Thoughts on Hydraulic Fracturing and Unconventional Production

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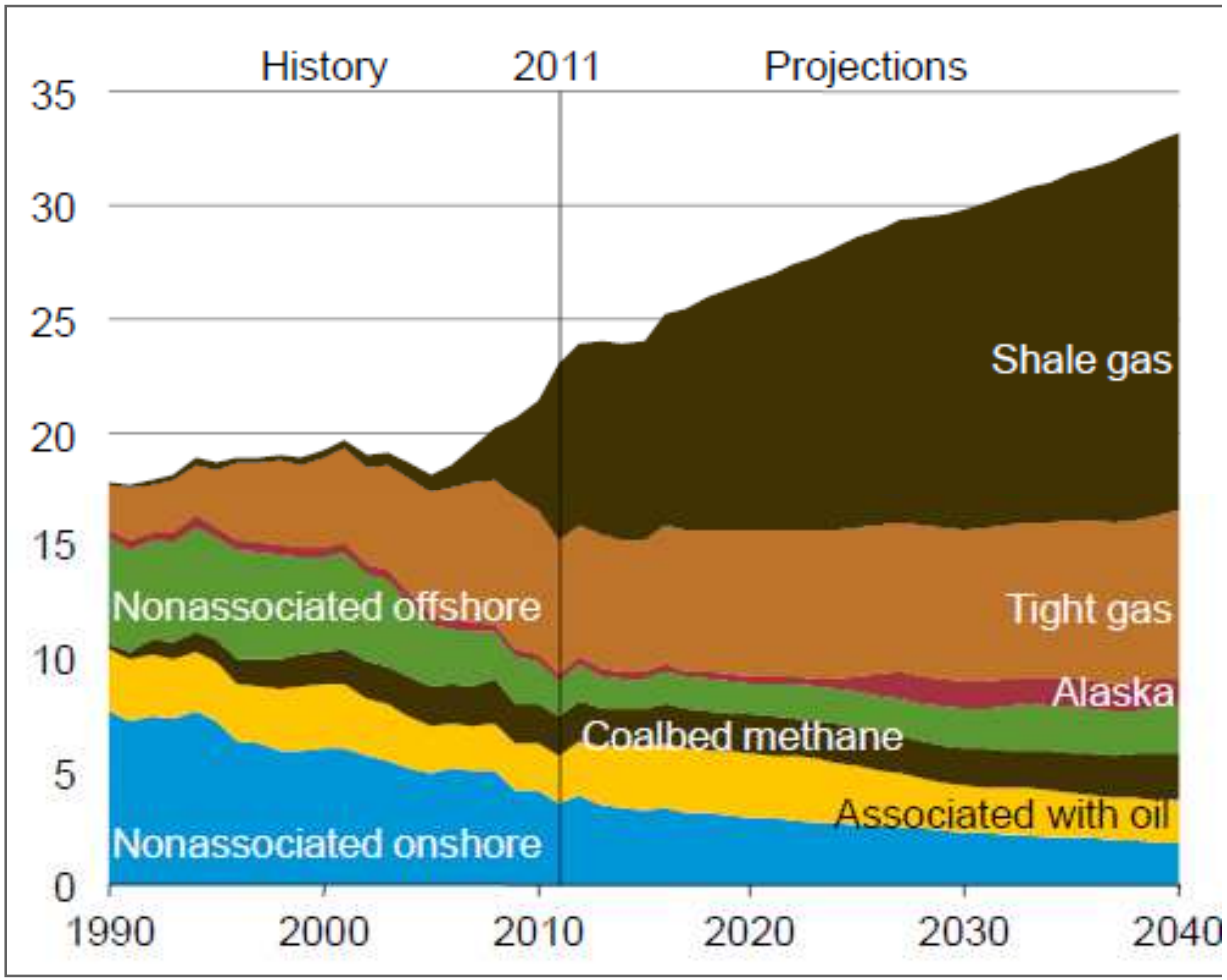
Topics for Discussion

- The importance of unconventional gas
- Shale gas water needs
- Hydraulic fracturing issues

