Fracking - Evil Scourge or Game-changing Technology?

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A New Frac Technology Discovered in Bolivia

Topics for Discussion

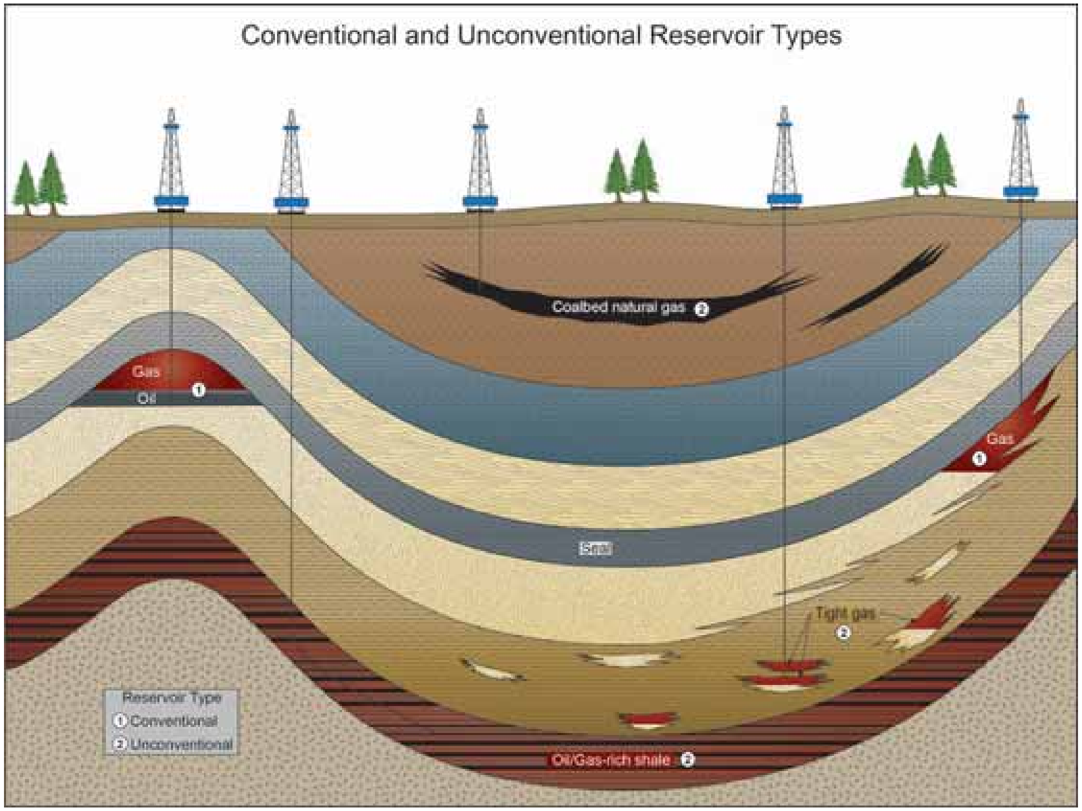
- The U.S. oil and gas playing field
- The importance of unconventional oil and gas to the U.S. and the world
- What is fracking (hydraulic fracturing – HF)?
- History of HF
- Managing HF wastewater
- Concerns about HF (perceived or real)

U.S. Oil and Gas Industry

- There are nearly 1 million active oil and gas wells in the U.S. in many fields across 31 states
- Unlike most countries where only a few companies operate oil and gas wells, in the U.S. thousands of companies own and operate wells
  - Giant majors to large independents to regional players to Mom & Pop companies with just a few wells
- The industry is supported by thousands of service companies
  - Large multi-national companies providing many services
  - Regional or local companies focusing in one type of service
- Most aspects of oil and gas operations are regulated at the state level, not at the federal level

Conventional vs. Unconventional Production

- Historically most oil and gas wells were drilled to intersect sections of porous formations where oil and gas had been trapped
  - Limestone
  - sandstone
- Unconventional oil and gas occurs over broader areas away from specific trapping mechanisms
  - Shale
  - Coalbed methane

