Global Shale Energy Production:
Evolving Process, Mitigating Risk, Growing Benefit

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Marcellus Center for Outreach and Research (MCOR)

- Conduct research related to shale development in PA, the U.S., and globally
- Collaborative approach with other institutions, government agencies, NGOs, etc
- Research related to down hole technologies and above ground impacts--best management practices (BMPs)
- Outreach sessions to create greater subject knowledge based in science
  - Various stakeholders and the general public
  - Trained & knowledgeable inspectors
  - Value of "social license"?? Access??

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"Teaching" the Science of Unconventional Gas

- Face to face Outreach
- Building appreciation of science in many willing stakeholders
- Who are the "real" stakeholders??
- Business forums
- Educational forums
- Stakeholder tours
- Partnership of government, industry, academia
- Workforce deve'l efforts
- Webinars
- Publications
- Media tours
- Local content
- Local business
- Academic by-in
- Collaborative research to fill the gaps

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Conveying Benefit vs. Risk

- What are the reasons for producing the energy
  - Demand for all energy
  - Economic rewards
  - New business dev'l
  - Workforce opportunities
  - "Bridge" to something else
    - Fossil vs. renewables
    - "all the above" strategy
- Possible vs. probable
  - Cars/food/fire/etc.
  - Well failure
  - Water contamination
    - Chemicals
    - Methane
  - Air emissions
  - Health
  - Gaps in research??