Importance of Shale Gas to the USA

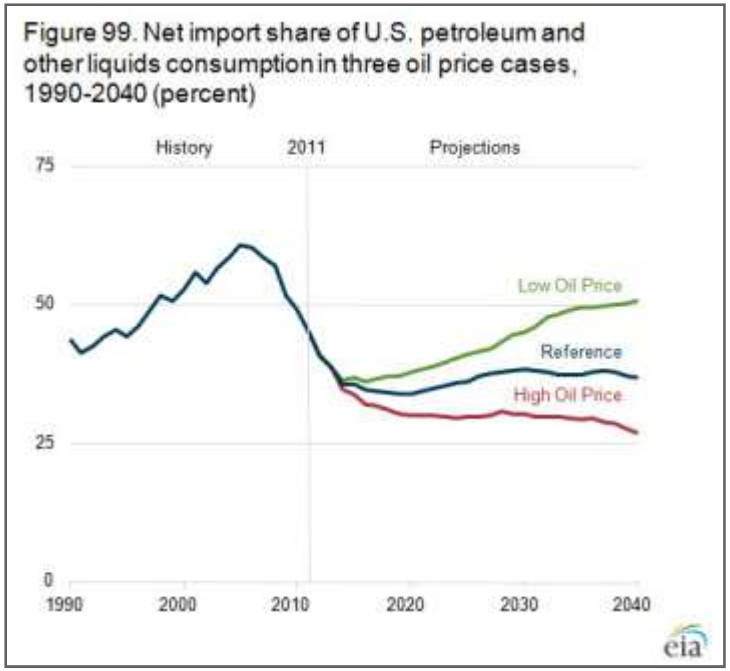
- Natural gas is an important energy source for the United States. Shale formations represent a growing source of natural gas for the nation and are among the busiest oil and gas plays in the country.



Source: DOE/EIA Annual Energy Outlook 2013

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).
- Natural gas prices remain low for home owners and factories.
- Energy policy is shifting to rely more heavily on gas-fired power plants and vehicles.
- Jobs are brought to previously depressed areas
- Tax revenue make substantial contributions to state and local governments



