Fracking:
Drilling into the Evolving Risks

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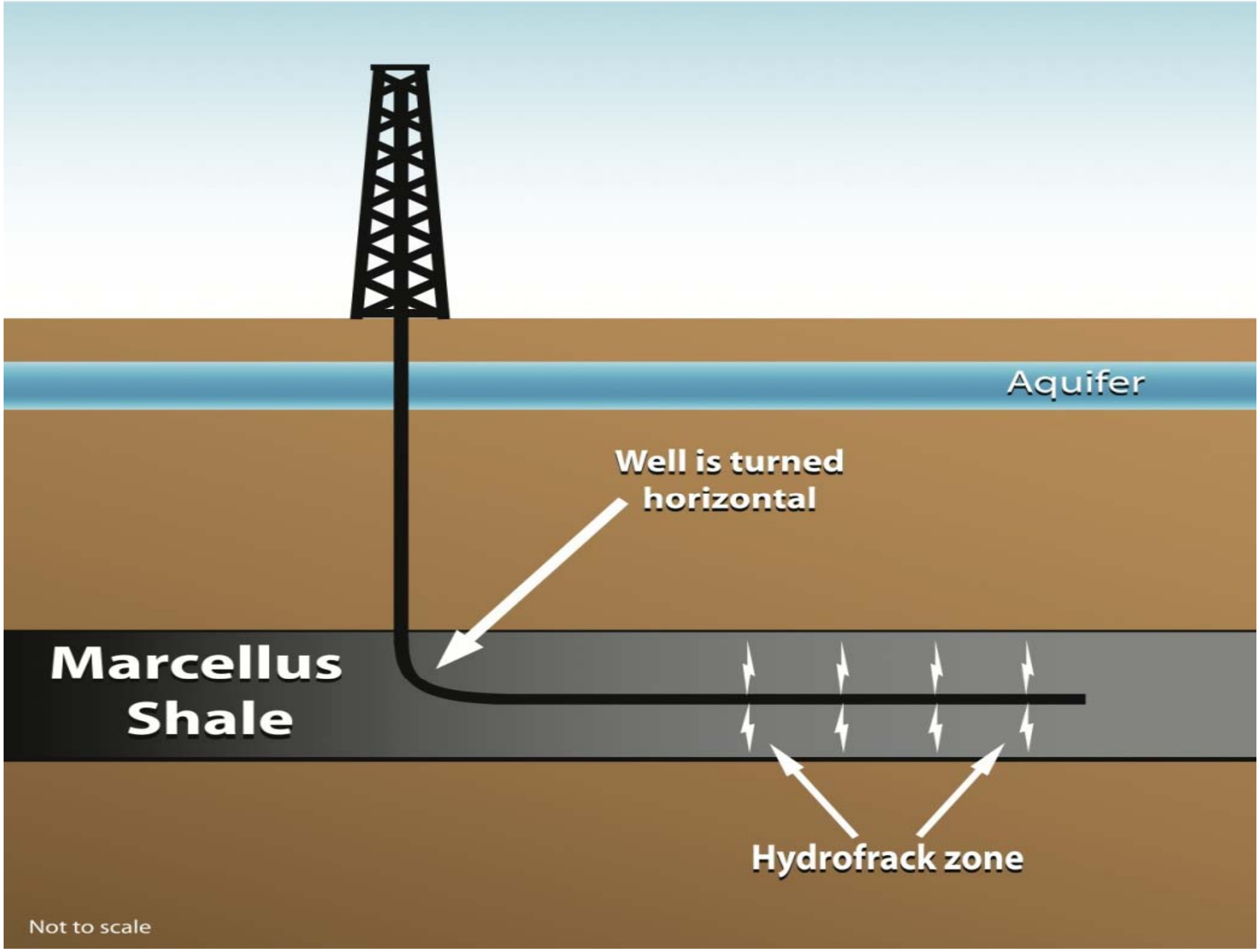
Summary of Presentation:

1. Description of the technology and its evolution
2. The economics and different types of fracking
3. The state of the law and litigation
4. The state of the science
5. Closing

What is “fracking?”

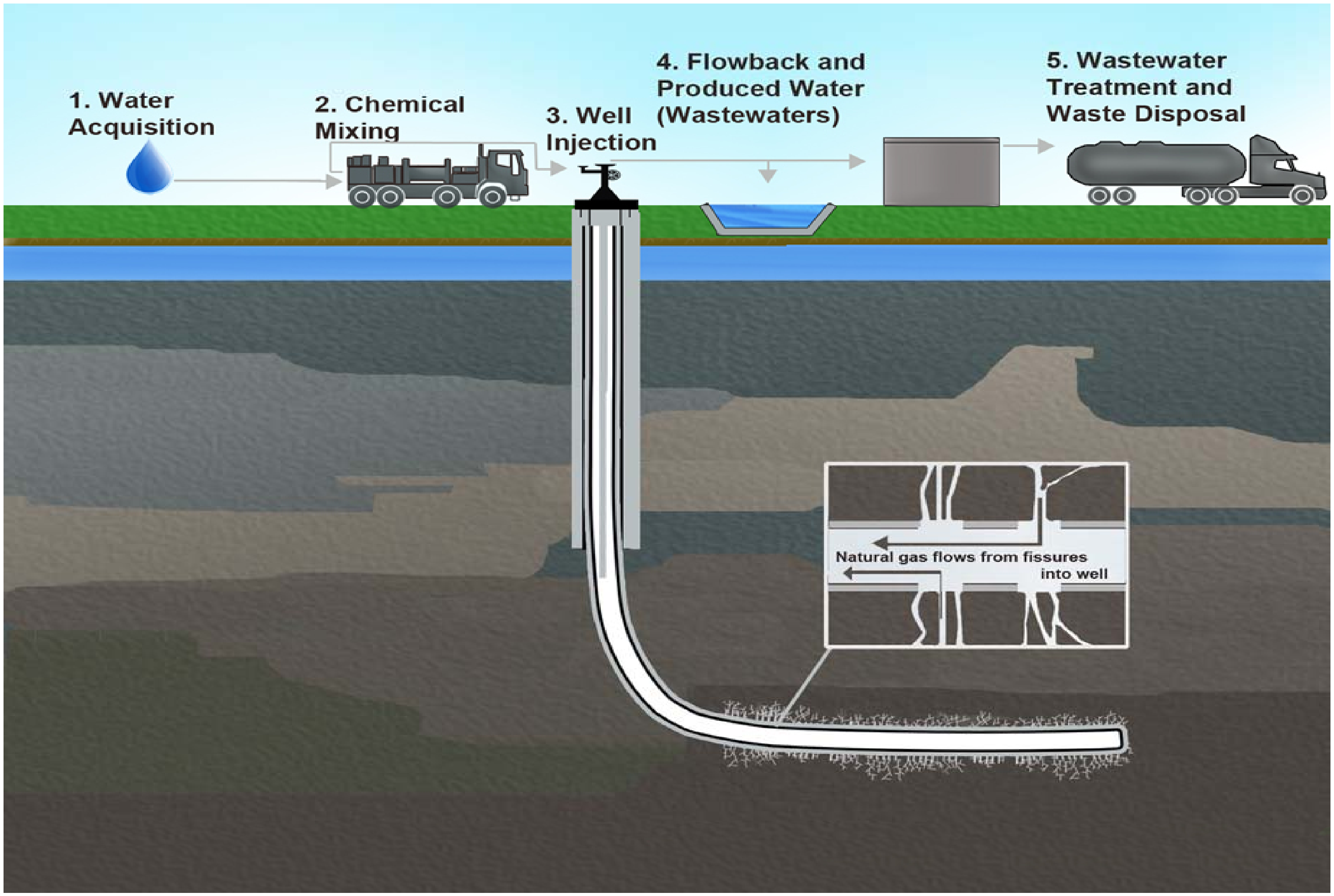
- Method for extracting oil & gas trapped in deep rock
- Combines vertical & horizontal drilling of wells (“conventional”) with hydraulic fracturing of rock (“unconventional”) to release oil & gas into wells
- Typically uses water, chemicals, and sand to fracture & then “prop” open the rock

How is it done?



