Why Frack and What are the Risks

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Statement of Task:

- Evaluate the scientific basis of available body of information
- Communicate current state of knowledge

Key steps:

- Review methodologies and approaches
- Identify gaps
- Suggest improvements
- Make recommendations for further research
Outline

• What is New about Shale Development
• How Do You Frack Wells
• Why Develop Shale
• Risks
  – Water
  – Air
  – Seismic
Conventional Production

- Source Rock: Shale
  - Low permeability
  - Not enough surface area in vertical well
- Oil Migration Upward over Millennia
- Reservoir Rock
- Barrier Trap
Shale Development

• Goal: Increase surface area of contact between the rock and the wellbore

• Key:
  – Horizontal Wells and Fracking
  – 1000 to 15000 feet
  – Multiple vertical fractures along its length
  – Fill fractures with sand to create high permeability channels to the wellbore

• Over 1 Million producing wells fracked since 1950
Outline

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Drilling a Well
Water Cycle

- Well Injection
- Produced Water Handling
- Chemical Mixing

Water Acquisition

Wastewater Disposal and Reuse
Fracking the Well
Producing Well Pad
Frack Fluid

Fracture Fluid Composition

- **WATER**: 90%
- **SAND**: 9.5%
- **OTHER**: 0.5%

Breakdown of 0.5%
- **SURFACTANT**: 25%
- **FRICTION REDUCER**: 18%
- **ACID**: 17%
- **KCl**: 12%
- **GELLING AGENT**: 11%
- **SCALE INHIBITOR**: 9%
- **OTHER**: 8%

National Energy Technology Library
<table>
<thead>
<tr>
<th>Most Common Frac Additives</th>
<th>Composition</th>
<th>CAS Number</th>
<th>Total amt. in avg frac (10k bbl)</th>
<th>Used in recycled water?</th>
<th>Alternate Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction Reducer</td>
<td>Polyacrylamide</td>
<td>9003-05-8</td>
<td>100 to 200 gallons.</td>
<td>50k to 70k ppm is upper limit</td>
<td>baby diapers, floc for drink water</td>
</tr>
<tr>
<td>Biocide</td>
<td>Glutaraldehyde</td>
<td>111-30-8</td>
<td>50 to 100 gallons.</td>
<td>decrease w/ increasing salinity</td>
<td>Medical disinfectant</td>
</tr>
<tr>
<td>Alternate Biocide</td>
<td>Ozone, Chlorine dioxide UV,</td>
<td>10028-15-6 10049-04-4</td>
<td></td>
<td>Turbidity &amp; v. high salinity hindrances.</td>
<td>Disinfectant in municipal water</td>
</tr>
<tr>
<td>Scale Inhibitor (if needed)</td>
<td>Phosphonate &amp; polymers</td>
<td>6419-19-8 &amp; others</td>
<td>10 to 100+ gallons – depends on local</td>
<td>Specific ions like calcium are a problem.</td>
<td>Some cleaners and medical treatment</td>
</tr>
<tr>
<td>Gellants (hybrid / gel)</td>
<td>Guar &amp; Cellulose</td>
<td>9000-30-0 9004-62-0</td>
<td>Depends on frac type ~1000 to 2000 lb.</td>
<td>Ca^{++}, Fe^{x} &amp; TDS problem.</td>
<td>Thickening ice cream / soup</td>
</tr>
<tr>
<td>Acid</td>
<td>5% TO 15% hydrochloric</td>
<td>7647-01-0</td>
<td>~0 to 2000 gals not universally</td>
<td>Yes</td>
<td>food prep, mfg, swim pools,</td>
</tr>
<tr>
<td>Acid Corrosion inhib.</td>
<td>Quat. Ammonium salts, Coa Coa Amines, etc.</td>
<td>Various</td>
<td>2 to 40 gals if acid is used</td>
<td>Yes</td>
<td>Industrial</td>
</tr>
</tbody>
</table>
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Importance of Shale Gas to the USA

- Natural gas is an important energy source for the United States. Shale formations represent a growing source of natural gas for the nation and are among the busiest oil and gas plays in the country.

Source: DOE/EIA Annual Energy Outlook 2011
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Water - Risks

• Fracking into Fresh Water Zone
  – No known case

• Leak from Casing

• Water Use

• Surface Leak from Pipeline or Truck
Water - Risks

• Fracking into Fresh Water Zone
  – No known case

• Leak from Casing
  – Has happened
    • Low probability
    • Local impact
    • Easily fixed

• Water Use

• Surface Leak from Pipeline or Truck
Proper Casing and Cementing Required
Leaks From Casing

- Well-studied failure in Bainbridge, Ohio, in 2008.
  - Incomplete casing cementing led to a return of fracturing fluid to the ground surface and upward migration of methane from near surface zones
  - Leading to contamination of drinking water wells and an explosion in a nearby home
- In a study of 211 groundwater contamination incidents in Texas associated with oil and gas activity (Kell, 2011), only 10 incidents were associated with oil and gas drilling and completion
  - None were associated with hydraulic fracturing
  - Many of the noted incidents occurred prior to 1969 and before the RRC revised regulations on cementing
- Because of the industrial nature of this activity, there always will be, some probability of casing failure leading to near surface contamination or contributing to surface spills due to flow up the failed casing
Water - Risks

