EMD Oil Shale Committee

EMD Oil Shale Committee Annual Report – 2015

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Executive Summary

Progress on oil shale continued in both the United States and around the world, but with a greater sense of urgency in countries with lesser quantities of conventional energy sources. New production capacity was brought on line in Estonia and China, and plans for production moved forward in Jordan. However, reductions and delays in development are starting to appear, particularly in the United States, due to the low price of crude oil. The current status is in flux, but it is too early to know whether we are seeing a repeat of the 1980s.

In the U.S., the Utah Division of Water Quality issued a groundwater permit to Red Leaf Resources, which now has the go-ahead to establish a small-scale commercial production system based on the EcoShale process as a joint venture with Total. A challenge by environmental groups was settled by allowing access to groundwater monitoring data. However, that project is now delayed by a year or more, and the time will be used to accelerate design optimization. TomCo received temporary approval to establish a commercial operation using the EcoShale process 15 miles from the Red Leaf operation. Enefit is making progress getting permits for development of its private lands in Utah and successfully resolved a potential environmental roadblock by working with local officials, who created a conservation plan for a potentially rare plant. However, a group of environmental groups have filed suit to stop Utah oil shale development by listing that plant as an endangered species.

For the U.S. Bureau of Land Management (BLM) Research, Development, and Demonstration (RD&D) leases, Enefit USA and American Shale Oil LLC continued efforts to demonstrate their oil shale processes, with the goal of conversion to a commercial lease. Natural Soda Holdings Inc. and ExxonMobil received approval of their Plans of Development for the second round of RD&D Leases, but there is little apparent activity. Shell continued activities related to disposition of their Colorado oil shale assets, preferring to concentrate on Jordan.

In Jordan, the Saudi Arabian Corporation for Oil Shale received approval for agreements related to a project that will start producing shale oil in five years and increase to 30,000 BOPD (barrels of oil per day) by 2025. The venture will use the Russian UTT-3000 technology, a version of a hot-burned-shale process. A Power Purchase Agreement was also finalized with the Attarat Power Production Company (majority owned by Eesti Energia) to produce electricity from oil shale, and

JOSCO (Shell) is continuing with the execution of its small-scale production pilot called Jordan Field Experiment (JFE).

Oil shale continues to be mined, retorted, and burned in power plants in Estonia, China and Brazil, and production is expected to rise significantly in 2015 and beyond. In Estonia, Viru Keemia Grupp continues to operate a second Petroter plant, and a third is expected to come on line in late 2015. Numerous Fushun and other small retort types are coming on line in China, and an Alberta Taciuk Process (ATP) unit is undergoing commissioning at Fushun to retort fines. Small-scale commercial production also continues in Brazil by Petrobras, and Irati Energy Limited is launching a feasibility study of its plan for an 8,000 BOPD shale oil plant.

Oil shale development activities also continued in Israel and Mongolia by Genie Energy using an in-situ process, although the Israeli project received a significant setback due to rejection of its pilot test permit application by a local planning committee, but the company plans to appeal. In Morocco, development efforts continued by San Leon Energy using the Enefit280 process and TAQA using the EcoShale process.

The National Oil Shale Association (Vawter, 2014) released a new report on water use associated with development of oil shale from the Green River Formation. The new study assumed a smaller industry of 500,000 BOPD and a mix of 40% ex-situ, 45% in-situ, and 15% modified-in-situ processes. Ranges of water consumption, including upgrading, were developed for each technology, with an overall average of 0.7 to 1.2 barrels of water per barrel of oil. This would amount to less than 1% of the water entering Lake Powell from the Colorado basin and only 5% of the trans-basin transfer of water from western Colorado to the Front Range, far less than previous estimates.

Oil Shale Symposia were held in Jordan and Colorado in 2014. Discussions continue to better coordinate international oil shale meetings in the future, and the U.S. symposium will be held October 5-9, 2015 in Salt Lake City, Utah.

Current and Projected Oil Shale Production

Current activity includes both production and development projects, with active oil shale production most important in Estonia and China (each about 15 million tonnes/year), and with Brazil a distant third (2.4 million tonnes/year). A summary of recent activity in Estonia and China (Hou, 2014) is shown in Figure 1.

A summary of various oil shale production and development projects is shown in Figure 2, and production projections up to 2030 are shown in Figure 3 (Boak, 2014). The projections in Figure 3 do not include potential in-situ projects, as that technology is still developmental. However, it does include projects that propose surface retorting technology that has not been demonstrated at scale. However, it is plausible that a more mature surface-retorting technology could be substituted with less disruption if the proposed technology does not come to fruition. Then again, these projections do not take the recent decline of crude oil prices into account.

Total global production of shale oil is currently about 35,000 barrels per day (BOPD), all from China, Estonia, and Brazil. Chinese production is estimated at 18,000 BOPD in 2014. Estonia produced about 13,000 BOPD, and Brazil nearly 4,000 BOPD. Current projections show that oil shale will not be a significant part of global production (>500,000 BOPD) for another decade. However, projects are in line over the next four to five years that could increase production significantly.

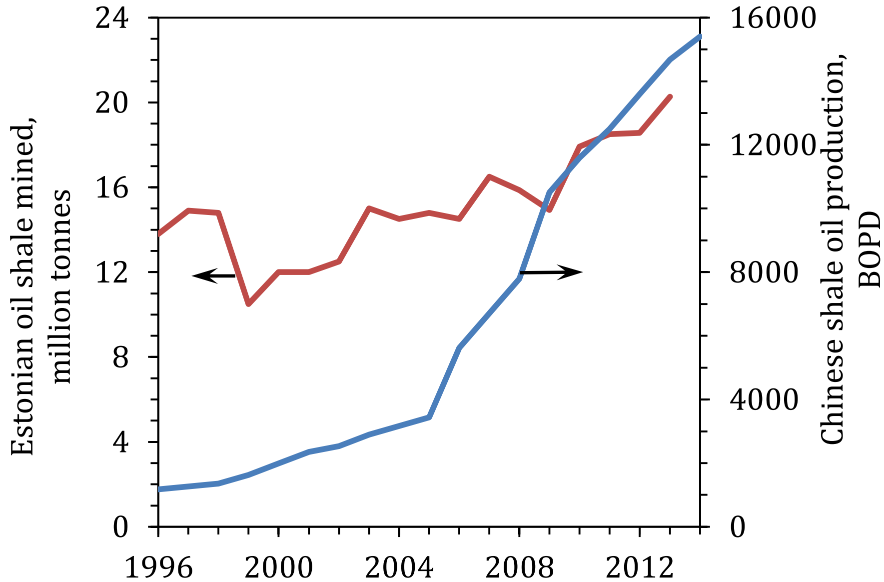


Figure 1. Recent history of oil shale mining in Estonia and shale oil produced in China.

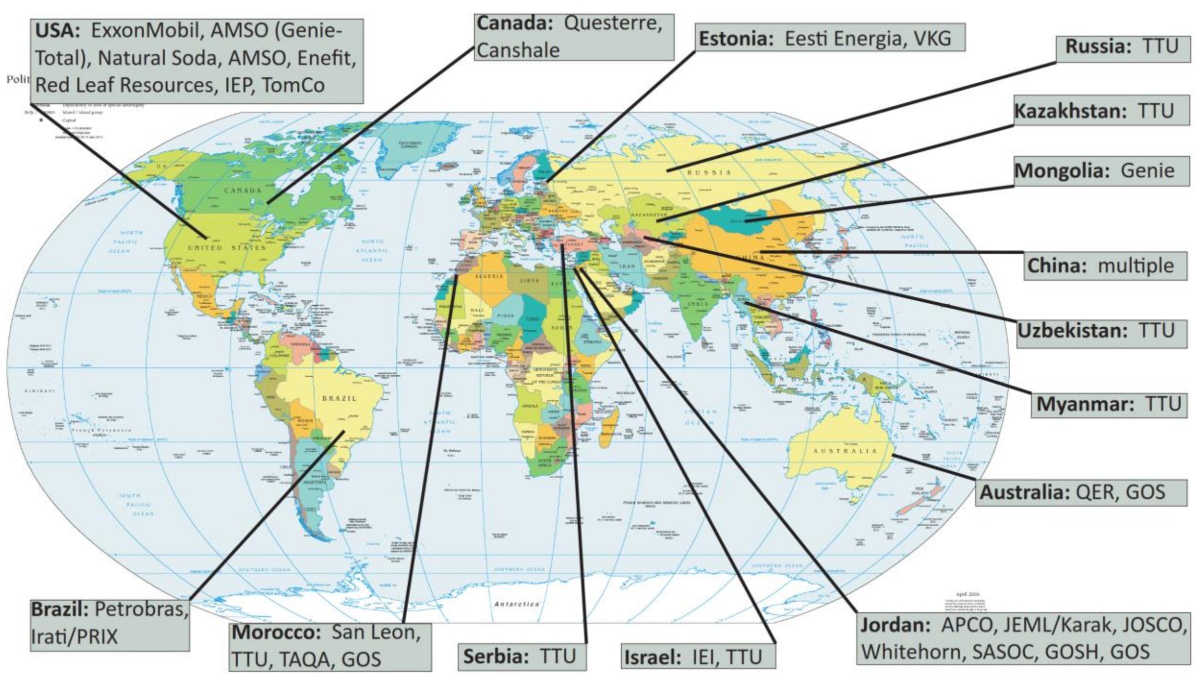


Figure 2: Oil shale projects around the world (Boak, 2014).