Source: http://blogs.cas.suffolk.edu/seveilleux/2012/02/09/natural-gas-hydraulic-fracturing-hydrofracking/ (Feb. 9, 2012)

Water and wastewater intensive

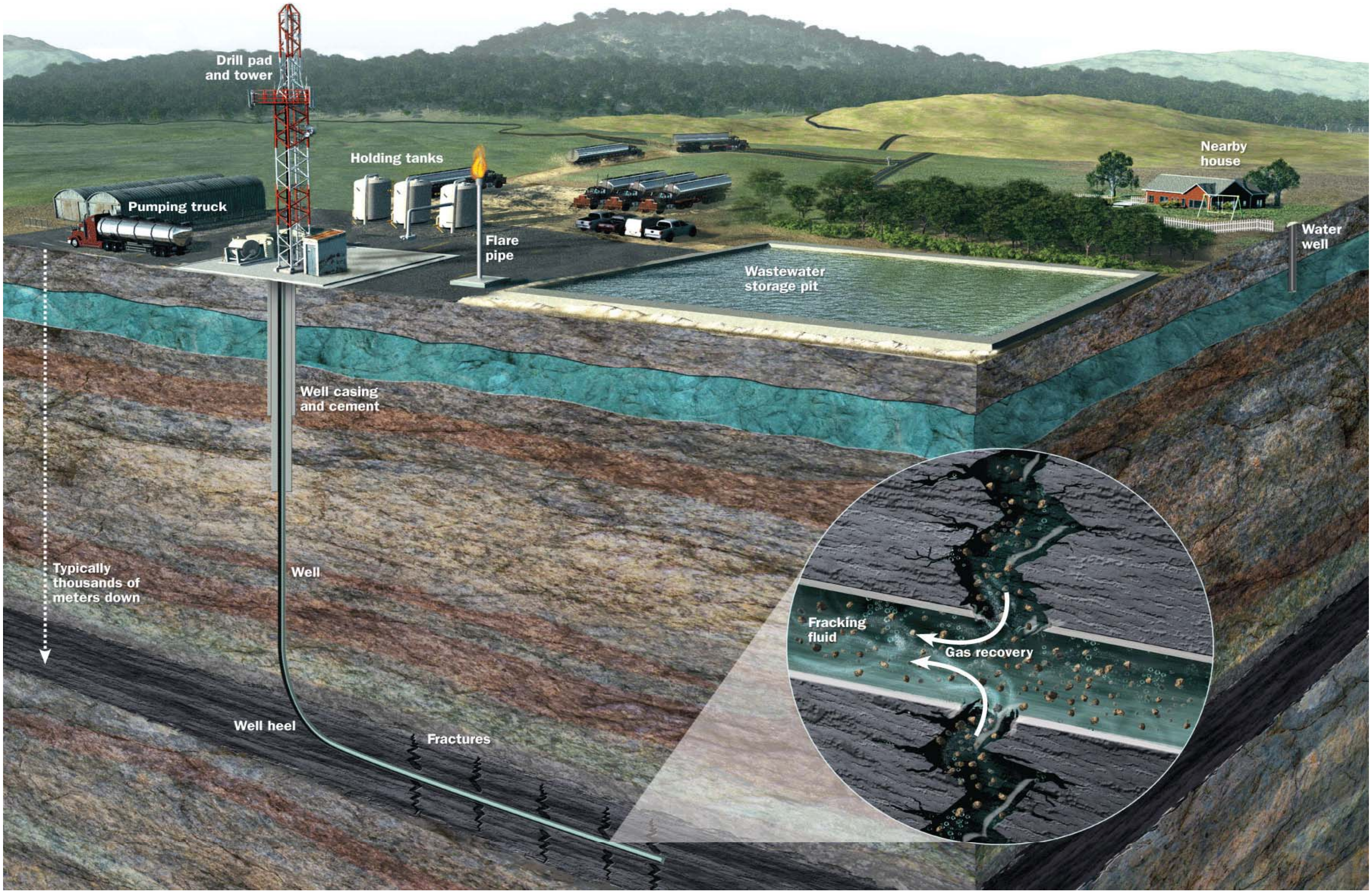


Source: EPA, http://www2.epa.gov/hfstudy/hydraulic-fracturing-water-cycle (last updated Sept. 19, 2013)

Conventional versus Marcellus Shale Gas Development*

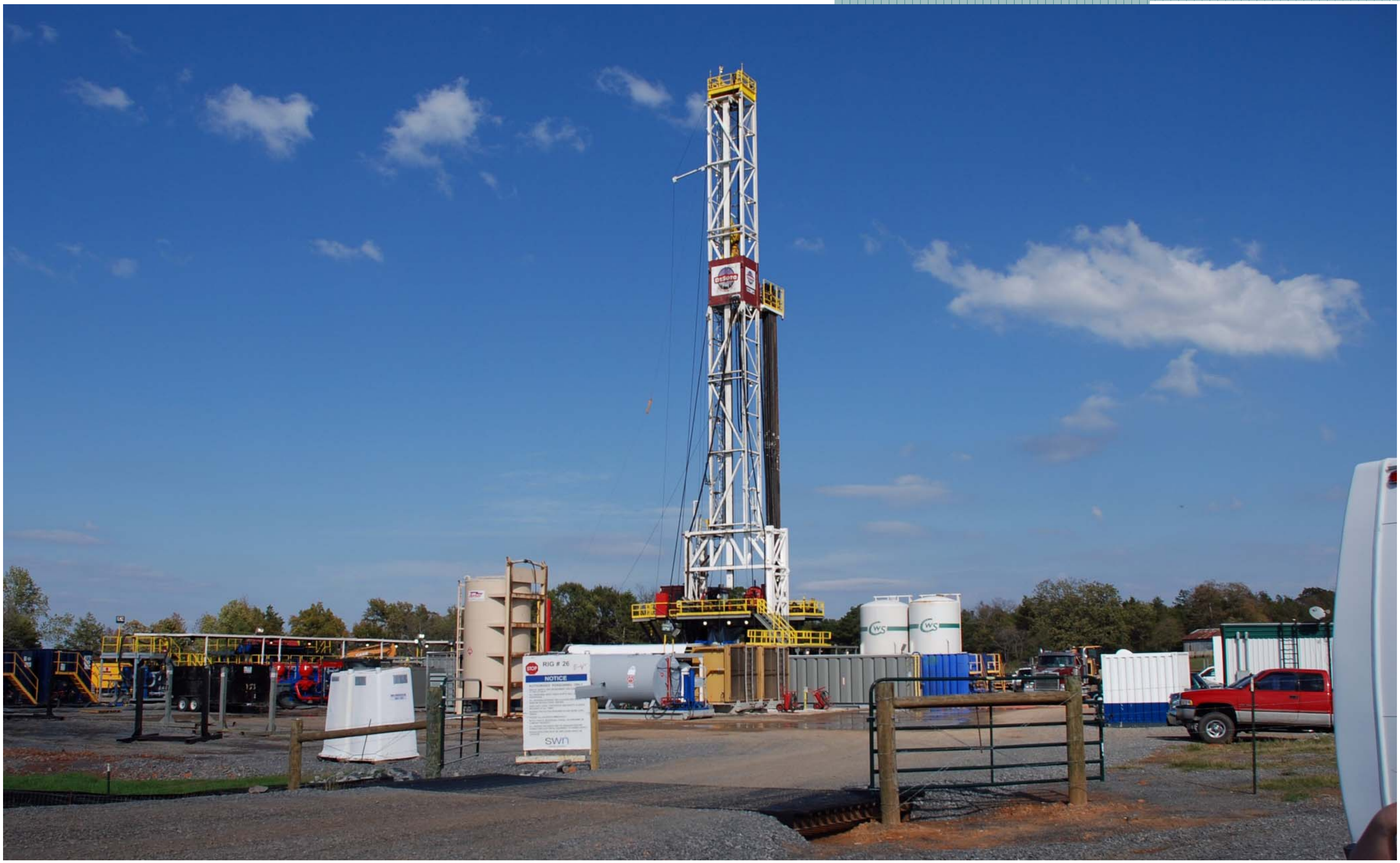
	Conventional	Marcellus Shale
Drilling:		
Water Use	116,514 gallons	199,924 gallons
Steel	55 metric tons	145 metric tons
Cement	115 metric tons	239 metric tons
Diesel Fuel	24,300 gallons	55,080 gallons
Fracking:		
Water Use	-	3.8 – 5.5 million gallons
Sand	-	6 million pounds
Chemicals	-	5,709 gallons

* Numbers from Argonne National Research Lab, DOE, December 2011



Source: http://greenplug.nu/hydraulic-fracturing-what-is-hydraulic-fracturing/ (April 25, 2013)

A water impoundment at a drill pad in the Fayetteville Shale gas play of Arkansas. The water will be used in the hydraulic fracturing process, where it will be combined with chemicals and sand, then used to create artificial fractures in gas-bearing rocks to allow the gas to be recovered. Source: U.S. Geological Survey/Photo by Bill Cunningham, available at http://energy.usgs.gov/GeneralInfo/HelpfulResources/MultimediaGallery/HydraulicFracturingGallery.aspx



A drill rig at a drill pad in the Fayetteville Shale gas play. The drill rig is used to drill the vertical and directional wells prior to the hydraulic fracturing process. Source: U.S. Geological Survey/Photo by Bill Cunningham, available at http://energy.usgs.gov/GeneralInfo/HelpfulResources/MultimediaGallery/HydraulicFracturingGallery.aspx

