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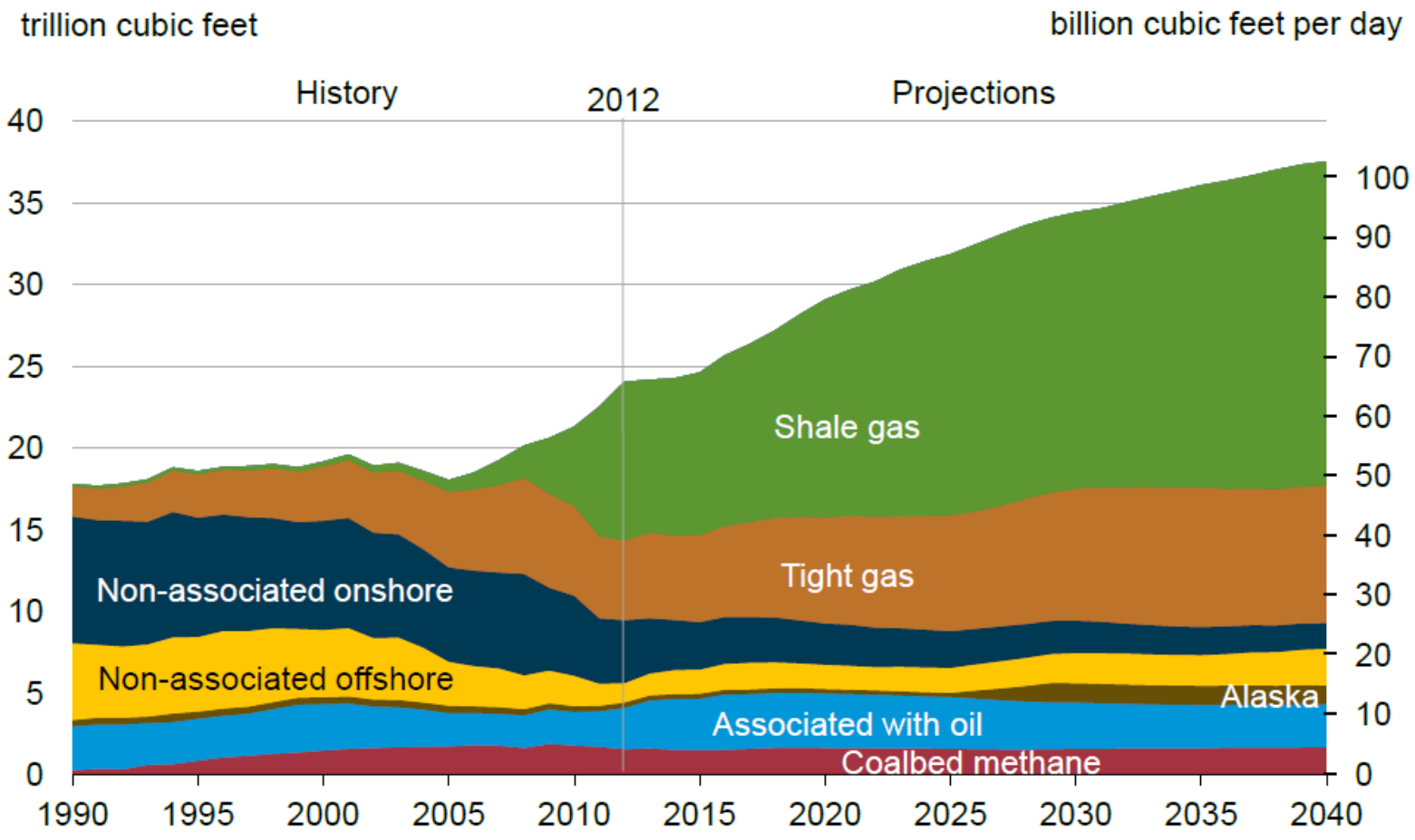
Shale Gas: What Regulators Need to Know

David J. Santley
Sr. Petroleum Specialist

US Dry Natural Gas Production



Source: EIA, Annual Energy Outlook 2014 Early Release

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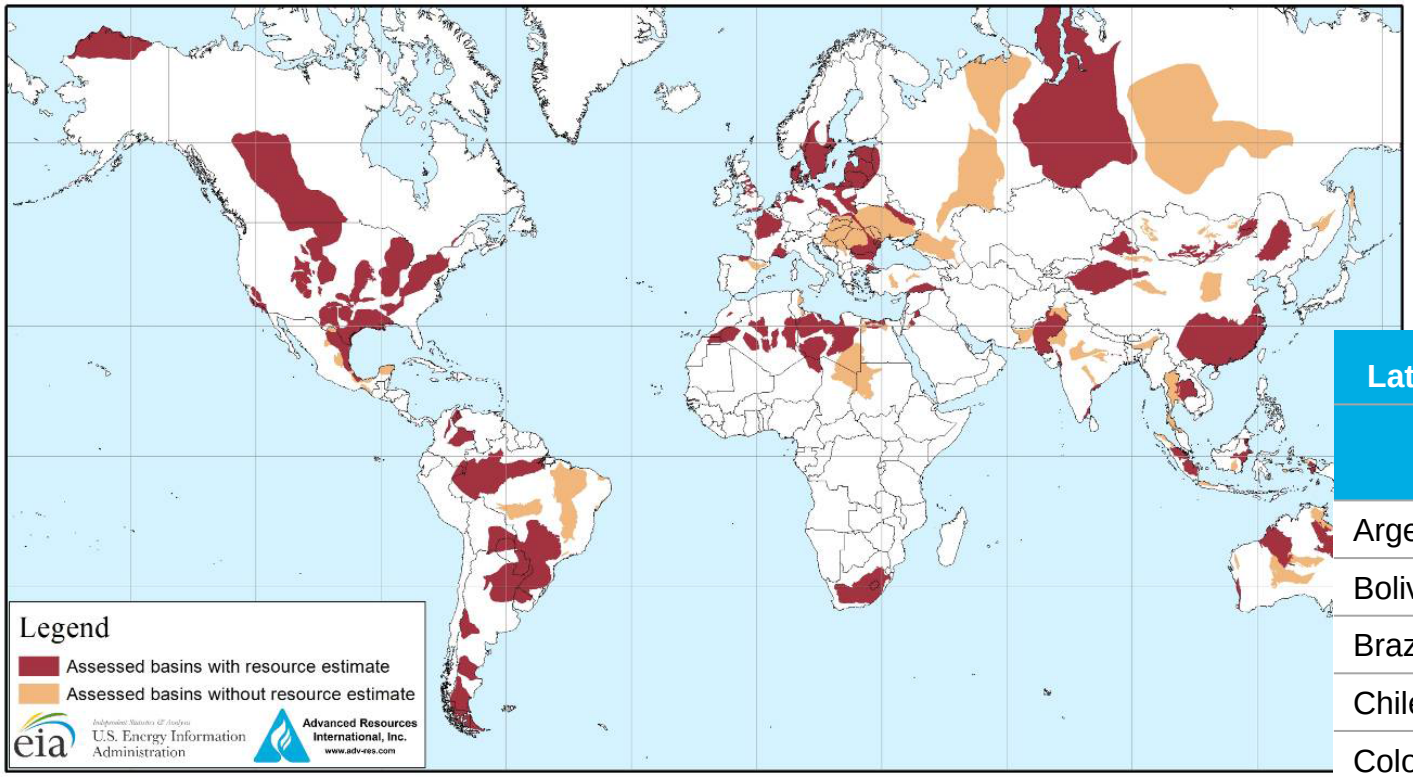
Technically Recoverable Shale Gas Resources