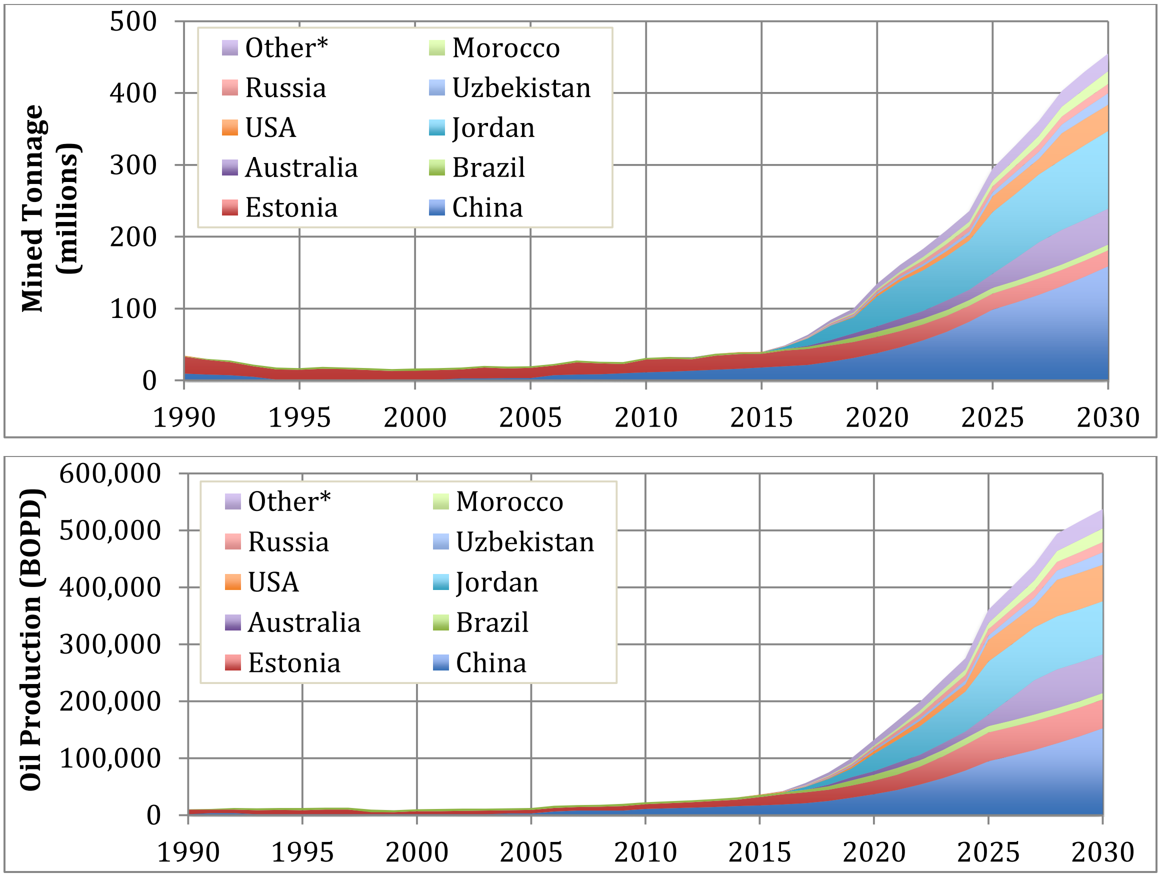


Figure 3: Current and projected quantities of mined oil shale and shale oil produced by pyrolysis. Much of the mined oil shale is burned directly to produce electricity.

Production and Development Activities around the World

China produces shale oil and electric power from oil shale mined in the Fushun, Huadian, Huangxian, Junggar, Maoming, and Luozigou Basins, and from the Dalianhu and Haishiwan areas. Operating oil-shale retorting plants are located in Beipiao, Chaoyang, Dongning, Fushun, Huadian, Jimsar, Longkou, Luozigou, Wangqing and Yaojie. Evaluation is continuing in four other basins and a number of other areas, with a billion-tonne resource recently discovered in Heilongjiang Province. The major producing and developing companies are the Fushun Mining Group, the Maoming Petrochemical Co. (owned by SINOPEC), Longkou Coal Mining Co, Longteng Energy Company, Gansu and Saniang Coal Companies, Julin Energy & Communication Corp., and Petrochina. The gas-combustion Fushun retort is the dominant technology, and the Fushun district is responsible for about half of Chinese production. A new open pit mine opened in 2014 in Fushun. New retorts are being built rapidly in China—about 130 in 2014. Most of them use lump oil shale, but some retorts are now being built to process fines. An ATP retort in Fushun completed a 40-day commissioning run in 2014 at 70-80% of design capacity. Oil shale fines are also burned in fluidized beds for power production.

In **Estonia**, the three producers are Viru Keemia Grupp (VKG), Eesti Energia (internationally known as Enefit), and Kiviõli Keemiatööstus. VKG is the largest oil producer in the country, commissioned a second Petroter plant in August 2014, and expects to bring a third unit on line in September 2015, which will raise their capacity to about 12,000 BOPD. VKG is planning a refinery targeting diesel fuel production with construction starting in 2016, and it continues efforts to reduce air emissions and produce building material from spent shale. Enefit produces 95% of Estonia's electricity from oil shale and operates two Enefit140 retorts producing shale oil at a rate of about 4,000 BOPD. It also continues commissioning its Enefit280 retort, and the plant has operated at over 80% capacity. New circulating-fluidized-bed technology has enabled Enefit to increase electricity production by 30% over the last five years while decreasing sulfur emission by 65%.

In **Brazil**, Petrobras continues mining and retorting Irati oil shale, producing about 4000 BOPD using the Petrosix technology, but it has no expansion plans. However, startup Irati Energy Limited, owned by Forbes & Manhattan, is based in Southern Brazil and controls >3,100 km^2, with over 2 billion barrels of potential oil shale resources. It plans an 8,000-10,000 BOPD shale oil plant based on the PRIX technology, which is an incremental improvement over the Petrosix technology.

Jordan is pursuing oil shale aggressively, with a goal of producing 14% of its energy from oil shale by 2020. It currently has numerous Concession Agreements, Memoranda of Understanding, and a Power Purchase Agreement in place. Attarat Power Company (APCO; 65% owned by Enefit) received approval from Jordan's Ministry of Environment to proceed with a 554 MW oil-shale-fired power plant. Jordan signed a Power Purchase Agreement in October 2014, and the plant is expected to be operational at the end of 2018. APCO signed an engineering, procurement and construction contract with Guangong Power International Corporation in November to build the power plant. Enefit is also negotiating a separate agreement with Jordan to construct a 40,000 BOPD shale oil plant. Jordan Oil Shale Company (JOSCO, owned by Shell) has performed exploration drilling on its concessions and is preparing for a small-scale pilot test of its In-situ Conversion Process (ICP). JOSCO has decommissioned one drilling rig as it transitions from a drilling phase to a piloting stage of operations, which will provide important information about the resource potential and determine the next stage of its operations. Karak International and parent Jordan Energy and Mining Ltd (JEML) have completed an interim funding agreement underwritten by Sentient Group funds to pursue shale oil production project. Karak holds a concession for the Lajjun deposit that contains approximately 300 million barrels of oil in place, where it proposes to use the ATP technology, and it also has a Memorandum of Understanding (MOU) to explore oil shale at Al Nadiyya. Another MOU has also been signed between Jordan and a consortium of China's Shandong Electric Power Construction Corp and HTJ Group and Jordan's Al-Lajjun Oil Shale Company to produce 900 MW of electric power. Jordan also signed a MOU in 2014 with China's Fushun Mining Group Co to conduct geological and geophysical studies in the Wadi Al Naadiyeh area. Jordan approved a concession in March 2013 to the Saudi Arabian Corporation for Oil Shale and a production agreement in March 2014 that is projected to produce 3,000 BOPD by 2019 and 30,000 BOPD using the Russian UTT-3000 technology. Other companies holding MOUs for shale oil production are Aqaba Petroleum for Oil Shale Co, which also proposes to use the UTT-3000 process, Global Oil Shale Holdings, which proposes to use the PRIX process, and Whitehorn Resources, which proposes to use the Red Leaf EcoShale Process.