Well Casing and Cementing

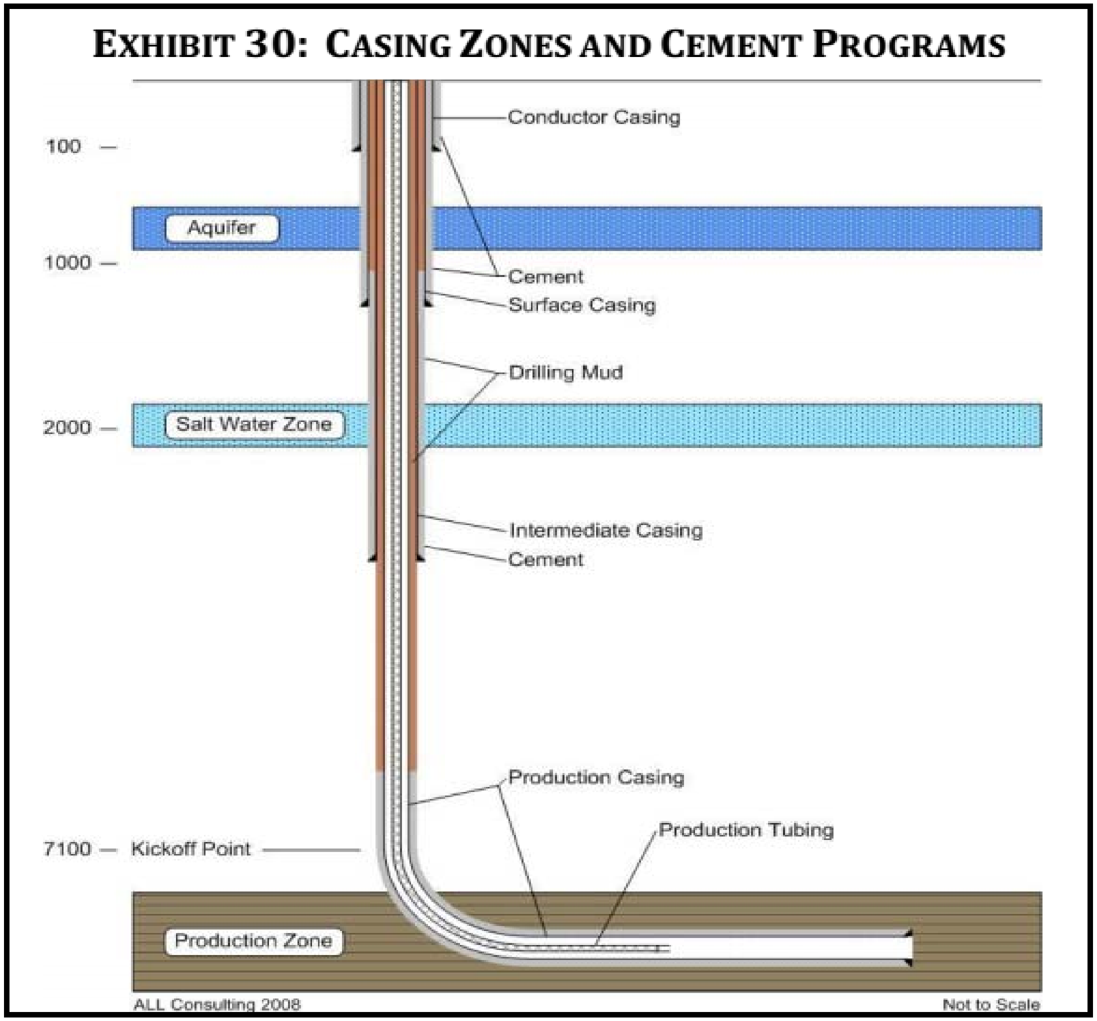


Image: Schematic of a typical well used for hydraulic fracturing (Ground Water Protection Council & ALL Consulting, 2009)

Four well heads at a drill pad in the Fayetteville Shale gas play of Arkansas. A hydraulic fracturing operation is underway. A mixture of water, chemicals, and sand is pumped into the well heads from the connecting pipes and then sent under high pressure into the shale formation to create artificial fractures. The dust in the background is from sand being added to the hydraulic fracturing fluid.
Source: U.S. Geological Survey/Photo by Bill Cunningham, available at
http://energy.usgs.gov/GeneralInfo/HelpfulResources/MultimediaGallery/HydraulicFracturingGallery.aspx

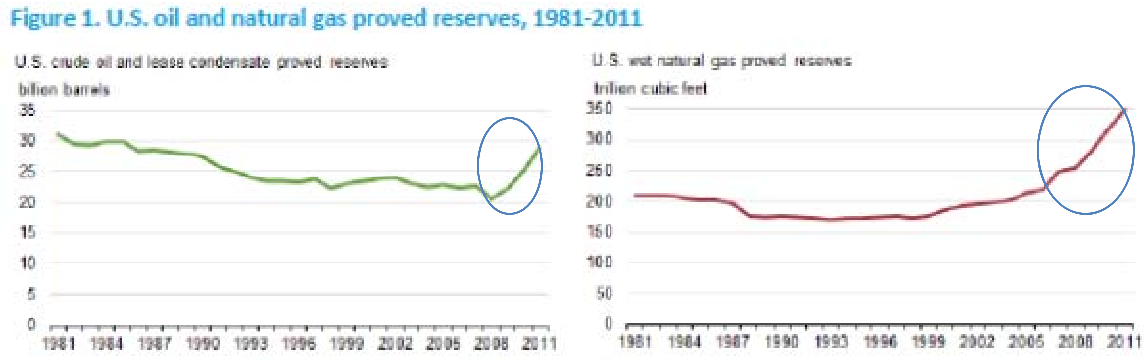
Table 2. Types of Additive, Example Chemicals, And Their Purpose in the Hydraulic Fracturing Process[a]

additive	example chemical	purpose
acid	hydrochloric or muriatic acid	helps dissolve minerals and initiate cracks in the rock
antibacterial agent	glutaraldehyde	eliminates bacteria in the water that produces corrosive byproducts
breaker	ammonium persulfate	allows a delayed break down of the fracturing gel
clay stabilizer	potassium chloride	brine carrier fluid
corrosion inhibitor	n,n-dimethyl formamide	prevents corrosion of pipes
cross-linker	borate salts	maintains fluid viscosity
defoamer	polyglycol	lowers surface tension and allows gas escape
foamer	acetic acid (with NH_4 and $NaNO_2$)	reduces fluid volume and improves proppant carrying capacity
friction reducer	petroleum distillate	minimizes friction in pipes
gel guar gum	hydroxyethyl cellulose	helps suspend the sand in water
iron control	citric acid	prevents precipitation of metal oxides
oxygen scavenger	ammonium bisulfate	maintains integrity of steel casing of wellbore; protects pipes from corrosion by removing oxygen from fluid
pH adjusting agent	sodium or potassium carbonate	adjusts and controls pH of the fluid
proppant	silica, sometimes ceramic particles	holds open (props) fractures to allow gas to escape from shale
scale inhibitor	ethylene glycol	reduces scale deposits in pipe
solvents	stoddard solvent, various aromatic hydrocarbons	improve fluid wettability or ability to maintain contact between the fluid and the pipes
surfactant	isopropanol	increases viscosity of the fracturing fluids and prevents emulsions

Source: Adgate, Goldstein, and Mckenzie, *Potential Public Health Hazards, Exposures, and Health Effects from Unconventional Natural Gas Development*, Environmental Science and Technology (Feb. 24, 2014), *available at* http://pubs.acs.org/doi/abs/10.1021/es404621d

Shale Gas, Tight Oil, and the US Energy Renaissance

Source: Wikimedia Commons – Lvklock



Source: EIA (2013): Annual Energy Outlook

Table 1. Comparison of the 2011 and 2013 reports

ARI report coverage	2011 Report	2013 Report
Number of countries	32	41
Number of basins	48	95
Number of formations	69	137
Technically recoverable resources, including U.S.		
Shale gas (trillion cubic feet)	6,622	7,299
Shale / tight oil (billion barrels)	32	345

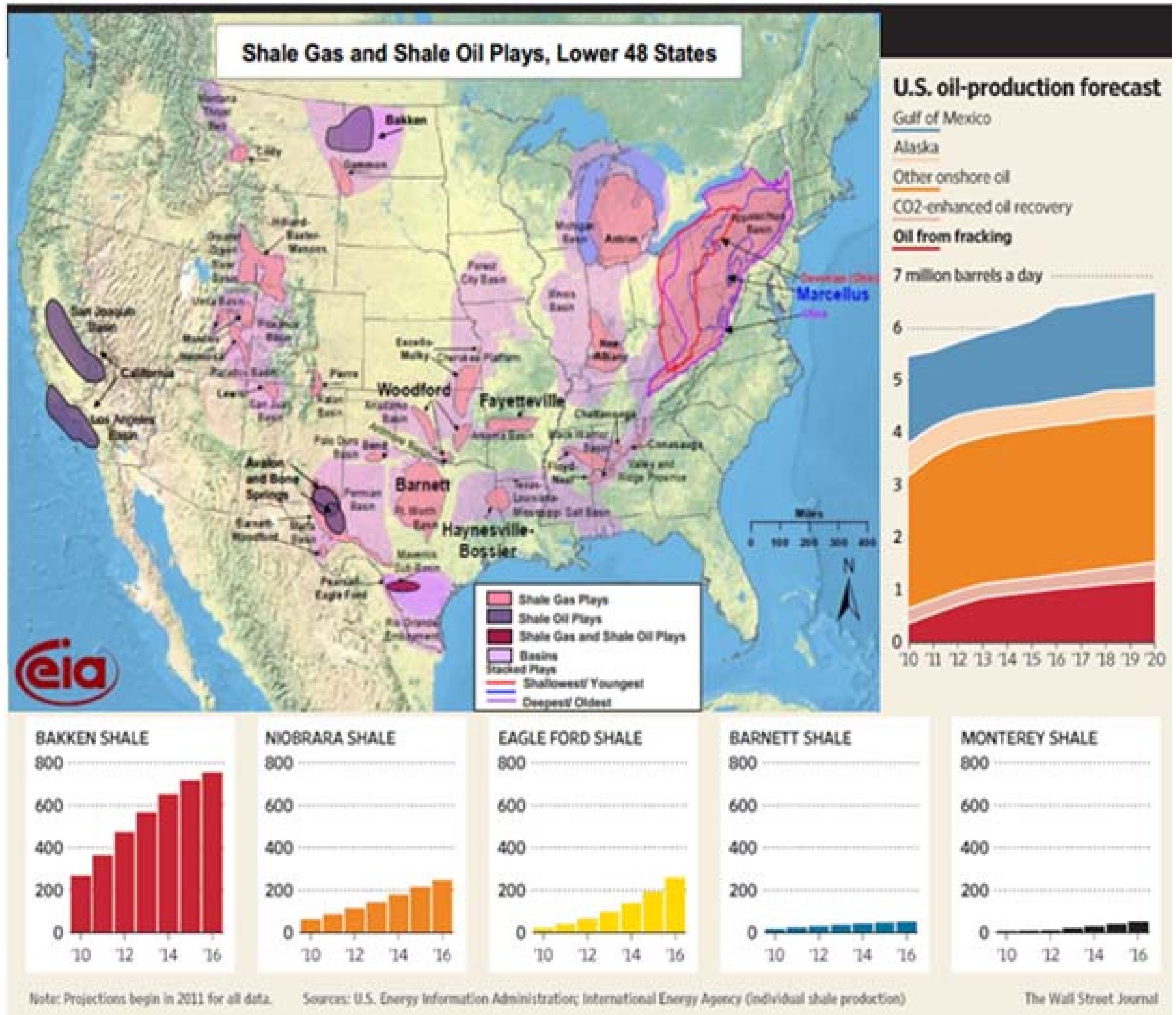
Note: The 2011 report did not include shale oil; however, the *Annual Energy Outlook 2011* did and is included here for completeness.

