Shale Reservoirs: Giant Resources for the 21st Century

John A. Breyer
School of Geology, Energy, and the Environment
Texas Christian University

US Energy Supply 2009

Natural Gas Consumption
US Annual 22 TCF

- 7 TCF Electricity
- 6 TCF Industrial
- 5 TCF Residential
- 3 TCF Commercial
- 1 TCF Other

source: www.eia.doe.gov
US Electricity Generation 2009

US Annual 22 TCF
- 7 TCF Electricity
- 6 TCF Industrial
- 5 TCF Residential
- 3 TCF Commercial
- 1 TCF Other

Natural Gas Consumption
- 23.4% Natural Gas
- 6.9% Hydroelectric
- 4.9% Coal
- 3.6% Other Renewables
- 1.0% Petroleum
- 20.3% Nuclear

source: www.eia.doe.gov

US CO₂ Emissions by Sector 2007

Electricity Generation from Coal 34%
- 7% Other Electricity Generation
- 4% Commercial
- 7% Residential
- 15% Industrial
- 33% Transportation

Natural Gas Consumption
- 22 TCF
- 7 TCF Electricity
- 6 TCF Industrial
- 5 TCF Residential
- 3 TCF Commercial
- 1 TCF Other

source: www.eia.doe.gov
Shale Resource Systems

“No generalization is worth a damn, …”

<table>
<thead>
<tr>
<th>Factor</th>
<th>Unit</th>
<th>Eagle Ford</th>
<th>Barnett</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geologic Age</td>
<td>Cretaceous</td>
<td>Mississippian</td>
<td></td>
</tr>
<tr>
<td>Basin</td>
<td>Gulf Coast</td>
<td>Fort Worth</td>
<td></td>
</tr>
<tr>
<td>Basin Type</td>
<td>passive margin</td>
<td>foreland basin</td>
<td></td>
</tr>
<tr>
<td>Origin of Hydrocarbons</td>
<td>thermogenic</td>
<td>thermogenic</td>
<td></td>
</tr>
<tr>
<td>Heat Source</td>
<td>geothermal gradient</td>
<td>geothermal gradient</td>
<td></td>
</tr>
<tr>
<td>%Ro Contours</td>
<td>mirror basin outline</td>
<td>don’t mirror basin outline</td>
<td></td>
</tr>
<tr>
<td>Economic Production</td>
<td>gas and liquids</td>
<td>gas</td>
<td></td>
</tr>
<tr>
<td>Targeted Facies</td>
<td>calcareous</td>
<td>siliceous</td>
<td></td>
</tr>
<tr>
<td>Depositional Setting</td>
<td>restricted shelf</td>
<td>mainly basinal</td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>6000-15,000</td>
<td>6000-8000 ft</td>
<td></td>
</tr>
<tr>
<td>CWC</td>
<td>$6-10 M</td>
<td>$2.5 M</td>
<td></td>
</tr>
</tbody>
</table>
A Conventional Petroleum System

source rock
reservoir
seal
trap

Shale Reservoirs

In these unconventional resources, the shale is the source rock, reservoir and seal. Traps are not necessary!

The source rock is the reservoir!
The problem is getting the gas out of nanometer-scale pore-systems.

$\mu m = 0.001 \text{ mm or } 10^{-6} \text{ meters}$  $1 \text{ nanometer} = 10^{-9} \text{ meters}$

A human hair is $\approx 100,000 \text{ nm or } \approx 100 \mu m$ in diameter
Shale with initial 6.41 wt% TOC

Original TOC (6.41 wt%)
- C_O (2.32 wt%)
- C_N (4.99 wt%)

C_O = 1.39
C_N = 3.93

0.97 bbl/acre-ft
(Expelled oil)

0.42 mcf/acre-ft
(Expelled gas)

0.38 mcf/acre-ft
(Original gas)

256 bbl/acre-ft
(Conventional resources)

821 mcf/acre-ft
(Unconventional resources)

Fracture Stimulation
Productive Barnett Shale

Ellenberger
(Water Bearing Formation)

Viola
(Frac Barrier)
How much of the gas can be recovered?

A patchwork airport
How do you get your money’s worth after paying $180 million just for the right to drill at Dallas/Fort Worth Airport? You drill it all. Chesapeake Energy’s development plan for D/FW stitches more than 300 wells from dozens of drilling sites to reach just about every foot of its 18,000-plus acres. Thanks to instruments that guide and track the drill bit’s path, the company expects to reproduce this precision “quilted” pattern in real life.
Hydraulic fracturing requires energy, water and proppant.
How Much Gas is There?

500 TCF EUR at 30-40% RE
≈25 year supply at current consumption!
2030 forecast: Gas to surpass coal for energy

Exxon Mobil also expects oil demand to rise. (Photo: Jim Hildebrand/StarTelegram)

By Jack S. Smith
jsmith@star-telegram.com

Exxon Mobil Corp. forecast Thursday that by 2030, natural gas will surpass coal as an energy source, with demand rising to 400 million barrels a day, and gasoline consumption will decline despite 400 million more cars on the world's roads.

Rex Tillerson, CEO of the Irving-based oil giant, forecast that “newly unlocked supplies of shale gas and other unconventional energy resources” will prove “vital” in meeting a projected 1.5 percent rise in overall energy demand.

Exxon Mobil, in its new edition of “Outlook for Energy: A View to 2030,” forecasts an expansion of natural gas supply, particularly in the U.S., where gas produced from shale, tight sandstone and coal-bed methane is expected to meet more than 16 percent of gas demand by 2030.

The outlook sees natural gas becoming the second-largest global energy source, behind oil, as electricity demand skyrockets more than 90 percent and natural gas is increasingly burned to generate electricity because it pollutes the air less than coal.

“Demand for natural gas for power generation is expected to rise by about 80 percent from 2005 to 2030, with natural gas providing more than a quarter of the world’s electricity needs,” Tillerson said.

The company said expanding global prosperity and booming world population will jack up energy demand, despite efficiency gains that could curb energy demand growth through 2030 by about 6 percent.

The outlook for rising demand “reflects improving living standards for people around the world,” Tillerson said in a statement. Demand is expected to jump 75 percent in China, the world’s most populous nation, where million.

More on FORECAST.