In the **United States**, Red Leaf Resources has obtained the necessary permits from the State of Utah and is proceeding with plans for a $5/8^{th}$ commercial-scale demonstration (>300,000 BO over 400 days) from its EcoShale® technology. However, due to the decline in oil prices, the project is being delayed at least one year to 2016 or later, and the process is being reoptimized during that delay in order to accelerate future progress. It settled a lawsuit with Living Rivers in return for sharing ground water monitoring information. It will produce >300,000 barrels of oil over 400 *days* in the $5/8^{th}$ scale demonstration retort. Meanwhile, TomCo Energy received temporary approval from the State of Utah in September 2014 for its Notice of Intention to Commence Large Mining Operations using the Red Leaf EcoShale process, but they will wait for the commercial-scale demonstration. Enefit American Oil (EAO) has oil shale resources associated with both private lands and an RD&D

Lease from the U. S. BLM. About 2/3 of the 2.6 billion barrel resource is on private land. It plans to use its Enefit technology and continues to refine it for Utah oil shale, including modifications to fix a fines generation problem. Their significant permitting effort has been to get permission for a utility corridor across federal land to its private lands, where initial development will occur. A second challenge was the potential listing of a rare plant under the Endangered Species Act, but that listing was prevented by a combination of environmental studies, local governmental protections, and conservation efforts on private lands. However, other environmental groups recently filed suit to force the listing in order to stop the Utah projects.

Further efforts in the United States occurred on the BLM RD&D Leases. Enefit used shale both from its RD&D lease holding and its private lands to demonstrate the applicability of the Enefit process to Utah oil shale through pilot testing. In Colorado, Shell cancelled in 2013 its multi-mineral test of sequential production of nahcolite and shale oil on one of its three RD&D leases. They plan no development activities on their other two RD&D leases and are currently reclaiming both their private and public lands. They are moving to dispose of all of their Colorado holdings. American Shale Oil Corp. (AMSO), a partnership of Total and Genie Energy, encountered problems with its downhole heater in 2013. AMSO is systematically evaluating different electrical and hot gas heater concepts to complete its pilot, with a nominal start date in late 2016. Although ExxonMobil and Natural Soda Holdings Inc. (NSHI) received approval from BLM of their Development Plans for in-situ projects on their second-round RD&D leases awarded in 2012, no visible progress has occurred.

In **Australia**, Queensland Energy Resources (QER) successfully completed the operation of its demonstration plant near Gladstone in November 2013. A favorable environmental review of the operation was issued by the Queensland Department of Environment and Heritage Protection, and the moratorium on oil shale development was lifted. The Australian Government Department of the Environment ruled in July 2014 that the development proposal will require assessment and approval under national environmental law before it can proceed. A draft Environmental Impact Assessment has been prepared for an 8300 bbl per stream day commercial plant located at the Stuart oil shale deposit near Gladstone, Queensland. Meanwhile, QER is moving ahead towards design and construction of a commercial plant and is seeking investors.

In **Morocco**, San Leon Energy determined in 2012-2013 that a yield of 17 gal/ton was achievable in two reservoir zones of the Tarfaya oil shale using Enefit Technolgy, and it began investigating Timhadit oil shale in 2013. They reported in August 2014 that shale oil had been produced successfully using bench tests of the Enefit280 process. San Leon Energy signed a MOU with Chevron Lummus Global to examine upgrading of Timahdit shale oil. The Abu Dhabi National Energy Company (TAQA) is also currently working on the Timhadit area in order to evaluate a potential development using the EcoShale Technology. Global Oil Shale PLC has established a fully owned subsidiary in the country and is continuing the evaluation of the Tarfaya oil shale resources by open pit mining.

In April 2013, Genie Mongolia and the Petroleum Authority of **Mongolia** entered into an exclusive five-year oil shale development agreement to explore and evaluate the commercial potential of oil shale resources on a 34,470 square kilometer area in Central Mongolia, the first such agreement in Mongolia. Genie Mongolia has begun surface mapping and other geophysical evaluation work as well as drilling exploratory wells, and has secured permits for additional exploratory wells. Further plans depend on both technical and regulatory developments. In September 2014, Mongolia held an international investors forum, with over 300 attendees from corporations such as Rosneft, Petrochina, British Gas, Sinopec and many other companies. The Prime Minister gave an opening speech describing legal reforms intended to increase investment.

In **Israel**, the government issued directives in April 2013 for the environmental impact statement that is required as part of Israeli Energy Initiative's (IEI) pilot test permit application in the Shefla Basin. IEI, a subsidiary of Genie Energy, prepared and initially submitted its pilot application in June of 2013 to the Jerusalem District Building and Planning Committee and supplied additional information in November. In August 2014, the Israeli Environmental Protection Ministry recommended against the project. In September, the Jerusalem District Committee for Planning and Building declined to issue IEI a permit for its pilot project. IEI is currently evaluating alternatives to determine the best course of action to advance the project and develop the resource covered by the exploration license.

In **Canada**, Chapman Petroleum Engineering Ltd. completed in February 2013 an NI 51-101 Engineering Evaluation Report of Contingent Resources and Commerciality Factors for Xtra Energy's Pasquia Hills oil shale permit located in northeastern Saskatchewan, estimating about 2 billion barrels of potential oil. In December 2013, Cencor acquired a 55% working interest in a Pasquia Hills oil shale project with a resource of 1.2 billion barrels of oil. Meanwhile, Canshale is evaluating commercial feasibility of its 3 billion barrel oil shale resource near the Hudson Bay in Saskatchewan using the ATP technology.

Uzbekistan could become the first Central Asian country to attempt to produce non-conventional hydrocarbons in oil and gas rich Central Asia as early as 2015 as part of plans by the government to address dwindling oil production and domestic fuel shortages. State oil and gas company Uzbekneftegaz is planning a $600 million oil shale project to launch production.

Estimated U. S. and International Resources/Reserves and Strategic Importance

The strategic significance of oil shale resources varies from country to country. In the U.S., much has been made of the size of the resource. However, its availability remains uncertain in large part due to regulatory uncertainty. Technology to produce the vast quantities of oil potentially recoverable is being tested, but only two developers are currently planning to produce by 2020—both using above ground technology in Utah. Current operations in other countries form a firm foundation for concluding that commercial technology is available for production in the U. S., but the recent drop in crude oil prices has reduced the urgency of oil shale development. However, especially for smaller countries with lower energy demands and no other liquid hydrocarbon resources (Estonia, Jordan, and Morocco, for example) development of this resource can be very important strategically, although recent discoveries of off-shore natural gas for Israel may reduce its sense of importance to that country in the near-term.

The current estimates of oil shale resources are probably low in most countries (other than the United States) because of limited exploration. For example, China just discovered a billion barrel resource in in Heilongjiang Province. Additional updates to the projected resources of oil shale come from Israel and Jordan. Each now estimates the potential for more than 100 billion barrels of oil (BBO) in place. Yuval Bartov of IEI suggested resources as high as 250 BBO, and JEML reports an estimated resource of 102 BBO for Jordan (pending peer review). Other increases are likely as more exploration and resource characterization is performed.

The U. S. Geological Survey has completed a reevaluation of oil shale resources of the Green River Formation in Colorado, Utah, and Wyoming (summarized in Birdwell et al., 2012). The results indicate Colorado resources increased from the 1.0 trillion barrel previous estimate to 1.52 trillion barrels, with Utah estimated at 1.32 trillion barrels of oil in place, and Wyoming with total resources of 1.44 trillion barrels. The total resource is estimated at 4.29 trillion barrels. A recent fact sheet on the resource available at various cutoff grades indicates that the marginally prospective resources (those with Fischer Assay oil yield above 15 gal/ton) are closer to 1.0 trillion barrels and are generally located in the Piceance Basin. Moreover, the most prospective resources (above 20 gal/ton) total about 700 billion barrels and are almost exclusively located in the Piceance Basin. It should be noted that even after applying a 20 gal/ton cut off, the in place *resource* is considerably larger than the US proved crude oil *reserves* (33 billion barrels, December 2012, EIA) which illustrates the potential importance of future oil shale development. Figure 4 shows the USGS estimates of these amounts. One caution in this comparison is that the remaining crude oil resource is considerably larger than the proved reserves for a variety of reasons, including improvements in recovery technology for other unconventional resources.