Source: EIA (2013): Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States

- Shale gas unlocked by fracking accounted for 40% of production in 2012
- Crude oil in tight formations unlocked by fracking now redrawing the world energy map

US Shale Energy: Present and Future

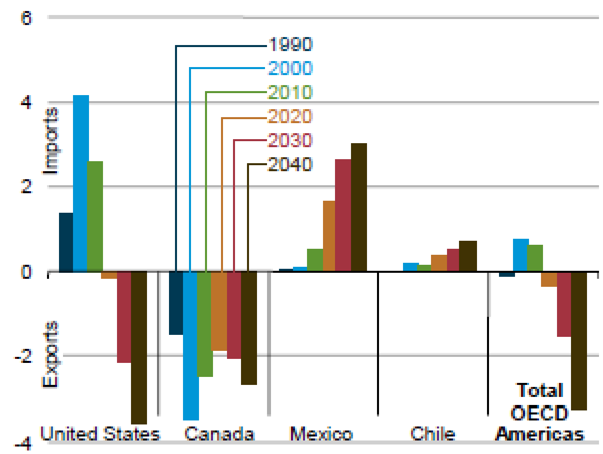
- Most US shale activity in low pop. density areas
  - Current exceptions: Colorado front range, Ohio, Pennsylvania, Dallas and San Antonio areas
- Is California next?
  - Monterey Shale at twice the size of Bakken and Eagle Ford combined
  - Regulatory, political, and technical difficulties
- Fracking for oil and gas offshore is also occurring…



Why is Shale Energy a "Big Deal"?

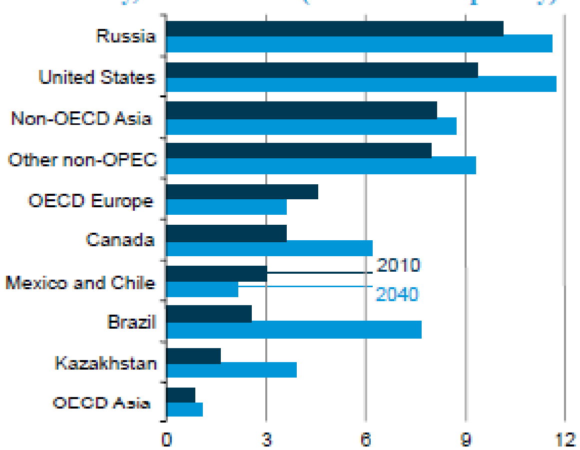
- The US will soon export liquified natural gas. As of Sept. 2013, applications for 34 bcf/d in LNG terminal capacity
- Shift to gas-fired electricity generation
- Strong possibility of US becoming net oil exporter by 2040

Figure 60. OECD Americas net natural gas trade, 1990-2040 (trillion cubic feet)



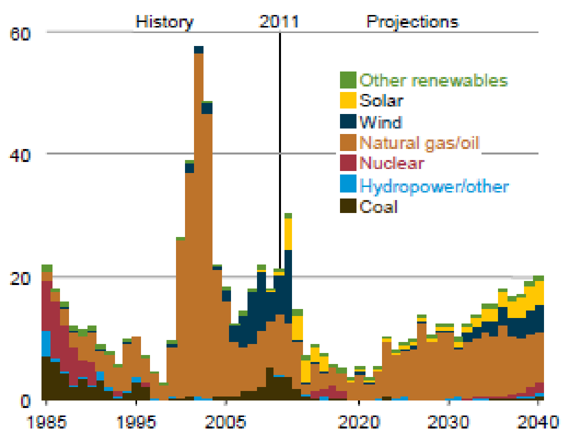
Source: EIA (2013): Annual Energy Outlook

Figure 31. Non-OPEC liquids production by region and country, 2010 and 2040 (million barrels per day)



Source: EIA (2013): Annual Energy Outlook

Figure 78. Additions to electricity generating capacity, 1985-2040 (gigawatts)



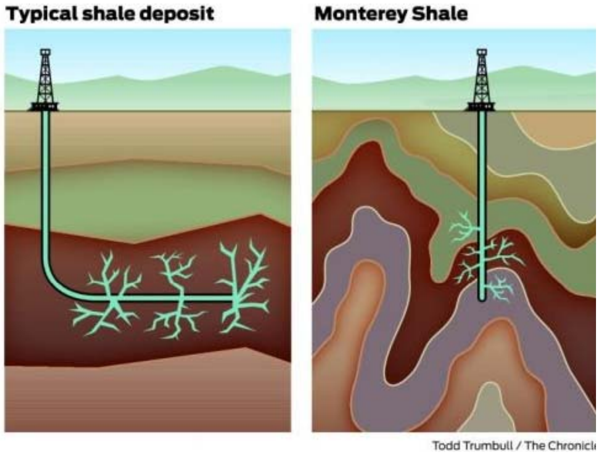
Source: EIA (2013): Annual Energy Outlook

Source: IHS CERA, as cited by Smith 2013
http://www.energyburrito.com/lng-exports-and-all-that-gubbins-part-1/

Shale Oil and Shale Gas: Three Critical Differences

© James & Gilles Paire \ Fotolia.com, www.alternativesjournal.ca/community/blogs/current-events/illusion-choice-pipeline-vs-rail

© New York Times /Redux/eyevine

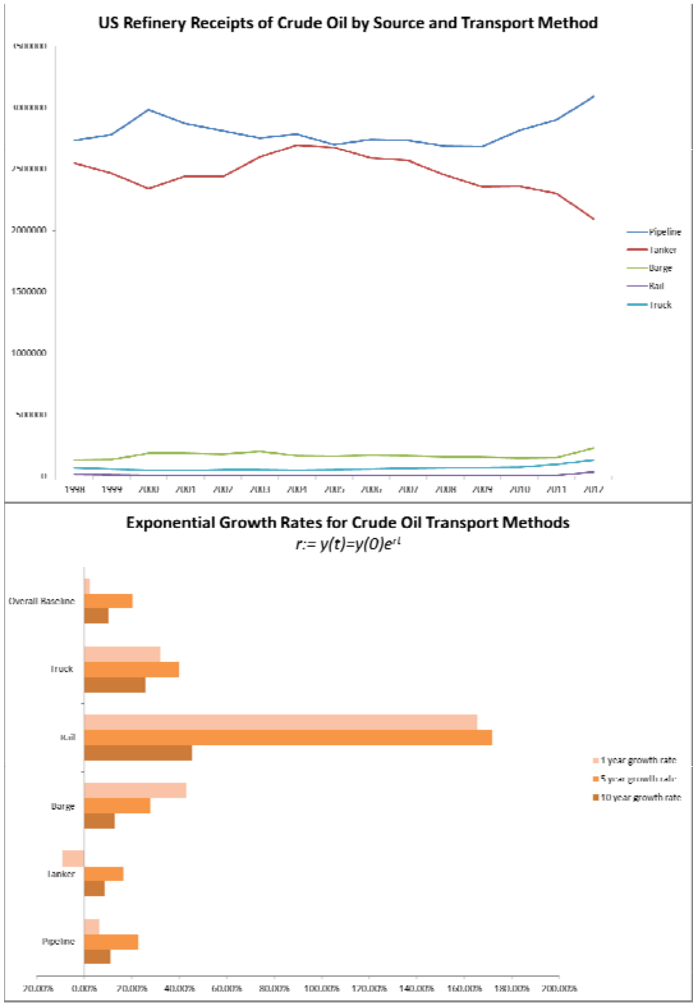


Source: http://www.sfgate.com/green/article/Acidizing-could-rival-fracking-in-Monterey-Shale-4760329.php

- Oil has more transport options
  - Rail or pipeline
  - Much easier to ship
- Gas associated with shale oil is not always worth recovering
  - Venting and Flaring

- Fracking is not always best to recover tight oil
  - In Monterey Shale, “acidizing” appears better
  - Technology evolving rapidly…

Will Crude by Rail Continue to Intensify?