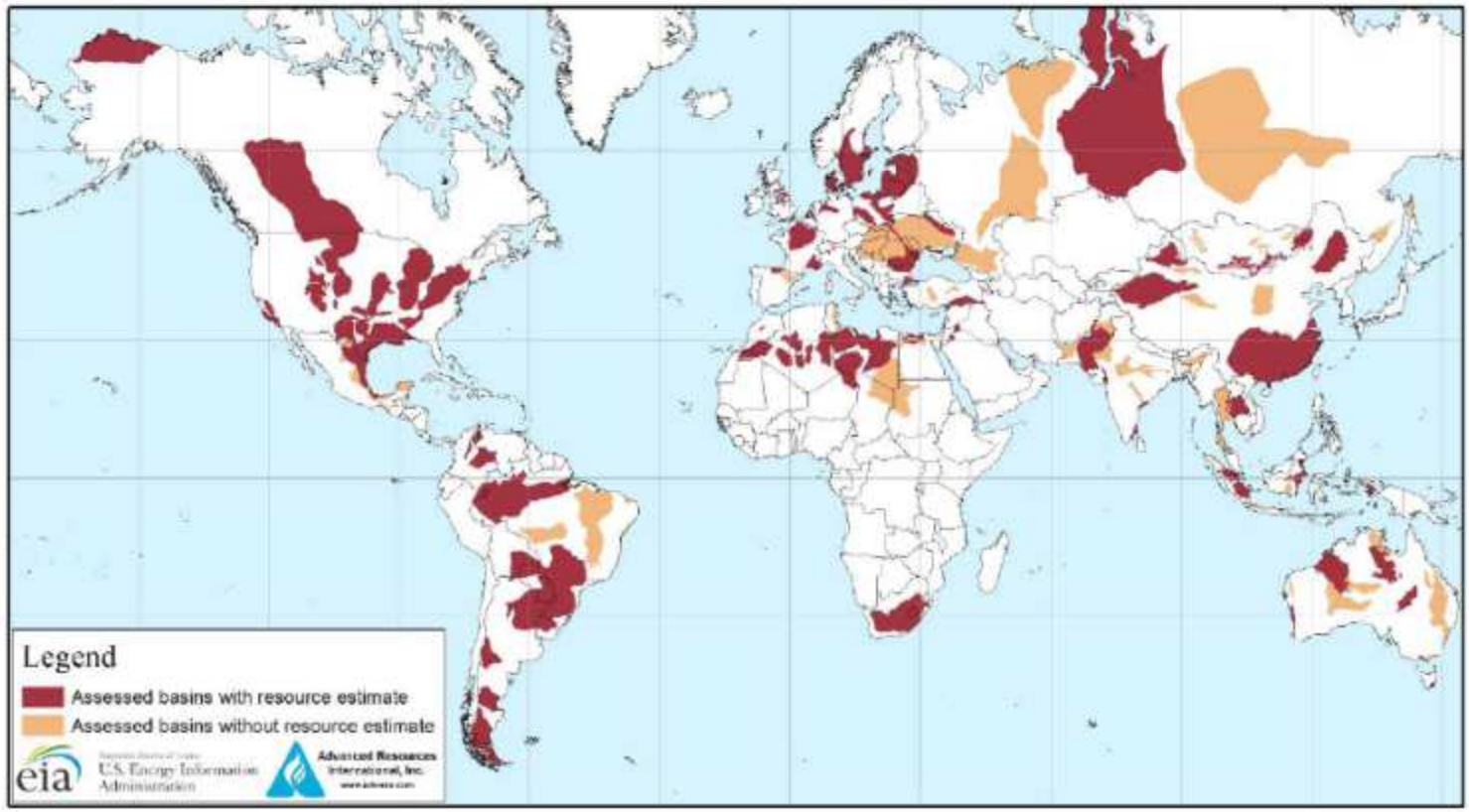
Source: DOE/EIA website

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**

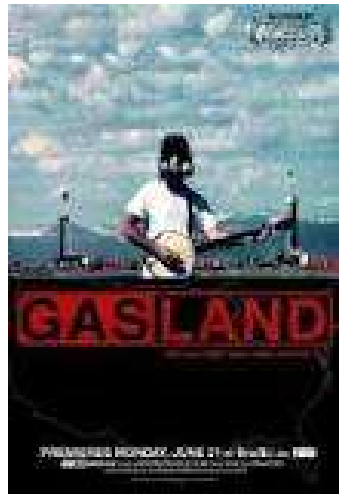
Source: Advanced Resources 2013

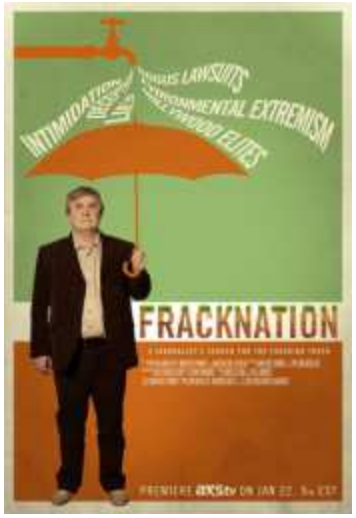
Perceived Issues and Concerns Relating to Shale Gas Production vs. the Real Story

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.
   - Industry will continue to look at renewables, but the public wants low-cost, reliable energy – natural gas provides that
2. Shale gas uses too much water – often in arid areas
   - In reality, in many areas (e.g., Marcellus), the water used for gas production represents a few tenths of 1% of all the water currently used in the regions
   - In other areas, (e.g., parts of Texas), water needs for gas production can be significant
   - Industry is already recycling some flowback and produced water and is evaluating lower-quality water sources
     - Treated sewage
     - Acid mine drainage
     - Brackish groundwater

Issues and Concerns (2)

3. Opponents have various vested interests against additional oil and gas development, often in regions that do not have long-term familiarity with oil and gas development
   - Some have financial interests in coal
   - Some countries may not want to lose their monopoly on gas supply
   - Affluent urban residents and celebrities can afford to pay more for oil and gas while blocking lower income rural residents from harvesting the natural resources beneath their properties
4. 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)
   - Industry groups like Energy in Depth refute the inaccuracies of the opposition movies





Issues and Concerns (3)

5. 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
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
   - Leaks from pipelines, valves, etc. can be detected easily with monitoring devices and can be fixed at a modest cost

Issues and Concerns (4)

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
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 (5)

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

Hydraulic Fracturing (HF)

