Technical and environmental aspects of oil shale assessment for western U.S. deposits

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Shale oil resource-in-place assessment

The “oil-in-place” estimates of the latest USGS Western Oil Shale Assessment Team provide an excellent resource on Green River Formation oil shale deposits.

Using Fischer Assay data from hundreds of thousands of analyses, total in-place resources have been estimated and GIS tools are being developed to make using this data simpler (e.g., the Oil Shale Calculator).
Major Green River Formation Deposits

Piceance Basin: 1,335 mi² (3,458 km²).  
**In place resource:** 1.52 trillion barrels

Uinta Basin: 3,834 mi² (9,930 km²).  
**In-place resource:** 1.32 trillion barrels

Greater Green River Basin: 5,500 mi² (14,244 km²).  
**In-place resource:** 1.44 trillion barrels

Johnson et al., 30th OSS, 2010.
“Has oil shale become a technically and economically viable alternative to conventional oil?”

J. Bartis, 26th Oil Shale Symposium, October 2006

“The prospects for oil shale development in the United States remain uncertain.”

# Environmental Impacts of an Oil Shale Industry

<table>
<thead>
<tr>
<th>Land Use</th>
<th>• Significant land use and ecological impacts (more so from surface retorting than in-situ conversion)</th>
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<tbody>
<tr>
<td>Air Quality</td>
<td>• Early plants could prevent future industry growth</td>
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<td>• Studies from the 1980s are no longer relevant</td>
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<td>Climate Change</td>
<td>• Significantly higher CO2 emissions than with conventional oil operations</td>
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<td>• Controlling emissions will lead to higher costs</td>
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<td>Water Quality</td>
<td>• Salts and toxics may leach from spent shale into the Colorado River drainage basin</td>
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<td>Water Consumption</td>
<td>• 3 barrels of water needed for each barrel of shale oil</td>
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<td>• Competes with other demands for water from the greater Colorado River Basin</td>
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*J. Bartis, 26th Oil Shale Symposium, October 2006*
Database GIS products developed during the resource-in-place assessment provides a basis for the next stage – estimating the recoverable resource.

But the recoverable resource is tricky to define:

- What will be the grade cut-off for different processes?
- Include liquid hydrocarbons and gas?
- How will recovery vary with different utilization approaches?
- Is the unrecovered resource lost?

**Recoverable resource estimate range (2006):**
500-1100 billion barrels of 1500-1800 billion barrels in place (RAND)
A wide range of technologies are available for oil shale utilization. Generation of liquid hydrocarbons (and gas) by \textit{retorting} is the most common approach discussed for western US oil shale utilization.

- What resources are amenable to mining & surface retorting?
- How will \textit{in situ} approaches be applied to different deposits?
- How do environmental impacts differ when different approaches are applied to a specific location?

Retorting conditions will determine the \textit{yield and quality} of products generated from oil shale.
Technically recoverable resources

Define resources:
Retort-generated hydrocarbon liquids and gas

Methods for estimating **Recovery Factors** are needed for oil and gas products, with compositional estimates based on laboratory and pilot scale tests.

This is needed for representative technologies that are expected to be implemented.

These estimates could change as new technologies are developed.
Minable Resources – *Surface retorting*

**How does it work?**
- Mine, crush and heat oil shale – rock residence times ~1 h
- Rapid heating to >500°C to convert kerogen to oil & gas

**Advantages**
- High yields
- Proven technology

**Concerns**
- Disposal of spent shale
- Product requires significant upgrading

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Alberta-Taciuk Process (horizontal rotary kiln)

(Fact Sheet: Oil Shale Conversion Technology, DOE Office of Petroleum Reserves – Strategic Unconventional Fuels)
Applicability of different retort methods

Much of the oil shale in the Green River Formation cannot be economically accessed by surface or underground mining and is more amenable to in situ approaches

In situ Methods:

Vadose zones – unsaturated deposits either deep enough to make mining impractical or utilized by in situ approaches because of advantages related to product quality, surface disturbance, etc.

Groundwater zones – will require site isolation to prevent GW contamination (freeze wall, grouting, etc.)

Sub-aquaclude zones – deep enough that GW issues are less relevant
In-situ retorting

How does it work?
- Isolate and dewater retort
- Insert heater and production wells
- Gradually heat deposit to convert kerogen to oil & gas

Advantages
- Minimal surface disturbance
- Access deep resources
- Higher quality oil product

Concerns
- Pyrolysis residues
- Impacts on groundwater

Shell’s In-situ Conversion Process
(Vinegar, H. 26th Oil Shale Symposium, 2006)
In-situ retorting

ExxonMobil Electrofrac Process
(Meurer et al., 28th Oil Shale Symposium, 2008)
In-situ retorting

AMSO In-situ Conversion Process
(AMSO website)
Applicability of different retort methods

Need to determine what, if any, limitations there are for applying particular *in situ* methods to the various resources in the GRF
Product characterization

**Oil composition**

Will vary depending on the particular retorting technology applied

**Gas composition**

**Residue composition**

**Oil and gas processing**

**Spent shale disposal or reclamation**

Is the same true for these development issues?
Oil Composition (Mahogany zone oil shale)

**Fischer Assay, 500°C, 1 h; API = 23.0°**

- Volatiles (<C15): 9.5
- Saturates: 35.3
- Aromatics: 22.2
- Resins: 29.1
- Asphaltenes: 3.9

**Elemental Ratios**
- H/C = 1.61, N/C = 0.023, O/C = 0.014

**In-situ Simulator, 360°C, 120 h; API = 50.0°**

- Volatiles (<C15): 60.7
- Saturates: 25.4
- Aromatics: 6.6
- Resins: 5.9
- Asphaltenes: 1.4

**Elemental Ratios**
- H/C = 1.85, N/C = 0.013, O/C = 0.006

Yield = 65 wt.% of Fischer Assay
Mitigation or prevention of environmental impacts

Water Use

CO$_2$ release

Surface impacts

Groundwater protection

Spent shale disposal or reclamation

Do we have a better understanding of these issues now than we did in 2006?
Other issues

Energy Return on Investment

Co-existing Mineral Resources
Nahcolite
Dawsonite

Reclamation

Long-term Monitoring
Your input

We are currently developing our approach for this Task.

Input from industry, academia and other government agencies would be greatly appreciated.

Thanks for your attention.