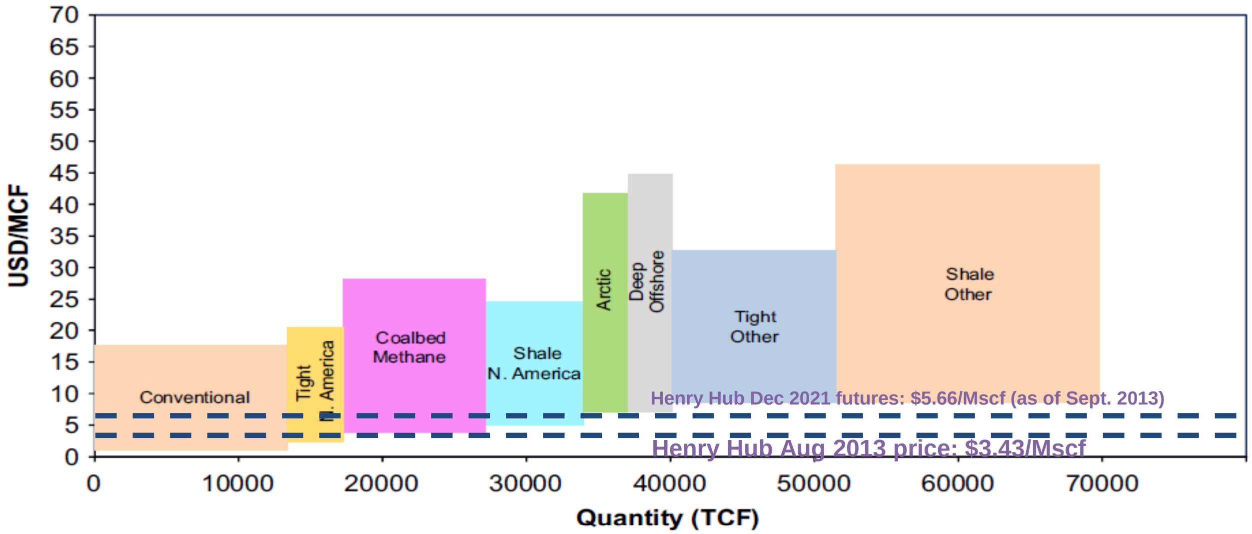
- Transport by all domestic modes up, tankers down
  - Rail has made huge gains, but remains a small share
  - Strain on fixed infrastructure?
- Pipelines dominate but fixed in place
  - Incentives for rail to continue to grow in medium term because of its flexibility

Based on EIA data series “Refinery Receipts of Crude Oil by Method of Transportation”, http://www.eia.gov/dnav/pet/pet_pnp_caprec_dcu_nus_a.htm

Train carrying crude oil from North Dakota derails in Western Alabama on Nov. 8, 2013 (Source/Photo Credit: WBMA via Reuters), available at http://america.aljazeera.com/articles/2013/11/8/train-carrying-oilderailsexplodesinalabama.html

The aftermath of the train derailment in Lac-Megantic, Quebec on July 6, 2013. Photo Credit: Transportation Safety Board of Canada. Source: Business Insider (July 26, 2013), available at http://www.businessinsider.com/photos-from-the-investigation-into-the-quebec-train-crash-2013-7?op=1

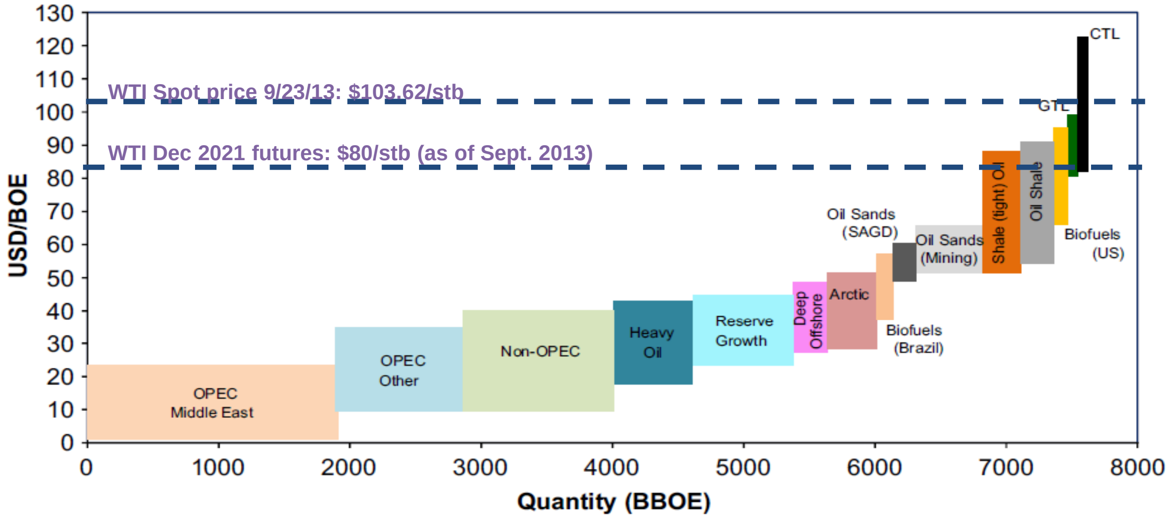
Natural Gas Prices Expected to Rise…



Adapted from Aguilera (2013). "Production costs of global conventional and unconventional petroleum". *Energy Policy* http://dx.doi.org/10.1016/j.enpol.2013.07.118

- Shale gas development profitable in select areas, down to $2/Mscf
  - New wells otherwise dropped off recently due to depressed prices
- Incentives for some return to fracking for natural gas
  - Coal-fired electricity plants retire and more natural gas plants come online
  - Liquefaction terminals and US gas exports come online

…While Oil Prices are Expected to Fall



Adapted from Aguilera (2013). "Production costs of global conventional and unconventional petroleum". *Energy Policy* http://dx.doi.org/10.1016/j.enpol.2013.07.118

- Unlike conventional oil, shale oil production highly price elastic
- Many pressures driving down domestic oil prices in the next few years including: domestic supply surge, export restrictions, utilization efficiency
- Experts expect US shale oil activity to continue for years

Relevant insurance coverage:

- Vehicles of all sorts (trucks, trains, cars)
- Heavy equipment (drill rigs, compressor stations)
- Homes
- Farms and ranches
- Municipal
- Workers
- D&O
- Pollution
- Wells
- Pipelines
- Collapse
- Explosion

Parade of Horribles

- Increased vehicle traffic and accidents
- Train derailments, spills, fires
- Stress on host communities (water, roads, police, fire)
- Residential/agricultural impacts (reports of sickened animals and lost crops)
- Worker safety
- Waste handling and transport
- Pipeline leaks
- Stress on water supply
- Contamination of water supply
- Public health and safety

