Water Resource Stewardship in Oil & Gas

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Outline

• Background – the impact of hydraulic stimulation

• Water usage and comparisons in perspective

• Complementary and competing technologies to fracturing

• Key takeaways
Section 1

BACKGROUND: THE IMPACT OF HYDRAULIC STIMULATION
We have seen a 40% increase in domestic oil production since 2008, the highest growth in oil output of any country in the world over that time period.

With thousands of new wells drilled, the EIA projects that natural gas supply could exceed demand by 2016, enabling the US to liquefy and export natural gas abroad.
Domestic Production Has Decreased Imports

**Total energy production & consumption 1970 – 2025 (quadrillion Btu)**

- Net oil imports have plummeted from more than a 60% share of domestic consumption in 2005 to less than 40% in 2013, the lowest dependence on foreign sources of oil in more than 20 years.

- The EIA estimates that the US has enough gas to last more than 100 years.

**Total energy production & consumption 1980 – 2040 (quadrillion Btu)**

Source: AEO 2003

Source: AEO 2014
## Economic Impact of the US Oil & Gas Revolution

<table>
<thead>
<tr>
<th>Category</th>
<th>2012</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jobs</td>
<td>2.1 million</td>
<td>3.3 million</td>
</tr>
<tr>
<td>Tax Revenue</td>
<td>$75B</td>
<td>$125B</td>
</tr>
<tr>
<td>GDP</td>
<td>$283B</td>
<td>$468B</td>
</tr>
<tr>
<td>Disposable Income</td>
<td>$1,200</td>
<td>$2,700</td>
</tr>
<tr>
<td>Capex</td>
<td>$121B</td>
<td>$189B</td>
</tr>
</tbody>
</table>

Source: IHS America’s New Energy Future: The Unconventional Oil & Gas Revolution and the US Economy, Volume 3

- Not just oil and gas: associated industries such as petrochemical and manufacturing have been booming
- As natural gas has replaced coal in electricity generation, US CO₂ emissions declined to their lowest levels in 20 years, the largest reduction of all countries
One Key Technology Underpins the Revolution: Hydraulic Fracturing

*Mixture of water, proppant and other additives pumped in at high pressure to create fractures*
Fluids for Fracture Stimulation

Water & Sand: ~98% (irrigation, mortar)

<table>
<thead>
<tr>
<th>General Ingredients</th>
<th>Other 2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>Cleaning fluid</td>
</tr>
<tr>
<td>Anti-bacterial Agent</td>
<td>Disinfectant</td>
</tr>
<tr>
<td>Breaker</td>
<td>Hair color</td>
</tr>
<tr>
<td>Clay Stabilizer</td>
<td>Low-sodium salt sub, KCl</td>
</tr>
<tr>
<td>Corrosion Inhibitor</td>
<td>Pharmaceuticals</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Soap</td>
</tr>
<tr>
<td>Friction Reducer</td>
<td>Make-up, nail &amp; skin products</td>
</tr>
<tr>
<td>Gelling Agent</td>
<td>Ice cream</td>
</tr>
<tr>
<td>Iron Control</td>
<td>Lemon juice</td>
</tr>
<tr>
<td>pH Adjusting Agent</td>
<td>Detergent</td>
</tr>
<tr>
<td>Scale Inhibitor</td>
<td>Household cleaners</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Glass cleaner</td>
</tr>
</tbody>
</table>

Source: Chesapeake Energy – Hydraulic Fracturing Fluid Makeup
Section 2

IN PERSPECTIVE: WATER CONSUMPTION AND COMPARISONS
Percentage of US Water Consumption by Type

- Thermoelectric Power: 41%
- Irrigation: 37%
- Public Supply: 12%
- Industrial: 5%
- Aquaculture: 2%
- Domestic: 1%
- Livestock: 1%
- Mining, Oil & Gas: 1%

Water Intensity of Transportation

Source: Carey King and Michael Webber, Environmental Science and Technology, 2008
Water for Fracturing Usage is Small vs. Other Uses

In 2011, Texans consumed 18x more water keeping their grass green than the industry used in frac jobs.

Landscape irrigation consumes 9 trillion gallons of water per year, 20x the EPA’s highest estimate for the amount of water used per year in fracturing.

In 2011, Texas used 26.6 billion gallons of water for fracturing, less water than used by 3 of the state’s 18 coal-fired power plants.

Source: CERES, Texas Water Development Board, Bureau of Economic Geology, UT Austin
How Much Water is 5 Million Gallons?
(Assume 5 million gallons water per average frac job)

Water a golf course for 23 days

Supply New York City for 6.5 minutes

Irrigate 7.8 acres of corn per season

Source: Our Water Counts
20 Months of US Frac Water Use = the Amount of Water that Flows Over Niagara Falls in One Day

Total Water Volume Used for US Fracturing (Jan 2011 -August 2012) in "Niagara Falls Tourist Hours" Flow

