EMD Oil Shale Report for the 2008 Annual meeting, Ron Johnson

Active oil shale areas: Estonia, Brazil, Jordan, Morocco, Israel, China, Australia, the Piceance Basin of western Colorado, the Uinta Basin of eastern Utah and western Colorado.

Current world production:

Shale oil is used for fuels in China, Brazil and Europe. Shale oil is used to make chemicals and coke in Europe and Russia, and cement is being made from spent shale in Europe, China, and Malaysia. Oil shale is used to generate power directly in Estonia, Israel, and Germany.

In 2007, China produced about 350,000 tons of shale oil most of which was used to generate power. In addition, 480,000 tons of oil shale is consumed directly to produce power using circulated fluidized bed combustion boilers with a generating capacity of 18 MW. The largest shale oil producer is the Fushun Mining Group that produced 300,000 tons of shale oil from 180 Fushun-type retorts. The Fushun operation is highly profitable because the oil shale overlies coal deposits that are being mined in a huge open pit mine, and the oil shale is a byproduct of that coal mining. Fushun is producing 300,000 tons/year of cement and 240 million bricks per year from spent shale. There are plans to process an additional 2 million tons of oil shale a year to produce 200,000 tons of shale oil, with the shale char used to generate power and the shale ash used as a building material.

Estonia accounts for about 70 percent of the world's oil shale production with about 14 million tons of oil shale mined each year. About 85 percent used directly for power generation accounting for 90 percent of Estonia's power needs. Recently, Estonia has developed fluidized bed technology for oil shale with efficiencies on the same level as has been reached for coal. The remainder of the oil shale is retorted to produce about 2.5 million barrels of oil each year. Estonia's above-ground retort designs are quite advanced with two types of retorts used, one for lump oil shale and another for fines. Due partly to pressure from the EU there is a concerted effort to find uses for the spent shale, and a state-of the-art cement plant is now operating. Since 1980, they have been using retorts with a capacity of 140 tons of shale per hour (the TSK retort) and are currently constructing a new larger retort, the TSK 280 retort designed to process 280 tons per hour.

In Brazil, Petrobras produces small amounts of shale oil using Petrosix retorts. The oil shale is from the Permian Irati Formation, surface mined near the town of Sáo Mateus do Sul in the State of Paraná, and retorted for oil, liquefied petroleum gas, sulfur, and fuel gas. Recently Petrobras invested in The Oil Shale Exploration Company (OSEC), which has oil shale leases in eastern Utah. OSEC plans to install a research-size Petrosix retort on their Utah property.

U.S. oil shale industry:

The United States is currently trying to restart an oil shale industry that has remained largely dormant for the past twenty five years. In 2004, DOE initiates study on what it would take to restart an oil shale industry in the U.S. Based on this study, the Energy Policy Act of 2005 contained specific language pertaining to restarting an oil shale industry. Specifically, the legislation set up 160 R&D lease tracts in each of the three oil shale basins that contain oil shale in the Eocene Green River Formation, the Piceance Basin of western Colorado, the Uinta Basin of eastern Utah and western Colorado, and the Greater Green River Basin of southwestern Wyoming and northwestern Colorado. These lease tracts could be expanded into much larger lease tracks for commercial development once viable extraction methods were demonstrated. The R&D leases were for ten years. Five lease tracks were awarded in the Piceance Basin, three to Shell, one to Chevron, and one to EGL Corp. All are for in-situ processes. One lease was awarded in the Uinta Basin for conventional mining and above ground retorting. No bids were received for the proposed tracts in Wyoming. All current projects are in the experimental stage, and thus are not currently producing significant quantities of oil.

The project in the Uinta Basin plans to us an underground mine combined with a surface retorts. The Oil Shale Exploration Company (OSEC) is developing the property with support from the Brazilian oil company Petrobras. They hope to get into production fairly rapidly by using proven technology instead of developing new. As a result, it is entirely likely that OSEC will be the first project in the United States to actually start commercial shale oil production. They will be experimenting with two different types of retorts; 1) the Alberta Taciuk Processor (ATP) retort similar to those that are presently being used for the Canadian tar sands deposits, and 2) the Petrosix retort used in Brazil. Detailed plans are currently being developed for mining and processing. There is an existing mine on the property, where the oil shale section occurs at a depth of about 1,000 ft, and this mine may be reopened and upgraded. Alternately, they may develop a new mine where the oil shale interval outcrops on the property. Power and water requirements are being estimated and possible sources for these critical resources are being investigated. Estimates of water requirements for above ground retorting generally run the range of 1-3 barrels of water per barrel of oil, which is used in the mining operation and on-site upgrading of the produced shale oil so that in can be piped to a refinery. At full production of about 50,000 barrels of shale oil per day, from 75,000 to 80,000 tons of oil shale will have to be mined each day. This fairly modest operation would require the largest underground mining operation in the world.