Latin America Shale Resources		
	Gas (TCF)	Oil (Bil Bbl)
Argentina	802	27.0
Bolivia	36	0.6
Brazil	245	5.3
Chile	48	2.3
Colombia	55	6.8
Mexico	545	13.1
Paraguay	75	3.7
Uruguay	2	0.6
Venezuela	167	13.4
TOTAL	**1,975**	**72.8**

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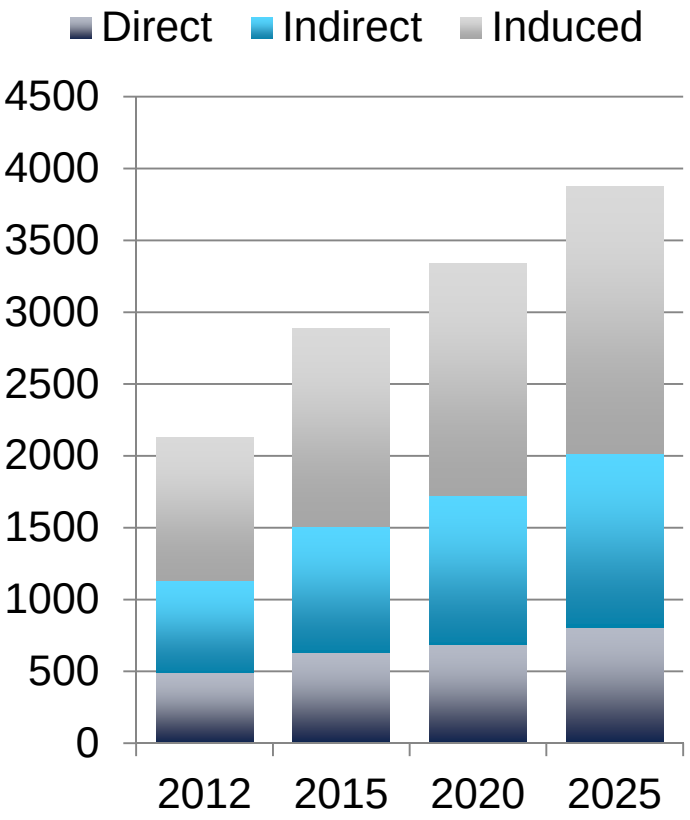
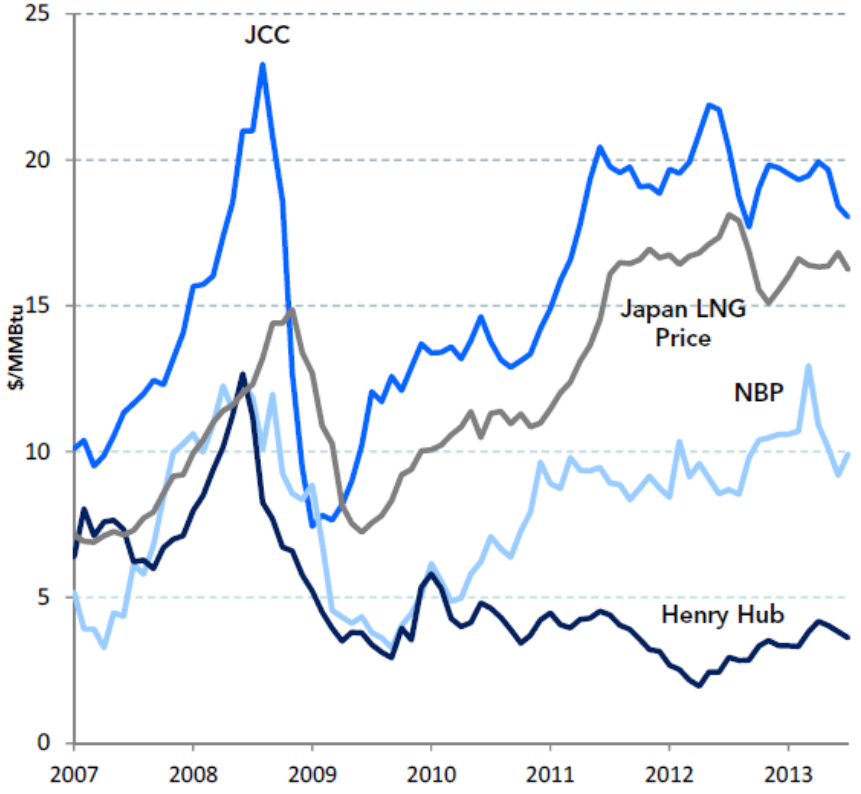
Economic Benefits