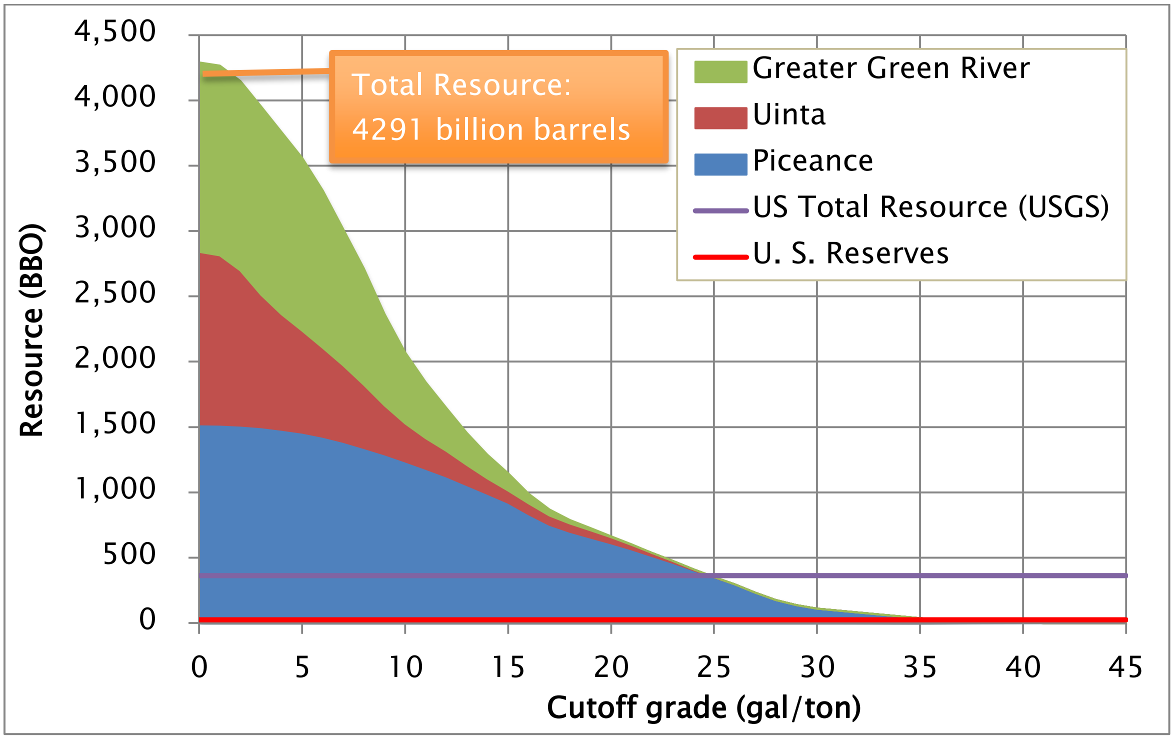


Figure 4: Oil Shale resource estimates for different grades of oil shale, from U.S. Geological Survey data (presented at the 32nd Oil Shale Symposium) compared to U.S. crude oil reserves.

Leading Companies (Additional details in the Appendix)

The top companies at this point (with areas of development) are:

- Viru Keemia Grupp (Estonia, Ukraine)
- Fushun Mining Group (China)
- Enefit (Estonia, Utah, Jordan, Morroco)
- Petrobras (Brazil)
- Irati Energy Limited (Brazil)
- Red Leaf Resources (Utah; Wyoming; licensees potentially in Jordan, Morocco, Canada)
- QER (Australia)/ ShaleTech International (Colorado and licensing Paraho worldwide)
- Total (Utah, Colorado, Jordan)
- Shell (Jordan)
- ExxonMobil (Colorado)
- Natural Soda (Colorado)
- Genie Energy (Colorado, Israel, Mongolia)
- UMATAC/Thyssen Krupp (China)

Independent Energy Partners (Colorado)
Jordan Energy Minerals Limited/Karak International Oil (Jordan)
San Leon (Morocco)
CanShale (Canada)
Centor Energy (Canada)
TomCo Energy (Utah) (EcoShale licensee)
Anadarko (Wyoming)
Global Oil Shale PLC (Morocco, Australia)

Research Focus (Additional details in the Appendix)

Current research on oil shale is best identified through presentation at the Oil Shale Symposium that has been held each October in Golden, CO, at the Colorado School of Mines, but starting in 2015 the symposium will be rotated between multiple host cities, including Golden, Salt Lake City, and others to be determined by the organizers. Abstracts, presentations, and papers for the 26th through 32nd Oil Shale Symposia are available at: http://www.costar-mines.org/oil_shale_symposia.html .

Proceedings of the 33rd Oil Shale Symposium are currently available for purchase and will be freely available sometime in 2015. The program and abstracts for the 33rd Oil Shale Symposium are posted at
http://mines.conference-services.net/programme.asp?conferenceID=3736&language=en-uk .

Proceedings of the 34th Oil Shale Symposium will be available for sale once assembly is complete. The program and abstracts for the 34th Oil Shale Symposium are posted at

http://mines.conference-services.net/programme.asp?conferenceID=4255&language=en-uk .

Research at the University of Utah under USTAR and other activities in oil shale are covered in the University of Utah Unconventional Fuels Conference:
http://www.icse.utah.edu/assets/archive/2013/ucf_agenda.htm .

General information about oil shale in the United States is provided by the National Oil Shale Association (NOSA): www.oilshaleassoc.org .

International research in oil shale processes and impacts is published in the journal Oil Shale, published in Estonia. The journal can be accessed at: http://www.kirj.ee/oilshale .

Information on oil shale research conducted by the U.S. Geological Survey Energy Resources Program is available at the Oil Shale Research Homepage:
http://energy.usgs.gov/OilGas/UnconventionalOilGas/OilShale.aspx .

Sources of Funding

Funding for oil shale research in the United States comes primarily from corporations actively pursuing oil shale development. U. S. Federal sources include the U.S. Department of Energy (USDOE) and U.S. Department of Interior, but such funding is negligible. Other companies may have provided smaller grants that are not widely publicized. Other private funding appears to support development at least of the Red Leaf Resources program. International funding comes from diverse sources, not all of them publicly acknowledged. It is clear that governments in Jordan and Morocco are actively supporting granting of concessions and dissemination of available data. Companies in Estonia (Eesti Energia, Viru Keemia Grupp), Brazil (Petrobras), and China (CNPC, Fushun Mining

Group and others) are supporting internal development and, in some cases, external development efforts.

Critical Technology Needs (Additional details in the Appendix)

Critical technology needs mainly concern the development of more energy efficient and environmentally friendly methods of extraction, production and upgrading of oil shale. Especially in the USA, issues have been raised about greenhouse gas emissions and water consumption by industry.

The primary source of emissions for in situ production is power plant emissions of CO_2. Minimizing energy use is essential to profitability and sustainability. AMSO has suggested sequestration of CO_2 in exhausted in situ retorts (Burnham and Carroll, 2009). An Enefit presentation at the 31st Oil Shale Symposium indicated that production from their Estonian retort system would result in a net carbon intensity of ~130 gCO_2/MJ of energy output (including burning of the fuel). This is ~30% higher than traditional crude oil. However, given a carbon offset for generating power in the Enefit unit rather than using a power plant, and for using ash as a cement clinker substitute, this could reduce CO_2 emissions to approximately that of crude oil.

In situ processes require robust heating technology, but none is fully demonstrated at present. Substantial progress has been made on electric heating cables that do not require splices between mineral-insulated cable segments. However, energy efficiency considerations are motivating work on non-electrical systems, including down-hole burners and hot circulating fluid systems such as propane, CO_2, and molten salts. The hot-fluid systems include demonstration of super-insulated piping systems to minimize heat loss from the surface.

NOSA has recently updated its estimate of water needs for an oil shale industry. Based upon 2014 input from developers such as Shell and Enefit, NOSA now estimates water usage of 0.7 to 1.2 barrels of water per barrel of shale oil (Bw/Bo) (16,000 to 29,000 acre feet per year for 500,000 barrels per day of marketable shale oil production). This is down from an average of 1.7 Bw/Bo in a 2012 estimate, which assumed a 1,500,000 barrel per day industry. Further details are in the appendix.

Developing criteria and methods for consistently structured resource assessments would be a contribution to the global development of this resource, and would potentially create good will between the U. S., the European Union, and the developing countries with oil shale resources. Critical to such assessments will be careful estimation of uncertainty regarding resource estimates where data are sparse.

Key Environmental and Socio-economic Concerns (Additional details in the Appendix)

The critical environmental issues are how to extract, produce and upgrade shale oil in an environmentally friendly and economically sound way such that:

1) Use of energy to pyrolyze the kerogen is minimized
2) Greenhouse gas emissions are reduced or compensated for by carbon trading or sequestration
3) Water used in construction, operation, power generation, and reclamation is minimized and does not deplete the water resources of arid regions
4) Extraction, production and upgrading of shale oil does not unduly affect the quality of the air, the native biological communities, or surface and ground water of the region.
5) Conduct projects in a manner that meets community expectations by keeping the public apprised of progress, being transparent, and being sensitive to changes in social dynamics.