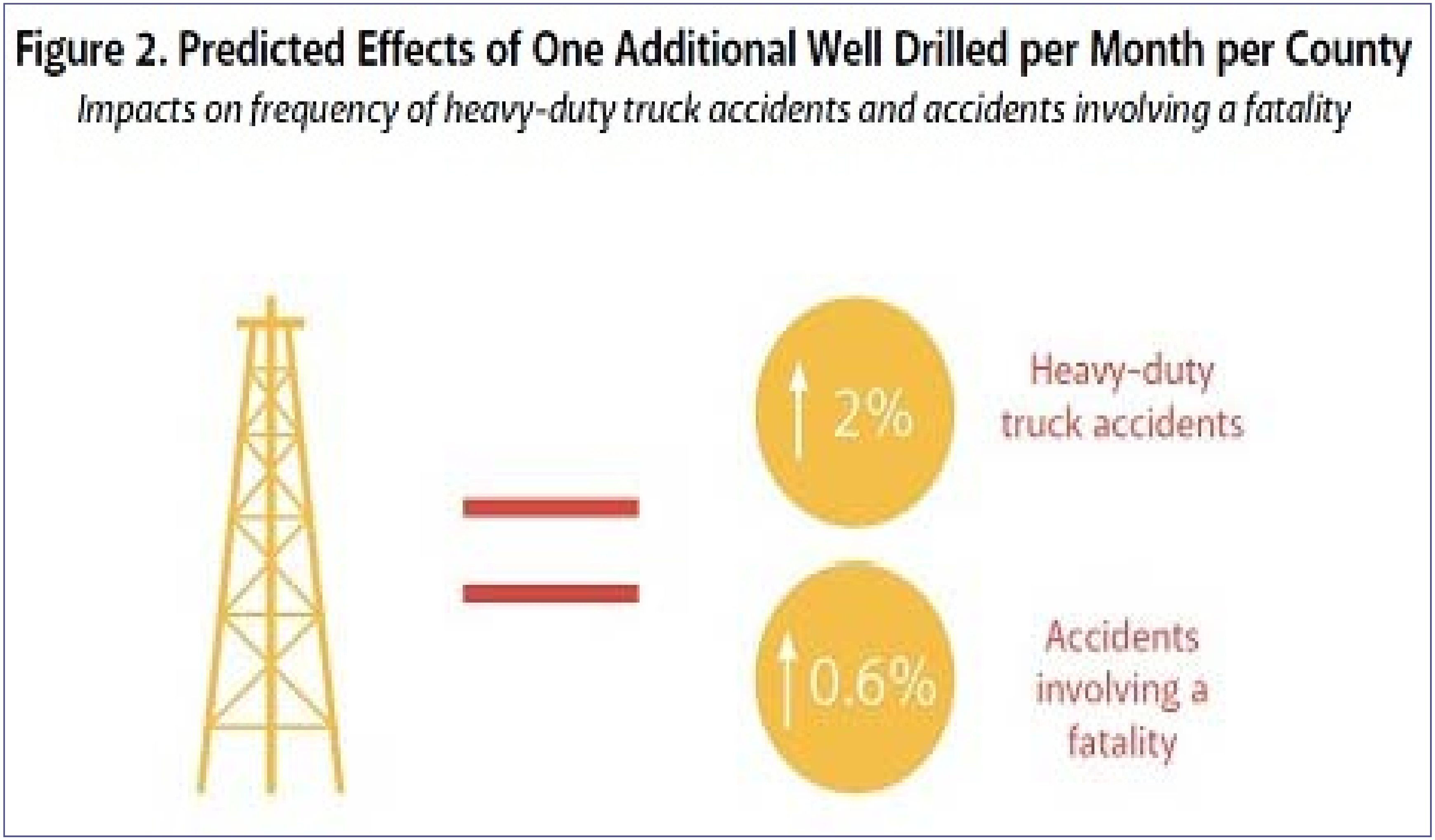


Figure 2. Predicted Effects of One Additional Well Drilled per Month per County
Impacts on frequency of heavy-duty truck accidents and accidents involving a fatality

Source: Resources for the Future, *Shale Gas Development Linked to Traffic Accidents in Pennsylvania*, Resources 185 (2014), available at http://www.rff.org/Publications/Resources/Pages/185-Infographic.aspx

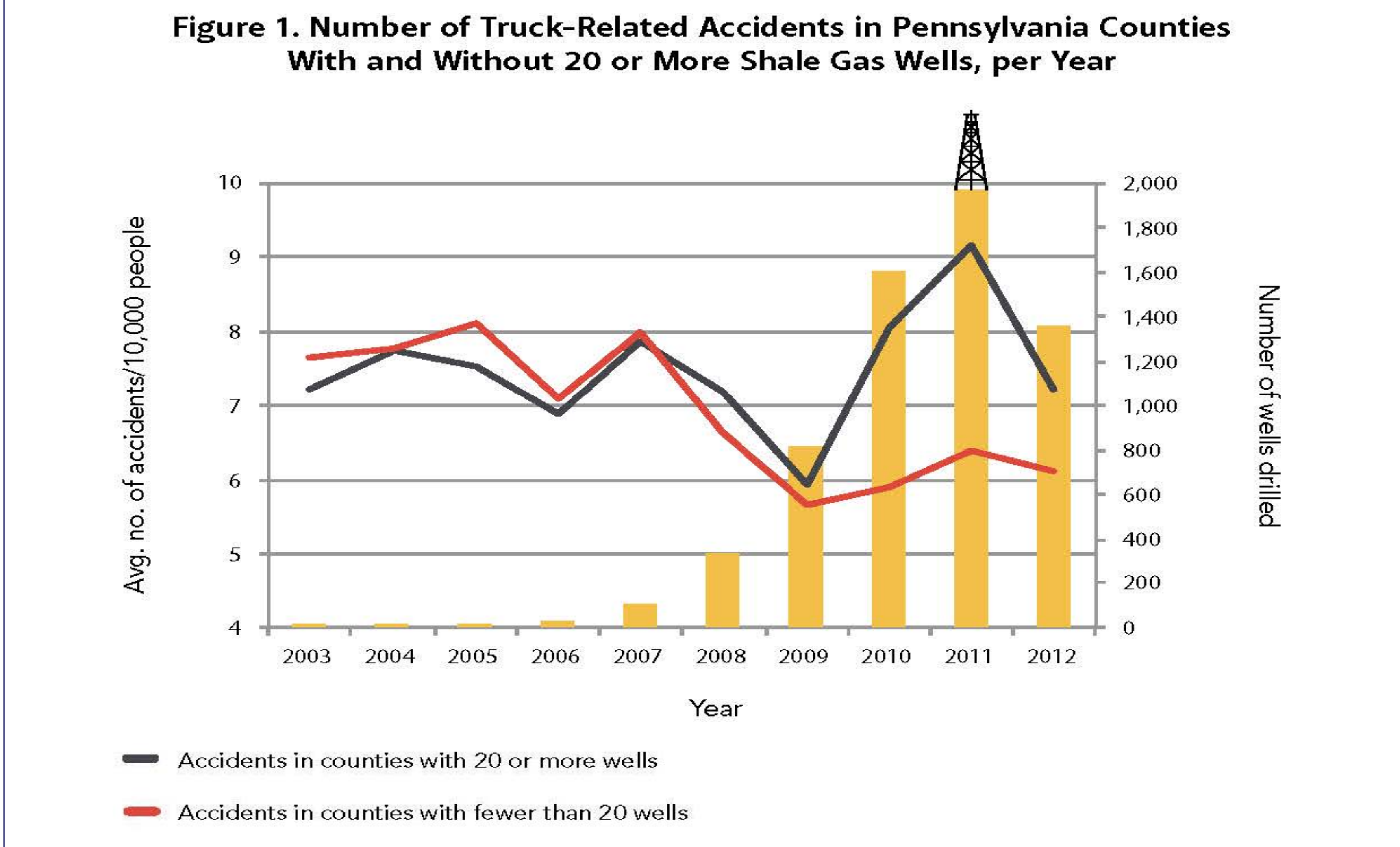


Figure 1. Number of Truck-Related Accidents in Pennsylvania Counties With and Without 20 or More Shale Gas Wells, per Year.

Source: Resources for the Future, *Shale Gas Development Linked to Traffic Accidents in Pennsylvania*, Resources 185 (2014), available at http://www.rff.org/Publications/Resources/Pages/185-Infographic.aspx

Health Impacts

- Inhalation of air emissions
  - Dust and particulates
  - Hydrocarbons (various) – some carcinogenic
  - Volatile organic compounds (VOCs)
  - Silica (worker exposure) – OSHA alert 2012
- Ingestion of well water
  - Hydrocarbons
  - Volatile organic compounds
  - Heavy metals
  - Radioactive material
- Skin contact with contaminated water
- Noise, light, odors, vibrations

Reported Symptoms

- Respiratory infections
- Headaches
- Fatigue
- Nausea
- Skin rashes
- Birth defects
- Miscarriages
- Tumors
- Neurological impairments

Complaints

- Colorado's Oil and Gas Conservation Commission: 496 between mid-2006 and late 2008
- Pennsylvania Dept. of Environmental Protection: approximately 1,306 since 2009
- Some states considering registries to track complaints
- Problem: drillers are very aggressive entering into leases; demand NDA's and complete releases
  - Information deficit

Litigation

1. Tort Theories
   - Trespass
   - Nuisance (loss of use and enjoyment)
   - Personal injury (medical monitoring claims and emotional distress)
   - Property damage (also diminution in property values)
   - Natural resource damage
   - Intentional misconduct
   - Unintentional mishaps
   - Strict liability: inherently dangerous activity
2. Contract Theories
   - Breach of contract (including lease terms)
   - Misrepresentation; fraud
3. Business Claims
   - Derivative shareholder suits
   - Negligent design, manufacture and/or construction

Parr v. Aruba Petroleum, Inc., et al.

No. CC-11-01650-E (Dallas County Court, April 22, 2014)

- Complaint: proximity to fracked wells exposed family and livestock to air pollution resulting in sickness, livestock deformities and deaths, and doctor ordering family to move out of their home.
    - Most defendants settled
- Jury awarded $2.95 million for personal injury (physical pain, suffering and mental anguish) and property damage:
    - Found that Aruba "intentionally" created a "private nuisance" by causing "unreasonable discomfort or annoyance to a [family] of ordinary sensibilities attempting to use and enjoy [their] land."
    - Under Texas law, a nuisance "is not excused by the fact that it arises from the conduct of an operation that is in itself lawful or useful."