US Employment Contribution



Source: IHS

Regional Gas Price Comparison



Source: Poten & Partners

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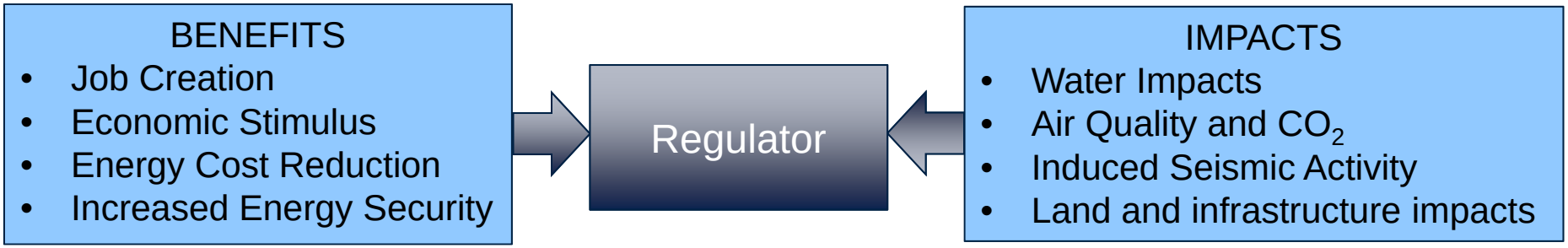
Regulators Are Under Pressure



The World Bank is Moving Cautiously

"Energy Directions" paper approved by WB Board in July 2013

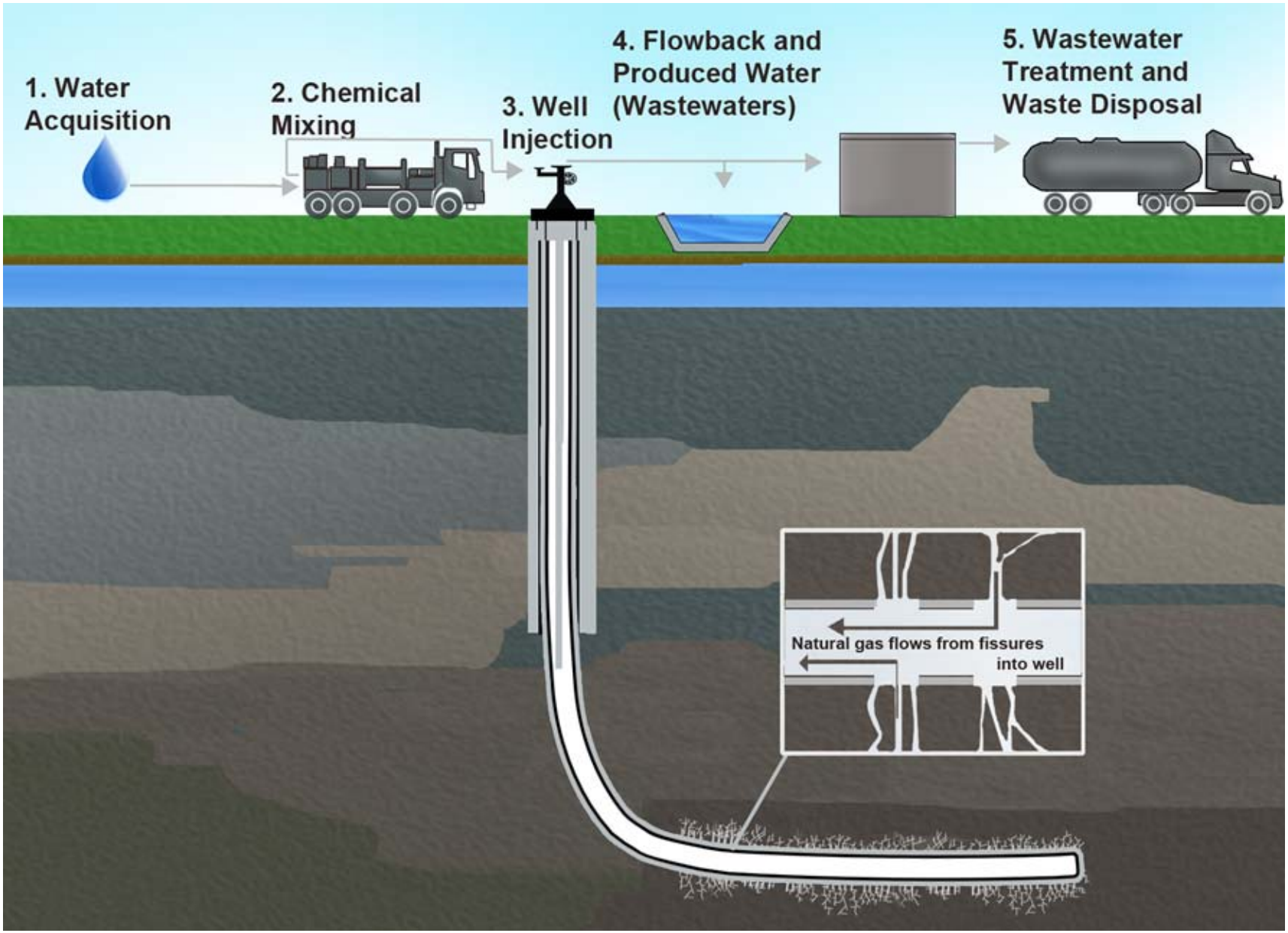
- Recognizes role of natural gas in reducing CO_2 emissions and assisting with implementation of renewable energy
- Calls for scaled up activities by the World Bank Group in natural gas
- Calls for increasing knowledge in the emerging technical and environmental elements surrounding unconventional gas

