

The logo for Rice University's Baker Institute features a light green, stylized world map in the background. Overlaid on the map is the text "RICE UNIVERSITY'S" in a dark green, serif font, and "BAKER INSTITUTE" in a larger, bold, dark green, serif font below it.

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Water and Energy: Understanding Impacts & Trade-offs to Facilitate Transitions

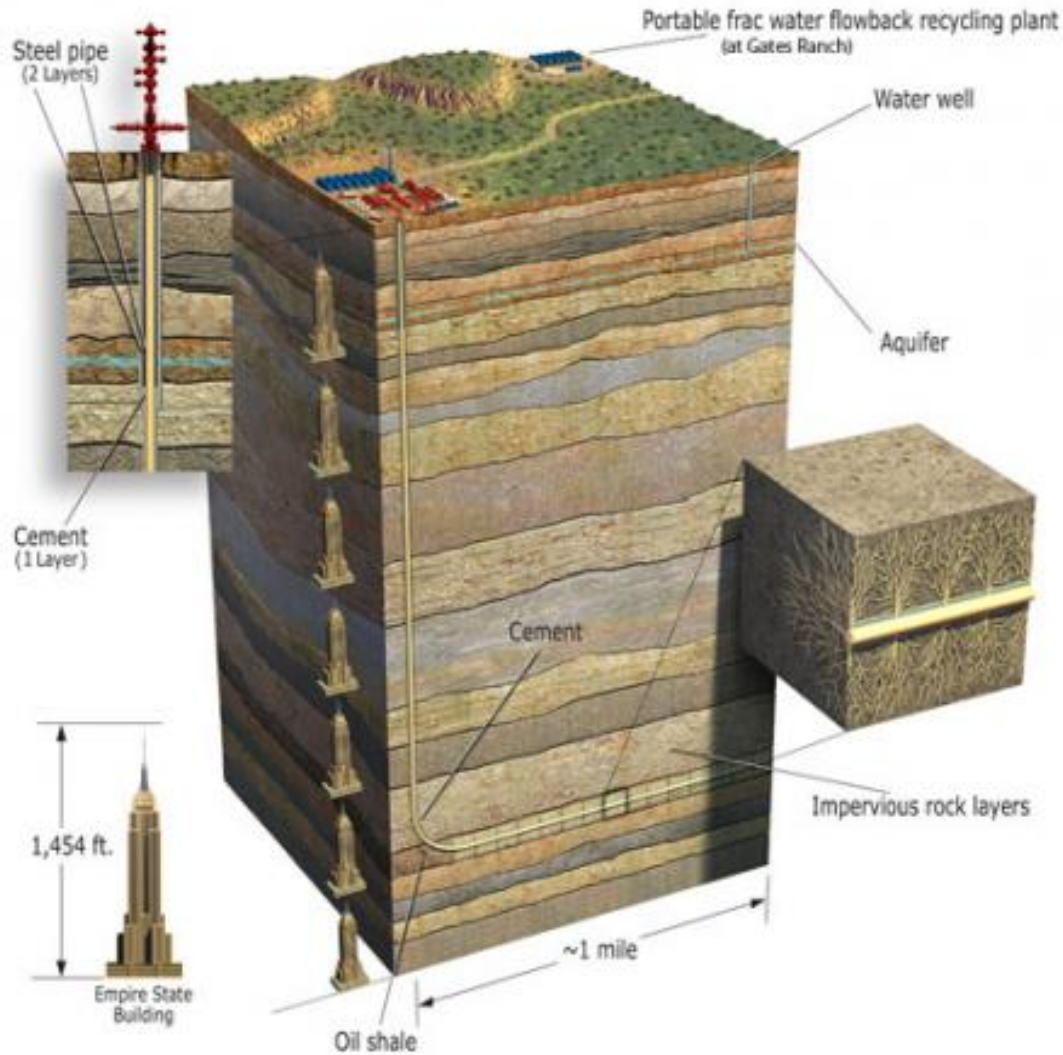
Prudent Development Study Objectives

- **Assess the N. American resource base – natural gas and oil**
 - Conventional
 - Unconventional
- **Describe the role of technology**
 - Environmental
 - Operational
- **Assess N. American supply and demand**
 - Through 2035
 - With a view to 2050
- **Identify the potential role of natural gas to lower emissions**
- **Meet national objectives: economic, environmental, security**