Relevant EMD Technical Sessions, Publications, Workshops

The primary conferences covering oil shale science and technology were the Jordan International Oil Shale Symposium, April 14-15, 2014 in Movenpick, Jordan, and the 34th Oil Shale Symposium, October 13-15, 2014, at the Colorado School of Mines in Golden, CO. Agenda are given in the appendix.

Appendix: Amplified Discussion of Oil Shale Commodity Activity

Highlights from Previous Report

The International Oil Shale Symposium (IOSS) was held in Tallinn, Estonia, June 10-13, 2013, and the 33rd Oil Shale Symposium was held October 14-16 at the Colorado School of Mines in Golden CO, with a field trip to Utah and Colorado October 17-18. There was some overlap in their content but also some distinct information.

Papers presented included a summary of progress on various oil shale projects around the world as well as scientific and technical papers related to oil shale recovery technology. The Golden, CO, meeting in 2013 was held during the shutdown of the US Federal Government, which prevented participation by governmental officials, including the keynote speaker.

Another significant event was the pullout of Shell Oil from oil shale activities in Colorado. This pull-out is symptomatic of the situation that oil companies have limited resources to pursue multiple opportunities around the world. Shell is still proceeding with their oil shale activities in Jordan.

A particularly important paper at the 33rd Oil Shale Symposium was a study by Shell that reduced expected water usage for oil shale extraction down to less than 2 barrels of water per barrel of oil. This is accomplished by a variety of actions, including the use of air-cooling instead of water evaporation for process needs and aggressively applying the latest low water use technological advances.

A series of papers by Enefit showed progress on bringing the Enefit280 process on line in Estonia, continued efforts to permit their plant construction in Utah, and progress on their Jordan project. Design modifications to the fluidized bed combustor were shown to reduce fines generation for Green River oil shale, which suffers greater attrition of rock particles than Estonian oil shale.

Other important papers and discussions addressed the social license to operate and the difficulty of raising capital for emerging technologies. The social license discussions emphasized the importance of proactive and continuous honest discussions of activities with the public to get and maintain its support. Trying to hide problems will eventually backfire. An example of successful proactive discussions was the turnaround of public opinion in Queensland Australia by QER , where more than 75% of the local community either support or strongly support the establishment of an oil shale project. The difficulty in raising capital for projects that are not self-financed by a major corporation centered around the hesitation of independent capital to fund projects that are not considered to use mature technology, but once the technology is established, the rate of funding and construction should increase if the economics are favorable.

Active Basins, Recent Focus, and Future Growth

Estimated U.S. and International Resources/Reserves and Strategic Impact

World resources of oil shale were previously estimated to be >3.0 trillion barrels, of which about two trillion barrels were located in the U.S.A. (Dyni, 2006). The largest oil shale deposit in the world is the Green River Formation of Colorado, Utah and Wyoming. The U.S. Geological Survey has completed its reevaluation of oil shale resources of the Green River Formation in Colorado, Utah, and Wyoming. The Colorado assessment was released in 2010, and increased the amount from the 1.0 trillion barrel previous estimate to 1.5 trillion barrels. The latest assessment of Utah resources indicates 1.32 trillion barrels of oil in place. A reassessment of Wyoming was completed in 2011, with total resources of 1.44 trillion barrels. The total resource is estimated at 4.29 trillion barrels. However, a recent fact sheet on the resource available at various cutoff grades indicate that the most favorable resources (those with Fischer Assay oil yield above 15 gal/ton) are substantially smaller, and that these better resources are far more concentrated in the Piceance Basin than is evident from the total resource numbers. The USGS data indicate the very large potential resource in the Green River Formation. At the fifteen gallon per ton cutoff generally considered the limit of marginal resources, there is more than one trillion barrels available. At the cutoff for rich resources of 25 gallons per ton, the amount still is equal to twice the anticipated remaining production from U. S. "conventional" oil.

The current estimates of oil shale resources are probably low in most countries (other than the United States) because of limited exploration. For example, China just discovered a billion barrel resource in in Heilongjiang Province. Additional updates to the projected resources of oil shale come from Israel and Jordan. Each now estimates the potential for more than 100 billion barrels of oil (BBO) in place. Yuval Bartov of Israel Energy Initiatives Limited suggested resources as high as 250 BBO, and JEML reports an estimated resource of 102 BBO for Jordan. However, these estimates have not been evaluated in a consistent manner, a critical need as the industry matures. On the other hand, resource estimates have generally been increasing, and one estimate of the Jordanian resource raises the possibility of more than one trillion BBO.

Measurements of oil shale yield by Fischer Assay, a method designed to approximate the recovery of surface retorting methods, provide the basis for most of these estimates. Most estimates of resource size tied to modern retort methods, whether retorting is done at the surface or in situ, are tied to this surrogate measurement. Some processes that focus on hydrogenation of the kerogen can recover amounts greater than the Fischer Assay. In addition, because the Fischer Assay calculates the gas fraction by difference, this measure does not adequately account for non-condensable hydrocarbon gases potentially present in the mass fraction lost during assay. In situ processes tend to have a higher gas/liquids ratio. Thus, it is difficult to provide consistent estimates of the potential resource of oil shale available at this time. The lack of estimates of the gas fraction can be of special significance, as this resource is likely to be used in the heating process, and therefore affect the external energy return of the processes.

The U.S. is the only place where extensive analysis and evaluation has been published for a large oil shale resource. However, the global estimates of Dyni are considered conservative assessments of the resource potential. Estimates of the recovery potential for U.S. oil shale were generally near 50%, but vary widely. The recent data suggests a recovery potential closer to 25%. The current Chinese estimate postdates Dyni's estimate, and significantly increases the world resources. However, China's assessment indicates that they also expect only about 25% recovery of the available resource. Some resource evaluations are very old, and may be highly uncertain. An up-to-date method for assessment of oil shale resources, and modern resource estimates would provide a better picture of the significance of this resource. The producing countries have provided reasonably reliable estimates of the resource in place, although these can be challenging to track down.

The strategic significance of oil shale resources varies from country to country. In the U. S., much has been made of the size of the resource. However, its availability remains uncertain. Technology to produce the vast quantities of oil potentially recoverable is currently being tested, but only two developers are currently planning to produce by 2020. Even so, it is wrong to assert that oil shale production is still non-commercial, as current operations in other countries form a firm foundation for concluding that commercial technology is available for production in the U. S and elsewhere. Especially for smaller countries with lower energy demands and no other hydrocarbon resources (Estonia, Jordan and Morocco for example) development of this resource can be very important strategically.

Leading Companies in Development of Oil Shale

Efforts by major international oil companies in the U.S. are generally led out of Houston, Texas, but AMSO has its field offices in western Colorado. International oil companies with activities in oil shale include (in alphabetic order):

- ExxonMobil
- Petrobras (Brazil)
- Shell (Jordan)
- Total (partner with Genie Oil in AMSO, and partner with Red Leaf Resources at Seep Ridge UT)

In addition, three other large oil companies have significant land holdings underlain by oil shale, and one major oilfield service company has acquired technology for oil shale evaluation and conducts research on the petrophysical properties of oil shale:

- Anadarko Petroleum Corporation
- ConocoPhillips
- Chevron
- Schlumberger

Smaller U.S. companies pursuing development, mostly in the U.S. include:

- Combustion Resources, Inc.
- Enefit American Oil
- EnShale Inc.
- General Synfuels International
- Genie Oil (partner with Total in AMSO/Israel/Mongolia)
- Independent Energy Partners
- Natural Soda, Inc.
- Red Leaf Resources
- Shale Tech International
- CanShale (Canada)
- Centor Energy (Canada)
- UMATAC/ThyssenKrupp (China/Jordan/Canada)
- TomCo Energy (Utah) (EcoShale licensee)
- Anadarko (Wyoming)
- Ambre Energy (trying to sell some but not all of their UT state leases)
- TomCo - UT state leases, licensee of Red Leaf EcoShale technology,
- Encana also has resource holdings in CO
- Uintah Gateway/Partners – property in CO and UT, developing regional upgrader project in UT that would start with black wax then expand for shale oil.