Shale Gas Workshop for regulators held in Washington in June 2013

- Researchers, US state regulators, and oil companies exchanging ideas with regulators from Latin America
- Next step: one-on-one dialog with client countries requesting assistance

But we remain cautious

- Shale gas development must be done responsibly or not at all


1. Water Acquisition
2. Chemical Mixing
3. Well Injection
4. Flowback and Produced Water (Wastewaters)
5. Wastewater Treatment and Waste Disposal
Natural gas flows from fissures into well

Source: EPA

Water Acquisition

- 5-30 million liters per well depending on shale properties
- Supply can come from surface water (Pennsylvania) or underground water (Texas)
- In Texas, fracking consumes 1% of water supply but locally this can reach 10-40%
- A typical well could require 1000 truck trips – traffic implications
- Use of re-cycled and non-potable water is increasing
- Best practice calls for tight coordination with local water supply plans and authorities

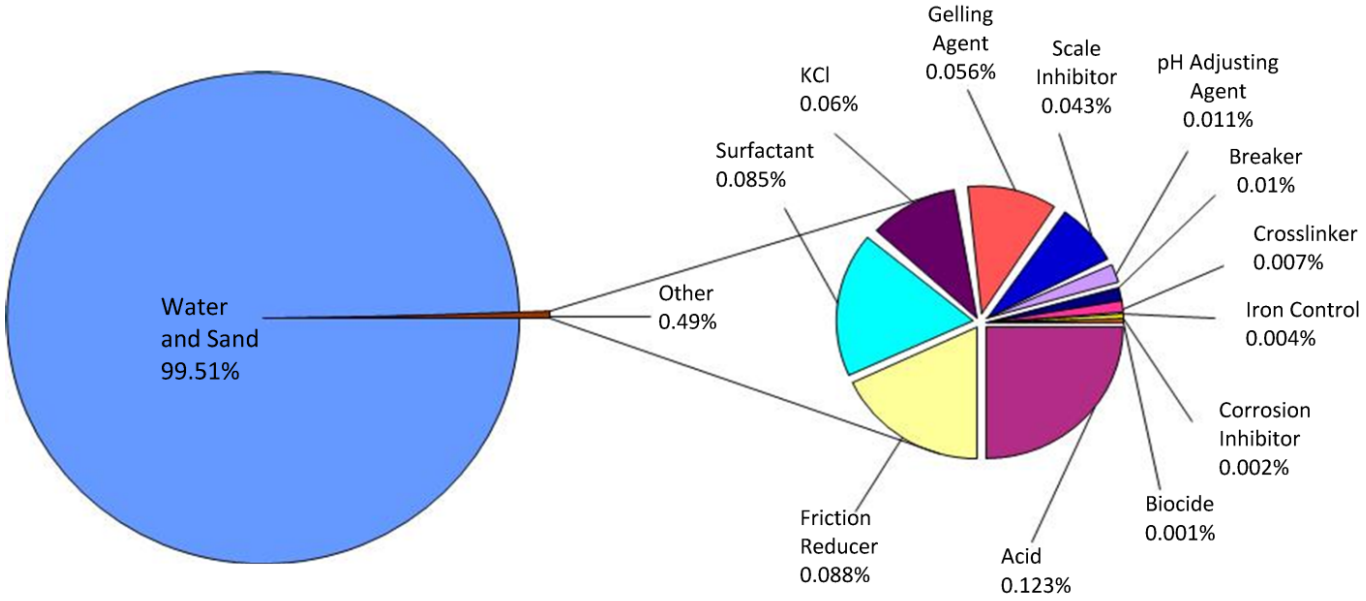
Texas: Eagle Ford 50 cm of precip/year

Pennsylvania: Marcellus 90 cm per year

Source: Robert Jackson

Chemicals Used in Fracking Fluid

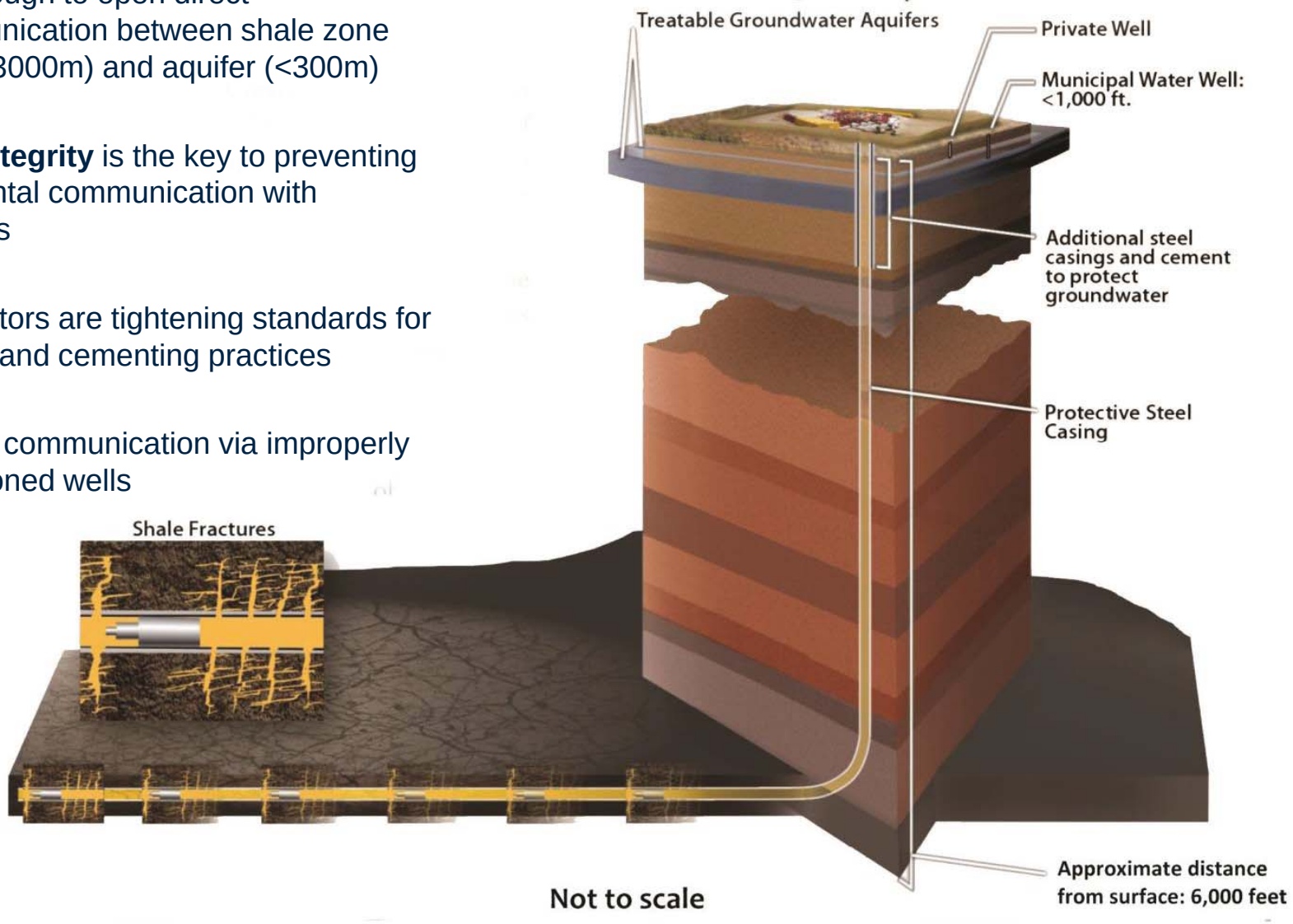
- Fracking fluid is >99% water and sand
- 600+ chemicals have been used, most of which are harmless (salt, citric acid)
- But use of carcinogens and hazardous pollutants have also been documented
- Regulators and industry are increasingly moving towards disclosure of chemicals