A New Frac Technology Discovered in Bolivia

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

Chemical Disclosure Registry

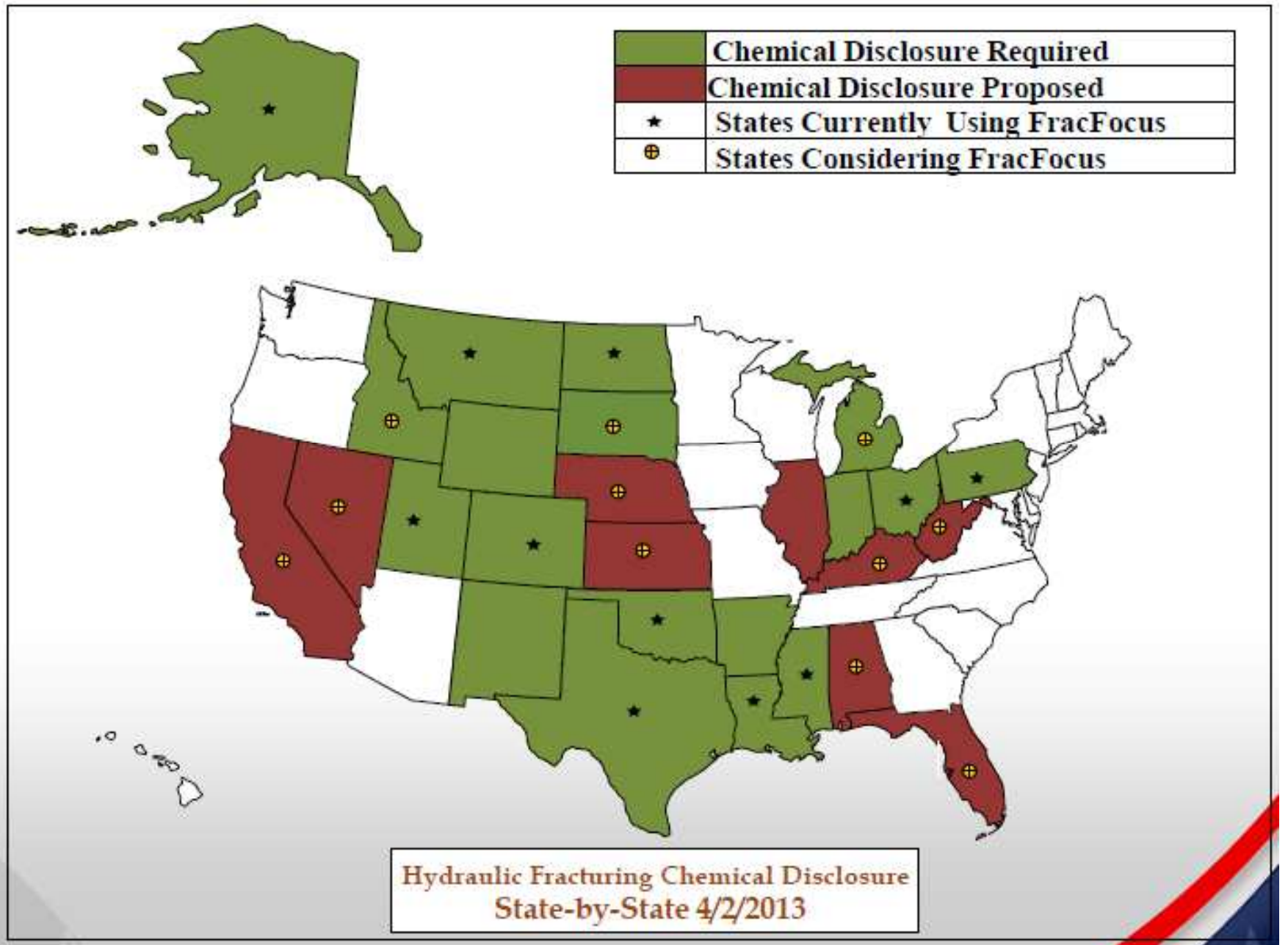
- In April 2011, the Ground Water Protection Council (GWPC) and the Interstate Oil and Gas Compact Commission (IOGCC) opened a new online system (FracFocus) to host information about the chemical additives used in frac fluids and their ingredients
  - The key feature was a chemical disclosure registry
- 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 75,000 entries from over 1,000 companies