International leadership is held mainly by companies producing oil shale at the present time and also currently pursuing development of oil shale:

- Eesti Energia/Enefit (Estonia)/Outotec (Finland)
- Fushun Mining Group (China)
- Petrobras (Brazil)
- Queensland Energy Resources (Australia) [demonstration plant]
- Viru Keemia Grupp (Estonia)
- Canshale Corporation (Canada)
- Altius Resources (Canada)
- Aqaba Petroleum for Oil Shale (Jordan)
- Global Oil Shale Holdings (Canada)
- Irati Energy Limited (Brazil)
- Israel Energy Initiatives Limited (Israel) – owned mostly by Genie Energy
- International Corporation for Oil Shale Investment (Incosin) [MOA in Jordan]
- Jordan Energy Minerals Limited (England) [Agreement in Jordan]
- San Leon Energy (Ireland) [concession in Morocco]
- TAQA (Abu Dhabi) agreement in Morocco

National agencies/oil companies involved in developing oil shale include:

- China National Petroleum Corporation (China)
- National Resource Administration (Jordan)
- Organization National des Hydrocarbures et des Mines (ONHYM), Morocco

Current Research

Current industry research focuses on development and testing of a variety of techniques for extracting oil from oil shale and on minimizing the environmental impacts of these techniques. These fall into three main categories: 1) mining and retorting, 2) in situ heating and extraction, and 3) in-capsule extraction.

The first is the traditional method of oil shale extraction, which has been pursued with some intermittency for more than one hundred years. Developments in this area generally relate to increasing the energy efficiency and decreasing the impact of retort operation by reducing water use and CO_2 emissions. The development of advanced fluidized bed reactors is a current area of research and development. In addition, research continues on the impacts of past mining and retorting, and on utilization of spent oil shale and oil shale ash from burning of oil shale in power plants. The most obvious applications involve use of spent shale and ash in cement and brick manufacture, but more advanced techniques involving extraction of various constituents from the material have been investigated. The Fushun Mining Group in China has set as an objective no net waste products from oil shale production.

The second method, in situ heating and extraction, is the focus of intensive research to develop a method to heat and pyrolyze kerogen-rich rocks underground and efficiently extract the resulting oil and gas from the formation. Shell has been a leader in this area using their In situ Conversion Process (ICP), but ExxonMobil, AMSO (a partnership of Total and Genie Oil), IEI (Israel Energy Initiatives, a Genie subsidiary) and others are investigating different processes. In situ heating takes longer (on the scale of years), but as a consequence pyrolysis occurs at lower temperatures, and additional reaction at depth leads to a lighter oil with a larger gas fraction. The amount of secondary processing to meet refinery requirements is generally considered to be less than for products from surface retorts. Research on in situ processes and on processing the resulting material is ongoing at companies developing these methods, but results are generally proprietary. Symposium presentations have described general results in containment, heating, extraction, refining, and reclamation.

The third method, in-capsule extraction is the method being pursued by Red Leaf Resources of Cottonwood Heights, Utah. It involves mining of oil shale, encapsulation in a surface cell akin to a landfill, heating and extraction of the products, and final sealing of the exhausted retort. The process is described in more detail at Red Leaf's website: http://www.redleafinc.com/. Red Leaf is not currently involved in supporting external research on its method, although it is working with engineering firms on process design. Its plans for a 2015 demonstration project have been delayed at least a year due to low oil prices, and the delay is being used to reoptimize the process. The company had anticipated producing 10,000 BOPD by 2017 and 30,000 BOPD sometime in the 2020s, but no new schedule information is available. If it does occur, it would be a globally significant development for oil shale.

The U.S. Geological Survey (USGS) continues to conduct research evaluating the nature and extent of oil shale resources in the United States. Research continues at the USGS on the process of generation of oil from organic rich sedimentary rocks, both naturally and under simulated conditions of in situ production. General research on the geology, stratigraphy, geochemistry and rock physics of oil shale are under way at a number of institutions, including the Colorado School of Mines, University of Utah, University of Wisconsin, Binghamton University (New York), University of New Brunswick and other North American and international universities.

Independent Energy Partners is testing its Geothermic Fuel Cell unit at the Colorado School of Mines in Golden, Colorado, in partnership with Delphi and Total. A downhole test of 30-ft module started in October 2014. Shale Tech International Services LLC (STIS) continues oil shale processing research at its R&D Center in Colorado with a scaled back staff. STIS provides analytical laboratory services and batch testing for client resources, as well as a technology licensing and project development program.

List of Specialists in the United States

Colorado School of Mines:

- Mike Batzle, Center for Rock Abuse, physical properties of oil shale
- Jeremy Boak, Center for Oil Shale Technology and Research (COSTAR), assessment of CO_2 emissions and water consumption by oil shale production; geologic characterization of oil shale.
- John Berger, COSTAR, modeling of fracturing in oil shale
- Mark Kuchta, underground methods for in situ production of oil shale
- J. Frederick Sarg, stratigraphy and sedimentology of Green River Formation, Colorado
- Wei (Wendy) Zhou, Geographic Information Systems for oil shale water resource evaluation

Idaho National Laboratory

- Hai Huang, geomechanical behavior of oil shale
- Earl Mattson, Idaho National Laboratory, Idaho Falls, ID, hydrology of oil shale deposits and water consumption patterns for oil shale production
- Carl Palmer (emeritus), mineralogic and chemical effects of pyrolysis on oil shale

Los Alamos National Laboratory

- Daniel Levitt, hydrology of oil shale deposits
- Jonathan Mace, explosives application to fracturing of oil shale

- Donatella Pasqualini, energy systems analysis for Western Energy Corridor

Schlumberger Doll Research Center
- Drew Pomeranz, pyrolysis of oil shale, kinetics, and characterization
- Michael Herron, mineralogic and chemical characterization of oil shale
- Malka Machlus, stratigraphy of Green River Formation oil shale
- Robert Kleinberg, characterization and pyrolysis of oil shale

ExxonMobil Upstream Research Company
- William Symington, thermal behavior of Green River Formation oil shale and technology for application of heat in situ
- Sartaj Ghai, in-situ extraction technology

Shell Exploration and Production Company
- Mariela Araujo, Extraction technology, thermal modeling
- Dave Burns, Heater development
- Tom Fowler, in situ production of oil shale, oil shale piloting
- Erik Hansen, Jordan and Piceance Basin hydrology
- John Karanikas, Chief Scientist unconventional technology
- Etuan Zhang, In situ oil characterization and generation

American Shale Oil LLC
- Leo Switzer, in situ extraction technology
- Roger Day, geology, drilling, and operations expertise in the Green River formation
- Vince Reiling, in situ extraction technology

Enefit American Oil

- Rikki Hrenko-Browning, , oil shale development
- Ryan Clerico, environmental issues and regulatory affairs

Red Leaf Resources LLC
- James Patten, Properties of Oil Shale, Ex Situ Retorting processes
- James Bunger, Geology, properties and kinetics, Lab and Modeling
- Les Thompson, Oil Shale Retorting Operations

Daub & Associates, Inc.
- Gerald J. Daub, geology, hydrology, environmental, permitting, rock mechanics, etc.

Norwest Corp
- Andrew Maxwell, oil shale properties, mining, retorting
- Konrad Quast, Green River Formation geochemistry

Shale Tech International Services LLC
- Justin Bilyeu, ex-situ oil shale processing technology
- Larry Lukens, ex-situ oil shale technology

U. S. Geological Survey
- Justin Birdwell, U. S. Geological Survey, Lakewood CO, organic geochemistry of oil shale and other source rocks
- Michael Brownfield, U. S. Geological Survey, Lakewood CO, geology, stratigraphy, sedimentology and resource evaluation of Green River Formation oil shale
- John Dyni, U. S. Geological Survey (ret.), Lakewood CO, geology and resource evaluation of oil shale

- Ronald Johnson, U. S. Geological Survey, Lakewood CO, geology, stratigraphy sedimentology and resource evaluation of Green River Formation oil shale
- Michael Lewan (emeritus), U. S. Geological Survey, Lakewood CO, organic geochemistry of oil shale and other source rocks

University of Utah

- Lauren Birgenheier, University of Utah, Salt Lake City UT, stratigraphy of oil shale
- Milind Deo, Institute for Clean and Secure Energy, University of Utah, Salt Lake City, UT, chemistry and simulation of oil shale retorting processes
- Ronald Pugmire, University of Utah, Salt Lake City, UT, chemistry and kinetics of oil shale pyrolysis
- Philip Smith, Institute for Clean and Secure Energy, University of Utah, Salt Lake City, UT, chemistry and simulation of oil shale retorting processes
- Jan Miller, University of Utah, Salt Lake City, UT, micro-CT scan of pre and post pyrolysis products
- John McLennan, University of Utah, Salt Lake City, UT, in situ geomechanical properties of oil shale