Source: US DOE

Well Injection

- Fracture pressure (5000-15000 psi) is not enough to open direct communication between shale zone (1000-3000m) and aquifer (<300m)
- **Well integrity** is the key to preventing accidental communication with aquifers
- Regulators are tightening standards for casing and cementing practices
- Risk of communication via improperly abandoned wells



Flow-back and Produced Water

- 20-70% of frack fluid flows back to the surface
- Produced water is saline (100,000-200,000 ppm) and may contain bromides, natural radioactive material, hydrocarbon, and toxic elements
- Alternatives to lined open pit storage being developed

Options for handling produced water

Preferred options
- Reinjection in disposal well (>95%)
- Disposal at commercial wastewater treatment plant
- Re-use in subsequent fracking operations

Bad ideas
- Spraying on land
- Disposal at municipal wastewater treatment plant

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Emissions and Air Quality Issues

- Level of fugitive methane emissions from shale gas is very controversial
- EPA: 1.5-2.4% of production gas leaks into atmosphere of which <.5% from production
- Break-even vs. coal is 3.2% – methane leakage offset combustion benefits
- 2015 EPA requirement for “green completions” – enhanced gas separation during flow-back
- Recent studies point out local health effects for residents near wells – more study needed

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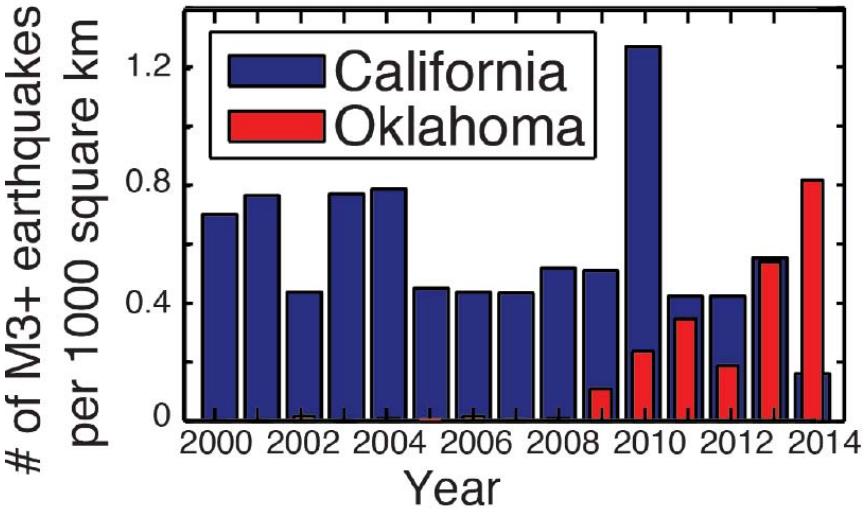
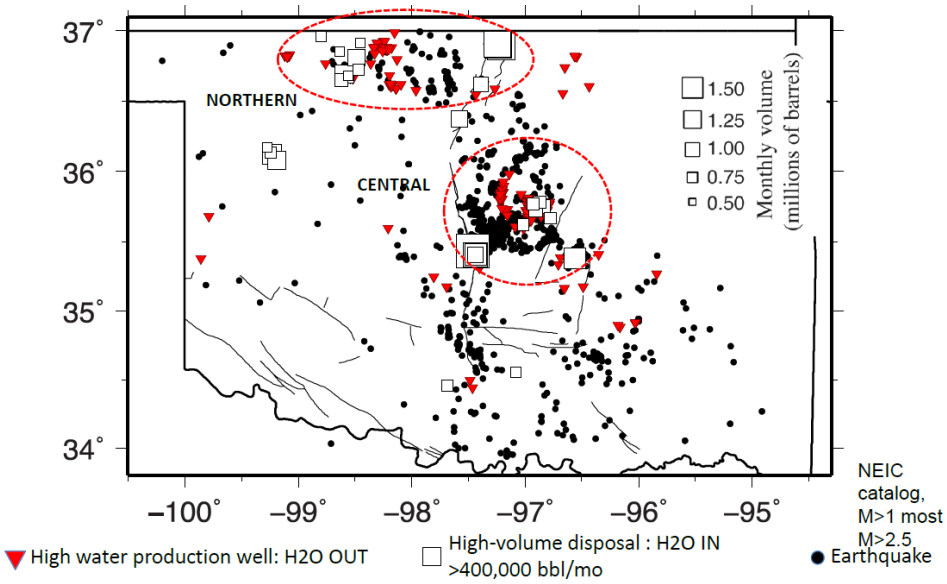
Induced Seismic Activity