Status of Other Litigation

- Several dozen filed. Some in process; most settled. For example,
  - *Warren Drilling Co., Inc. v. ACE American Insurance Co., et al.*, No. 2:12-CV-00425 (S.D. Ohio, filed May 17, 2012); ACE settled in January 2013
  - *Fiorentino v. Cabot Oil and Gas Corp*., No. 09-CV-2284 (M.D. Pa) (residents/lessors presenting various tort, breach of contract, and fraudulent misrepresentation claims regarding fires, explosions, and water contamination) (settled)

Statutory Exemptions

- Clean Water Act, 33 U.S.C. § 1342(L)(2)
  - Exempts uncontaminated stormwater runoff from site preparation from permitting
- Resource Conservation and Recovery Act, 42 U.S.C. § 6921(b)(2); 40 C.F.R. § § 261.4(b)(5)
  - Excludes drilling fluids, produced waters, and other wastes from definition of "hazardous waste"
- CERCLA/Superfund, 42 U.S.C. § 9601 (14)
  - Excludes crude oil, petroleum, natural gas, natural gas liquids, and liquified natural gas from definition of "hazardous substance" and picks up RCRA exclusion

Statutory Exemptions

- EPCRA/SARA Title III, 42 U.S.C. § 11023(b)(1)(A)
  - Does not apply to SIC Code 13, oil and gas extraction
- Safe Drinking Water Act, 42 U.S.C. § 300h(d)(1)(B)(ii)
  - UIC program excludes fluids or propping agents (other than diesel fuels) pursuant to hydraulic fracturing for oil, gas or geothermal production (known as the Cheney or Halliburton exemption)
  - NOTE: use of injection well to dispose of fracking fluids would be regulated by SDWA
- Clean Air Act, 42 U.S.C. § 7412(n)(4)
  - Emissions from production well and associated equipment and pipeline compressor shall not be aggregated to calculate major source threshold
  - "Green" well completions required as of 1/1/2015 to control VOC emissions, not methane. 77 Fed. Reg. 49490 (Aug. 16, 2012)

Varying Degrees of Regulation at State and Local Levels

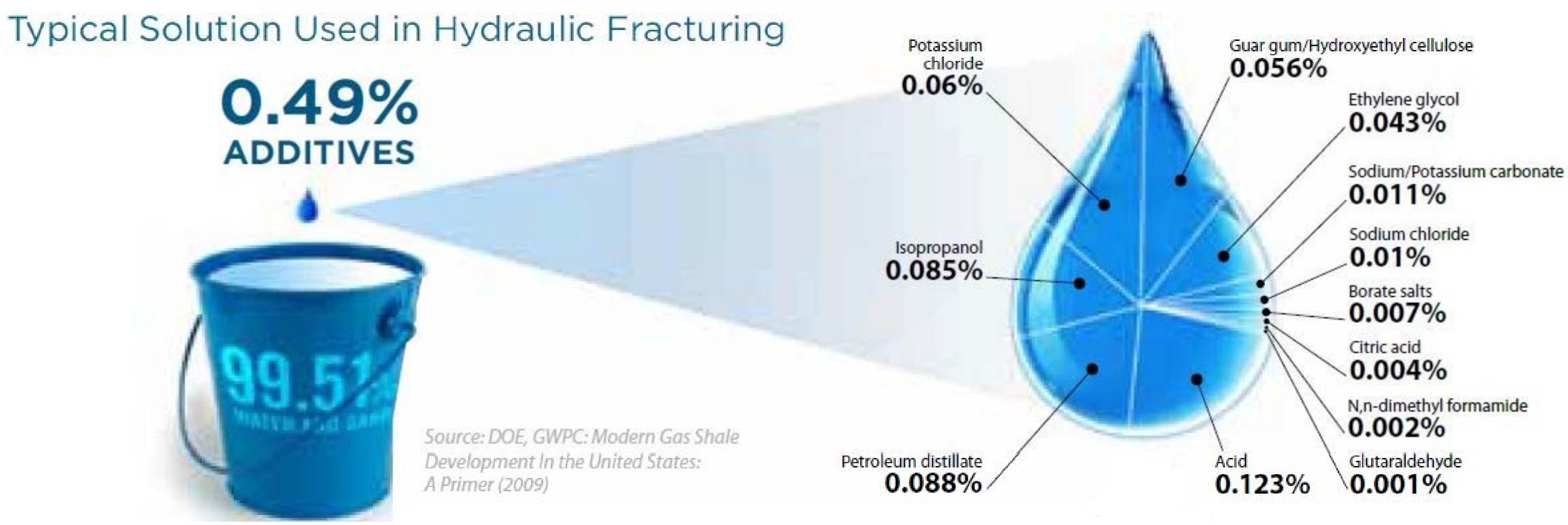
<u>**No**</u> uniform or mandated set of best practices

<u>**No**</u> systematic or effective data collection or analysis

Key Risk = Absence of meaningful financial assurance for operations <u>and</u> post-closure

- When drillers put up security, they act more responsibly
- States vary: Ohio = $15k; California = $2million
- Bond **<u>amounts</u>** = **<u>fraction</u>** of actual cost
  - Blanket bonds covering all wells are even worse
  - Colorado allowed $235K to cover 3600 wells
- Bonds are **<u>released too soon</u>**
- Only 4 states require liability insurance: Ohio, Illinois, Colorado, Maryland

Just What is Fracking Fluid?



Source: Marcellus Shale Coalition. Reprinted at http://marcellussolutions.wordpress.com/, "Chemical Disclosure". April 4, 2011.

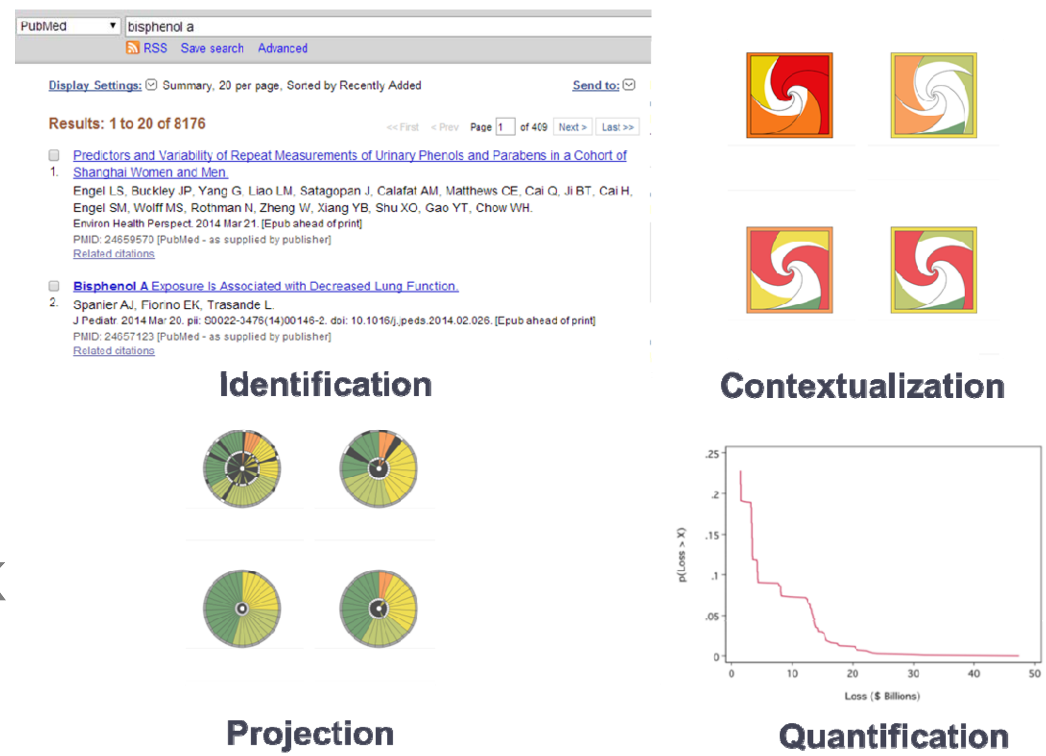
- Typical frack: 5 million gallons water, 450,000 gallons of silica and 25,000 gallons of chemical additives

Another View of Fracking Fluid

Which view does science support?

The Praedicat® Emerging Risk Approach to Casualty Risk Analytics

- "Fracking" – a set of activities and chemicals in a stream of commerce – is an emerging risk
- Praedicat identifies and tracks the science, links a risk with companies, and quantifies its implications



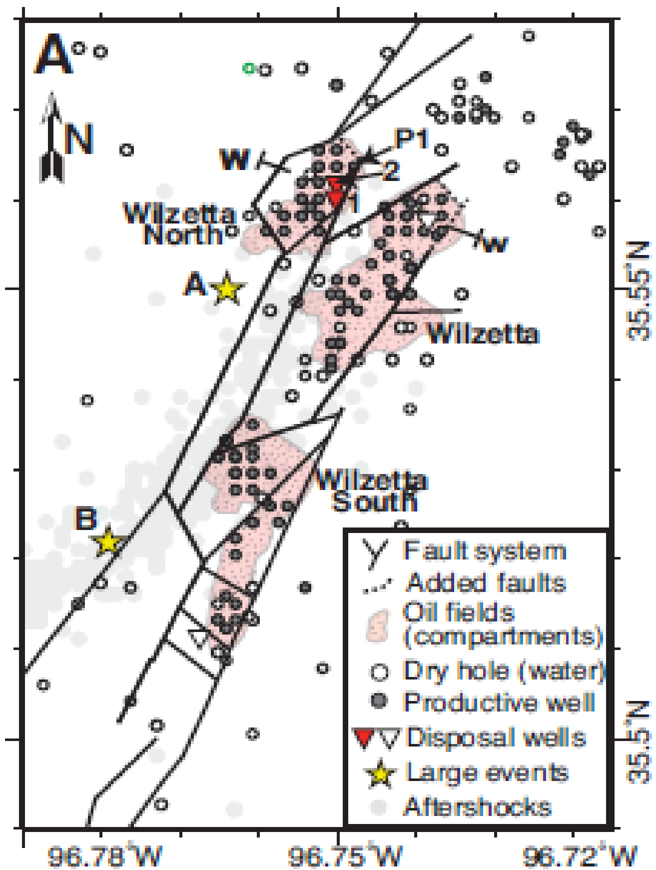
What Does the Science Say?

