EIA/ARI World Shale Gas and Shale Oil Resource Assessment

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Unconventional Resources • Enhanced Recovery • Carbon Sequestration
The EIA/ARI “World Shale Gas and Shale Oil Resource Assessment” report represents a major new shale resource assessment:

- 41 distinct countries (42 with U.S.).
- 95 shale basins with 137 shale gas and shale oil formations.
- ~700 page report with 26 Chapters.
- ~200 original maps; prospective areas, reservoir properties, resource quality.
World Shale Gas and Shale Oil Resources

- **Shale Gas.** U.S., China, Argentina, Algeria, Canada and Mexico account for nearly two-thirds of the assessed, technically recoverable shale gas resource.

- **Shale Oil.** Russia, U.S., China, Argentina and Libya account for nearly two-thirds of the assessed, technically recoverable shale oil resource.
Our Resource Assessment Methodology

Our shale gas and shale oil resource assessment methodology consisted of four main steps:

1. Conduct geologic and reservoir characterization of major shale basins and formation(s):
   - Minimum TOC (>2%)
   - Prospective Depth Range (1,000 m to 5,000 m)
   - Thermal Maturity “Windows”
   - Shale Mineralogy
   - Other (Overpressure, Geologic Complexity, Volumetric Data)

2. Define prospective area and risk factors for each shale formation.

3. Estimate risked shale gas and shale oil resource in-place.

4. Calculate risked, technically recoverable shale gas and shale oil resource (TRR).
Using Thermal Maturity To Delineate Areas Prospective For Shale Gas and Shale Oil.

- Oil prospective area has vitrinite reflectance (Ro) of 0.7% to 1%.
- Wet gas/condensate prospective area has Ro of 1.0% to 1.3%.
- Dry gas prospective area has Ro greater than 1.3%.
- Higher thermal maturity settings also create nanopores which contribute to additional porosity in the shale matrix.
Importance of Mineralogy on Recoverable Resources

The mineralogy of the shale, particularly its relative quartz, carbonate and clay contents, governs the efficiency of the hydraulic fracture.

- High clastic content shales are brittle and shatter, providing multiple fractures.
- High clay content shales are plastic and absorb energy, providing planar fractures.
- Recovery factors of 15% to 30% for shale gas and 3% to 7% for shale oil (resource in-place) were assigned based on mineralogy (as well as pressure, TOC and geologic complexity).

Source: CSUG, 2008
Shale Gas Resources of Neuquen Basin, Argentina

One example of 137 shale formations assessed worldwide.

Prospective area of Vaca Muerta Fm: estimated 308 Tcf of dry, wet, associated shale gas resources (TRR).
## Selected Comparison and Discussion of Differences

The chart on the left compares the risked, technically recoverable shale gas resource for 16 major countries: 2011 Report vs. 2013 Report.

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>April 2011 Report</th>
<th>June 2013 Report</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. North America</td>
<td>Canada</td>
<td>388</td>
<td>573</td>
<td>7 basins vs. 12 basins.</td>
</tr>
<tr>
<td></td>
<td>Mexico</td>
<td>681</td>
<td>545</td>
<td>Better data on areal extent.</td>
</tr>
<tr>
<td>2. South America</td>
<td>Argentina</td>
<td>774</td>
<td>802</td>
<td>Improved dry and wet gas areal definitions.</td>
</tr>
<tr>
<td></td>
<td>Brazil</td>
<td>226</td>
<td>245</td>
<td>New dedicated chapter.</td>
</tr>
<tr>
<td></td>
<td>Venezuela</td>
<td>11</td>
<td>167</td>
<td>Included associated gas; better data.</td>
</tr>
<tr>
<td>3. Europe</td>
<td>Poland</td>
<td>187</td>
<td>148</td>
<td>Higher TOC criterion, better data on Ro.</td>
</tr>
<tr>
<td></td>
<td>France</td>
<td>180</td>
<td>137</td>
<td>Better data on SE Basin in France.</td>
</tr>
<tr>
<td></td>
<td>Norway</td>
<td>83</td>
<td>0</td>
<td>Eliminated speculative area for Alum Shale.</td>
</tr>
<tr>
<td></td>
<td>Ukraine</td>
<td>42</td>
<td>128</td>
<td>Added major basin in Ukraine.</td>
</tr>
<tr>
<td></td>
<td>Russia</td>
<td>-</td>
<td>285</td>
<td>New dedicated chapter.</td>
</tr>
<tr>
<td>4. Africa</td>
<td>Algeria</td>
<td>230</td>
<td>707</td>
<td>1 basin vs. 7 basins.</td>
</tr>
<tr>
<td></td>
<td>Libya</td>
<td>290</td>
<td>122</td>
<td>Higher TOC criterion; moved area to oil.</td>
</tr>
<tr>
<td></td>
<td>South Africa</td>
<td>485</td>
<td>390</td>
<td>Reduced area due to igneous intrusions.</td>
</tr>
<tr>
<td></td>
<td>Egypt</td>
<td>-</td>
<td>100</td>
<td>New dedicated chapter.</td>
</tr>
<tr>
<td>5. Asia</td>
<td>China</td>
<td>1,225</td>
<td>1,115</td>
<td>Better data; higher TOC criterion.</td>
</tr>
<tr>
<td></td>
<td>India/Pakistan</td>
<td>114</td>
<td>201</td>
<td>Expanded assessment for Pakistan.</td>
</tr>
</tbody>
</table>
International Shale Gas and Shale Oil Revolution

In addition to the U.S., six areas of the world have large, attractive shale gas and shale oil resources:

<table>
<thead>
<tr>
<th>Active Shale Development</th>
<th>Active Shale Exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Canada</td>
<td>• China</td>
</tr>
<tr>
<td>• Argentina</td>
<td>• Algeria</td>
</tr>
<tr>
<td></td>
<td>• Mexico</td>
</tr>
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<td></td>
<td>• Australia</td>
</tr>
</tbody>
</table>
Shale Gas (BC): Devonian marine shales in Horn River, Cordova and Liard basins.