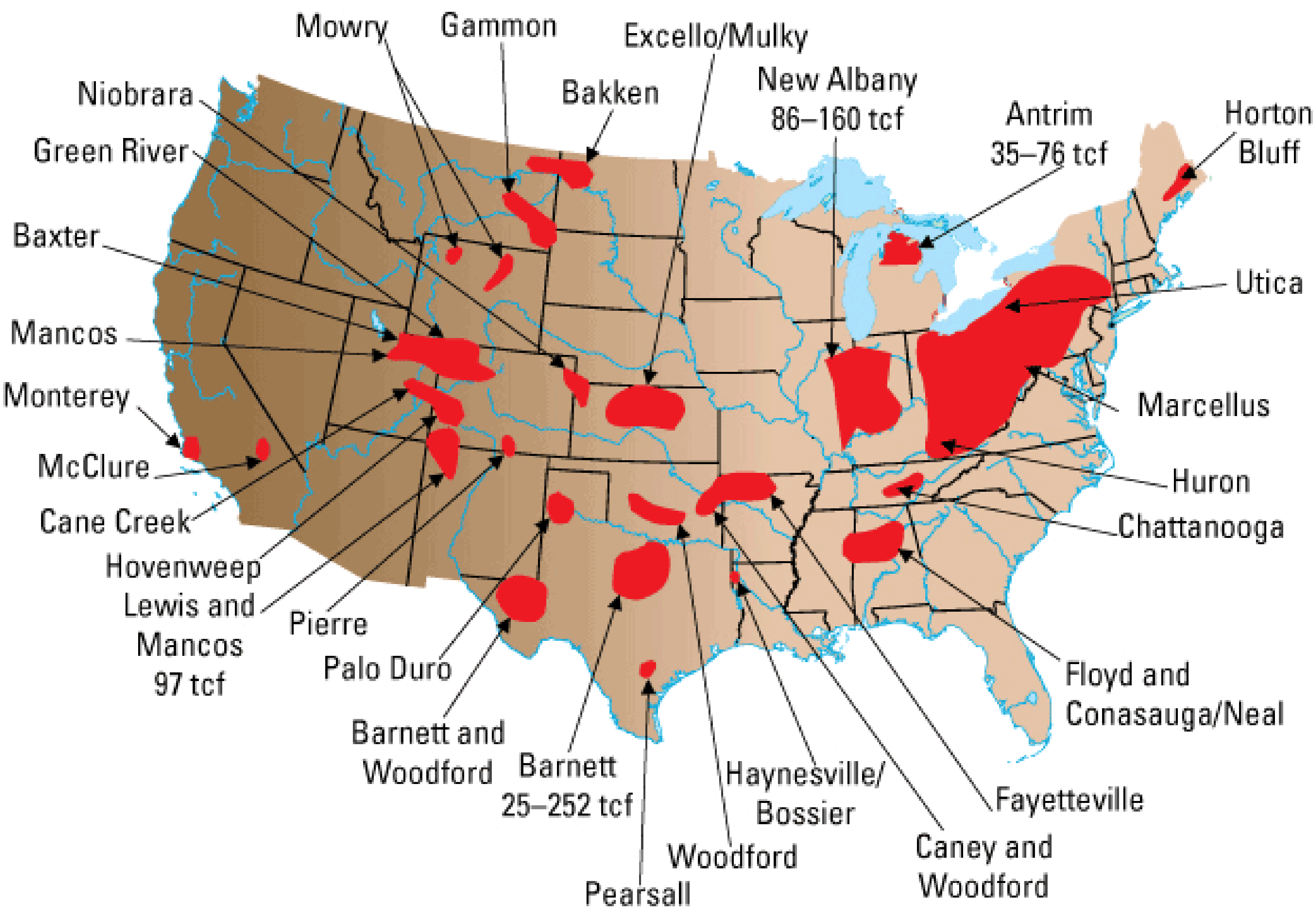


Source: Wyoming State Geological Survey

Conventional vs. Unconventional Wells

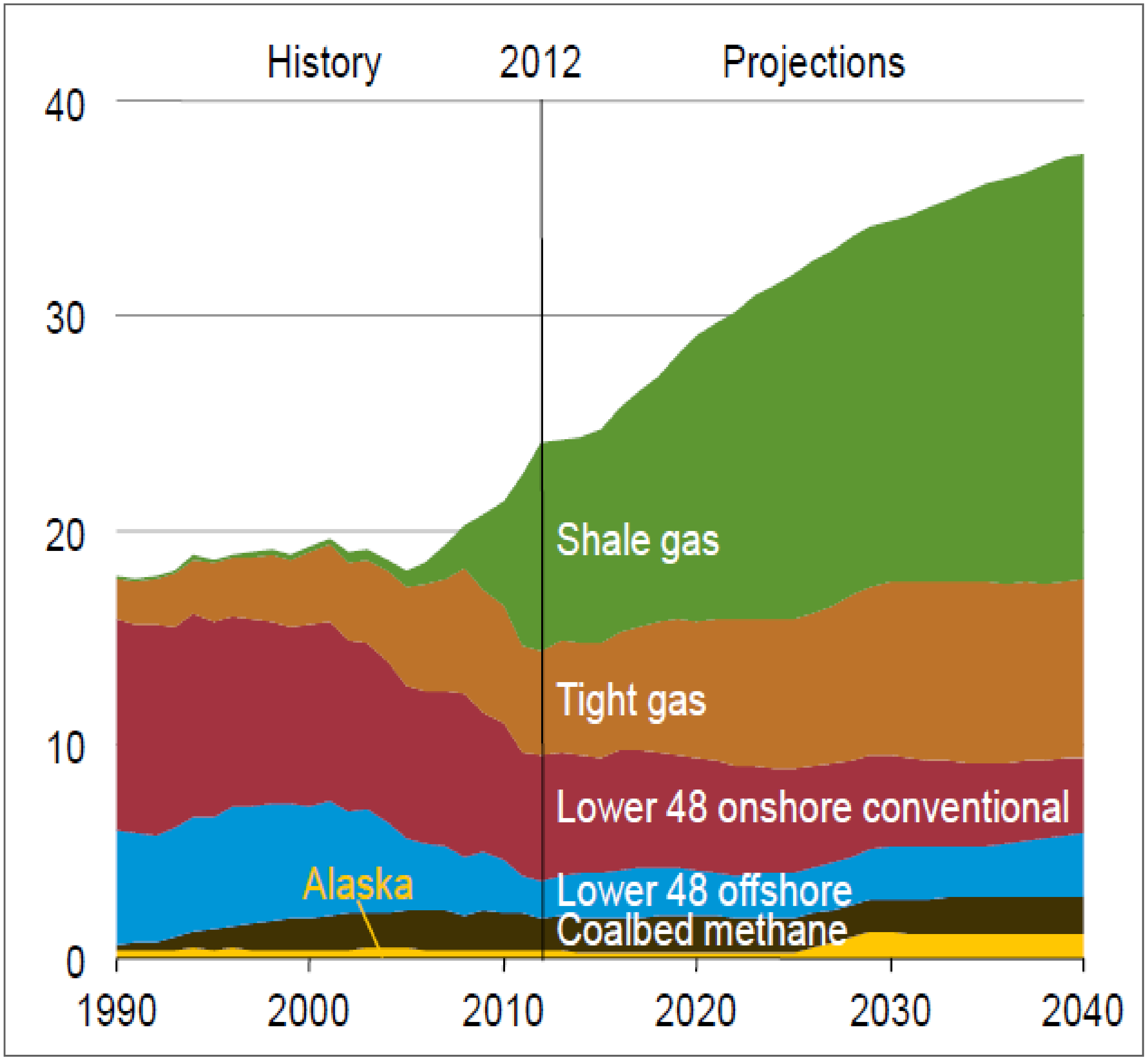
- Conventional formations have produced oil and gas for more than 100 years
  - Generally the formations have good porosity and permeability
  - Typically produced using vertical wells
- Unconventional formations (e.g., shale) are known to geologists to hold abundant hydrocarbon resources
  - They generally have very low permeability, such that conventional, vertical wells cannot collect enough oil and gas to make the wells economic
  - When external methods to enhance permeability are applied along with using horizontal well construction, unconventional formations can produce a great deal of oil and gas at an affordable cost