- Increased seismic activity in Oklahoma has been traced to high-volume water disposal wells
- Best practice advice is to avoid high-volume disposal near large faults
- Very few documented cases of earthquakes linked to fracturing operations

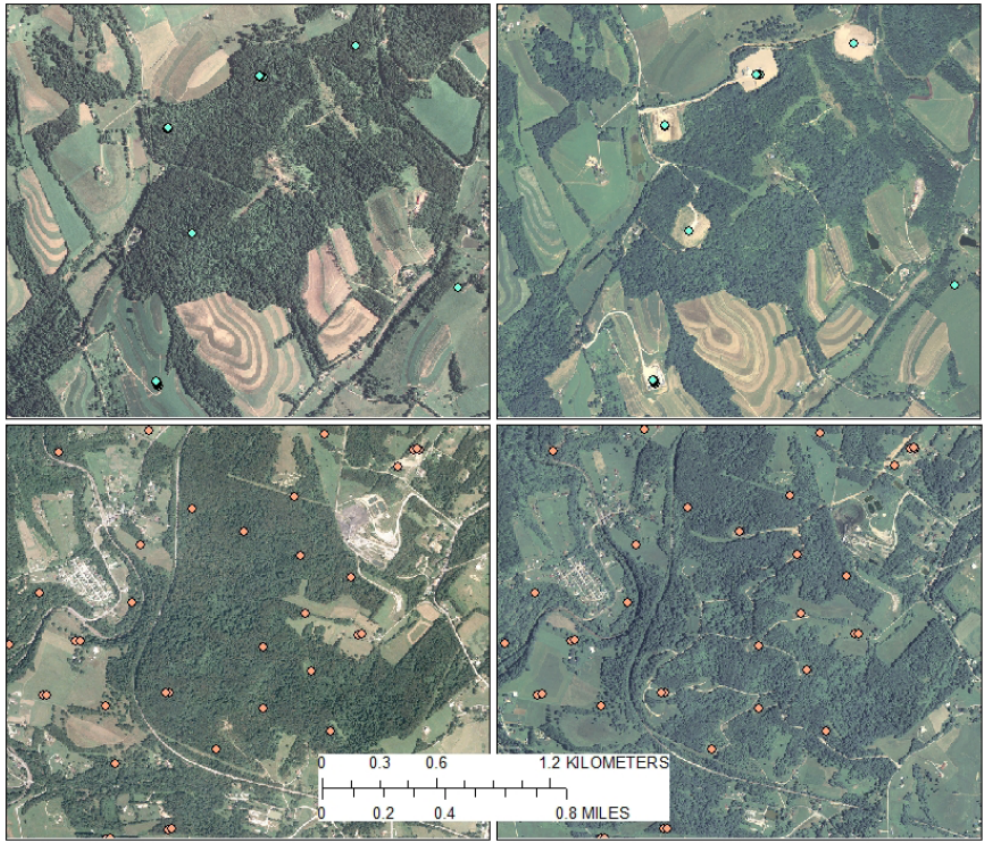




Source: Katie Keranen

Land Impacts

- Wellpad occupies approx. 2 hectares
- Potential alteration of ecosystems and wildlife habitats
- Traffic issues: congestion, accidents, road degradation
- Best practice: planned development, careful well-site selection, use of existing right-of-ways
- Increasing use of piped water



Source: David Yoxthiemer

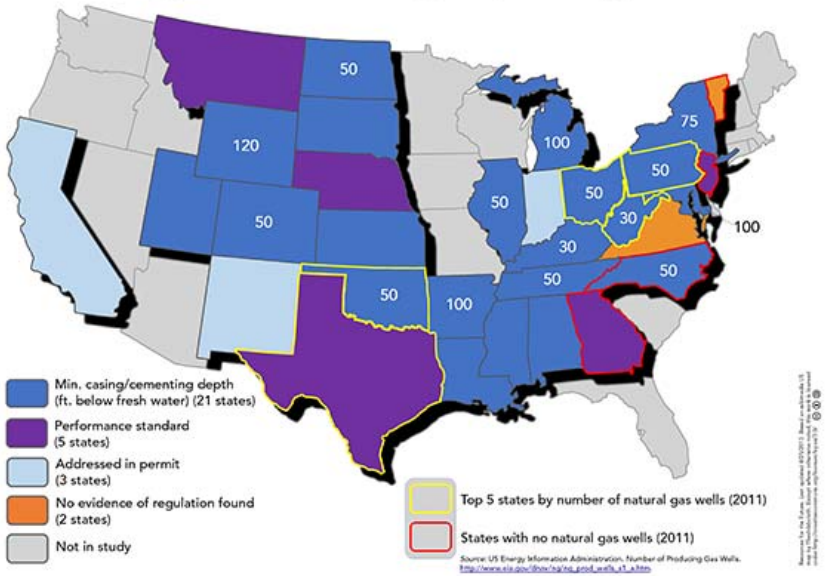
Key Lessons from the US Regulatory Experience