- Favorable geology, high resource concentrations, commercial production (~1 Bcfd)
- Environmental and market challenges
- Apache, EnCana and EOG using long Hz wells, pad drilling

Shale Gas and Shale Oil (Alberta/Sask.)
Devonian through Jurassic marine shales.

- Massive areas, moderate resource concentrations
- Major activity in Canadian Bakken Shale; just starting in Duvernay Shale

Shale Gas Eastern Canada: Ordovician Utica and Mississippian Horton Bluff shales; development on-hold.

Risked TRR: 573 Tcf and 8.8 Billion barrels
**ARGENTINA**

**Risked TRR:** 802 Tcf and 27.0 Billion barrels

**Shale Gas:** Jurassic-Cretaceous marine shales in Neuquen Basin.
- Geologically perhaps best shale basin outside N. America
- L. Cretaceous non-marine shales in Golfo San Jorge and Austral basins

**Shale Oil:** High quality, shallower rocks in less thermally mature areas.

**Activity:** >50 shale gas/oil wells, mostly vertical.
- YPF operating 37 shale wells; Vaca Muerta vertical wells w/5 fracs, IP 180 to 600 bbl/d
- Apache Los Molles 2100’ Hz well w/9-stage frac, IP 4.5 MMcfd
- Chevron and CNOC with $1+ Billion programs
- EOG, Exxon and others also active
CHINA

Risked TRR: 1115 Tcf and 32.2 Billion barrels

Shale Gas: Paleozoic marine source rocks in Sichuan Basin and southern China.
- Current focus of shale exploration.
- Good rock quality; structurally complex, drilling problems, high stress
- Goal of 6 to 10 Bcfd by 2020.

Shale Oil: Mesozoic lacustrine source rocks in Junggar, Tarim, and Songliao basins.
- Some early shale exploration
- Also structurally complex and faulted
- Will clay-rich non-marine shales efficiently fracture?

Activity: >100 exploration wells, vertical and horizontal.
- PetroChina, Sinopec, Chinese startups
- Shell, ConocoPhillips, Chevron, others
- Promising but still low gas rates, high costs
ALGERIA

Risked TRR: 707 Tcf and 5.7 Billion barrels

Shale Gas and Shale Oil: Silurian Tannezuft and Devonian Frasnian marine “hot shales”.

- Seven major basins (Ghadames, Illizi, Timimoun, Ahnet, Mouydir, Reggane, Tindouf)
- Complex, thrusted geology; remote basin settings
- High TOC, overpressured, medium clay

Activity: Comprehensive shale gas and shale oil basin characterization by Sonatrach.

- Private exploration studies by Statoil and Repsol
- Plans by Sonatrach for pilot wells to test shale productivity in target basins
- Proposed hydrocarbon leasing round in 2013
MEXICO

Risked TRR: 545 Tcf and 13.1 Billion barrels

Shale Gas: High quality Eagle Ford and Tithonian (Haynesville) marine shales in Burgos Basin.
- Sabinas Basin faulted; Tuxpan, Tampico, Veracruz less so
- Goal of ~2 Bcf/d by 2025

Shale Oil: Same high quality rocks in thermally less mature areas.

Activity: Pemex drilled 6 Eagle Ford shale wells with modest results.
- Expect commercial production by 2015
- High well costs but modest production: IP 3 MMcfd (steep decline)
AUSTRALIA

Risked TRR: 437 Tcf and 17.5 Billion barrels

Shale Gas and Shale Oil: Precambrian-Cretaceous marine and lacustrine shales.

- Six major basins (Cooper, Maryborough, Perth, Canning, Georgina and Beetaloo)
- Canning Basin’s Ordovician marine shales most prominent
- Beetaloo and Georgina shale basins remote, leased but lightly explored

Activity: Demonstrated shale gas production in Cooper Basin by Santos and Beach Energy.

- Recent Carynginia Shale well in Perth Basin
- Brue Energy/Mitsubishi and NSE/Conoco-Phillips JVs in Canning Basin
- Petro Frontier/Statoil JV in Georgina Basin
- Falcon/Hess JV in Beetaloo Basin
Concluding Thoughts and Next Steps

The June 2013 “World Shale Gas and Shale Oil Resource Assessment” is the second step on a pathway toward a more rigorous understanding of the location and quality of the shale resource - - “It all starts with the rocks.”

- Understanding finding, development and other costs.
- Defining policy/regulatory and environmental barriers.
- Identifying opportunities for transferring North America shale E&P technology to other countries.
- Assessing remaining major regions and countries (Middle East, Central Africa, Kazakhstan, etc.)