U.S. Shale Fields



Importance of Shale Gas to the USA

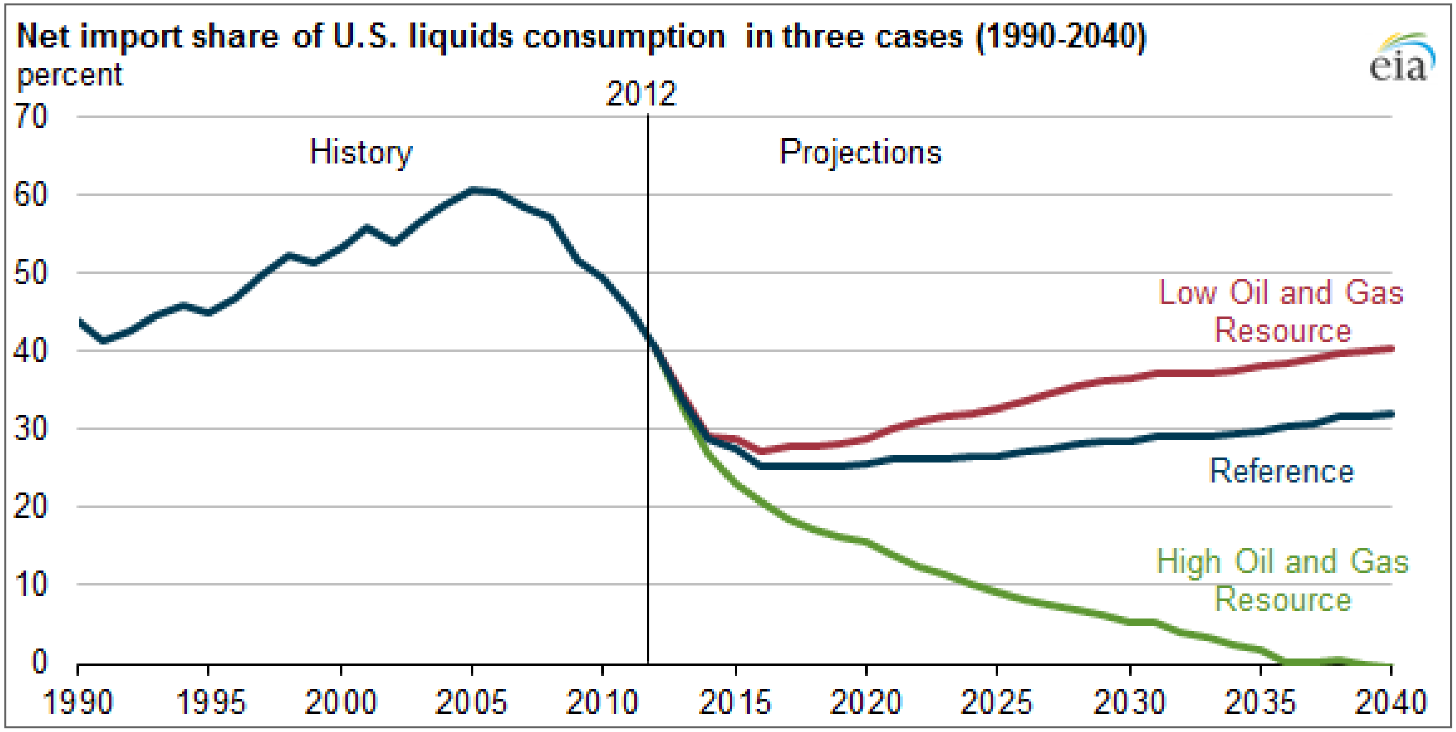
- Natural gas is an important energy source for the United States. Shale formations represent a growing source of natural gas for the nation and are among the busiest oil and gas plays in the country.



Source: DOE/EIA Annual Energy Outlook 2014

Implications of Shale Oil and Gas Production for the USA

- Significantly lowered our imports (often from unsettled parts of the world)
- Less than a decade ago, the U.S. planned to open a series of LNG import terminals. Now those are no longer being planned. Instead, there are plans for LNG exports (pending political approval).