Others

- Gary Aho, Rifle, CO, oil shale production technology
- Adam Brandt, Stanford University, Stanford CA, assessment of CO_2 emissions from oil shale production
- Brad Bunnett, Natural Soda, Dallas TX, sodium mineral extraction from oil shale
- Alan Burnham, Consultant to Total and AMSO, in-situ oil shale retorting technology.
- Alan Carroll, COSTAR, University of Wisconsin, Madison, WI, stratigraphy, sedimentology and geochronology of Green River Formation, Wyoming; lacustrine stratigraphy and sedimentology
- Ed Cooley, ERTL Inc., Rifle, CO, ex-situ oil shale processing technology
- Mike Day, Independent hydrologist, Piceance Basin hydrology
- Jim Finley, Telesto Solutions Inc, Green River Formation hydrology & geochemistry
- Thomas Fletcher, Brigham Young University, Provo, UT, oil shale chemistry
- Alan Goelzer, Jacobs Consultancy, Durham, New Hampshire, modeling of retorting and hydrogenation processes
- Terry Gulliver, Oil shale hydrology
- John Hardaway, Environmental restoration for in situ production
- Benjamin Harding, AMEC Environmental, Boulder CO, water use for oil shale production
- Timothy Lowenstein, COSTAR, Binghamton University, Binghamton NY, chemistry and formation of evaporite minerals and spring deposits of the Green River Formation, Colorado and Wyoming
- Seth Lyman, Bingham Research Center, Utah State University, Vernal, UT, Air quality measurement and instrumentation
- Glenn Mason, Indiana University Southeast, New Albany, IN, geology of Green River Formation oil shale
- Bill Merrill, Western Water and Land, hydrology of the Green River Formation
- Jim McConaghy, Antero Engineering, Salida CO, ex-situ and in-situ oil shale extraction technology
- Judith Thomas, U. S. Geological Survey, Colorado Water Science Center, Grand Junction, CO, hydrology of Piceance Creek Basin
- Michael Vanden Berg, Utah Geological Survey, Salt Lake City, UT, geology, stratigraphy, and hydrogeology of oil shale, Uinta Basin

- Glenn Vawter, ATP Services LLC, oil shale extraction technology
- Henrik Wallman, ProCo, Modeling of in situ and ex situ oil shale processing
- Glen Miller, oil shale geology and mineral resources

List of International Specialists

Enefit

- Alo Kelder, ex-situ oil sale processing technology
- Priit Raud, ex-situ oil shale processing technology
- Indrek Aarna, ex-situ oil shale processing technology
- Erkki Kaisla, oil shale mining
- Oleg Nikitin, oil shale mining
- Renee Ioost, oil shale gas
- Tõnis Meriste, environmental issues
- Andres Anijalg, oil shale development (Jordan)

Viru Keemia Grupp

- Jaanus Purga, ex situ oil shale processing technology

Israeli Energy Initiatives

- Yuval Bartov, lacustrine stratigraphy, Green River Formation and Israel
- Harold Vinegar, general oil shale technology, development of Israeli oil shale

TOTAL SA

- Pierre Allix, Geology, properties and kinetics, resource evaluation, retorting processes
- Jean Deridder, oil shale project development
- Olivier Garnier, retorting processes, oil shale development, upgrading
- Samuel Lethier, ex situ oil shale process engineering
- Eric Chabal, ex situ oil shale project development
- Francoise Behar, geochemistry, oil shale kinetics
- Alexandre Lapene, process modeling and simulation

QER

- John Parsons, ex situ oil shale technology
- Ian Henderson, ex situ oil shale technology
- David Cavanagh, ex situ oil shale technology

UMATAC

- Gordon Taciuk, ex situ oil shale processing technology
- Steven Odut, ex situ oil shale processing technology
- John Barge, ex situ oil shale processing technology
- Lucas Rojek, ex situ oil shale processing technology
- Daniel Melo, ex situ oil shale processing technology

Others

- Omar Al-Ayed, Al-Balqa Applied University, Faculty of Engineering, Amman Jordan, properties of Jordanian oil shale and shale oil
- Mohammed Bencherifa, Organization National des Hydrocarbures et des Mines (ONHYM), Rabat, Morocco, engineering and geology of Moroccan oil shale
- Jaan Habicht, University of Tartu, Estonia, Environmental effects of oil shale ash and spent shale

- Uuve Kirso, Tallinn Technical University, Tallinn, Estonia, Environmental effects of spent shale and oil shale ash
- Shuyuan Li, China University of Petroleum, Beijing, China, Properties of oil shale in China
- Zhaojun Liu, Jilin University, Changchun, China, Geology, stratigraphy, and resource evaluation of Chinese oil shale
- Tsevi Minster, Geological Survey of Israel, Jerusalem, Israel, Resource characterization for Israeli oil shale
- Väino Puura, University of Tartu, Resource assessment of oil shale
- Erik Puura, University of Tartu, ash leaching, contaminant transport and ash utilization
- Jialin Qian, China University of Petroleum, Beijing, China, Properties of oil shale in China
- Aya Schneider-Mor, Ben-Gurion University of the Negev, Beer Sheva, Israel, Geology and stratigraphy of Israeli oil shale
- Walid Sinno, San Leon Energy, London England, Development of Tarfaya oil shale
- Jyri Soone, University of Tartu, Tallinn, Estonia, Environmental effects of oil shale ash and spent shale
- Kati Tanavsuu-Milkeviciene, Statoil, stratigraphy and sedimentology of Green River Formation, Colorado
- Mahmoud Zizi, ZIZ Geoconsulting, Rabat Morocco, Geology and engineering for Moroccan oil shale

Research Funding Sources

Funding for oil shale research in the United States comes primarily from corporations actively pursuing oil shale development or by companies developing oil shale technology with the goal of selling technology/equipment to developers. These include Federal RD&D leaseholders (Shell, American Oil Shale/Total) and others holding land underlain by the Green River Formation (NSHI, ExxonMobil). U.S. Federal sources include the USDOE through its National Energy Technology Laboratory, as part of the Fossil Fuel program. However, such funding has been essentially zero for oil shale this year. Other companies may have provided smaller grants that are not widely publicized. Other private funding appears to support development at least of the Red Leaf Resources program. International funding comes from diverse sources, not all of them publicly acknowledged. It is clear that governments in Jordan and Morocco are actively supporting granting of concessions and dissemination of available data. Companies in Estonia (Enefit/Eesti Energia, Viru Keemia Grupp), Brazil (Petrobras), Canada/Germany (UMATAC/ThyssenKrupp) and China (CNPC, Fushun Mining Group and others) are supporting internal development and, in some cases, external development efforts.

Critical Technology Needs

Critical technology needs mainly concern the development of more energy efficient and environmentally friendly and less costly methods of extraction, production and upgrading of oil shale. Especially in the U. S., issues have been raised about the greenhouse gas emissions and water consumption of an oil shale industry.

The primary source of emissions for in situ production is power plant emissions of CO_2, and power plant water consumption is the largest use for a Shell-type in situ operation (Boak, 2008; 2012). So minimizing energy use for these processes is essential. ExxonMobil has suggested air-cooled power plants to reduce water use, but these may increase CO_2 emissions (Thomas, 2010) as well as CAPEX. Shell has been developing their Circulating Molten Salt (CMS) heater, which is expected to reduce fuel consumption—and therefore CO_2 emissions—by approximately 30-40% compared to operations powered by electrical heaters. AMSO has examined the potential for sequestration of CO_2 in exhausted in situ retorts (Burnham and Carroll, 2009). A presentation by Enefit at the 31st Oil Shale Symposium indicated that production from their Estonian retort system would result in a net carbon intensity of ~130 gCO_2/MJ of energy output (including burning of the fuel). This is ~30% higher than traditional crude oil. However, given a carbon offset for generating power in the Enefit unit rather than using a power plant, and for using ash as a cement clinker substitute, this could reduce CO_2 emissions to a level comparable to that of crude oil.

In the United States, understanding and mitigating the environmental effects of oil shale production across entire productive regions is clearly not the responsibility of individual leaseholders, but rather of the majority steward of the land, the Federal government. In the past, the USDOE managed an Oil Shale Task Force charged with defining and integrating baseline characterization and monitoring needs for environmental impacts within the basins of the Green River Formation. The Task Force included representatives of government and industry, including the environmental firms retained by major potential producers. Congress does not recognize this as a critical need, and therefore the need is not being addressed systematically. Similar issues may arise in other countries where multiple oil shale deposits are being developed, such as Jordan. Funding for the national effort to manage the environmental baseline and integrated database could be a significant issue, but can only be addressed by a Federal government interested in executing this duty.

Internationally, there is a lack of consistently structured resource assessments. As the energy security of the world stands to benefit from enabling otherwise resource poor developing countries to develop indigenous energy sources, it may be beneficial to support the development of resource assessment tools for countries that do not have the large database of Fischer Assay and other measurements available in the U. S. Developing criteria and methods for such assessments (e.g., Canadian National Instruments NI-43-101 Standards of Disclosure for Mineral Projects and NI-51-101 Standards of Disclosure for Oil and Gas Activities) would be a contribution to the global development of this resource, and would potentially create good will between the U. S., the European Union, and the developing countries with oil shale resources. Critical to such assessments will be careful estimation of the uncertainty regarding resource estimates where data are sparse.