Hydraulic Fracturing



Frac Focus Homepage

Example of Registry Record for Well in Texas

Trade Name	Supplier	Purpose	Ingredients	Chemical Abstract Service Number (CAS #)	Maximum Ingredient Concentration in Additive (% by Mass)**	Maximum Ingredient Concentration in HF Fluid (% by Mass)**
Fresh Water		Carrier/Base Fluid				86.12803%
Sand (Proppant)		Proppant				12.83614%
Acid, 15% HCl	CUDD ENERGY SERVICES	Acid	Water	007732-18-5	85.00%	0.06070%
			Hydrochloric Acid	007647-01-0	15.00%	0.01071%
I-22	CUDD ENERGY SERVICES	Corrosion Inhibitor	Formic Acid	000064-18-6	60.00%	0.00053%
			Aromatic aldehyde	N/A	30.00%	0.00026%
			Haloalkyl heteropolycycle salt	N/A	30.00%	0.00026%
			Oxyalkylated Fatty Acid	N/A	30.00%	0.00026%
			Isopropanol	000067-63-0	5.00%	0.00004%
			Methanol	000067-56-1	5.00%	0.00004%
			Organic sulfur compound	N/A	5.00%	0.00004%
			Quaternary ammonium compound	N/A	5.00%	0.00004%
			Benzyl Chloride	000100-44-7	1.00%	0.00001%
SG-15M	CUDD ENERGY SERVICES	Gelling Agent	Petroleum Distillate	064742-47-8	55.00%	0.06860%
			Guar Gum	009000-30-0	50.00%	0.06236%
			Clay	014808-60-7	2.00%	0.00249%
			Surfactant	068439-51-0	2.00%	0.00249%
BUFFER H	CUDD ENERGY SERVICES	pH Adjusting Agent	Water	007732-18-5	94.50%	0.02070%
			Sodium Hydroxide	001310-73-2	51.50%	0.01128%
			Sodium Chloride	007647-14-5	5.00%	0.00110%
GB-4	CUDD	Breaker	Proprietary	N/A	100.00%	0.00120%
	ENERGY SERVICES					
CX-14G	CUDD ENERGY SERVICES	Cross Linker	Petroleum Distillate Hydrotreated Light	064742-47-8	60.00%	0.01454%
GB-2	CUDD ENERGY SERVICES	Breaker	Ammonium Persulfate	007727-54-0	100.00%	0.00083%
NE-21	CUDD ENERGY SERVICES	Non-Emulsifier	Methanol	000067-56-1	30.00%	0.01218%
			Oxyalkylated alcohols	N/A	30.00%	0.01218%
			Ethoxylated Alcohols	N/A	10.00%	0.00406%
CX-14A	CUDD ENERGY SERVICES	Cross Linker	Sodium Tetraborate	001330-43-4	25.00%	0.00056%
CS-125C	CUDD ENERGY SERVICES	Clay Stabilizer	No Hazardous Components	NONE		0.00000%
FRA-4	CUDD ENERGY SERVICES	Friction Reducer	No Hazardous Components	NONE		0.00000%
MC B-8642 (WS)	MULTI-CHEM GROUP LLC	Anti-Bacterial Agent	Glutaraldehyde (Pentanediol)	000111-30-8	60.00%	0.01180%
			Quaternary Ammonium Compound	068424-85-1	10.00%	0.00197%
			Ethanol	000064-17-5	1.00%	0.00020%
MC S-2510T (WS)	MULTI-CHEM GROUP LLC	Scale Inhibitor	Ethylene Glycol	000107-21-1	60.00%	0.00605%
			Sodium Hydroxide	001310-73-2	5.00%	0.00050%

Chesapeake Resources Well BSOA 14-14-15 H-1, De Soto County, LA, frac date 3/21/11

Issues and Concerns Raised about FracFocus

- Does not give enough information to public
- Encourages more natural gas development instead of renewable energy sources
- Cannot directly compile records from multiple wells in a spreadsheet
  - At least two organizations have developed algorithms to “scrape” the data from FracFocus and make them available in a more user-friendly format
- Secretary of Energy’s Advisory Board wanted to see more transparency and fewer chemicals listed as “proprietary”