Four Major Findings

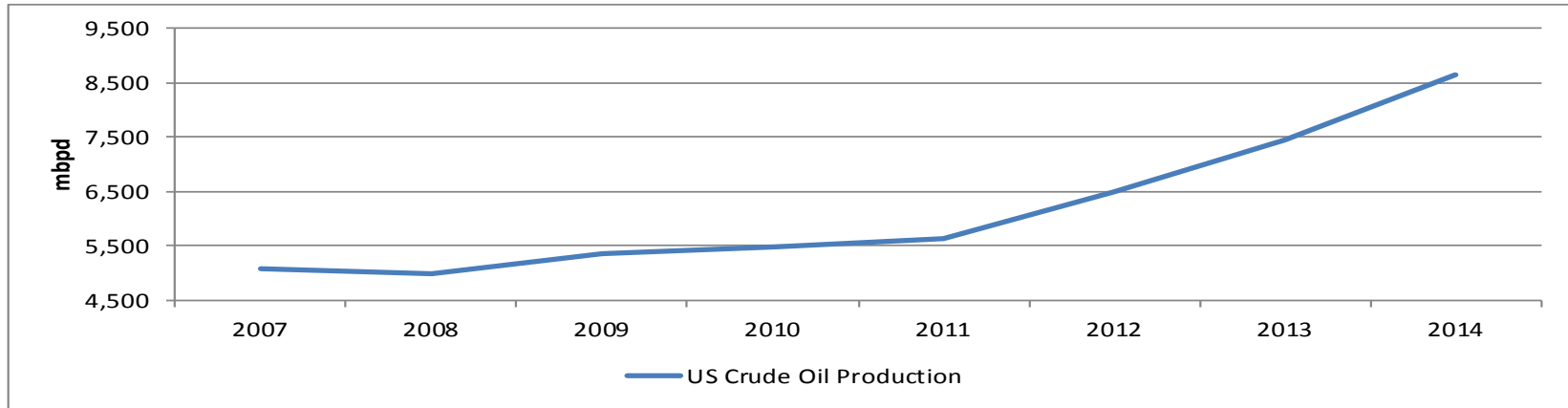
- **First, the potential supply of North American natural gas is far bigger than was thought even a few years ago**
- **Second – and perhaps surprising to many – America’s oil resources are also proving to be much larger than previously thought**
- **Third, we need these natural gas and oil resources even as efficiency reduces energy demand and alternatives become more economically available on a large scale**
- **Fourth, realizing the benefits of natural gas and oil depends on environmentally responsible development**