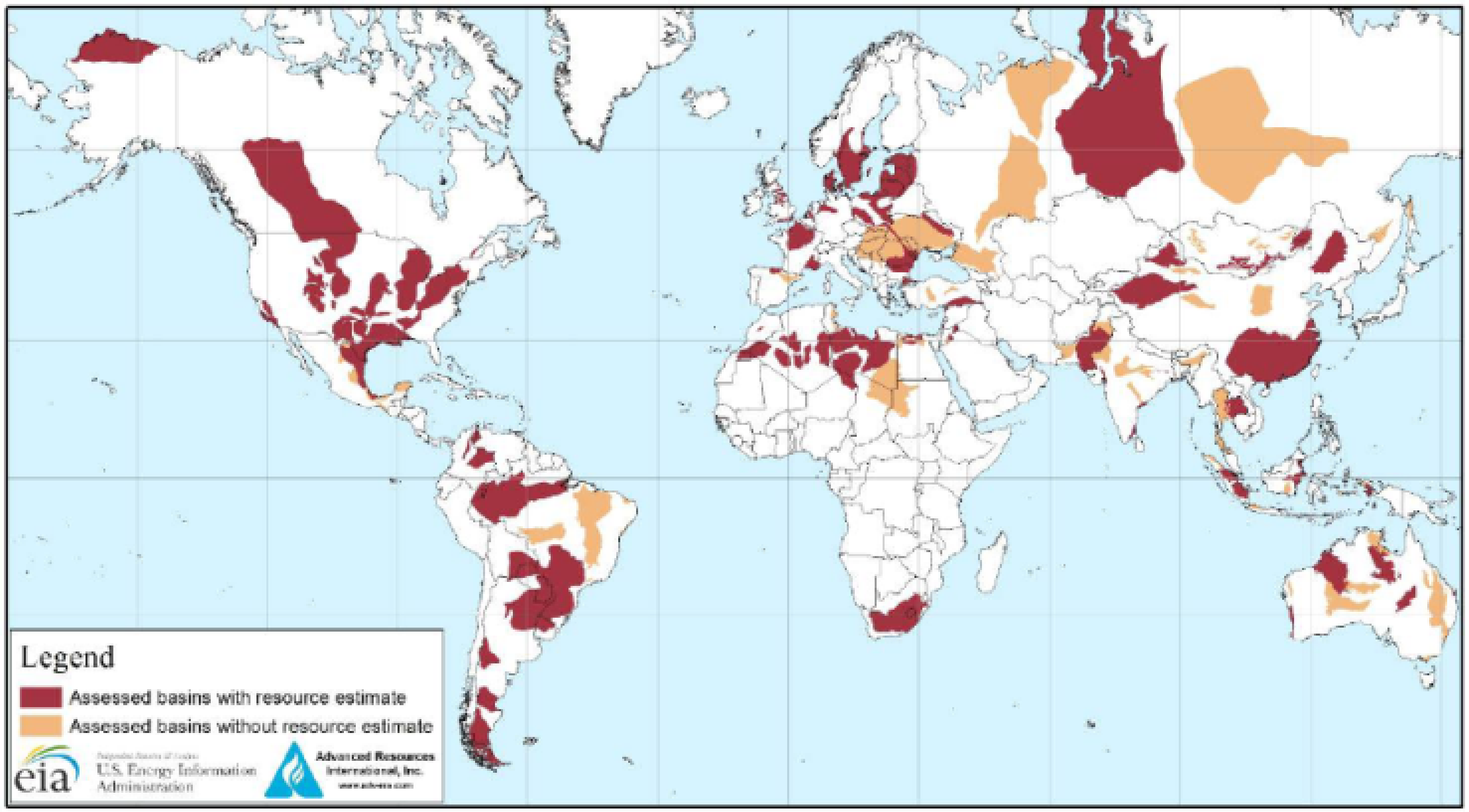
Source: DOE/EIA website

Shale Plays in Other Parts of the World

2013 Report on Global Shale Oil and Gas Reserves

- U.S. Department of Energy released a new report in June 2013 that assessed 137 shale formations in 41 countries.
  - Prepared by Advanced Resources International

http://www.eia.gov/analysis/studies/worldshalegas/



Risked Shale Gas and Oil In-Place and Technically Recoverable – by Continent

Continent	Shale Gas (Tcf)	Shale Oil (billion bbl)
North America (other than U.S.)	1,118	21.9
Australia	437	17.5
South America	1,431	59.7
Europe	883	88.6
Africa	1,361	38.1
Asia	1,403	61.1
Sub-Total	6,634	286.9
U.S.	1,161	47.7
Total	***7,795***	***334.6***

Source: Advanced Resources 2013

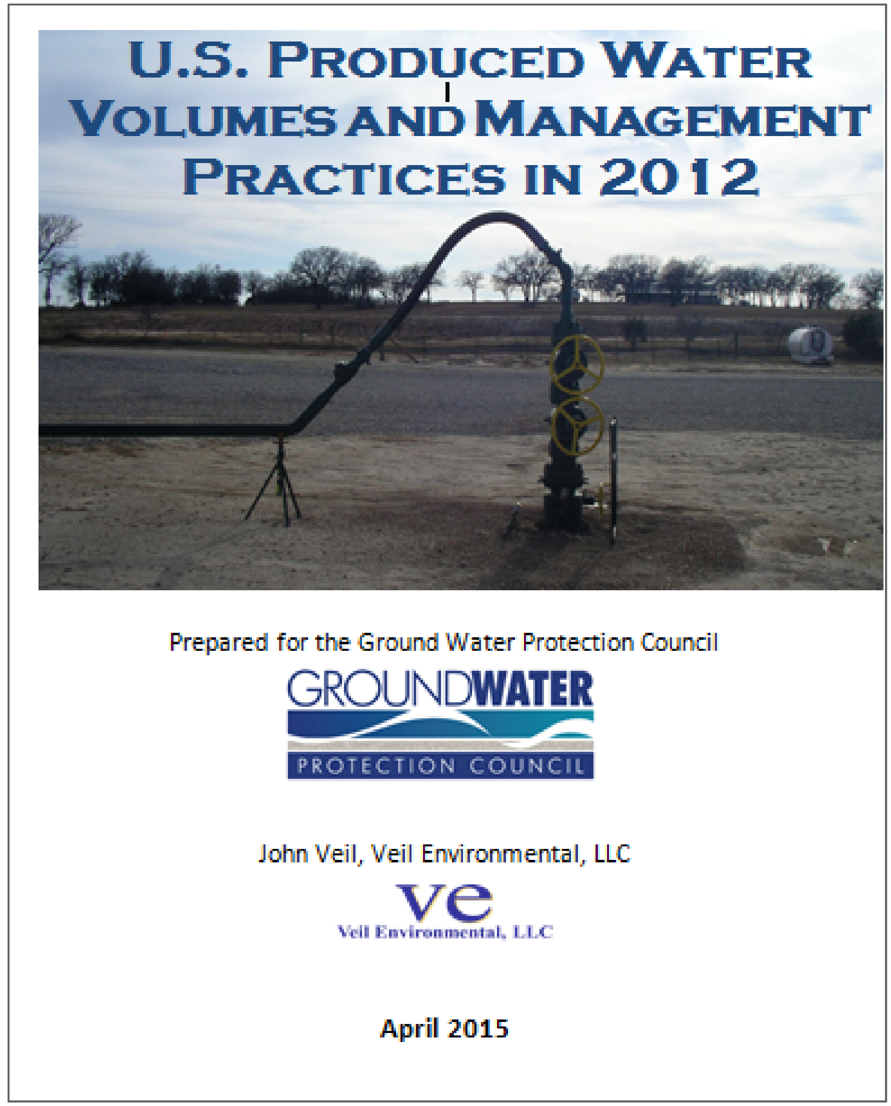
Estimated Technically Recoverable Shale Oil and Gas Resources – Top 10 Countries

Technically Recoverable Shale Gas Resources (Tcf)	
1. U.S.	1,161
2. China	1,115
3. Argentina	802
4. Algeria	707
5. Canada	573
6. Mexico	545
7. Australia	437
8. South Africa	390
9. Russia	285
10. Brazil	245
11. Others	1,535
TOTAL	**7,795**

Technically Recoverable Shale Oil Resources (Billion Barrels)	
1. Russia	75
2. U.S.	48
3. China	32
4. Argentina	27
5. Libya	26
6. Australia	18
7. Venezuela	13
8. Mexico	13
9. Pakistan	9
10. Canada	9
11. Others	65
TOTAL	**335**

