WORKSHOP ON GOVERNANCE OF RISKS OF UNCONVENTIONAL SHALE GAS

National Research Council

August 15, 2013

Governance Considerations from a Technical Perspective

Mark D. Zoback
Professor of Geophysics
Minimizing the Environmental Impact of Shale Gas Development

Courtesy N.Fuller, SayoStudio.com
Governance Considerations from a Technical Perspective Are Multi-faceted

- **Community Issues**
  - Induced Seismicity
  - Setbacks
- **Industrial Processes**
  - Truck traffic, engine noise, local pollution, water concerns
- **Water Issues**
  - Regional Water
  - Surface Water
  - Ground Water
- **Atmospheric Issues**
  - GHG Emissions
  - Local Air Quality
- **Land Issues**
  - Ecosystem Impacts
  - Land Disturbance
  - Local Air Quality
  - Regional Air Quality

Zoback and Arent, in press *The Bridge*, 2013
Opportunities and Challenges of Shale Gas Development

• The proven ability to produce large quantities of natural gas from organic-rich shale formations has dramatically changed the energy picture in North America and has the potential to do so in many parts of the world.
• There seems little question that rapid shale gas development coupled with fuel switching from coal to natural gas for power generation can have beneficial affects on air pollution, greenhouse gas emissions and enhanced energy security in many countries.
• In this context, shale gas resources represent a critically-important transition fuel toward achieving a decarbonized energy future.
• For these benefits to be realized, however, it is imperative that shale gas resources be developed with effective environmental safeguards to reduce its impact on land use, water resources, air quality and the communities impacted by development.

Zoback and Arent, in press *The Bridge*, 2013
• Review of Four SEAB Recommendations

• A Few Words About Well Construction, Aquifer Contamination and Methane Leakage
DOE Shale Gas Subcommittee

- John Deutch – MIT
- Stephen Holditch – Texas A&M
- Fred Krupp – Environmental Defense Fund
- Katie McGinty – Pennsylvania DEP
- Sue Tierney – Massachusetts Energy
- Dan Yergin – Cambridge Energy Research
- Mark Zoback - Stanford
Shale gas can be developed in an environmentally responsible manner

but.....

The SEAB Subcommittee Made 20 Recommendations About How to Develop Shale Gas Resources in a More Environmentally Responsible Manner
Four SEAB Recommendations

- Full Disclosure of the Composition of Drilling/Hydraulic Fracturing/Flow Back Fluids

- Full Manifesting of Drilling Fluids/Frac Fluids

- Creation of Regional Centers to Address Issues Such as Finding Optimal Ways to Minimize the Cumulative Impacts of Shale Gas Development

- Sustained Research Support for Continual Improvement of Resource Recovery and Environmental Protection
Full Disclosure of Frac Fluids?

Last updated July 9, 2012

- Disclosure required*
- Proposed disclosure requirements
- Addressed in permit or not regulated
- Unable to classify
- Specific chemical exclusions
- Not in study

* Require volume disclosure: MD, MI, NM, OH, OK. Concentration disclosure: WY. Volume and concentration: AR, LA, MT, PA

Four SEAB Recommendations

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• Sustained Research Support for Continual Improvement of Resource Recovery and Environmental Protection
• Formerly Institute for Gas Drilling Excellence

• Achieved agreement on proactive action from operators, NGOs

• ~15 high-level performance-based standards for Pennsylvania (& Marcellus)

• Company-level certification*

• Establishment of regional centers

*Well site activities need to be certified (as well as the companies that carry them out)
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• Creation of Regional Centers to Address Issues Such as Finding Optimal Ways to Minimize the Cumulative Impacts of Shale Gas Development

• Sustained Research Support for Continual Improvement of Resource Recovery and Environmental Protection
• Review of Four SEAB Recommendations

• A Few Words About Well Construction, Aquifer Contamination and Methane Leakage
Governance of Well Construction Is a Major Issue

Table 16. Percentage of Experts Who Selected Accidents as a Priority for Additional Action

