What’s the big deal with natural gas and unconventional oil?
What is hydraulic fracturing?
How much proppant is needed?
What are the environmental considerations for hydraulic fracturing for unconventional oil?
Natural Gas U.S. Reserves Estimates

Source: Power Magazine 2011
Shale Revolution Timeline

U.S. Shale Gas Production Has Increased Six-Fold Since 2006

Shale gas has grown to over 15% of U.S. gas production and is expected to grow to 45% by 2035.

1Source: EIA, Annual Energy Outlook 2011 Reference Case,  2Source: EIA
Magnitude of Supply

- A trillion cubic feet is enough gas to:
  - Heat 15 million homes for 1 year
  - Generate 100 billion kilowatt-hours of electricity
  - Fuel 12 million natural gas vehicles for one year
  - Marcellus alone ≈ 50 – 500 tcf

- 120 year supply in U.S.
- Lots of oil too (Utica, Eagle Ford, Bakken, etc.)

Source: EIA
Natural Gas Characteristics

- We have lots of it.
- Cleanest combustion fuel available (half the CO₂ of coal). But fugitive loss of CH₄ is 25xCO₂ potency for GHG.
- “Bridge” fuel for transition to renewables, and “leveling” fuel for wind and solar.
- Extensive transmission / distribution network already in place.
- Underutilized gas power generation capacity can achieve 20 percent CO₂ emissions reduction rapidly.
- Current supply far exceeds demand.
Supply > Demand so Natural Gas is Affordable

- 1 barrel of oil = $97.23 (May 10, 2012)
- 1 MMBtu of gas = $2.56 (May 10, 2012)
- 1 barrel of oil equivalent (BOE) = 5.8 MMBTU
- Price of 1 BOE of natural gas = $14.85
Premier Webinar Series

Dedicated to excellence in the practice of environmental engineering to ensure the public health, safety, and welfare to enable humankind to co-exist in harmony with nature.

U.S. Clean Energy Challenges Focus on Hydraulic Fracturing

Moderator--
Hunter Nolen, P.E.,
BCEE, President,
Industrial Services,
CDM Smith

Colorado Governor (ret)
William Ritter, Director,
Center for the New Energy Economy, Colorado State University

Kevin Rice, Senior
Business Development
Manager, Baker Hughes

Tom Tomastik, Geologist,
Ohio DNR, Division of Oil and Gas Resources Management

www.aaee.net
Oil Migration & Entrapment, Conventional Model

Source: University of Texas at Austin, Bureau of Economic Geology, Annual Report, 2011
U.S. Shale and Tight Gas Basins

Source: EIA based on data from various published studies.
Horizontal Drilling and Hydraulic Fracturing

Marcellus Shale Outcrop

Release of Natural Gas from Shale Rock

Source: BNK Petroleum

Horizontal laterals

-1.5 to 3 Km long each

Multiple stages hydraulically fracture stimulated
Fracturing Network

- Currently developing and evaluating different techniques to alter the near wellbore stress field and promote more secondary fractures
- The average number of stages per well in 2011 was 16+

Clustering method

Alternating clusters in adjacent wells

Frac Height: 50 to 200 feet
Frac Width: ½ inch
Frac Length: 500 to 1500 feet
Fracturing Proppants

Fractures are created, then held open with a proppant, creating a conductive path.

Sand

Ceramic
Sand $\text{SiO}_2$

w & w/out resin coating

20/40 Mesh (per in) Proppant

Bauxite

Proppant Shortage JPT April 2011
Pricing and Production

Current Data from Wisconsin
Current capacity ~ 14 mmt
Proposed ~ 11 mmt
Cost to mine ~$20-$30/ton
Current cost ~$100/ton
Projected cost ~$ 50/ton

The Coming Tsunami Of Frac Sand Supply; Seeking Alpha, Aug 2012

St Peter Sandstone in Wisconsin
Proppant Shortage JPT April 2011
Transport Volume
(How accurate is this estimate?)

Back of the envelope estimate
Capacity per car = 250,000lbs = 125tons
Wisconsin production capacity = 14 to 25 mmt/yr
   (St Peter sandstone)
Number of cars = 25,000,000/125 =

200,000 cars = 2000 unit trains
Proppant Fines

SiO$_2$

Natural materials are not uniformly graded.

To contain only 20 to 40 mesh size grains proppants need to be sieved

Wash sieve before shipping??
Hydraulic Fracturing
The Shale Development Solution & Environmental Controversy

- Frac Water Volume: 2 to 6 million gallons per well
- Additional components include biocides, corrosion inhibitors, O₂ scavengers, proppant, etc.
- 20-40% frac “flowback” water recovery requires collection, handling, and disposal / treatment / reuse

History of Fracturing

- **Late 1800's**  Explosive fracturing
- **1940's**  First hydraulic fractures
- **1988**  Common practice (1 million performed to date)
- **2006**  Advent of multistage fracturing of horizontal well
- **2011**  60% - 80% of all O&G wells are hydraulically fractured (35,000 per year and 2.5 million to date)

*Source: Baker Hughes*
HYDRAULIC FRACTURING IN OHIO

- Hydraulic fracturing was first used in Ohio in 1951 and met with considerable success – particularly in the tight, Clinton sandstone
- Hydraulic fracturing dramatically reduced the number of dry holes drilled in Ohio
- Tens of thousands of oil and gas wells have been successfully hydraulic fractured in Ohio since 1951
REGULATORY REFORM HAS HELPED!

Incidents Caused by Regulated Activities by Year and Key Regulatory Reforms

Legend
- Plugging & Abandonment
- Off-Site Waste Management/Disposal
- Production/Workover Waste Storage Treatment
- Well Stimulation
- Drilling & Completion
- Site Preparation
- Annular disposal rules
- Orphan well emergency program
- Urban drilling rules
- Annular disposal mechanical integrity test
- Closure of all produced water earthen pits
- Reserve pit construction standards
- Authority to order water supply replacement
- Produced water tracking
- Established deep injection of produced water as preferred disposal method

Class II UIC Primacy

Year

Total Number of Incidents
Shale Gas Water Use Requirements

- Power generation: 5,930
- Industrial: 1,680
- Public water systems: 1,550
- Other: 268
- Mining: 182
- Marcellus Shale Drilling: 30

Estimated Marcellus water use at expected peak drilling rate (3,000 wells per year)

Source: USGS Pennsylvania Water Consumption
# Shale Gas: Water Use Efficiency vs. Other Energy Sources

<table>
<thead>
<tr>
<th>ENERGY SOURCE</th>
<th>Water Use per Unit Energy Produced (gal/MMBTU)</th>
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<td><strong>Shale Gas</strong></td>
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<td>Biodiesel Refining</td>
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<td>Ethanol Processing</td>
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<td>Uranium Processing</td>
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<td>Coal Liquefaction</td>
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<td>Coal Mining</td>
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</tbody>
</table>


*Source: GSI Environmental, Houston, Texas, 2010*
Groundwater & Surface Water Concerns

Surface Activities

Well Completion

Fracturing?
Pricing and Production

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The Coming Tsunami Of Frac Sand Supply; Seeking Alpha, Aug 2012