Source: Advanced Resources 2013

Produced Water Volume



U.S. PRODUCED WATER VOLUMES AND MANAGEMENT PRACTICES IN 2012

Prepared for the Ground Water Protection Council

GROUNDWATER PROTECTION COUNCIL

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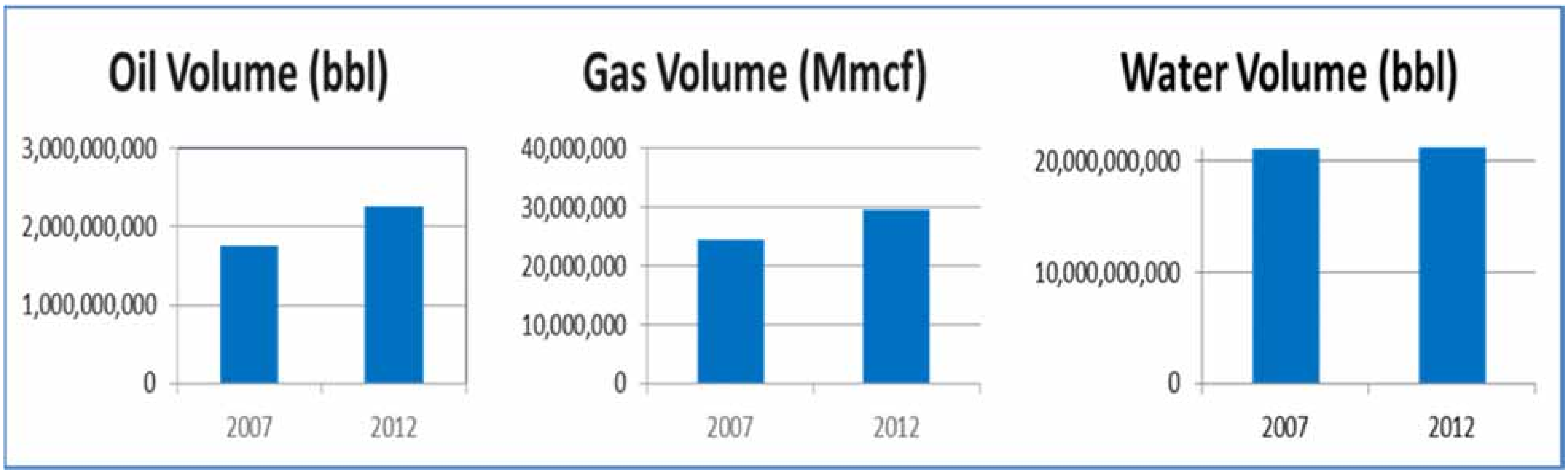
April 2015

http://www.veilenvironmental.com/publications/pw/prod_water_volume_2012.pdf

Five Year Changes in Fluid Production

- Between 2007 and 2012
  - U.S. oil production increased by 29%
  - U.S. gas production increased by 22%
  - U.S. water production increased by <1%
    - 21.2 billion bbl vs. 21 billion bbl



Why Did Oil and Gas Increase While Water Remained the Same?

Here is my hypothesis:

- Conventional production generates a small initial volume of water that gradually increases over time. The total lifetime water production from each well can be high
- Unconventional production from shales and coal seams generates a large amount of produced water initially but the volume drops off, leading to a low lifetime water production from each well
- Between 2007 and 2012, many new unconventional wells were placed into service and many old conventional wells (with high water cuts) were taken out of service
- The new wells generated more hydrocarbon for each unit of water than the older wells they replaced

Top Ten States in 2012 Water Production

Ranking	State	2012 Water (bbl/yr)	% of Total Water
1	Texas	7,435,659,000	35
2	California	3,074,585,000	15
3	Oklahoma	2,325,153,000	11
4	Wyoming	2,178,065,000	10
5	Kansas	1,061,019,000	5
6	Louisiana	927,635,000	4
7	New Mexico	769,153,000	4
8	Alaska	624,762,000	3
9	Federal Offshore	358,389,000	2
10	Colorado	320,191,000	2

Produced Water Management Practices

2012 Produced Water Management Practices

- Water management follows similar trends to the 2007 data
  - Nearly all water from onshore wells is injected (93%)
  - Nearly all water from offshore wells is treated and discharged (80%)

	Injection for Enhanced Recovery (bbl/yr)	Injection for disposal (bbl/yr)	Surface discharge (bbl/yr)	Evaporation (bbl/yr)	Offsite Commercial Disposal (bbl/yr)	Beneficial Reuse (bbl/yr)	Total Prod Water Managed (bbl/yr)
%	45.1	38.9	5.4	3.4	6.7	0.6	100.0