<table>
<thead>
<tr>
<th>Accidents</th>
<th>NGO</th>
<th>Industry</th>
<th>Academia</th>
<th>Gov’t</th>
<th>All Experts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement failure</td>
<td>80.0</td>
<td>58.7</td>
<td>57.1</td>
<td>66.7</td>
<td>63.3</td>
</tr>
<tr>
<td>Casing failure</td>
<td>68.6</td>
<td>46.7</td>
<td>61.9</td>
<td>57.1</td>
<td>56.7</td>
</tr>
<tr>
<td>Impoundment failure</td>
<td>71.4</td>
<td>33.3</td>
<td>61.9</td>
<td>45.2</td>
<td>50.2</td>
</tr>
<tr>
<td>Surface blowout</td>
<td>54.3</td>
<td>34.7</td>
<td>49.2</td>
<td>40.5</td>
<td>43.3</td>
</tr>
<tr>
<td>Storage tank spills</td>
<td>42.9</td>
<td>30.7</td>
<td>46.0</td>
<td>28.6</td>
<td>36.7</td>
</tr>
<tr>
<td>Truck accidents</td>
<td>37.1</td>
<td>40.0</td>
<td>34.9</td>
<td>28.6</td>
<td>35.8</td>
</tr>
<tr>
<td>Pipeline ruptures</td>
<td>42.9</td>
<td>30.7</td>
<td>38.1</td>
<td>33.3</td>
<td>35.3</td>
</tr>
<tr>
<td>Surface valve failure</td>
<td>40.0</td>
<td>21.3</td>
<td>27.0</td>
<td>26.2</td>
<td>27.0</td>
</tr>
<tr>
<td>Underground well comm.</td>
<td>37.1</td>
<td>14.7</td>
<td>28.6</td>
<td>23.8</td>
<td>24.2</td>
</tr>
<tr>
<td>Other spills</td>
<td>22.9</td>
<td>20.0</td>
<td>20.6</td>
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<td>21.4</td>
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<td>Hose bursts</td>
<td>22.9</td>
<td>17.3</td>
<td>14.3</td>
<td>16.7</td>
<td>17.2</td>
</tr>
<tr>
<td>Other fires or explosions</td>
<td>8.6</td>
<td>13.3</td>
<td>7.9</td>
<td>14.3</td>
<td>11.2</td>
</tr>
<tr>
<td>Other not listed here</td>
<td>8.6</td>
<td>5.3</td>
<td>11.1</td>
<td>2.4</td>
<td>7.0</td>
</tr>
<tr>
<td>All 14 accidents</td>
<td>40.6</td>
<td>27.2</td>
<td>34.2</td>
<td>30.8</td>
<td>32.2</td>
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<tr>
<td>Average # of accidents selected as high priority</td>
<td>5.69</td>
<td>3.81</td>
<td>4.79</td>
<td>4.31</td>
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Notes: Darkest red is the most often selected for each group, middle red is the second—most often selected, and light red is the third—most selected.
Governance of Well Construction Is a Major Issue

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Adopt best practices in well development and construction, especially casing, cementing, and pressure management. Pressure testing of cemented casing and state-of-the-art cement bond logs should be used to confirm formation isolation.

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GOOD MECHANICAL INTEGRITY:
No leaks in or behind the casing strings

CONDUCTOR PIPE
SURFACE CASING
PRODUCTION CASING
FRESH WATER AQUIFER ZONE
SHALLOW PRODUCING ZONE
INTERMEDIATE PRODUCING ZONE
TARGET PRODUCING ZONE

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Casing and Cementing Critical

Aquifers
Coal Seam
Saline Aquifer
Minor Gas Producing Shales
Top of Cement
Secondary Casing
Production Casing

Surface Casing at 500 ft.

API Recommended Practice

Additional Casing at 2000 ft. Provides Secondary Barrier to Leakage

Best Practice

George King, SPE 152596 (2012)
Cementing of Intermediate Casing?

Last updated July 9, 2012

Range Resources
Washington County, Pennsylvania

Well Construction
Well Construction
Well Construction
Natural Gas and the Transformation of the U.S. Energy Sector: Electricity

Jeffrey Logan, Garvin Heath, Jordan Macknick
National Renewable Energy Laboratory
Elizabeth Paranhos, William Boyd
University of Colorado Law School
Ken Carlson
Colorado State University
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