<table>
<thead>
<tr>
<th>Rank</th>
<th>State</th>
<th>Fracs Reported</th>
<th>Average (gal)</th>
<th>Total Used</th>
<th>% of Total Water Used</th>
<th>Hours of Niagara Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Texas</td>
<td>11,922</td>
<td>2,573,701</td>
<td>30,683,667,301</td>
<td>47%</td>
<td>11.39</td>
</tr>
<tr>
<td>2</td>
<td>Colorado</td>
<td>4,205</td>
<td>1,242,158</td>
<td>5,223,274,238</td>
<td>8%</td>
<td>1.94</td>
</tr>
<tr>
<td>3</td>
<td>Pennsylvania</td>
<td>1,884</td>
<td>4,328,886</td>
<td>8,155,620,871</td>
<td>12%</td>
<td>3.03</td>
</tr>
<tr>
<td>4</td>
<td>North Dakota</td>
<td>1,353</td>
<td>2,010,931</td>
<td>2,720,789,835</td>
<td>4%</td>
<td>1.01</td>
</tr>
<tr>
<td>5</td>
<td>Arkansas</td>
<td>1,305</td>
<td>5,223,972</td>
<td>6,817,283,249</td>
<td>10%</td>
<td>2.53</td>
</tr>
<tr>
<td>6</td>
<td>Wyoming</td>
<td>1,131</td>
<td>761,048</td>
<td>860,745,353</td>
<td>1%</td>
<td>0.32</td>
</tr>
<tr>
<td>7</td>
<td>Oklahoma</td>
<td>1,113</td>
<td>3,756,270</td>
<td>4,180,728,158</td>
<td>6%</td>
<td>1.55</td>
</tr>
<tr>
<td>8</td>
<td>Louisiana</td>
<td>930</td>
<td>5,341,088</td>
<td>4,967,211,610</td>
<td>8%</td>
<td>1.84</td>
</tr>
<tr>
<td>9</td>
<td>New Mexico</td>
<td>789</td>
<td>663,868</td>
<td>523,791,968</td>
<td>0.8%</td>
<td>0.19</td>
</tr>
<tr>
<td>10</td>
<td>Utah</td>
<td>783</td>
<td>352,288</td>
<td>275,841,828</td>
<td>0.4%</td>
<td>0.10</td>
</tr>
<tr>
<td>11</td>
<td>California</td>
<td>314</td>
<td>167,507</td>
<td>52,597,101</td>
<td>0.1%</td>
<td>0.02</td>
</tr>
<tr>
<td>12</td>
<td>West Virginia</td>
<td>178</td>
<td>4,720,082</td>
<td>840,174,633</td>
<td>1.3%</td>
<td>0.31</td>
</tr>
<tr>
<td>N/A</td>
<td>All Other States</td>
<td>432</td>
<td>1,383,994</td>
<td>597,885,252</td>
<td>0.9%</td>
<td>0.22</td>
</tr>
</tbody>
</table>

* by # of fracs

Total US Usage: 26,339

Source: FracFocus.org, EcoWatch
Water Resource Stewardship: The Right Thing To Do

- Fracturing accounts for less than 1% of water use – nationwide as well in the state of Texas
- In local areas the water use number can be higher from basin to basin. In the Permian Basin, for instance, that figure has reached double digits
- In other shale basins there are also situations of water distress, or legal mandates requiring water conservation efforts
- Reducing water usage can present a net savings opportunity for the operator, truly a win-win situation

Source: Texas Railroad Commission, US Drought Monitor
For every gallon of water used to produce natural gas through hydraulic fracturing

Texas saved 33 gallons of water by generating electricity with that natural gas instead of coal (in 2011)

Source: Jackson School of Geosciences, University of Texas at Austin
Section 3

COMPLEMENTARY AND COMPETING TECHNOLOGIES TO FRACTURING
Fracturing: Water Conservation Solutions

- Water Management
- Fluid-free Fracturing
- Brackish Water Fracturing
- Alternative Fluids Fracturing
- Hydrocarbon-based Fracturing
Closed Loop Water Management: A Holistic Approach

Source: Save the Water.org
Hydrocarbon-Based Fracturing

- **A sound technical concept** – pump hydrocarbon into a rock saturated with hydrocarbon, less damaging to productivity.
- **Pressure transmission not as effective as that of water** - an incompressible fluid (ideal for pressure transmission).
- **No flowback waste** – any unrecovered fluid pumped in eventually gets produced back and can be sold.
- **Fraught with operational hazards** (pumping volatile fluids under high pressure).
- **US EPA moratorium on diesel-based frac systems**.
- **Alternative fluid systems sidestep the government ban**, but adoption rate has remained low.

*Source: Wikipedia, Gasfrac, Wisegeek, CBS*
Alternative Fracturing Fluids

• Non-flammable gas
  – Similar in concept to LPG-based frac fluids
  – Operational challenges & cost hurdles

• CO2-based energized foam
  – CO2 availability and cost a major hurdle
  – Operational issues (pressure transmission, friction pressure)

• N2-based energized foam
  – N2 availability and cost a major hurdle
  – Operational issues (pressure transmission, friction pressure)
Fluid-Free Fracturing

- Still on the drawing board for the most part
- Cost, practical applicability, and widespread availability still unknown, but could potentially address specific situations
- Some examples:
  - Metal oxides combined with pumice “dry frac” systems
  - Targeted acoustic energy to shatter rock, analogous to “sonic cannon” or LRAD (Long Range Acoustic Device) weapon systems in the military
  - Targeted downhole laser applications
Section 3

KEY TAKEAWAYS
Summary

• Regulation of oil and gas water use is on the rise and could push the industry towards various alternate solutions to fracturing with fresh water

• Currently, industry effort is primarily focused on recycling produced and flowback water at the site (Marcellus) as well as tapping into previously ignored brackish aquifers particularly in drought prone areas (Permian)

• Service and production companies are addressing water stewardship in a variety of ways

• The future of water management could look similar to that of refineries where well sites become zero liquid discharge zones and could encompass technology that has yet to be developed commercially in the field

• Water stewardship is the key to expanding into international plays abroad where many undeveloped shale plays underlie water constricted zones

• Continued innovation and technology will unlock the future energy potential of the world while conserving fresh water
QUESTIONS?
Water Stress Increasing Across the Globe

Source: World Resources Institute, Aqueduct
Growing Competitive Pressure on Water Supplies

Source: Ceres
Freshwater: A Limited Resource

Source: United Nations

Source: United Nations