Hydraulic Fracturing

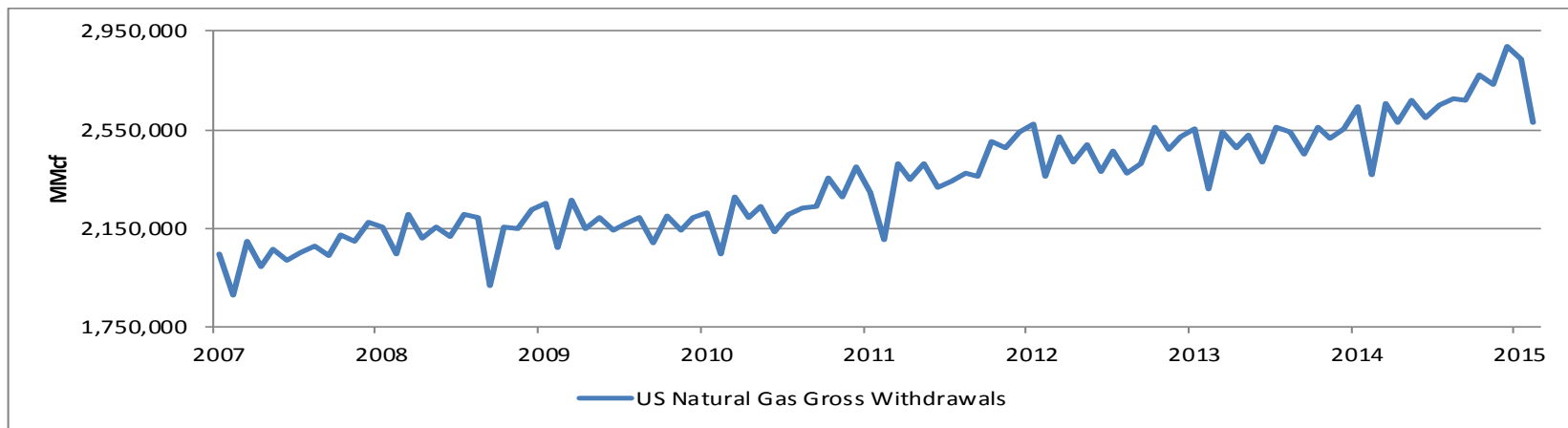


US Oil and Gas Production

Crude Production

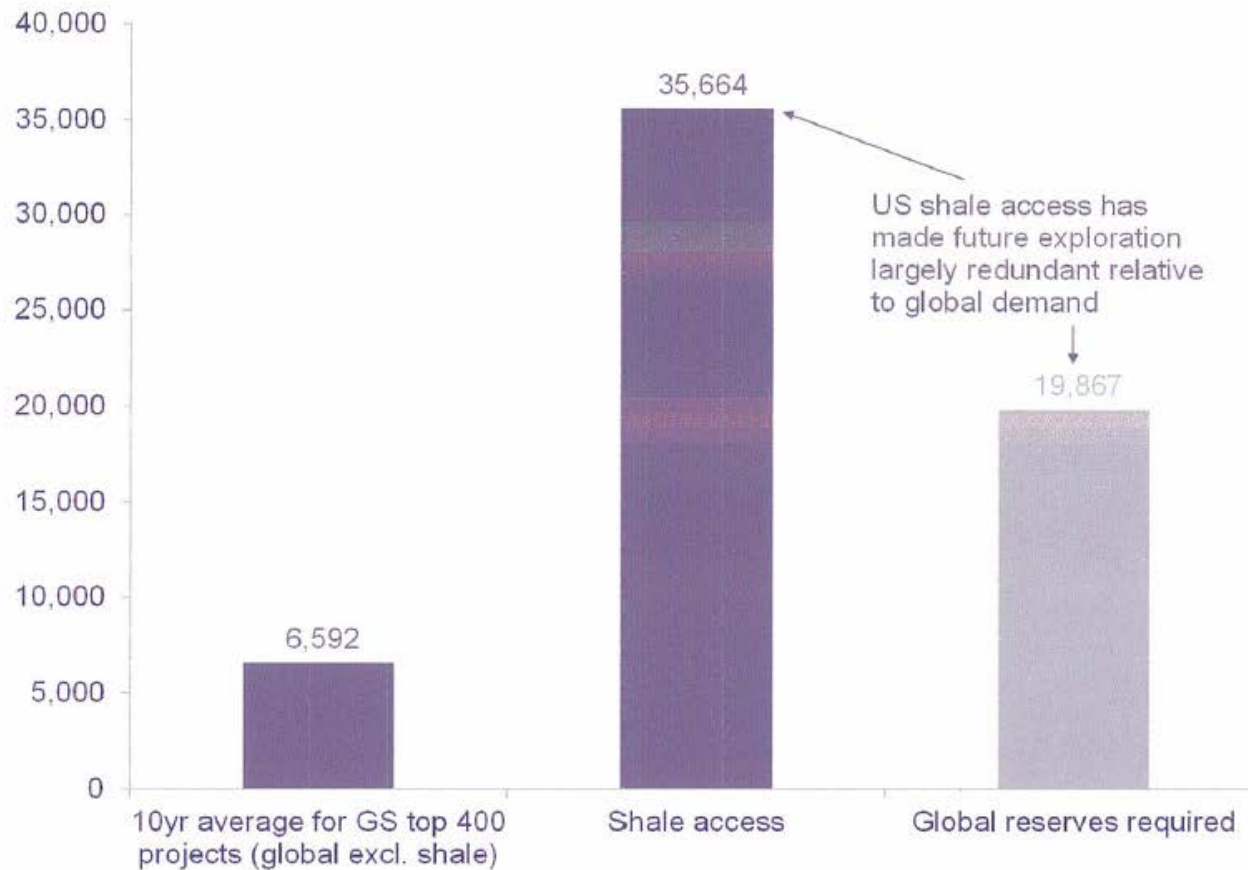


Natural Gas Production



More than enough to go around