• Fracking into Fresh Water Zone
  – No known case

• Leak from Casing
  – Has happened
    • Low probability
    • Local impact
    • Easily fixed

• Water Use

• Surface Leak from Pipeline or Truck
Water Use in Texas
Texas Water Development Board

Irrigation (55%)
Municipal (30%)
Manufacturing (9%)
Power (3%)
Livestock (2%)
Mining (1%)
Water Use for Hydraulic Fracturing
From TAMEST report

- Life cycle water use for shale oil and gas is substantially less than life cycle water use for other forms of energy (e.g. coal, nuclear and biofuels)

- Statewide, total freshwater use for shale oil and gas is <1% of total statewide freshwater use. Future use likely to decrease as brackish and produced water use increases

- Locally, freshwater use can be significant, particularly in rural counties without large amounts municipal or agricultural freshwater use

- Use of brackish and produced water can substantially reduce the impact of shale development on freshwater resources
Water - Risks

• Fracking into Fresh Water Zone
  – No known case

• Leak from Casing
  – Has happened
    • Low probability
    • Local impact
    • Easily fixed

• Water Use

• Surface Leak from Pipeline or Truck
  – Highest risk
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Air Emissions - Risks

• During flowback of well and before sufficient production is confirmed to justify a pipeline, gas may be flared
  – Venting yield methane
  – Flaring yields CO2
  – Mainly a problem with oil wells

• Fugitive Emissions
  – Production facilities
  – Compressor stations
  – Gas processing to remove ethane, propane, butane and other natural gas liquids
  – Industry voluntary reductions and monitoring
    • Obama regulations
    • ExxonMobil and others advising Government not to role back
Comparison to Coal for Electric Generation

- NOAA (2012) Emissions in 2012 23% lower than if coal made up same percent of fuel as in 1997
- Alvarez (2012)
  - Need methane leakage rate of less than 3% for gas to be better than coal
  - Actual leakage rate less than 1%
- NETL (2017)
  - Total national average methane gas emission intensity is 1.7%
Confusing Emissions from Oil Wells with Emissions from Gas Wells

  – 0.7% of high gas to oil ratio sites had detectable emissions
  – 1.4% of medium gas to oil ratio sites had detectable emissions
  – 20.6% of low gas to oil ratio sites had detectable emissions
  – 90% of detectable emissions were from storage tanks
Recent federal and state regulations have reduced emissions from multiple types of emission sources.

**Examples: Federal**
- New Source Performance Standards OOOO and OOOOa (2014):
  - Requirements of reduced emission well completions for gas wells
  - Tanks with potential emissions of >6 tons/yr must have emission controls
  - Leak Detection and Repair Standards

**Examples: State**
- State permits can require emission controls beyond federal standards, particularly in regions that do not meet National Ambient Air Quality Standards
Emissions in many categories associated with shale resource production are dominated by a small sub-population of high-emitting sources.

- ~50,000 wells (of the roughly 500,000 natural gas wells in the United States) vent during a process referred to as a liquid unloading, a small fraction (~3 to 5%) likely account for half of unloading emissions - Allen (2015)

- Pneumatic controllers use pressurized natural gas to control the opening and closing of control valves, and are estimated to be the largest source of methane emissions in the petroleum and natural gas supply chains; ~20 percent of pneumatic controllers at natural gas sites account for 95 percent of pneumatic controller emissions – Prasino (2013), Allen (2015), Gibbs (2015)
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Seismic Risks

• NRC (2012)
  1. Fracking does not pose a high risk for inducing felt seismic events
  2. Injection of water derived from energy technologies into the subsurface poses some risk for induced seismicity, but very few events have been documented over the past several decades relative to the large number of disposal wells in operation
  3. Carbon Capture and Storage (CCS), due to the large net volumes injected may have potential for inducing larger seismic events.
## Energy Levels from Fracking

<table>
<thead>
<tr>
<th>Richter Magnitude</th>
<th>Earthquake effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>Not felt by people</td>
</tr>
<tr>
<td>2-3</td>
<td>Felt little by people</td>
</tr>
<tr>
<td>3-4</td>
<td>Ceiling lights swing</td>
</tr>
<tr>
<td>4-5</td>
<td>Walls crack</td>
</tr>
<tr>
<td>5-6</td>
<td>Furniture moves</td>
</tr>
<tr>
<td>6-7</td>
<td>Some buildings collapse</td>
</tr>
<tr>
<td>7-8</td>
<td>Many buildings destroyed</td>
</tr>
<tr>
<td>8-Up</td>
<td>Total destruction of buildings, bridges and roads</td>
</tr>
</tbody>
</table>
Produced Water

- Almost all oil and gas wells produce flowback or connate water
- In US oil and gas wells produce between 40 and 55 million BWPD
- Between 2007 and 2012 U.S. oil production increased by 29%, gas production increased by 22%, but water production increased by less than 1%.
  - Many of the older conventional wells that generated a high lifetime volume of water were closed.
  - Many of the newer wells that were drilled were unconventional wells that generated a lower lifetime total of water.
- Almost all onshore water production is disposed of subsurface
Disposal Wells- Class II Injection Wells

• Approximately 180,000 injection wells in US
• Water injected below frack pressure into highly porous formations
• Earthquakes can occur due to increased pore pressure near old inactive faults

• Solution:
  – Stringent review of injection well permits near historic earthquake locations
  – Legal authority to suspend permit if well is suspected of causing an earthquake
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