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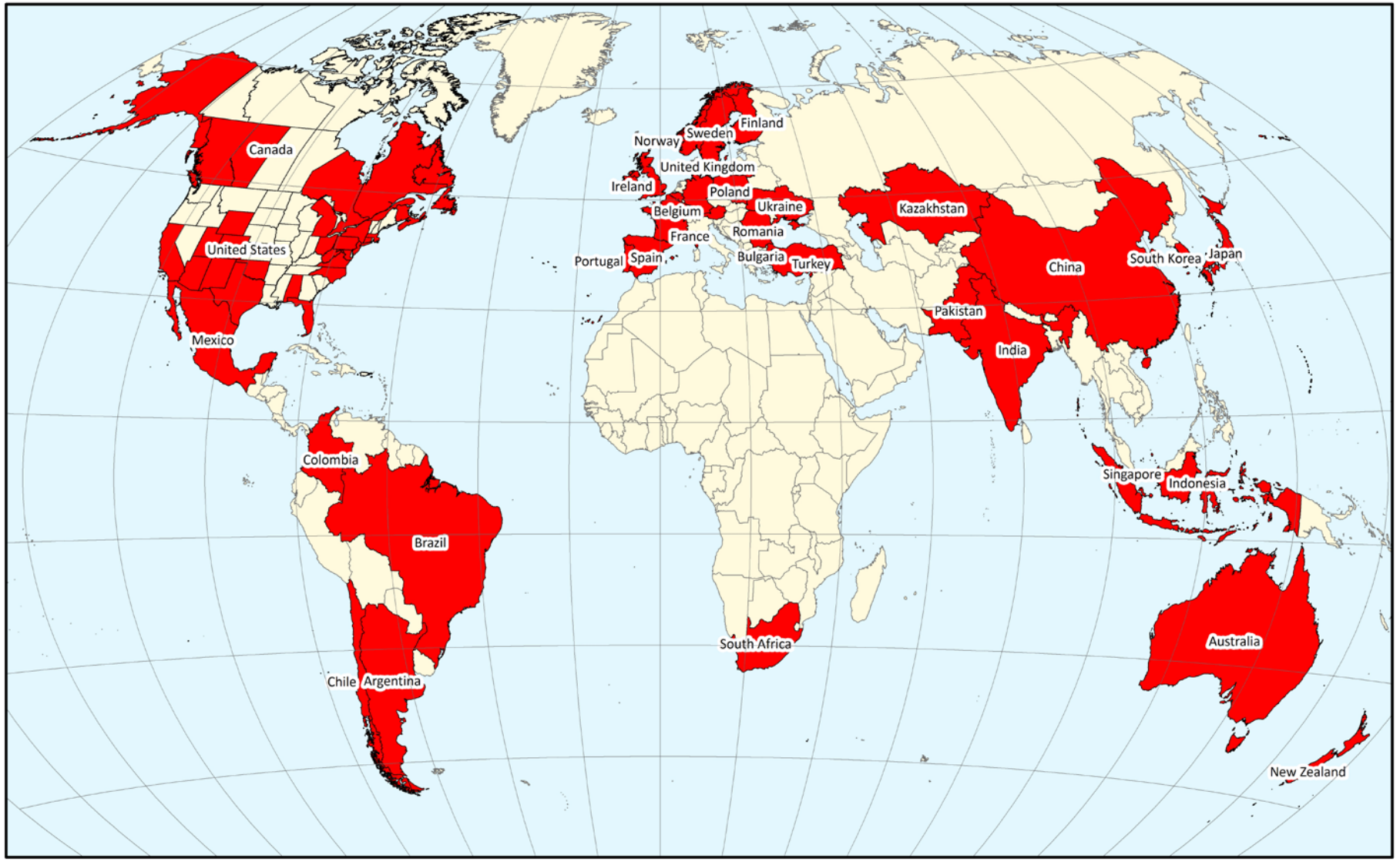
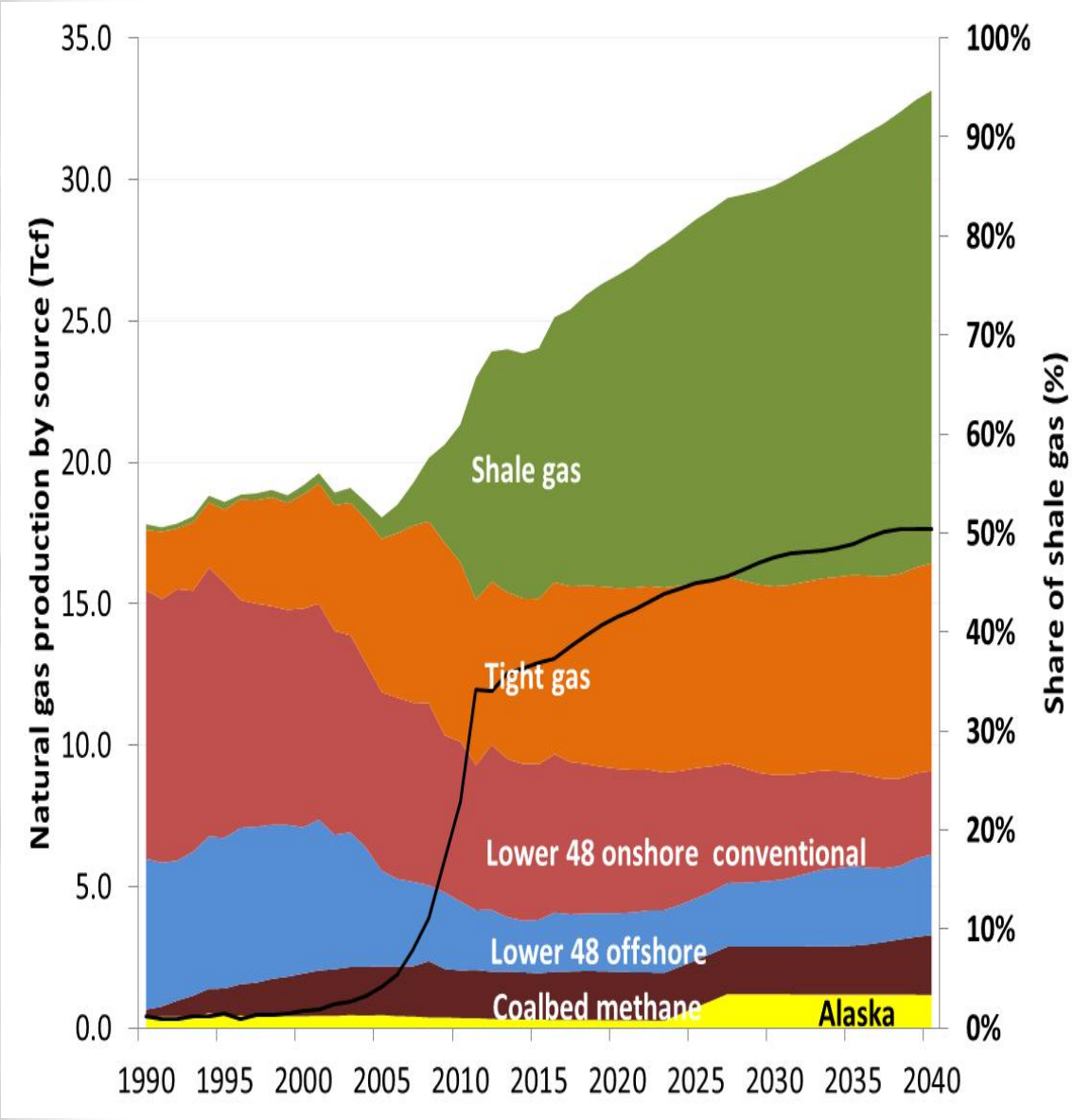
World Shale Leadership