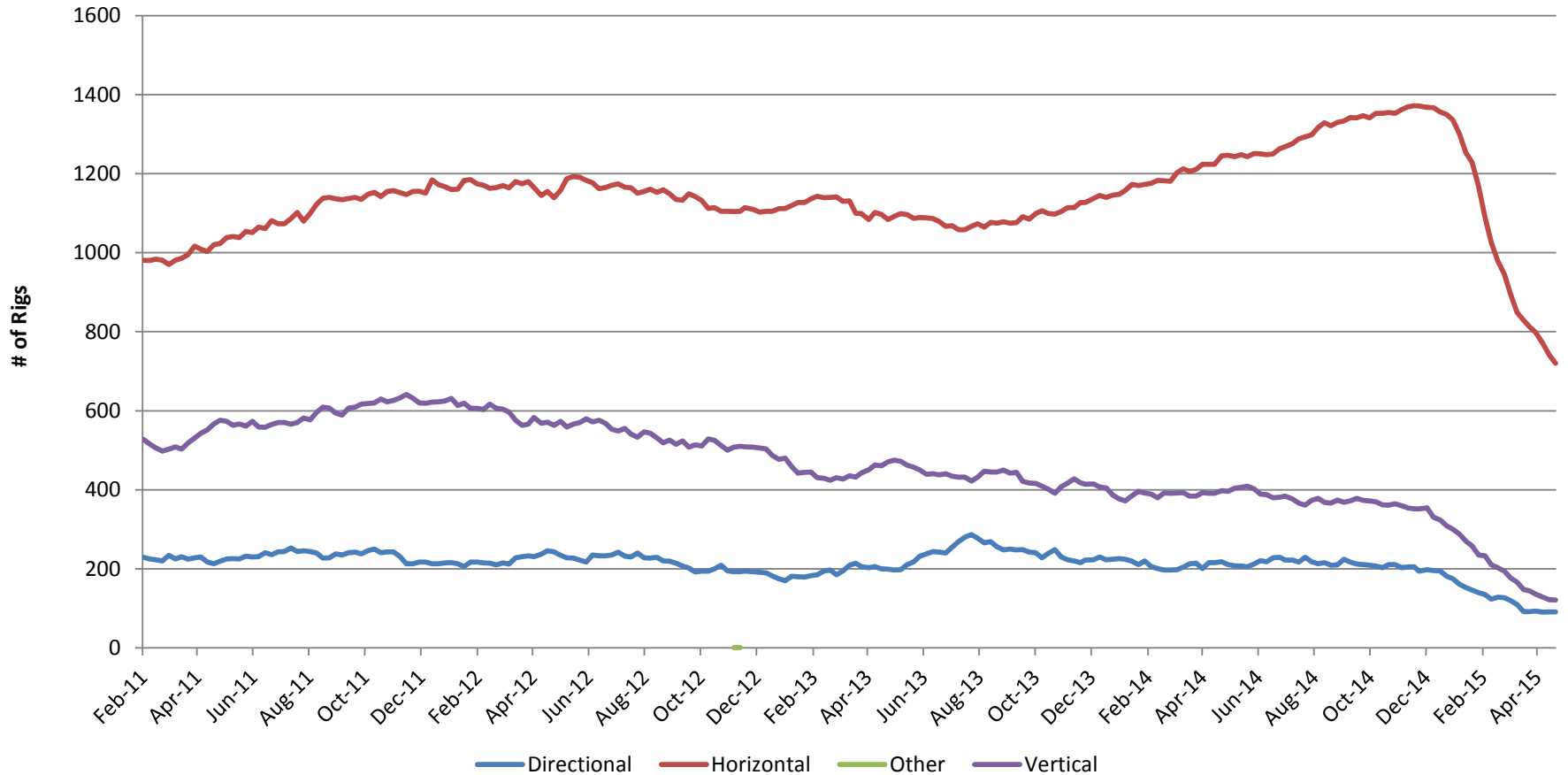
Average oil reserves added vs. global reserve requirement, million barrels per annum



Source: Goldman Sachs Global Investment Research (April 2015)