Critical Environmental or Geohazard Issues and Mitigation Strategies

The critical environmental issues are how to extract, produce and upgrade shale oil in an environmentally friendly and economically sound way such that:

1) The use of energy to pyrolyze the kerogen is minimized
2) The greenhouse gas emissions are reduced or compensated for by carbon trading or CO_2 sequestration
3) The water used in construction, operation, power generation, and reclamation is minimized and does not deplete the water resources of arid regions
4) The extraction, production and upgrading of the shale oil does not unduly affect the quality of the air, the native biological communities, or surface and ground water of the region.
5) Any Subsidence caused by mining or in-situ retorting does not cause unacceptable disruption of natural surface features or human structures

Socioeconomic impacts are also issues of concern. It is important that projects are conducted in a manner that meets community expectations by keeping the public apprised of progress, being transparent, and being sensitive to changes in social dynamics

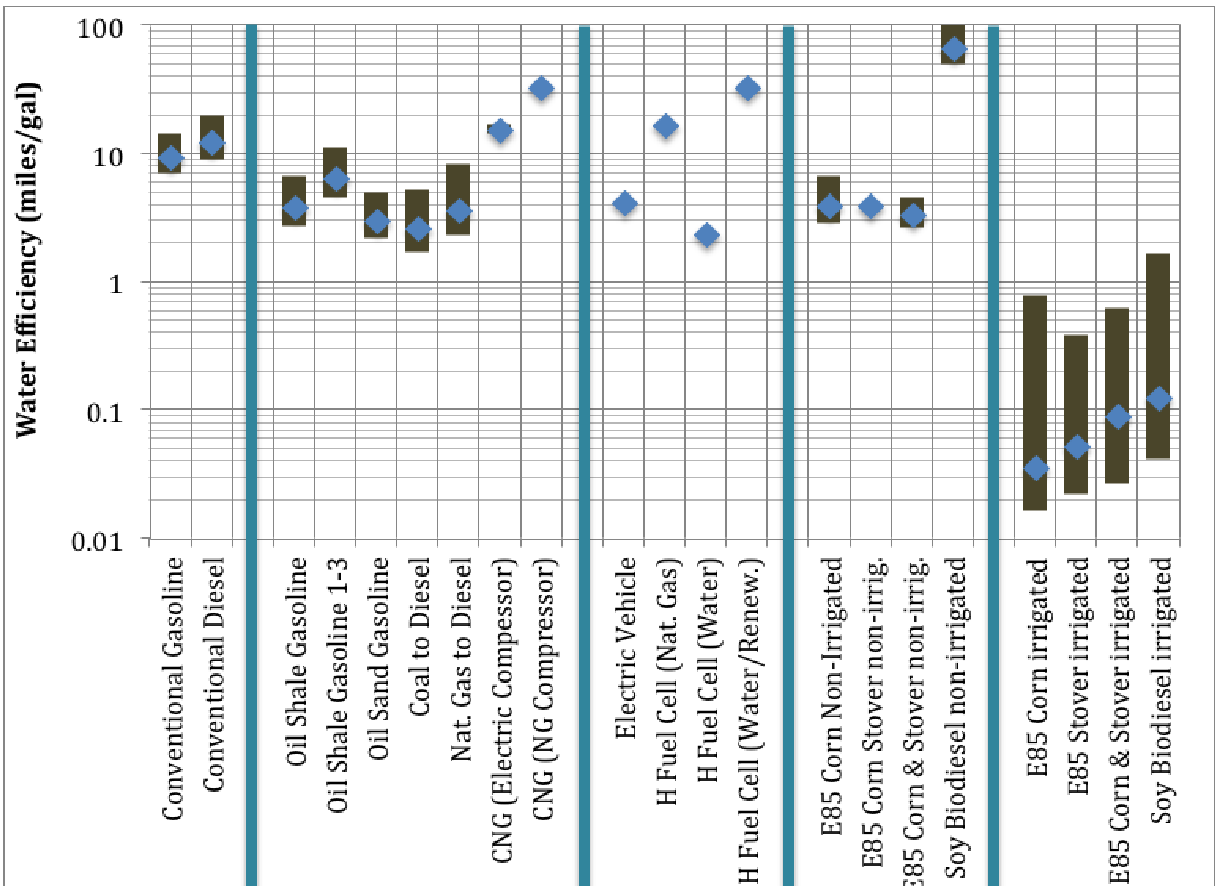
The recent offering of RD&D leases required that each of these concerns be addressed explicitly in the lease application. Numerous companies have highlighted the requirement for multiple rounds of interaction with regulatory bodies before production can begin. These interactions include at least two separate environmental impact assessment stages likely to focus on the same impacts, in addition to the numerous other permits that often require a public comment and review component and multiple agency coordination processes, which are often overlapping and may result in conflicting requirements from multiple agencies. It remains unclear whether this structure, with potential for heavy and potentially duplicative burdens of documentation will have a net protective effect on the environment.

Water use has been highlighted as an important environmental issue recently, with reports from the U.S. Government Accounting Office on water issues which heavily stressed a number of potential environmental impacts with little regard to whether these impacts were novel to oil shale development, or had been reasonably mitigated in the past. Many of the water numbers in the report were out of date, exaggerated, or from very limited studies intended to highlight pre-existing uncertainty in the water use estimates. The industry has had previously been claiming a water usage amount in the range of 1-3 barrels of water per barrel of oil to reasonably covers the technology likely to implemented for oil shale production, and that lower values may be achievable as industry progresses. The high end was for in-situ processes where aquifer remediation was required. More recently, with in-situ processing in the Piceance Basin planned only below the aquifers, this lower range is more appropriate. Water consumption, as reported in the 2013 Colorado symposium for Shell's ICP process in the zones excluding the nahcolitic interval, is approximately 0.3 bbls of water per bbl of oil production (Wani et al., Shell 2013).

The National Oil Shale Association has recently updated its estimate of water needs for an oil shale industry (Vawter, 2014). Based upon 2014 input from developers such as Shell and Enefit, NOSA now estimates water usage of 0.7 to 1.2 barrels of water per barrel of shale oil (Bw/Bo) (16,000 to 29,000 acre feet per year for 500,000 barrels per day of marketable shale oil production). This is down from an average of 1.7 Bw/Bo in a 2012 estimate. The major reductions came from more aggressive water conservation efforts and the elimination of water needed for ground water flushing after in situ retorting. Most developers now believe that a bulk of future in situ development will be carried out in areas where there is no mobile ground water, and thus ground water mitigation technology such as a freeze wall will not be necessary.

Technology	**Shale Oil B/D**	**Gross Bw/Bo**	**Net Bw/Bo**	**Net Acre-Ft/Yr**
In situ	225,000	0.6 – 1.3	0.3 – 1.0	3,180 - 10,600
Ex situ	200,000	2.4 – 2.6	1.4 – 1.6	13,200 – 15,100
Modified In situ	75,000	0.5 – 1.1	0.0 – 0.9	0 – 3,180
Total	*500,000*		*0.7 – 1.2*	*16,400 – 28,900*

While still maintaining that water use is not defined, opponents and even the BLM have yet to provide any indication of whether or why these estimates are not adequate. In the absence of a clear statement that three barrels per barrel is too high (and a technical rationale for that assertion), the vague claims of both Government and opponents that not enough is known have the distinct ring of political motivation. Figure 4 shows water consumption in miles per gallon for a variety of traditional, unconventional and alternative fuels. The bars indicate the range of estimated values, whereas the diamond represents the average value. An additional bar has been added to reflect up-to-date industry estimates for water consumption. From this it is clear that oil shale is comparable to most non-irrigated biofuel, and far lower in water consumption than irrigated biofuels. Consistency would seem to require equal Federal anxiety about biofuel production in Colorado and other states.



Source: King, C. W., and M. E. Webber, (2008) *Water Intensity of Transportation*, Environmental Science & Technology, vol. 42, no. 21, p. 7866-7872

Figure 4: Water efficiency (in miles per gallon) of various conventional, unconventional, and alternative fuels. Diamond is mean value and bar represents range of estimates. An additional bar has been added to represent current industry estimates to produce shale oil of 1-3 barrels of water per barrel of oil, which is on the high side of current expectations.

Relevant EMD Technical Sessions, Publications, Workshops

The primary conferences covering oil shale science and technology in 2014 were the Jordan International Oil Shale Symposium, April 14-15, 2014 in Movenpick, Jordan, and the 34th Oil Shale Symposium, October 13-15, 2014, at the Colorado School of Mines in Golden, CO. Detailed agendas were shown in the 2014 oil shale commodity report. The next US Oil Shale Symposium will be held in Salt Lake City, October 5-9, 2015,

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