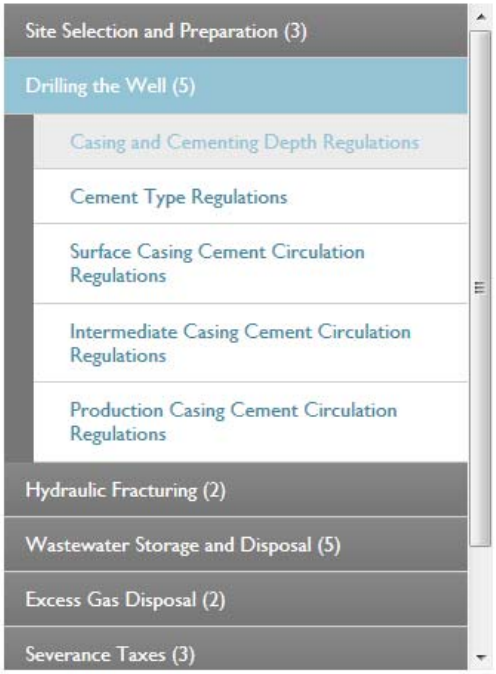
- Responsible exploitation of shale gas requires cooperation and trust between industry and regulator
- Reputable companies willingly assume their side of the bargain to protect the environment and the communities in which they operate
- Regulators must act with transparency, integrity and predictability
- Regulators can manage the pressures from pro-fracking and anti-fracking camps by educating themselves on the fundamental science
- Capacity building is the biggest challenge, particularly in countries with no experience in conventional oil and gas exploitation

Center for Energy Economics and Policy

A Review of Shale Gas Regulations by State

http://www.rff.org/centers/energy_economics_and_policy/Pages/Shale_Maps.aspx





Casing and Cementing Depth Regulations

Casing is steel pipe of varying diameter that separates the wellbore from surrounding rock. Cement is circulated within the gap (annulus) between each layer of casing. Almost all surveyed states regulate the depth to which well casing must extend and be cemented. Of those, 21 have specific casing and cementing requirements; 15 of these require casing to be set and cemented to a specified minimum depth below the base of layers or zones containing freshwater—between 30 and 120 feet, with an average of about 64 feet.

http://fracfocus.org/

http://www2.epa.gov/hfstudy

EPA United States Environmental Protection Agency

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EPA's Study of Hydraulic Fracturing for Oil and Gas and Its Potential Impact on Drinking Water Resources

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At the request of Congress, EPA is conducting a study to better understand any potential impacts of hydraulic fracturing for oil and gas on drinking water resources. The scope of the research includes the full lifespan of water in hydraulic fracturing. The progress report was released in December 2012 and a draft report is expected to be released for public comment and peer review in 2014.

What is the hydraulic fracturing water cycle?

Key Links

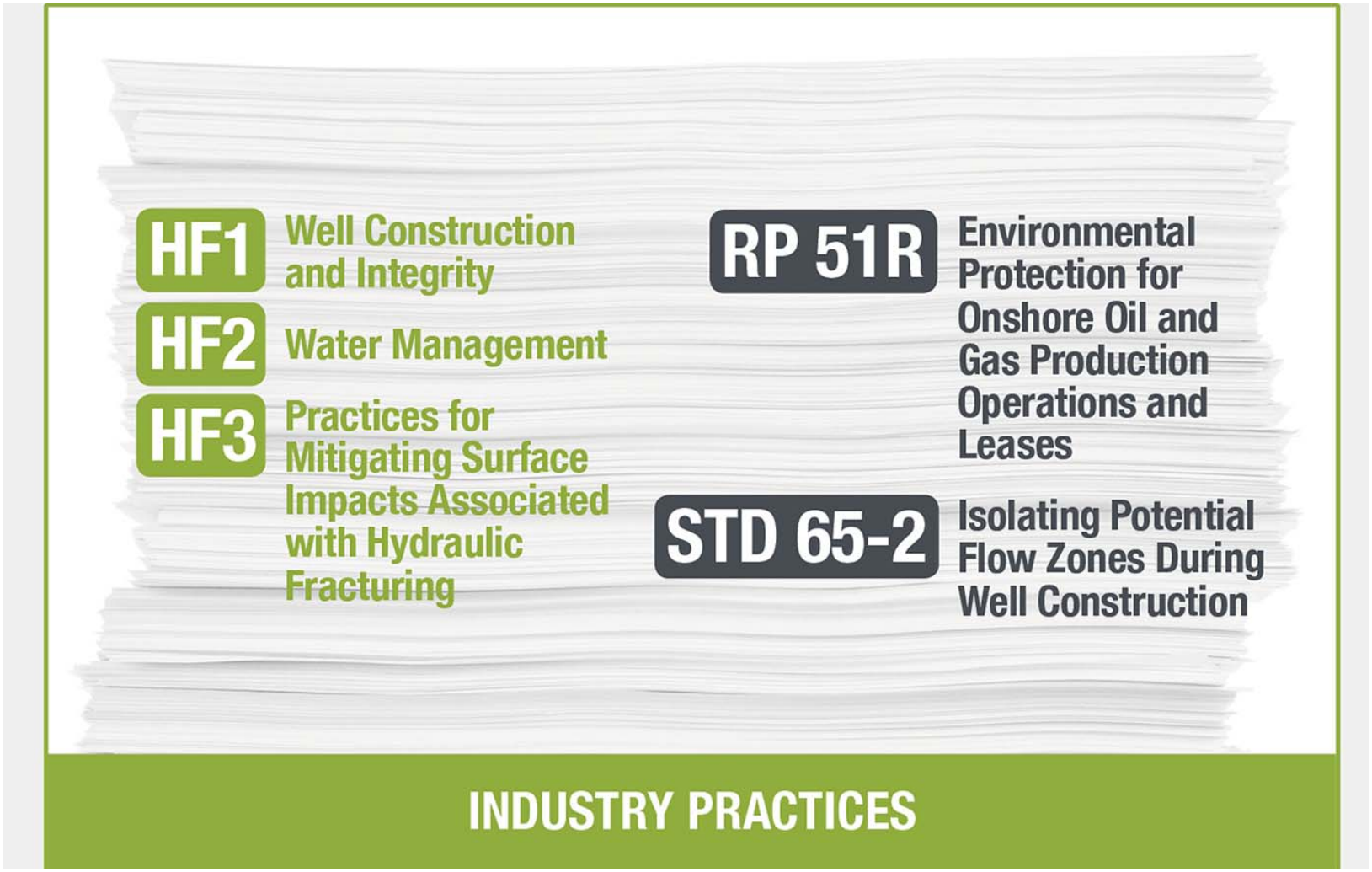
- Published Scientific Papers
- 2013 Technical Roundtable
- Progress Report 2012
- Questions and Answers