Does Fracking Cause Widespread Groundwater Contamination?

- Relatively few studies on groundwater effects completed
  - EPA has pushed off their report to 2016
  - Small sample of studies → greater uncertainty
- Will fluids remain imbibed in formation?
  - E.g. Flewelling *et al.* 2013 *Geophysical Research Letters* vs. Myers 2012 *Groundwater*
- Large scale surveys on methane migration mixed
  - E.g. Molofsky *et al.* 2013 *Groundwater* vs. Jackson *et al.* 2013 *Proc. Nat. Acad. Sci.*

What Does the Science Say?

Does Produced Water from Fracking Cause Other Issues?

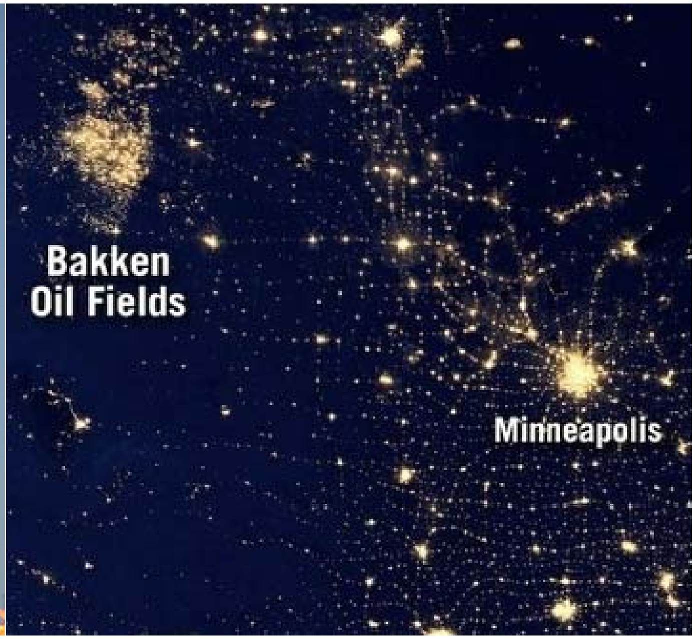


Keranen *et al.* 2013 *Geology*

- Injection of produced water for disposal may pose seismic risk (NRC 2012)
  - Keranen *et al.* 2013 *Geology* link a 5.7 quake to injection
  - Other quakes in AR, OH, TX
- USGS (2013): chance of 5.5+ earthquake in OK significantly increased

Flaring: Massive VOC Emissions

Source: Fracking complex in Houston, PA (taken on July 15, 2013), by KatrencikPhotoArchives on Flickr, http://www.flickr.com/photos/45501032@N00/10934940385/in/photolist-hEhqNV-ftH7Dg-aNW1hV-bpUEE6-aNW1at-fLf6vs-aNW1ut-jzDiwG-dixXHo-bAE7Zc-bnKhqm-cxEchE-irABXJ-aRrd6c-ayo2xx-kfMKst-ftH6un-h8Kd



Source: "North Dakota Gas Flares Light the Night Sky". Ceres.org https://www.ceres.org/industry-initiatives/oil-and-gas/Ceres_NightFlaresMap.jpg

- Yields H_2S, benzene, formaldehyde, and more
- Science has yet to generally link gas field flaring to bodily injury
  - Again, relatively and equivocal literature
  - To date, most literature focuses on refinery flares: e.g. D'Andrea and Reddy (2013) *Pediatric Hematology and Oncology*

Risk Reduction Opportunities

- Baseline environmental testing
- "Greener," safer practices as condition for coverage
  - Less water in; less wastewater out
  - Fewer chemicals; "safer" chemicals
  - Benign tracer chemicals
  - More durable cement for well casings
  - Self-healing and flexible options
  - Look for patterns and establish better practices
- Audits of insured's practices
  - Check protocols for selection and oversight of subcontractors
  - Is insured requiring contractors and subcontractors to carry insurance and/or financial assurance?
  - Require use of "best" management practices (lined pits, leak monitoring)
- Financial assurance for well-closures, remediation, post-closure monitoring; press state and federal legislatures

Exposure Checklist

Operations

- Is the drilling company in compliance with all federal and state regulatory measures?
- What experience does the drilling company have in high pressure, high volume drilling?
- Will the drilling operation be conducted near populated areas?
- Is the drilling site fenced-in to reduce "attractive nuisance" and keep others from trespassing?
- If the drilling operator must cross third-party land to get to drilling sites, have they obtained legal permission to do so?
- Are abandoned production or exploration wells plugged?
- What is the number, age, type and condition of the drilling equipment?
- Does all machinery and equipment contain the proper machine guards?
- How often is maintenance performed on equipment? How often is equipment inspected and tested to assure proper operating integrity and reliability?
- Are safety procedures in place to prevent leaks and spills during the fracturing operation?
- How often is soil and water tested for contamination?
- Is the driller hauling wastewater to treatment plants?
- Are all fracture fluids managed properly on site before, during and after the fracturing process?
- Are contractors and other responsible parties involved in the transportation and handling of fluids, chemicals and other material associated with the process properly trained?
- Are sewage/water treatment plants accepting fracking brine? If so, are appropriate safety measures taken into consideration?

Coverage

- Are the risks properly classified?
- Is there a "mutual hold harmless" agreement in place where each party agrees to assume responsibility for its own personnel and properties?
- Should there be an exclusion for pollution or contamination of groundwater or water aquifer?
- Is environmental liability subject to a sublimit under the policy?
- Are terms provided on an "occurrence basis" or "claims-made basis"?
- Are fines, penalties and punitive damages covered (where insurable by law)?
- Are emergency-response costs included? If so, are they sublimited?
- Is coverage for natural-resource damage included?
- Is coverage provided for non-owned disposal sites?
- Are defense costs inside or outside the limits of liability?
- Does the drilling company have a driller blow-out policy or well blow-out coverage?

Source: Munich RE, Focus On: Hydrofracking (May 2012), available at https://www.munichreamerica.com/mram/en_US/publications-expertise/research-spotlight/hydrofracking/index.html

“Greener” Practices

- Fracking fluids → substitute toxic chemicals with “safer” substances:
  - CleanStim® by Halliburton uses food industry ingredients
  - Vernium uses enzymes in place of hydrochloric acid
  - GasFrac replaces water use with a gel that turns to vapor
- Improved wastewater treatment and recycling →filtration & reuse:
  - Chesapeake’s Aqua Renew Process
  - Halliburton’s Clean Wave® Frac Flowback
  - OmniWater Solutions’ Hydro Innovation Purification Platform for Oil and Gas
  - Ecosphere
  - Others in development
- Methane and VOC leak detection and controls are developing:
  - EPA’s Natural Gas STAR Program
  - EPA’s Green Completions rule (eff. Jan. 1, 2015)
  - National Renewable Energy Laboratory (NREL) developing microbes to convert methane to liquid diesel fuel

In Closing

- Fractured industry
- Huge range in size, experience and financial wherewithal of the drillers and operators
- Drillers and well operators don't own pipelines or compressor stations
- Multiple layers of contracting distributes risk to those with shallowest pockets
- Economic conditions will continue to be favorable for development
- Much research remains to be done

Q & A

Bio for Wendy B. Jacobs, Esq.

Wendy B. Jacobs is a Clinical Professor at Harvard Law School and Director of the Emmett Environmental Law and Policy Clinic. In the Clinic, she and her students work on a variety of complex environmental law and policy projects focusing on renewable energy, sea level rise, regional stormwater management and other aspects of climate change adaptation, sustainable aquaculture, hydraulic fracturing, carbon capture and sequestration, mountaintop removal mining, and improved oversight and management of offshore drilling. Prior to joining Harvard Law School, Ms. Jacobs practiced administrative and environmental law as a partner in the Boston law firm Foley Hoag LLP for nearly 20 years, and before that as an appellate attorney and special litigator for the U.S. Department of Justice in its Environment Division in Washington, D.C. Ms. Jacobs received her J.D. with honors in 1981 from Harvard Law School, where she was an editor of the Harvard Law Review.

Bio for R. J. Briggs, Ph.D.

As Praedicat, Inc.'s Energy Economist, R. J. develops analytics for emerging risks in energy markets to improve underwriting and the management of liability catastrophe risk. Prior to joining Praedicat, he worked alongside engineers, scientists, and economists as an Assistant Professor of Energy and Environmental Economics in Penn State's Department of Energy and Mineral Engineering. R. J. holds a Ph. D. from the University of Texas at Austin in Economics with fields in Environmental and Resource Economics and Public Economics. After earning a dual Bachelor's degree in Mathematics and Economics from the University of California, Davis, he joined the RAND Corporation and worked on diverse projects ranging from education policy to terrorism and national defense.

Praedicat, Inc. is dedicated to improving the underwriting and management of casualty risk. Praedicat is the world's first "liability cat" modeling company.