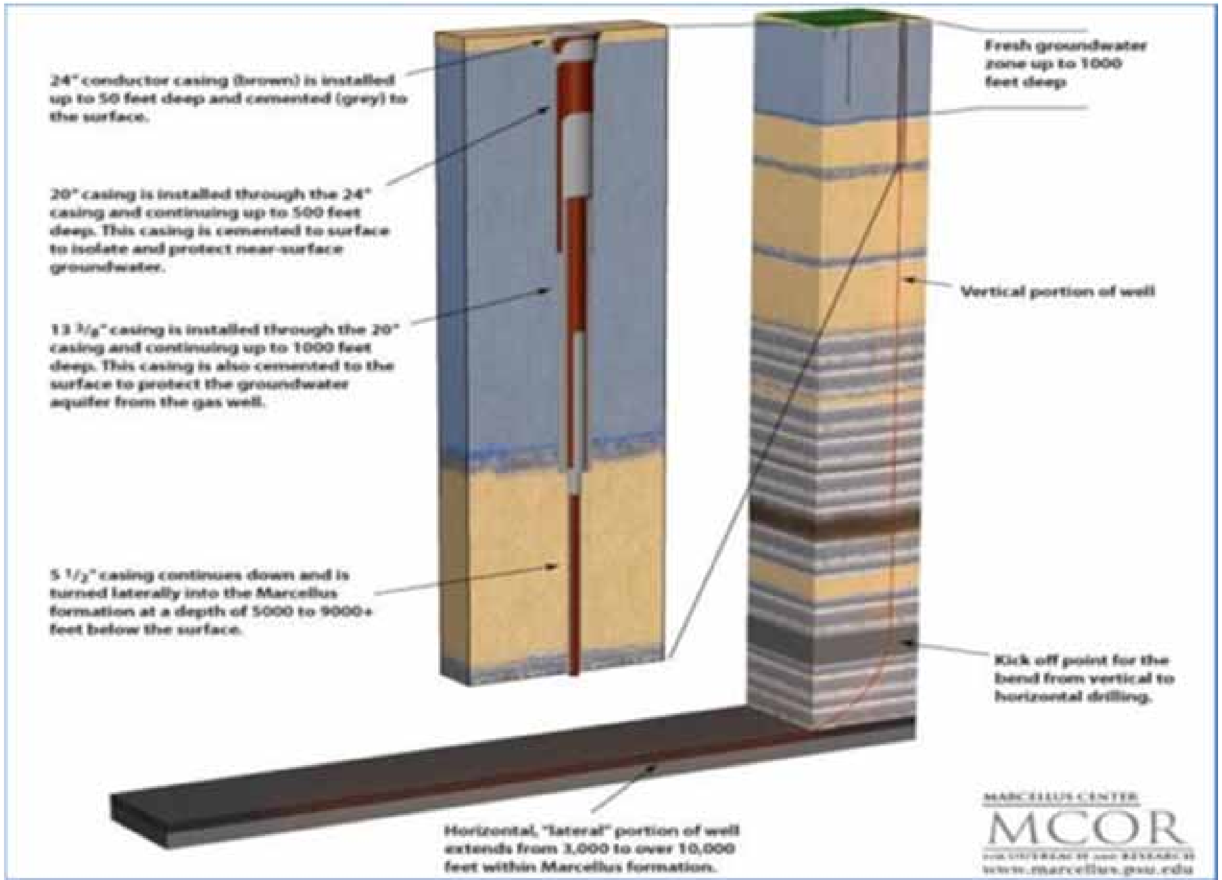
The Shale Gas Development Process

Steps in the Shale Gas Process

Gaining Access to the Gas (Leasing)
Searching for Natural Gas
Preparing a Site
Drilling the Well
Preparing a Well for Production (Well Completion) *This is where hydraulic fracturing occurs*
Gas Production and Water Management
Moving Natural Gas to Market
Well Closure and Reclamation

Well Completion Process

- Most shale gas wells are drilled as horizontal wells with up to 1 mile of lateral extent through the shale formation
- In order to get gas from the formation into the wellbore, companies must follow two completion steps:
  - Perforation
  - HF



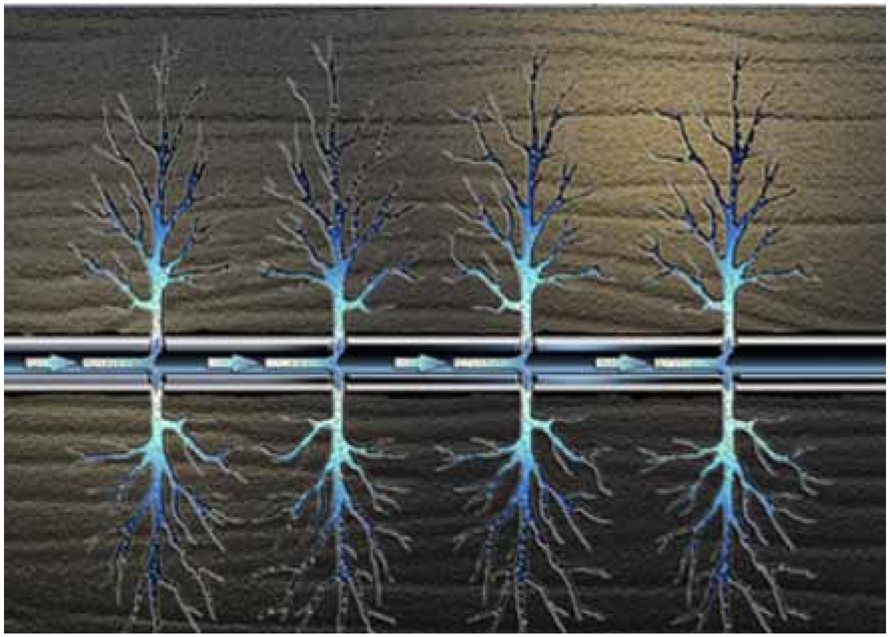
Source: T. Murphy – Penn State Marcellus Center for Outreach and Research

Visit http://videos.loga.la/horizontal-drilling-animation to see a good video of these steps

Well Completion Process (2)

- On a long horizontal leg, completion is done in a series of stages, each of which is a few hundred feet long
  - Perforations are made using small explosive charges that are lowered to the desired depth on a cable
  - HF is done for several hours for each stage
  - Pressure is held on the well and a plug is set to isolate that fractured interval and allow stimulation of the next stage
  - The next stage is perfed and fracced
  - When all stages are completed, the plugs are drilled out, and some of the water returns to the surface

Source: J. Veil



Source: Frac Focus website

Hydraulic Fracturing (HF)

Why Is HF Used?

- Shale rock is very dense and has low permeability
  - HF creates a network of small cracks in the rock that extend out as far as 1,000 feet laterally and vertically away from the well
- Virtually no shale gas wells in the U.S. would be developed unless HF is done
- It is controversial and expensive, but is a critical element in cost-effective production