Water Needs for Hydraulic Fracturing

Water Withdrawal and Consumption

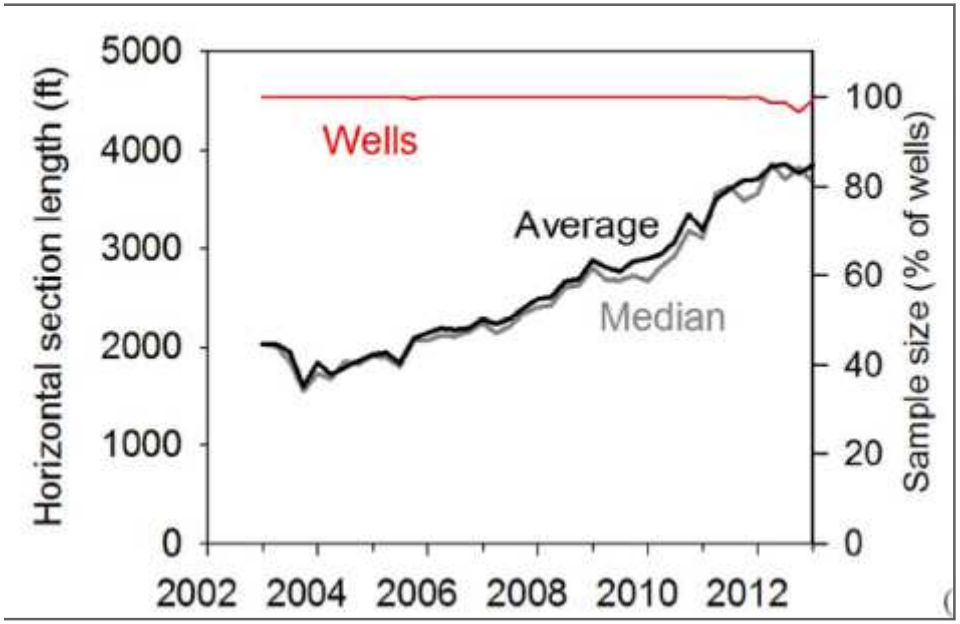
Sector	Volume Withdrawn (bgd)	Volume Consumed (bgd)	% Consumed
Public supply and domestic	48	19.8	41
Agriculture (irrigation, livestock, and aquaculture)	139	52.9	38
Thermoelectric	143	3.9	3
Industrial	17	2.5	15
Mining (includes oil and gas)	2.3	0.6	26
Total	350	79.8	23

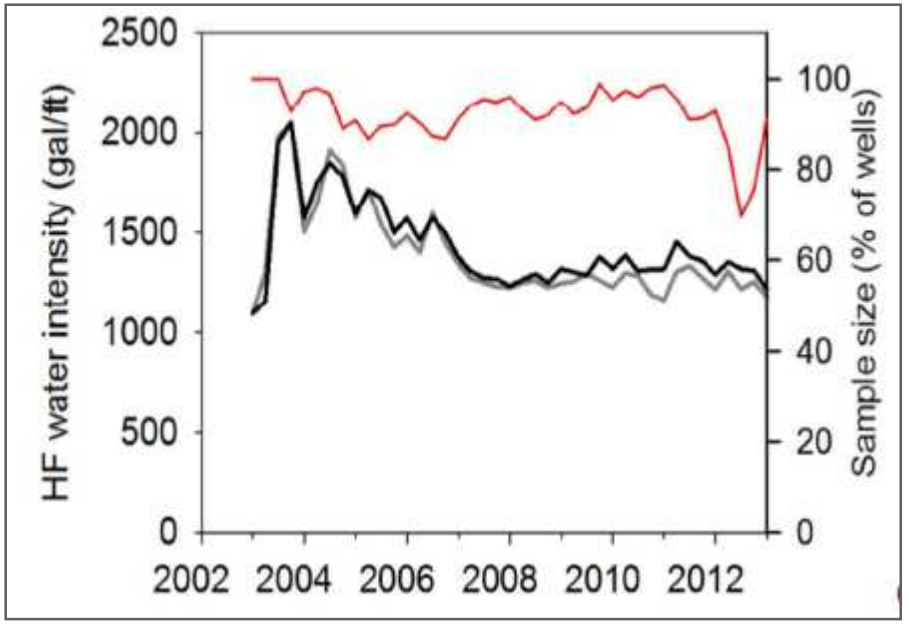
Source: Volume withdrawn (Kenny et al. 2009); volume consumed (EPRI 2014)

Water Availability in Marcellus and Fayetteville Shales

- In both of these shale plays, the water needed to support a hypothetical maximum well fracturing year represents a fraction of 1 percent of the total water already used in the regions.
- This suggests that sufficient water should be available
  - ***Not in every location or on every stream tributary***
  - ***Not during every week of the year***
- Requires good advanced planning to withdraw water from rivers when flows are high and store the water until needed for fracturing.
- Will require local or regional fresh water storage impoundments.
- New data from Ground Water Protection Council analysis.