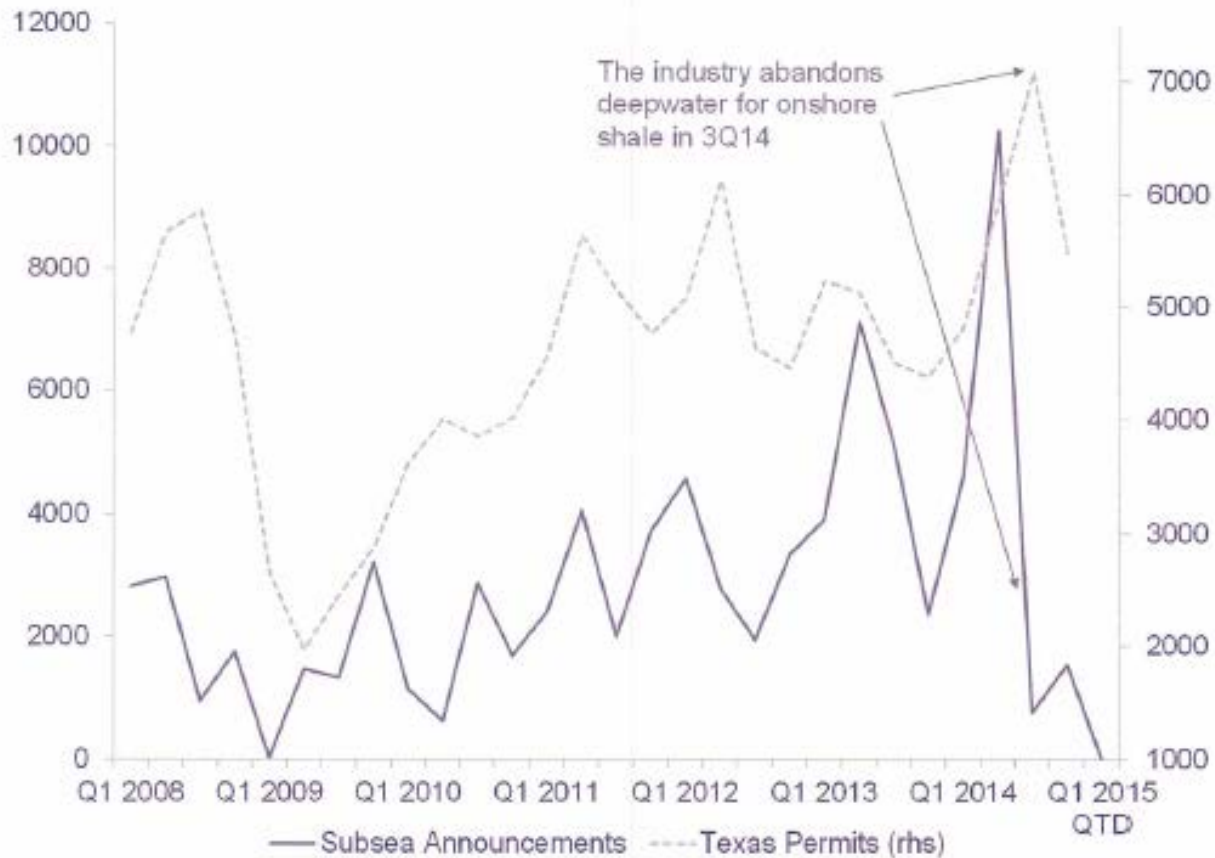
SENDERO
MIDSTREAM

US Rig Count – February 2011 to Present



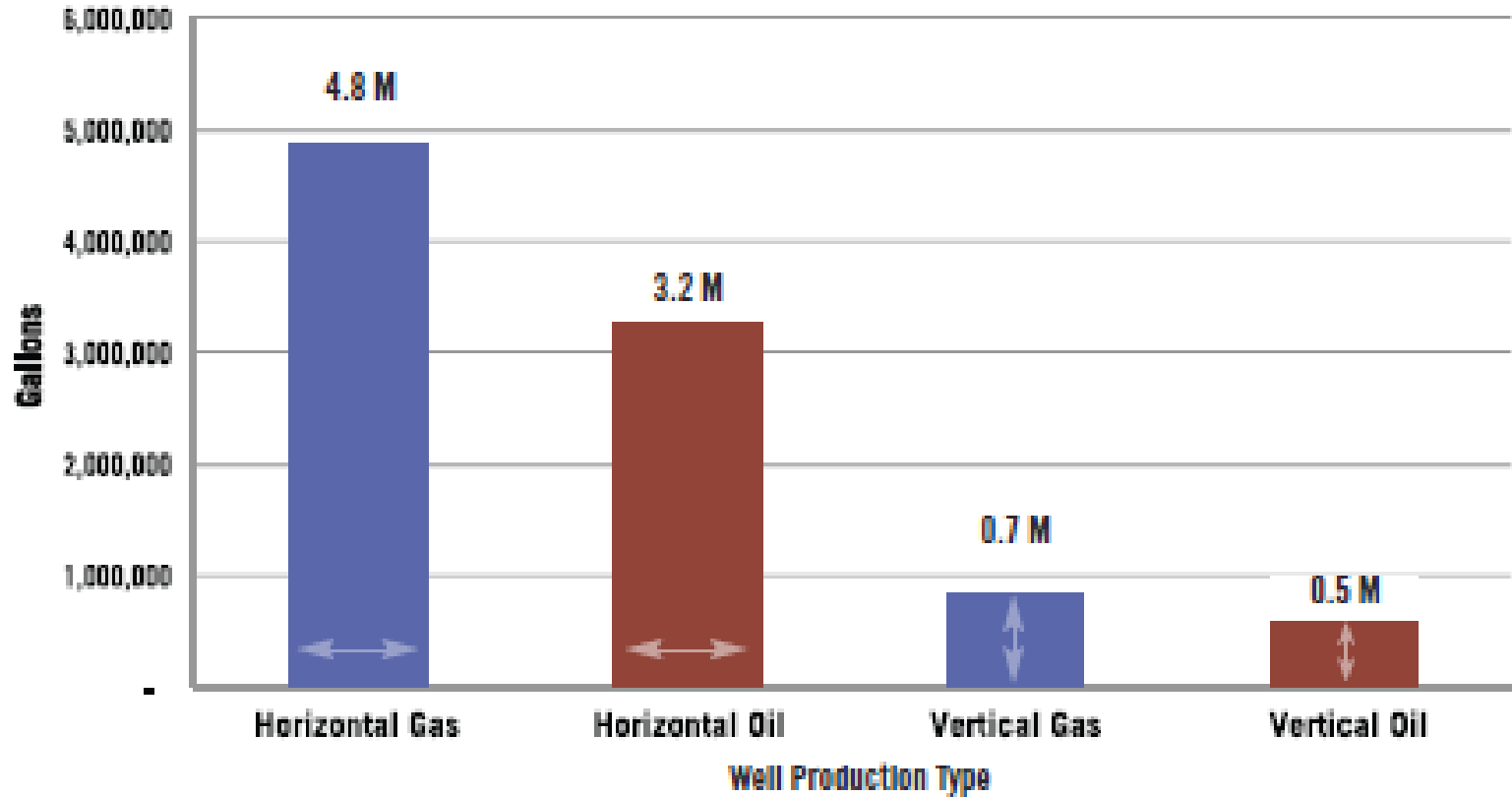
Drilling in water isn't easy

Subsea announced orders (lhs) vs. Texas permits (rhs)



