First-generation commercial-scale plants were expected to be economically competitive, based on oil price forecasts that followed the Arab Oil Embargo of 1973 and the supply disruptions and price shocks associated with the 1979 Iranian Revolution.

By 1984, reduced tensions in the Middle East , the availability of new petroleum supplies from non-OPEC sources, including the North Sea, and decreases in world petroleum demand, caused prices to fall from $31/ Bbl to as low as $10 / Bbl.

Public and private sector decisions to terminate investments in R&D and large-scale demonstration projects were made largely based on evolving economic uncertainties associated with the supply and price of conventional petroleum, as well as oil shale plant design issues. For example, design issues in the Unocal retort created production bottlenecks that played a major role in Unocal's decision to shut down rather than retrofit its pilot plant.

Investment uncertainty was further compounded by regulatory and policy uncertainty. These uncertainties are now being resolved as petroleum prices firm, the regulatory environment matures, and the need for additional, diverse energy supplies brings renewed focus to government policy.

In many cases, the technologies developed to produce and process oil from shale were not abandoned, but rather "mothballed" for adaptation and application at a future date when market demand for shale oil would increase, oil price risk would attenuate, and major capital investments for oil shale projects could be justified.

Perceptions that oil shale projects in the 1980s and 1990s were terminated due to the quality of the resource are incorrect. In fact, it was the abundance, concentration, and high quality of the oil shale resources of the Green River Formation that attracted the billion$^+$ dollars of investment in the first place.

Many of the companies involved in earlier oil shale projects still retain their oil shale technology and resource assets.

Current U.S. Oil Shale Development Activity

Today, with oil prices in excess of $60 per barrel, domestic oil shale and tar sands are now attractive resources for the production of secure, domestically sourced transportation fuels.

Fortunately, the body of knowledge and understanding established by past efforts exists to provide the foundation for emerging advances in oil shale mining, retort, and processing and supports the growing interest in oil shale.

Public and private interest and activity in oil shale resources and technology development continues, both in the United States and elsewhere in the world, despite the fact that major U.S. efforts to commercialize oil shale were terminated with the closure of the Unocal effort in 1991.

At that time, many technologies had advanced well beyond proof of concept in the lab to engineering, design and field-testing at pilot or semi-works scale.

New Technologies are Emerging; New Challenges Being Addressed

These efforts are – and must be – clearly focused not only on overcoming the technical challenges of the past, but also on meeting new challenges that face 21st century producers of domestic energy resources.

New Technologies That Address Past and Present Oil Shale Challenges

- Indirect heating for in situ – instead of direct combustion (several variations)
- Direct current heating
- RF Microwave heating for in-situ
- Oil Tech Vertical Retort
- Freezewall barriers for groundwater protection in in-situ
- Impermeable barriers to prevent leaching and protect ground water
- Solvent-based liquefaction versus pyrolysis
- Hot gas recycle and solid-to-solid heat transfer for surface processes (Alberta Taciuk Processor and Gas Combustion Retort)

Major New Industry Challenges and Objectives

- Efficient production to maximize recovery and conserve resource
- Conservation of water supplies
- Preservation of air quality
- Net carbon emissions equal to or less than conventional petroleum (wells to wheels)
- Protection of groundwater quality from in-situ processes
- Protection of ground water from surface operations

This continuing interest and effort has enabled the art and science of oil shale mining, conversion of oil shale to hydrocarbon liquids and gases, and shale oil processing to advance in several very significant ways:

- Technology performance and efficiency are significantly improved – more barrels of oil equivalent can be produced from a given resource per unit of energy expended.
- Capital and operating costs per barrel of production capacity are falling to the point where they are likely to be economically competitive with conventional crude oil at current and expected market prices.
- Environmental monitoring, control, and remediation technologies have become more effective, reliable, and less costly.
- More efficient in-situ and surface retorting processes leave less residual carbon behind, both increasing product yield and improving the environmental safety of the spent shale or residual subsurface formations.
- Technologies to reduce water requirements, to use previously unsuitable water resources, and to capture, clean-up, and re-use water have improved dramatically, reducing water demand estimates significantly.
- Technologies to capture, concentrate and use or store produced carbon dioxide are advancing and the locations, opportunities, and strategies for storing produced carbon dioxide are far better understood.

Today, building on the lessons learned and technologies developed in past efforts, more than 30 companies are moving technologies forward toward commercial scale development. Research and development interest and activity is intensifying. Renewed interest in commercial-scale oil shale development is evident.

Several technologies are sufficiently developed and field-tested to approach readiness to enter Phase III – Demonstration efforts at commercially-representative scale. The current efforts include both surface and in-situ technologies

COMPANY PROFILES

The 27 Company Profiles that follow describe companies that are currently and actively engaged in domestic oil shale and heavy oil resource and technology development. Each profile describes the company, its role in oil shale or tar sands development, the nature and features of its process technology (if any), the location of its resource holdings or leases (if any), the status of technology or project development efforts, and plans for further efforts.

The information provided in the company profiles was provided by the subject companies or garnered from information in the public domain found on company websites or in public filings. The Department of Energy makes no representation as to the accuracy of this information.