U.S. Natural Gas Production



- Natural gas production increase by 39% from 2012 through 2040.
- Shale gas increase by 105% from 2012 through 2040.
- Shale gas accounts for 50% of the natural gas production by 2040

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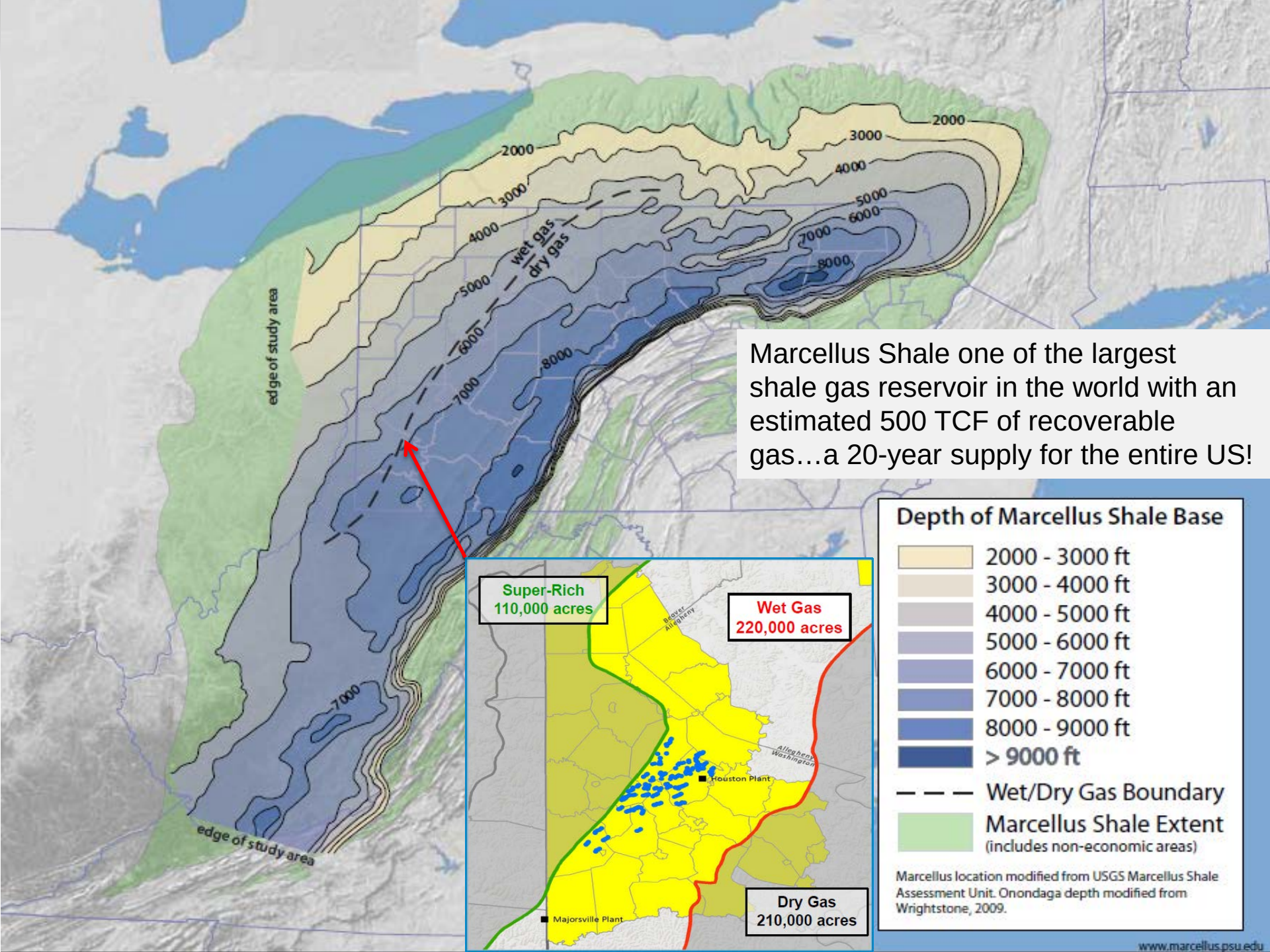
2000
3000
4000
5000
6000
7000
8000
wet gas
dry gas
edge of study area
edge of study area
Marcellus Shale one of the largest shale gas reservoir in the world with an estimated 500 TCF of recoverable gas…a 20-year supply for the entire US!
Super-Rich
110,000 acres
Wet Gas
220,000 acres
Dry Gas
210,000 acres
Houston Plant
Majorsville Plant
Depth of Marcellus Shale Base
2000 - 3000 ft
3000 - 4000 ft
4000 - 5000 ft
5000 - 6000 ft
6000 - 7000 ft
7000 - 8000 ft
8000 - 9000 ft
> 9000 ft
Wet/Dry Gas Boundary
Marcellus Shale Extent
(includes non-economic areas)
Marcellus location modified from USGS Marcellus Shale Assessment Unit. Onondaga depth modified from Wrightstone, 2009.
www.marcellus.psu.edu