Source: Railroad Commission of Texas, Goldman Sachs Global Investment Research (April 2015)

Average Water Use per Well



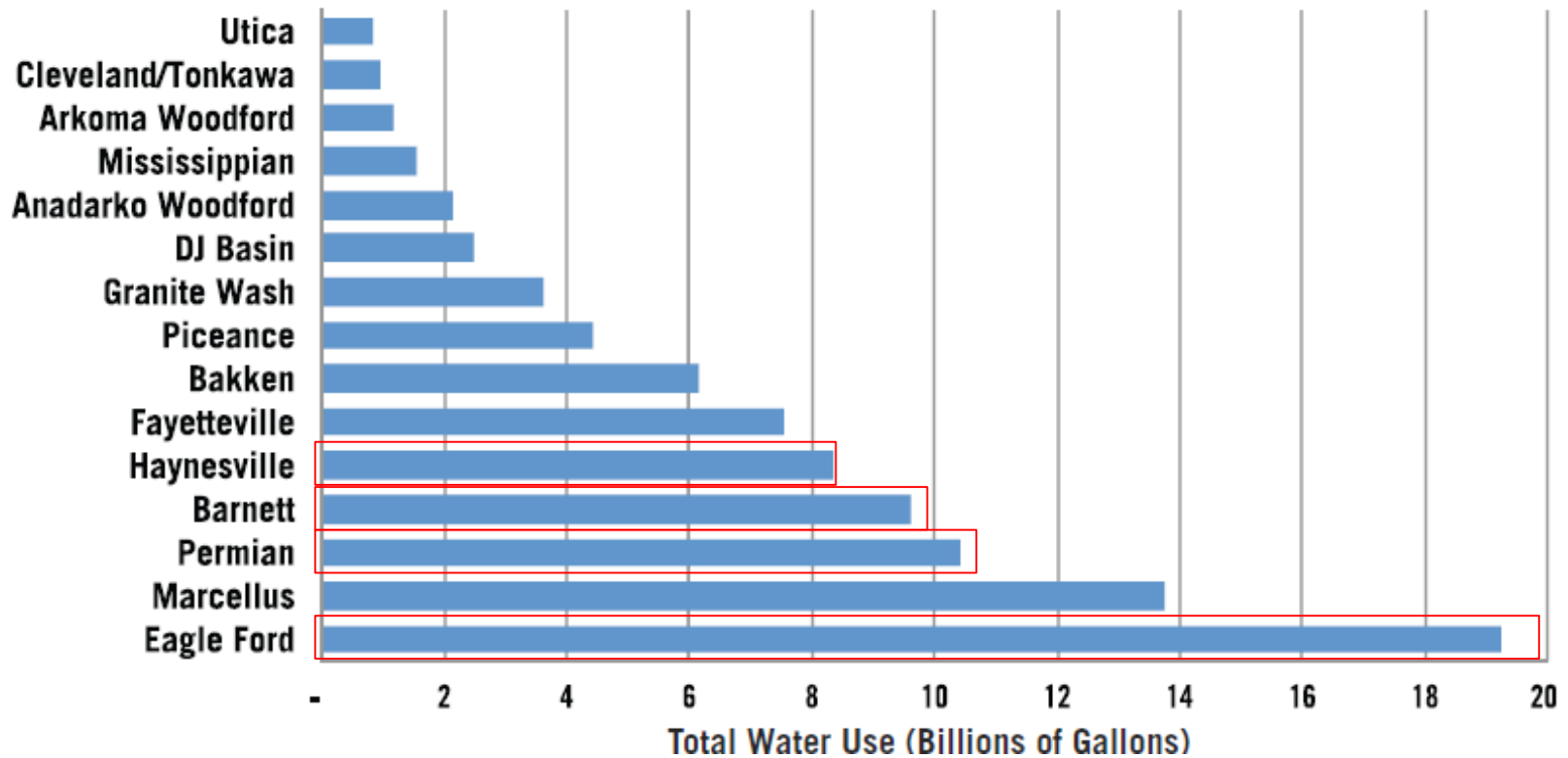
Source: Ceres analysis using PacWest FracDB from FracFocus data from wells drilled January 2011-May 2013.

