What Does Environmental Justice Have to Do With Me?
A Student’s Guide to the Responsibilities of Engineers

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ENGINEERING
Risk
Uncertainty
Modeling

ETHICS
Acceptable Risk
Plurality
Inquiry into Values

Deliberation
Pedagogy
ENGINEERING  ETHICS

Workshop 1, November 2014

Engineering, Modeling and Risk

Workshop 2, April 2015

Ethics, Policy and Pedagogy
A Framework

the Lab

the Field

the Forum
Hydraulic Fracturing

- Hydraulic fracturing is the process of injecting fluids into the rock mass under high pressure.
- Propping agents are introduced to maintain the fractures open upon fluid withdrawal.
- The economical extraction of shale gas more than doubles the projected production potential of natural gas, from 125 years to over 250 years.

Shale production is projected to increase from 23% of total US gas production in 2010 to 49% by 2035 - International Energy Agency (IEA).

[Gregory et al., Elements, 2011]
Hydraulic fracturing started at the beginning of the twentieth century in Kentucky’s Devonian shale.

It was based on explosives until the 40’s.

Lately, the technique of horizontal drilling created a revolution in unconventional oil and gas exploitation.
What are the reserves, energy needs and economic impacts?

- At present, **85% of the energy power consumed in the world is produced by fossil fuel combustion.**
- The United States produce about **20% of the natural gas consumed worldwide**, which represents **4% of the world’s current energy demand.**

- In the past twenty years, the production of shale gas from wells in the United States raised from less than 2% to **more than 40% of U.S. gas production.**
Shale in the U.S

[Vengosh et al., Env. Sc. & Technology, 2014]
A Few Terms

Hazard
Risk
Uncertainty
Acceptable Risk
Acceptable Risk

What are the risks?  Which risks are acceptable?

descriptive  normative

What level of risk may we reasonably expect people to put up with?
Acceptable Risk

Benefit

Equity

Consent
Environmental Justice

Equity and Consent regarding:
- Exposure to Risk
- Protection from Risk
- Access to Benefits
- Inclusion in Decisions
Local Control

- Zoning laws do not allow drilling
- Each municipality must vote on if the residents want to allow drilling or not.
You may be asking:
What does all this have to do with me?
In the Lab
What is Shale?

- One third of U.S. natural gas is extracted from shale.
- Shale is a structured rock, containing clay flakes forming porous flocules of up to tens of micrometers.
In the Field
Economic Impacts for PA

- $19.5 billion to the state’s labor income annually
- 339,000 jobs, or 4.7% of employment in PA
- **No Property tax increase** in Washington county for the past 5 years
- State Impact fees have generated **over $630 million over the past 3 years** and are given as grants to help communities
Water Consumption

• 8000 to 100 000 m³ (2–13 million gallons) per unconventional well (3 to 38 olympic swimming pools)

Alternatives:
• As of 2012, companies were recycling 14% of the fracking water used, up from 1% in 2010. Recycling the water can cost up to 80% less than using an injection well.
• Other options include use of gels instead of fresh water-based fluids.
Water Pollution

- **Groundwater contamination** by salts or dissolved constituents and stray gases

- **Surface water contamination** from spills, leaks and disposal of untreated wastewater, HF fluids and backflow fluids
# Water Pollution

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Composition (% by vol)</th>
<th>Example</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water and sand</td>
<td>99.50</td>
<td>Sand suspension</td>
<td>“Proppant” sand grains hold microfractures open</td>
</tr>
<tr>
<td>Acid</td>
<td>0.123</td>
<td>Hydrochloric or muriatic acid</td>
<td>Dissolves minerals and initiates cracks in the rock</td>
</tr>
<tr>
<td>Friction reducer</td>
<td>0.088</td>
<td>Polyacrylamide or mineral oil</td>
<td>Minimizes friction between the fluid and the pipe</td>
</tr>
<tr>
<td>Surfactant</td>
<td>0.085</td>
<td>Isopropanol</td>
<td>Increases the viscosity of the fracture fluid</td>
</tr>
<tr>
<td>Salt</td>
<td>0.06</td>
<td>Potassium chloride</td>
<td>Creates a brine carrier fluid</td>
</tr>
<tr>
<td>Scale inhibitor</td>
<td>0.043</td>
<td>Ethylene glycol</td>
<td>Prevents scale deposits in pipes</td>
</tr>
<tr>
<td>pH-adjusting agent</td>
<td>0.011</td>
<td>Sodium or potassium carbonate</td>
<td>Maintains effectiveness of chemical additives</td>
</tr>
<tr>
<td>Iron control</td>
<td>0.004</td>
<td>Citric acid</td>
<td>Prevents precipitation of metal oxides</td>
</tr>
<tr>
<td>Corrosion inhibitor</td>
<td>0.002</td>
<td>n,n-dimethyl formamide</td>
<td>Prevents pipe corrosion</td>
</tr>
<tr>
<td>Biocide</td>
<td>0.001</td>
<td>Glutaraldehyde</td>
<td>Minimizes growth of bacteria that produce corrosive and toxic by-products</td>
</tr>
</tbody>
</table>

*Source: Gregory et al., Elements, 2011*
Air Pollution

“Natural gas plays a key role in our nation's clean energy future.”
EPA, 2014

• Methane emissions have decreased 16.9% since 1990
• Green House Gas emissions reduce by ½ as power plants switch from coal to natural gas
Air Pollution

- Methane is a very potent greenhouse gas that, according to the latest IPCC report, is ~ 84 times as potent as CO2 over a 20 year time frame and ~ 36 times as potent over 100 years.
- Because of the methane problem, the US EPA came out with proposed rules for new and modified sources in the oil and gas sector this past fall.
- Natural gas development from shale offers no climate advantage and, at current rates of leakage during production and transmission, may actually be worse than coal from a lifecycle perspective.

U.S. methane emissions, 1990-2013 (EPA)
Induced Micro-seismicity

- Felt seismic events (M>2) officially correlated with hydraulic fracturing for shale gas development: Blackpool, England, 2011 (NRC, 2013); Prague, Oklahoma, 2011 (USGS, 2014; Sumy et al., 2014)

- Other possible earthquake sequences may be associated with hydraulic fracturing in Oklahoma.

- Reoccurring problem in induced seismicity studies: the seismic events are small, the regional networks are sparse, and the data quality is often too poor to fully confirm a causal link to fluid injection for energy development.
Induced Micro-seismicity

Energy geotechnology vs. natural faults (NRC, 2013)
Explosions

- A failed gland nut (28) and lock screw assembly caused the loss of well control
- The completion of the well was delayed due to weather
- Pressure of gas builds up
- Well is not sealed properly
- Lockpin releases gases

- Insufficient casing, BOP (blow out preventer), cement or wait on cement to prevent waste from conservation well.
- Failure to use casing of sufficient strength and other safety devices to prevent blowouts, explosions and fires.
- Failure to provide free and unrestricted access.

EPA recommendations put the responsibility to prevent future explosions on the well owners, inspectors, contractors and engineers associated with the well.
In the Forum

At its best:
Deliberation
Argument
Consensus

At its worst:
Maneuvering
Manipulation
Division
In the Forum

Hydraulic Fracturing

Technical Problems

Human Problems
In the Forum

Challenges for Engineers:
Communication
Navigation
Trust
Modesty
In School

The Formation of Responsible Engineers
  Stand-Alone Courses
  Integration into Degree Programs
  Work Experience
  Events
  Campus Culture
What can you do now?