Latest News

- Check out our published scientific papers. More papers coming soon!

energy API
AMERICAN PETROLEUM INSTITUTE

http://www.api.org/policy-and-issues/hf



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http://www.dnv.com/industry/oil_gas/services_and_solutions/technical_advisory/process_integrity/gas_consulting/shale_gas/

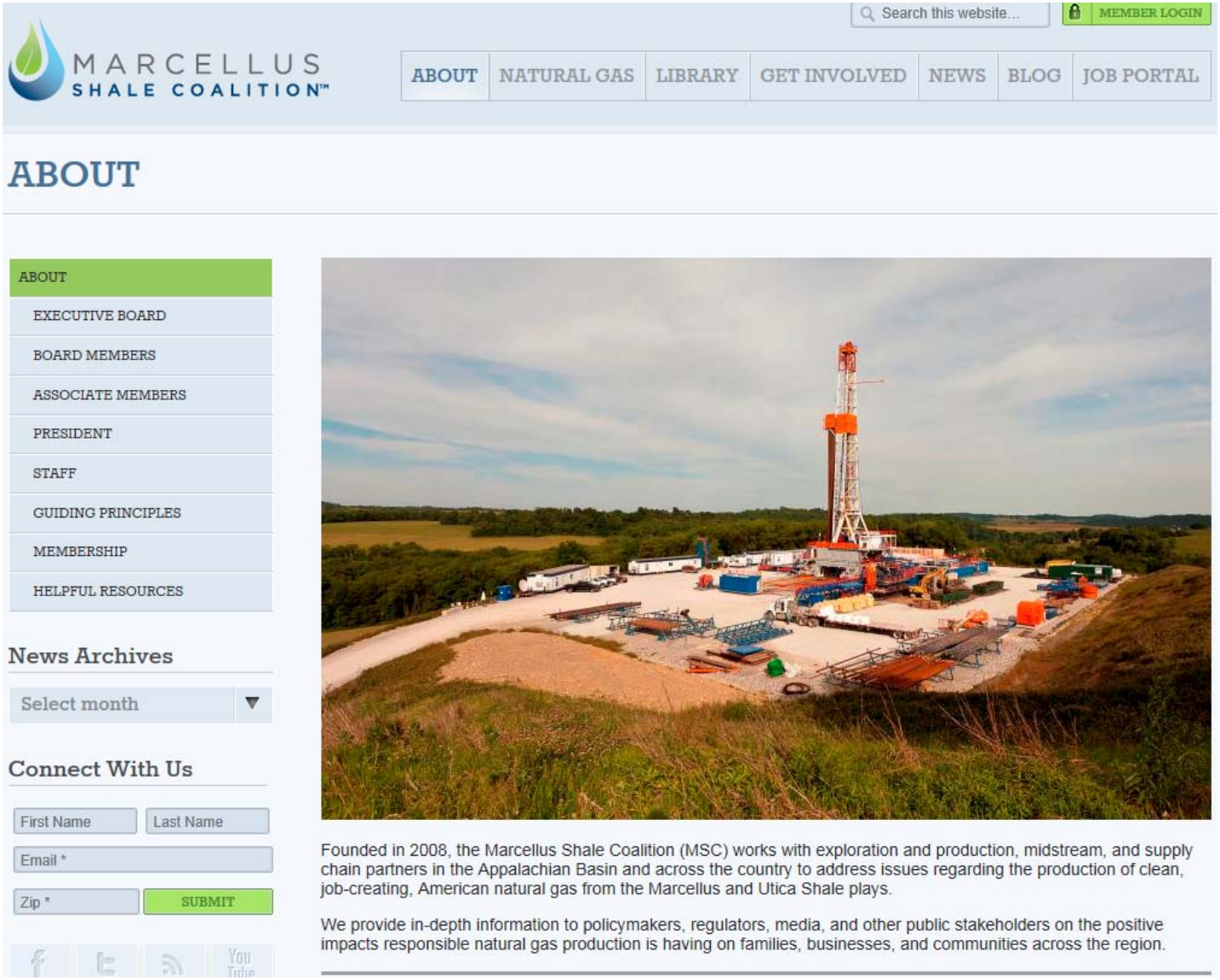
RECOMMENDED PRACTICE

DNV-RP-U301

Risk Management of Shale Gas Developments and Operations

JANUARY 2013

http://marcelluscoalition.org/



http://www.marcellus.psu.edu/

U.S. Department of Energy • Office of Fossil Energy
National Energy Technology Laboratory

State Oil and Natural Gas Regulations Designed to Protect Water Resources

GROUNDWATER PROTECTION COUNCIL

NETL

U.S. DEPARTMENT OF ENERGY

http://www.gwpc.org/sites/default/files/state_oil_and_gas_regulations_designed_to_protect_water_resources_0.pdf

ENVIRONMENTAL Science & Technology

Critical Review

pubs.acs.org/est

A Critical Review of the Risks to Water Resources from Unconventional Shale Gas Development and Hydraulic Fracturing in the United States

Avner Vengosh,*[†] Robert B. Jackson,[†,‡] Nathaniel Warner,[§] Thomas H. Darrah,[∥] and Andrew Kondash[†]

ENVIRONMENTAL Science & Technology

Critical Review

pubs.acs.org/est

Air Impacts of Increased Natural Gas Acquisition, Processing, and Use: A Critical Review

Christopher W. Moore,*[†] Barbara Zielinska,[†] Gabrielle Pétron,[‡,§] and Robert B. Jackson[∥,⊥]

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Thank you!