UT Austin Study – September 2014

- Hydraulic fracturing is a process in which liquid is injected into geological formations at high pressure to extract oil or natural gas. Because of economics, in recent years production has shifted from predominantly dry gas plays, such as the Barnett and Marcellus formations, to more oil-rich plays in the Eagle Ford, Permian and Bakken formations.
- The public perception is that hydraulic fracturing uses extremely large quantities of mostly fresh water.
 - ▶ This underscores the importance of quantifying water use.
- A study performed by UT-Austin's Bureau of Economic Geology (September 2014) found that increases in water use for oil production are due to increased energy production and not a higher intensity of water use.

Top 15 Plays by Water Use

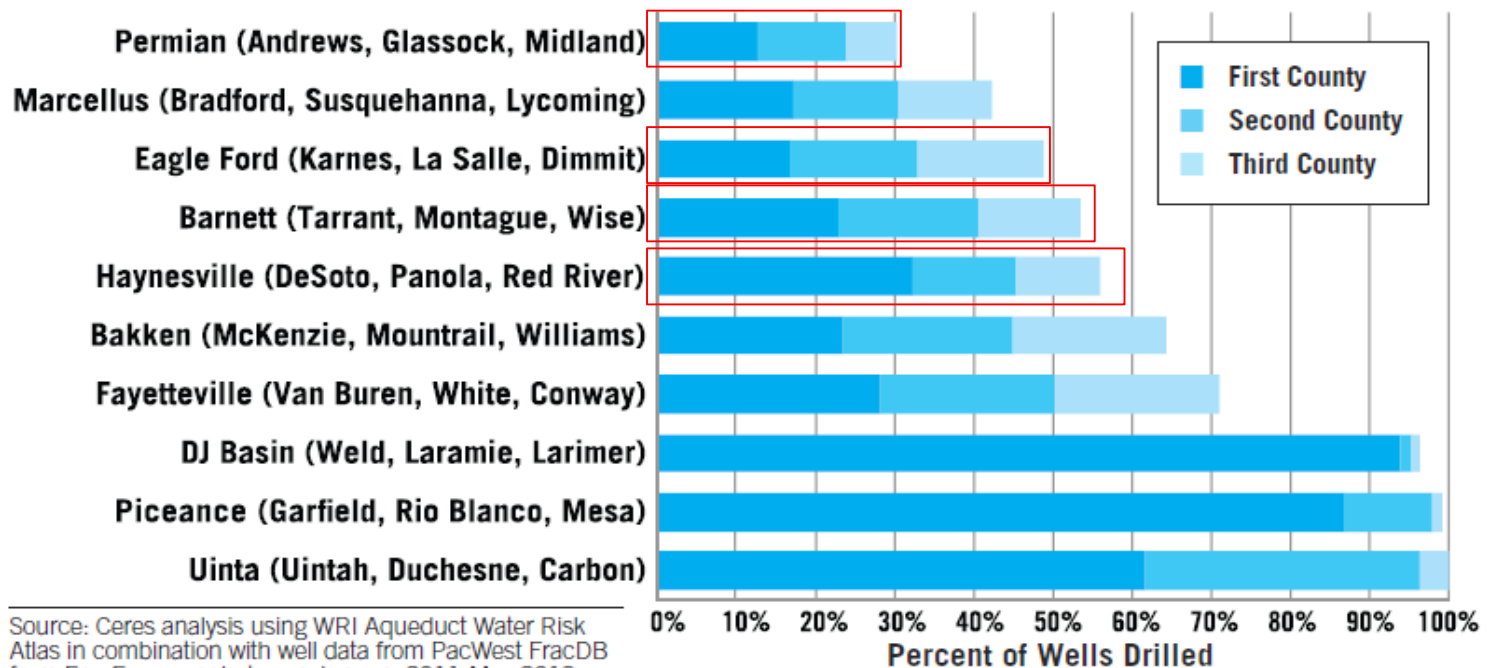
The Eagle Ford play in south Texas had the highest total water use, over 19 billion gallons, followed by the Marcellus, Permian, Barnett and Haynesville plays.