Three experimental projects are on-going in the Piceance Basin, and all use an in-situ process where the oil shale is heated to retort temperatures while still in the ground. Heating will be accomplished using electric heaters in vertical holes, but natural gas heaters may be used in the future. Shell is farthest along developing their in-situ retorts and has successfully tested their process in a very small pilot project. Shell plans to use a freeze wall to keep hydrocarbons in and groundwater out. They are currently developing a freeze wall that is about 1,500 ft high around a roughly square area 225 ft making it the largest freeze wall ever attempted. Freeze holes were drilled every eight feet and are very straight, deviating less than two feet throughout their entire length. Liquid ammonia has been pumped into the freeze holes for about a year thus far. According to Shell, they are close to producing a complete freeze wall. Once completed, they will conduct a series of tests to determine the robustness of the wall. Shell does not plan to heat and retort the oil shale within the present freeze wall. A

commercial freeze wall would have to encompass a much larger area, as a 100-300 ft buffer zone between the freeze wall and the heater holes is required. Spacing for electric heater holes has not been determined but will probably have to be in the range of 20-40 ft in order to heat the oil shale in a reasonable amount of time. Heating duration will be in the range of a few years. Shell has stated that they will not proceed to producing a large in-situ retort until their freeze wall technology is perfected.

Exxon-Mobil is also developing an in-situ method that will not use a freeze wall because it will be exploiting an interval of oil shale that is considered to be completely isolated from regional ground water. Exxon-Mobil plans to heat the oil shale using horizontal wells beneath the oil shale section. The wells will be fractured and material that conducts electricity will be injected into the fractures. Exxon-Mobil plans to try their experiment on an interval that contains large quantities of nahcolite, a sodium bicarbonate mineral. They plan to produce the oil first and the nahcolite second. Much of the nahcolite occurs in isolated aggregates, and it is hoped that fracturing produced during the conversion of kerogen to oil will assist in producing the nahcolite through solution mining once the oil has been extracted. Nahcolite breaks down to soda ash at temperatures well below retorting temperatures thus releasing large quantities of carbon dioxide. Exxon-Mobil plans to store the carbon dioxide and recombine it with the soda ash to once again produce nahcolite once the retorting is finished. Exxon-Mobil has conducted extensive laboratory experiments and extensive modeling of their in-situ designs but has not yet attempted a field test of their retort.

The following update on ExxonMobil's in-situ method was provided by Machael Allen on March 3, 2008.

"ExxonMobil is serious about pursuing oil shale technology and has at least two research concepts that require field testing, Electrofrac and Vaporfrac. Electrofrac is the leading technology candidate at this point... we recently were granted a patent for it. The method heats oil shale in situ by hydraulically fracturing the rock and filling the fracture with an electrically conductive material, forming a circuit through which electric current can flow thus creating a heating element. The hydrocarbons from the heated shale can then be brought up to the surface with vertical wells much like conventional oil and gas. The biggest advantage over other in situ wellbore heaters currently being tested in that Electrofrac should require only 1-2 heater wells per acre, an order of magnitude fewer.

The current field research involves small-scale test(s) of Electrofrac conductive fracture construction on land owned by ExxonMobil in Garfield County at the Colony site. The scope of this work does not include heating the oil shale to the point of hydrocarbon production. Staffing is temporary, housed in hotels; it does not include temporary living quarters. We have obtained the required technical revision to the Colony reclamation permit, and we have obtained permits for our work trailers on the site.

You heard Jesse's talk, and so are aware that we also have a patent pending on a process to develop the oil shale resource while preserving the mineral

value of the nahcolite resource and increasing its possible recovery. The process looks like this:

Heating converts nahcolite ($NaHCO_3$) to soda ash (Na_2CO_3).
The increased solubility of soda ash allows it to be solution-mined and converted back to nahcolite using a common industry process of CO_2 addition on the surface. Both minerals have commercial value.
Synergies exist for flushing the heated zone for groundwater protection and solution mining of the sodium minerals after shale oil production.

We are not testing that however at our Colony site, which was originally designed as an ex situ development and its shale is located close to the surface. We will use Colony outcrops for early testing of elements of Electrofrac, but it is not necessarily a good candidate for in situ research and development and we remain interested in securing leases better suited to that.

Going forward, we anticipate a careful, phased approach that allows for prudent technical, social and environmental planning and execution. None of the in situ technologies currently under study has yet demonstrated commercial viability. A long-term commitment to field research will be required to develop one that is, so it is important (we believe) to continue to encourage a broad range of technologies and many different companies to find the best commercial solutions."

EGL , a privately held company is conducting the third experimental in-situ project in the Piceance Basin. They also plan to use horizontal heater wells beneath the oil shale interval, but will conduct their experiment on the illitic oil shales that occur beneath the carbonate-rich oil shales that are the focus of the other two experiments in the Piceance Basin. These oil shales do not contain nahcolite, are highly impermeable, and thus a freeze wall is not planned. EGL also has done extensive modeling but has not yet attempted a field experiment.