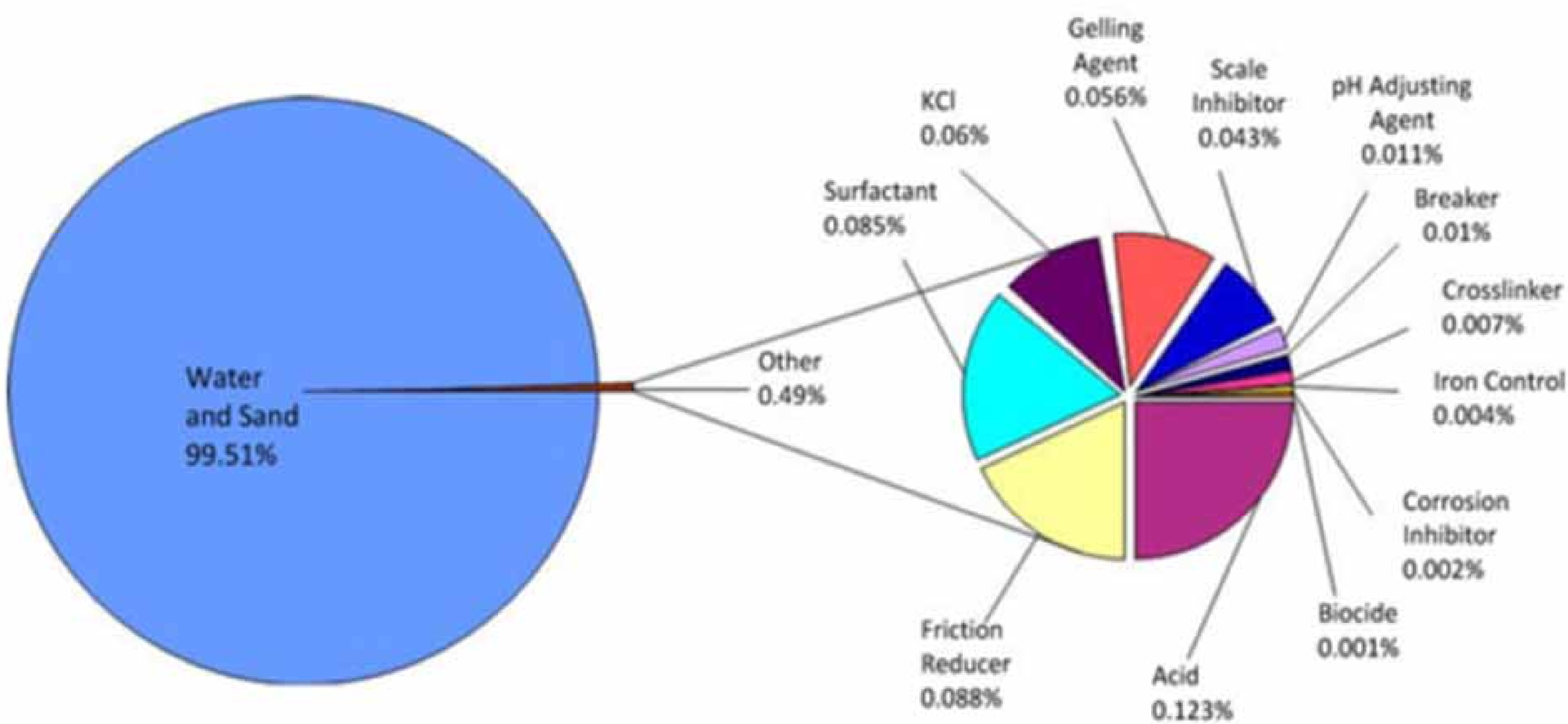
History of Fracturing

- First U.S gas well drillled in 1825 in Fredonia, NY
- First frac job (not hydraulic) in 1858 in Fredonia
  - Used black powder in multiple stages
- First commercial hydraulic fracturing job took place in 1949 in Velma, OK
- First use of the combination of horizontal drilling and HF began in the 1985 in Texas.
- More than 1 million wells have been hydraulically fractured.
  - Few, if any, cases of environmental impact were attributed to the actual process of HF
- Use of nuclear explosions for fracturing
  - Project Gasbuggy exploded nuclear device in NM in 1967
    - Resulting gas was too radioactive to use
  - Later tests (Project Rulison and Rio Blanco) did not show good results either

Chemicals in Frac Fluids

Frac Fluid Composition

- Water makes up ~90% of volume
- Sand makes up ~10% of volume
- All other chemical additives make up ~0.5% of volume



Source: Shale Gas Primer, GWPC and ALL

Chemical Disclosure Registry

- In April 2011, the Ground Water Protection Council (GWPC) and the Interstate Oil and Gas Compact Commission (IOGCC) opened a new online system (FracFocus) to host information about the chemical additives used in frac fluids and their ingredients
  - The key feature was a chemical disclosure registry
- Any interested person can visit the website and search for data on a specific well

www.fracfocus.org

Registry (2)

- Initially, chemical data entry into the Registry by the oil and gas companies was voluntary, but since then, many states adopted regulations requiring data on the chemicals used in frac fluids to be disclosed
- Since going live in April, 2011 the FracFocus system has received over 95,000 entries from over 1,000 companies

Wastewater Management Practices

Shale Gas Wastewater - Flowback and Produced Water

- Some of the injected water returns to the surface over the first few hours to weeks. This ***frac flowback*** water has a high initial flow, but it rapidly decreases
  - Over the same period of time, the concentration of TDS and other constituents rises
- A smaller volume of water continues to flow from unconventional wells for many months (***produced water***)

TDS values (mg/L) in flowback from several Marcellus Shale wells

Location	Day 0*	Day 1	Day 5	Day 14	Day 90
A	990	15,400	54,800	105,000	216,000
B	27,800	22,400	87,800	112,000	194,000
C	719	24,700	61,900	110,000	267,000
D	1,410	9,020	40,700		155,000
E	5,910	28,900	55,100	124,000	

* Day 0 represents the starting frac fluid conditions

Source: Tom Hayes, 2009.

Management of Shale Gas Wastewater

- Five management options
  - Injection into disposal well (offsite commercial well or company-owned well)
  - Treatment to create clean brine
  - Treatment to create clean fresh water
  - Evaporation or crystallization
  - Filtration of flowback to remove suspended solids (i.e., sand grains and scale particles), then blend with new fresh water for future stimulation fluid.

Examples of Good and Bad Water Management Practices from Marcellus Shale

(from my personal experience)

Example 1 – Large Producer – Planned Tour – October 2010

- A large gas company provided a tour of a well site in northeastern PA that was scheduled for a frac job on the following day.
- All equipment was in place
- Full pad was covered with gravel
- Central working area had geotextile liner and berm to collect any drips or spills
- It was raining that day, and workers were removing collected precipitation from the lined area using vacuum hoses. Collected wastewater went into vacuum trucks for offsite disposal.
- Company had a dedicated set of frac tanks to capture all flowback for subsequent reuse.

Example 2 – Very Small Producer – Unscheduled Visit – May 2010

- A small gas company that drilled only a few wells each year had fractured a vertical well in western PA on the previous day.
- A downhole tool got stuck in the well. The company brought in a coiled tubing rig to try to remove the tool.
- In the meantime, the well was flowing back to the surface. Some of the wastewater was collected in a small lined pit, then was pumped to a larger lined pit for subsequent treatment.
- A portion of the flowback sprayed from the top of a ~30 ft pipe. Depending on the wind direction, the spray moved to various sections of the well site. We received occasional flowback showers during our visit.