Source: Ceres analysis using PacWest FracDB from FracFocus data from wells drilled January 2011-May 2013.

Percentage of Wells in Top Three Most Active Counties per Play

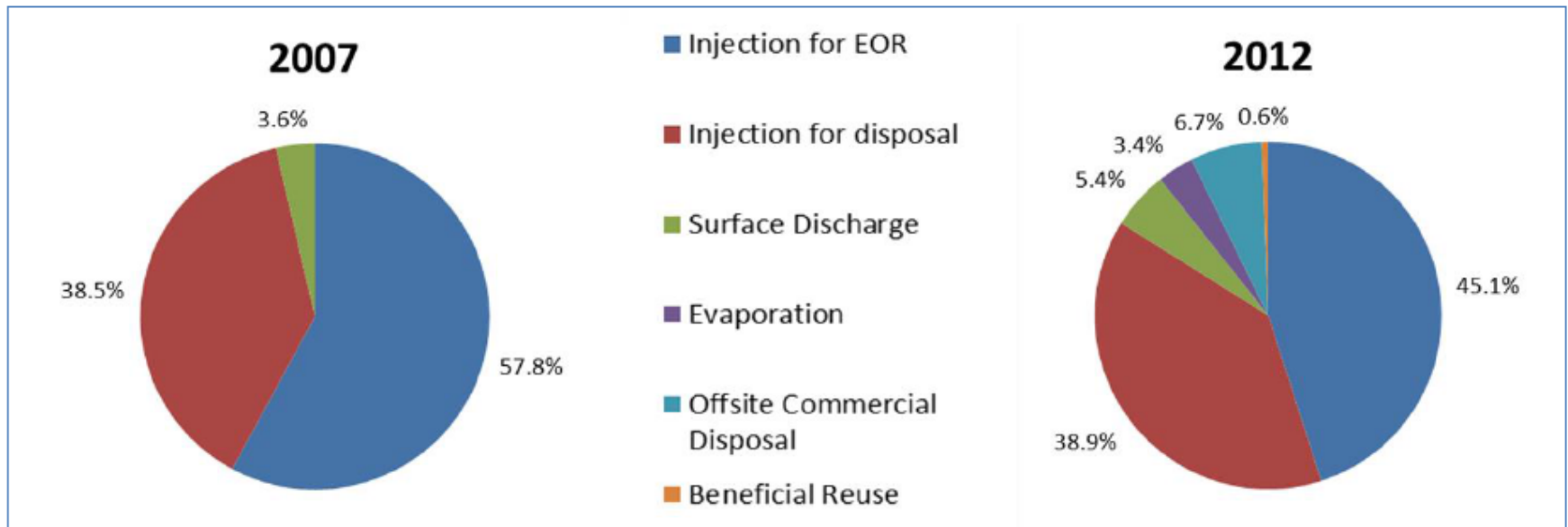
Water use in certain counties can be very high because shale development tends to concentrate in “sweet spots” where wells may be particularly productive. As a result, development often focuses on a small number of counties within each play or basin.



Source: Ceres analysis using WRI Aqueduct Water Risk Atlas in combination with well data from PacWest FracDB from FracFocus.org between January 2011-May 2013.

Produced Water Management

- Produced water is generated from most of the nearly 1 million actively producing oil and gas wells in the United States.
- Produced water is the largest volume by product or waste stream associated with oil and gas exploration and production.
- The cost of managing such a large volume of water is a key consideration to producers.
- The table below shows how produced water was managed by percentage in both 2007 and 2012.



Source: Ground Water Protection Council (April 2015)

National Petroleum Council Recommendations - Industry

- The natural gas and oil industry should establish regionally focused councils of excellence in effective environmental, health, and safety practices.
- Natural gas and oil companies should engage affected communities to establish shared understandings of expectations and awareness of issues and facts.
- Engagement should include sharing of information relevant to the community on a transparent and comparable basis
- All levels of the industry should use appropriate predevelopment planning, risk assessment, and innovative applications of technology....
- Every company that uses hydraulic fracturing should participate in FracFocus...

National Petroleum Council Recommendations – Government & Regulators

- **State and federal agencies should seek a balance between prescriptive and performance based regulations to encourage innovation and environmental improvements....**
- **Regulators should gain practical insights from the work of credible councils for excellence in effective environmental, safety, and health practices**
- **The industry and state and federal agencies must develop and disseminate science-based information on practices and risks to inform the public and build public confidence**

If not us, then who?