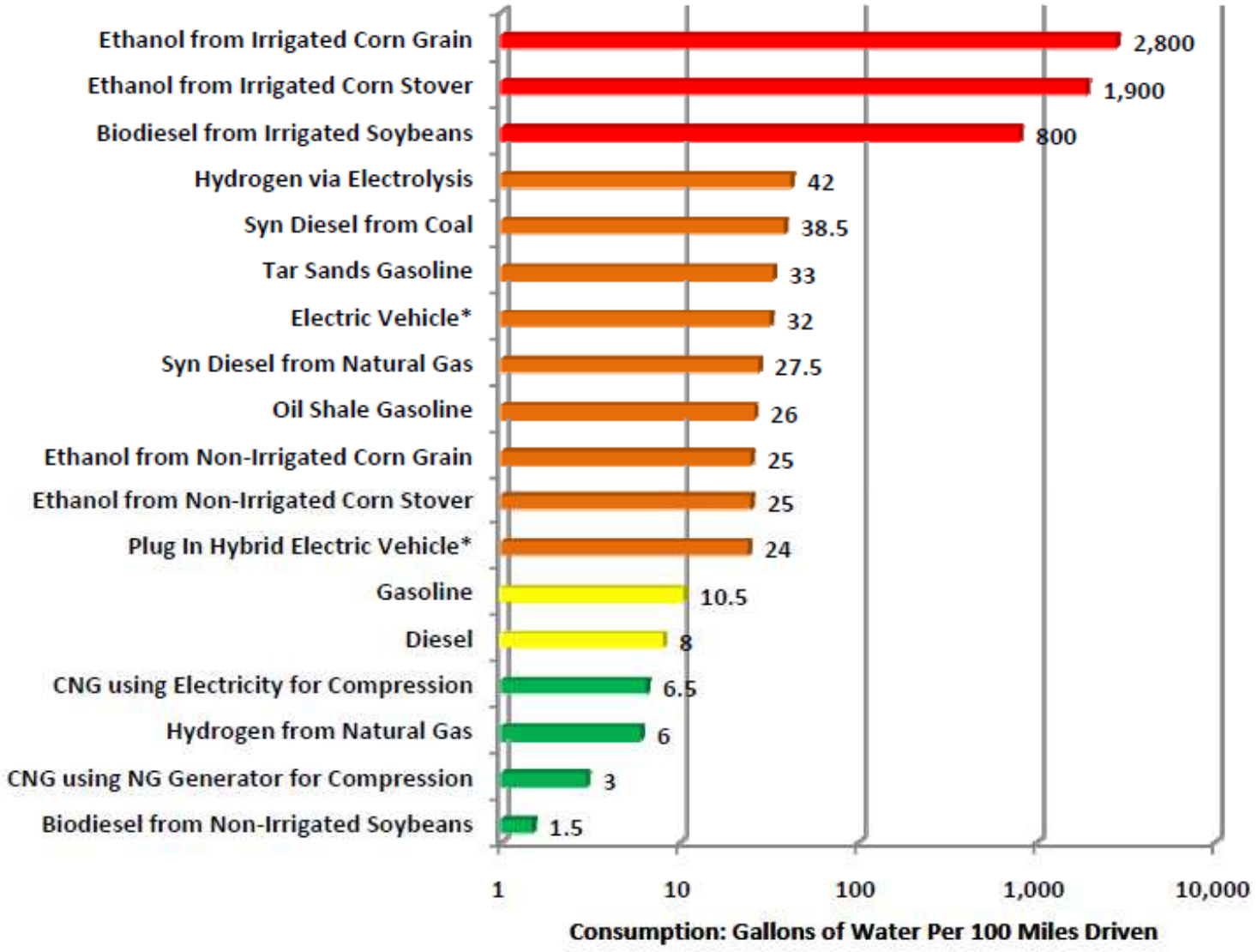
Water Needs for Barnett Shale





Source: Nicot et al., Environmental Science & Technology, 2014.

Water Intensity of Transportation Fuels



Source: Mantell (2009) based on data from King and Webber (2008)

Water Used for Hydraulic Fracturing – Lost or Not?

- 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.

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.
- Hydraulic fracturing uses a lot of water for each well, but when viewed in perspective of other water uses, it is not significant on a statewide level