Normal Flowback Water Capture System




Unplanned Flowback Shower

Perceived Issues and Concerns Relating to Shale Gas Production and HF vs. Factual Information

Issues and Concerns #1

Increasing production of inexpensive oil and gas delays the transition to renewable energy sources

- This is a key concern of the most diehard opponents, especially those with a focus on climate change
- Industry will continue to look at renewables, but the public wants low-cost, reliable energy

Issues and Concerns #2

Shale gas uses too much water – often in arid areas

- In reality, in most states, the water used for gas production represents a few tenths of 1% of all the water currently used in those states
- When you zoom in to smaller geographical areas (e.g. field, region, county), water needs for unconventional production can be much higher
- Industry is already recycling some flowback and produced water and is evaluating lower-quality water sources
  - Brackish groundwater
  - Treated sewage

Issues and Concerns #3

Shale wastewater injected into disposal wells is lost from the hydrosphere

- Some critics have commented that deep well injection of flowback water from shale gas wells completely removes water from the hydrologic cycle.
- While those specific water molecules are removed, the natural gas from those wells generates new water when the gas is combusted.
- Mantell (2010) calculates that about 10,675 gallons of water are produced for each million cubic feet of natural gas that is combusted.
- Using that ratio, a Marcellus Shale gas well would need to produce about 525 million cubic feet of natural gas to generate an equivalent amount of water used in a Marcellus frac job. This represents less than six months of gas production.

Issues and Concerns #4

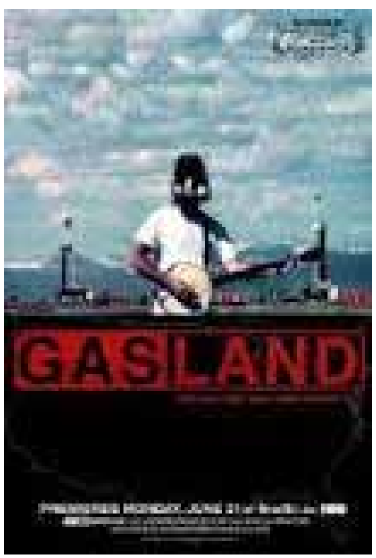
Opponents have various vested interests against additional oil and gas development

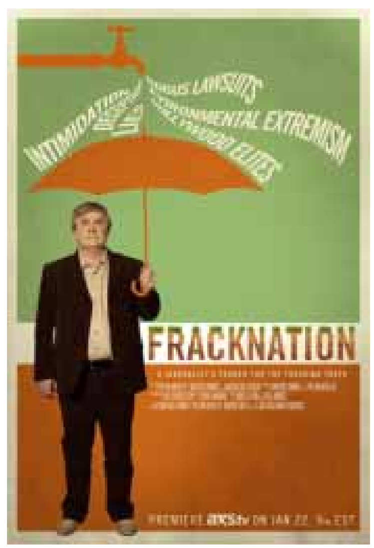
- Some have financial interests in coal
- Some countries may not want to lose their monopoly on gas supply

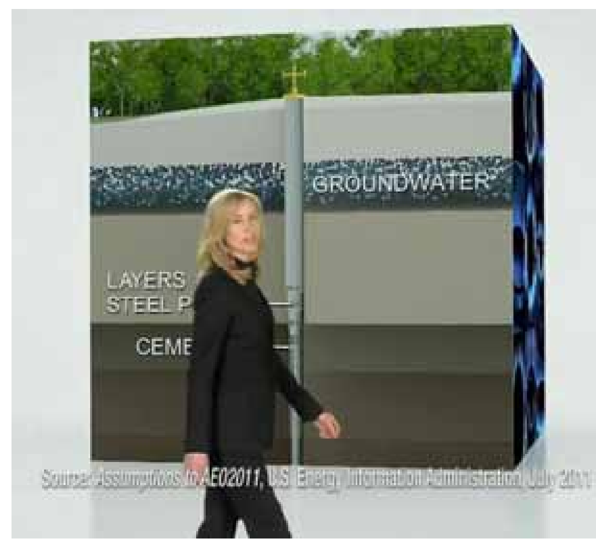
Issues and Concerns #5

Slickly made Hollywood productions (e.g., Gasland, Promised Land) use photogenic and likeable actors to convey a message that is only partially based on facts

- The public is more likely to believe those persons rather than a spokesperson from an oil and gas company or industry association
- Some efforts have been made to create other films that portray a different side of the story (FrackNation) or API commercials with a photogenic actress







Issues and Concerns #6

Shale gas and frac jobs create too much air emissions and greenhouse gases

- The process of drilling wells, fracturing them, and disposing the wastewater does generate air emissions
- The preponderance of studies over the last few years show that natural gas from shale formations results in a reduction of emissions and greenhouse gases

Issues and Concerns #7

Increased truck traffic on rural roads

- This is a significant legitimate issue and may be the issue that causes the most objections from local residents
- Companies are looking for ways to use pipelines to transport clean and dirty water or to recycle the wastewater in the field

Issues and Concerns #8

Other socioeconomic issues

- When oil and gas production comes to an area with a depressed economy, it quickly introduces lots of new money into the local economy
- It also changes the availability and price of objects (e.g., shortage of hotel rooms)
- Those residents that have mineral rights and those that have jobs providing services and goods to outside oil and gas workers are winners. The rest of the residents see limited gains but put up with a noticeable change to their bucolic lifestyle

Issues and Concerns #9

Use of chemicals in drilling and fracturing

- Transportation and storage of large quantities of chemicals in rural areas creates risks and fears
- Industry’s reluctance to share information about the actual chemicals used, their ingredients, and the volumes used reinforced the fear and lack of trust

Issues and Concerns #10

Shale gas wastewater (flowback and produced water) are a serious problem

- Not really – the volume of shale gas wastewater represents less than 10% of all the produced water generated in a year in the U.S.
- There are options for managing wastewater with various practicalities and a range of costs
- However, one area of growing concern is the potential linkage of injection of large volumes of wastewater into disposal wells with enhanced seismic activity
  - More than 150,000 Class II injection wells in U.S., with probably at least 25,000 of those serving as disposal wells
  - Only a small percentage of these are suggested as being linked to seismic activity
  - Several organizations have ongoing workgroups trying to develop regulatory guidelines and policies for state agencies

Final Thoughts

- Unconventional production over the past decade has been a real game-changer for the United States
- Hydraulic fracturing is a necessary component of that production
- Opponents have introduced numerous negative aspects of “fracking”. Some of these are valid, others are hype and scare tactics.
- Like all other forms of energy, oil and gas production aided by HF has risks
- My personal opinion is that the benefits outweigh the risks in most locations as long as the operators construct their wells correctly and follow prudent management and operational procedures