Resource Triangle

Conventional Reservoirs
Small volumes that are easy to develop

Unconventional
Large volumes difficult to develop

Increased pricing
Improved technology
Implications

• All natural resources are distributed log normally – gold, silver, oil, gas, etc.
• The high grade deposits are difficult to find but easy to extract
• As you get deeper into the resource triangle, you need adequate product prices and improved technology
Implications

• Low quality reservoirs can be enormous
• There should be a log normal distribution of resources by quality in every oil and gas basin we now produce
• Thus, there should be very large volumes of gas and oil in unconventional reservoirs around the world
Natural gas production has increased over the last few years, largely due to increased unconventional gas production.

Consumption: 23.8 Tcf/year
UG: 13.2 Tcf/year.
Conventional gas: 7.8 Tcf
Net imports: 2.8 Tcf

Source: EIA, Annual Energy Outlook 2011
Horizontal Drilling has been an enabling technology.

Much of the Horizontal Drilling technology was developed during the Austin Chalk development in Texas in the 1990's.
Geo-steered wellbore
Hydraulic Fracturing
Mapped microseismic height for Barnett shale

- **Top:** shallowest microseism; **Bottom:** deepest microseism
- **Aquifers:** USGS deepest water wells by county

**Smallest height growth at shallow depths**

Large spikes are likely fault interactions
Mapped microseismic height for Marcellus shale

- Top: shallowest microseism; Bottom: deepest microseism
- Aquifers: USGS deepest water wells by county

Smallest height growth at shallow depths

From Pinnacle
Freshwater Users in the Barnett Shale Region

- Natural Gas Development

Annual Water Use
1000's Acre-Feet

- Municipal
- Steam Electric
- Irrigation
- Manufacturing
- Livestock
- Mining
- Barnett Drilling

2005 and 2010 (Projected)
Forecasted Water Use

- There are 6-8 very active basins and dozens more that will be developed
- One can assume 2000 – 4000 wells drilled per year per basin
- Also 1-4 million gallons of water per well
- This adds up to 8-16 billion gallons of water per basin per year
- Much of this water can be recycled
Water Issues Changing Rapidly
Using Salt Water

- Industry now starts with fresh water
- But the first thing it adds in 2-6% KCl
- Why not just start with salt water?
- We would need to adjust the recepi
- We can use salt water from brackish aquifers
- It would solve a lot of problems
- We are working on this solution at TAMU
Hydraulic Fracture Treatment Water Composition

Water = 90.6%

- Proppant, 8.96%
- Other, 0.44%
- Acid, 0.11%
- Breaker, 0.01%
- Bactericide/Biocide, 0.001%
- Clay Stabilizer/Controller, 0.05%
- Corrosion Inhibitor, 0.001%
- Crosslinker, 0.01%
- Friction Reducer, 0.08%
- Gelling Agent, 0.05%
- Iron Control, 0.004%
- Scale Inhibitor, 0.04%
- Surfactant, 0.08%
- pH Adjusting Agent, 0.01%
# Fracturing Fluid Additives and Usage

<table>
<thead>
<tr>
<th>Additive</th>
<th>Main Compound</th>
<th>Common Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diluted Acid</td>
<td>Hydrochloric or Muriatic Acid</td>
<td>Swimming Pools</td>
</tr>
<tr>
<td>Biocide</td>
<td>Glutaraldehyde</td>
<td>Dental Disinfectant</td>
</tr>
<tr>
<td>Breaker</td>
<td>Ammonium Persulfate</td>
<td>Bleaching Hair</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Borate Salts</td>
<td>Laundry Detergents</td>
</tr>
<tr>
<td>Iron Control</td>
<td>Citric Acid</td>
<td>Food Additive</td>
</tr>
<tr>
<td>Gelling Agent</td>
<td>Guar Gum</td>
<td>Biscuits</td>
</tr>
<tr>
<td>Scale Inhibitor</td>
<td>Ethylene Glycol</td>
<td>Antifreeze</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Isopropanol</td>
<td>Glass Cleaner</td>
</tr>
<tr>
<td>Friction Reducer</td>
<td>Polyacrylamide</td>
<td>Water and Soil Treatment</td>
</tr>
</tbody>
</table>
What is Being Done?

Barnett & Marcellus Water Committees

Mission of the Committees is to develop best management practices (BMP's) and technical solutions for shale developments to ensure that water is managed in an efficient and environmentally responsible manner.
20 Billion Pounds of Salt Spread per Year for Snow and Ice Control
This rock could power the world

Why shale can solve the energy crisis

By Bryan Walsh

A century's worth is buried in our backyards... ...but drilling for it threatens our land
But we still have a lot of work to do!