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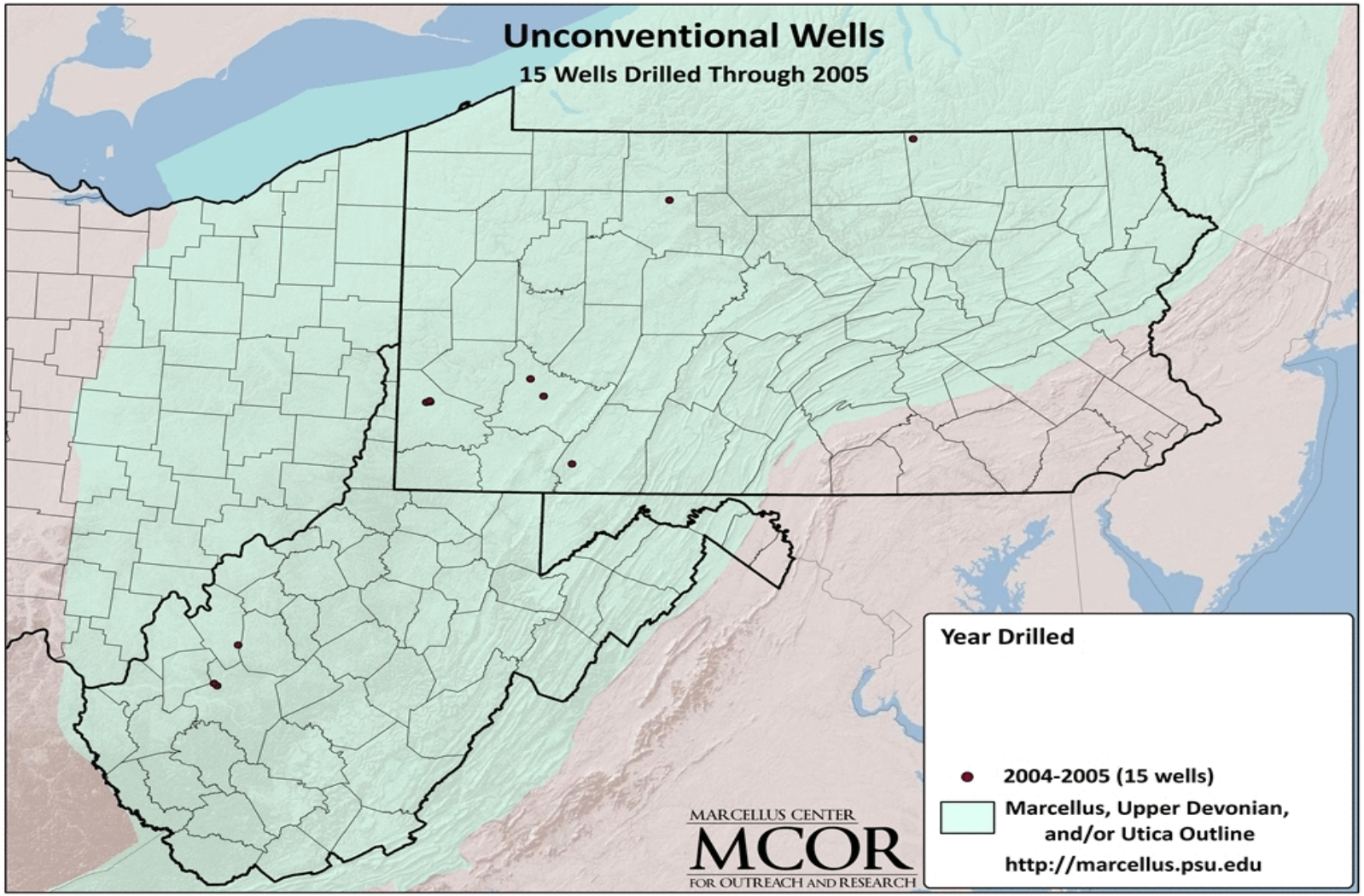
Unconventional Development in NE U.S.



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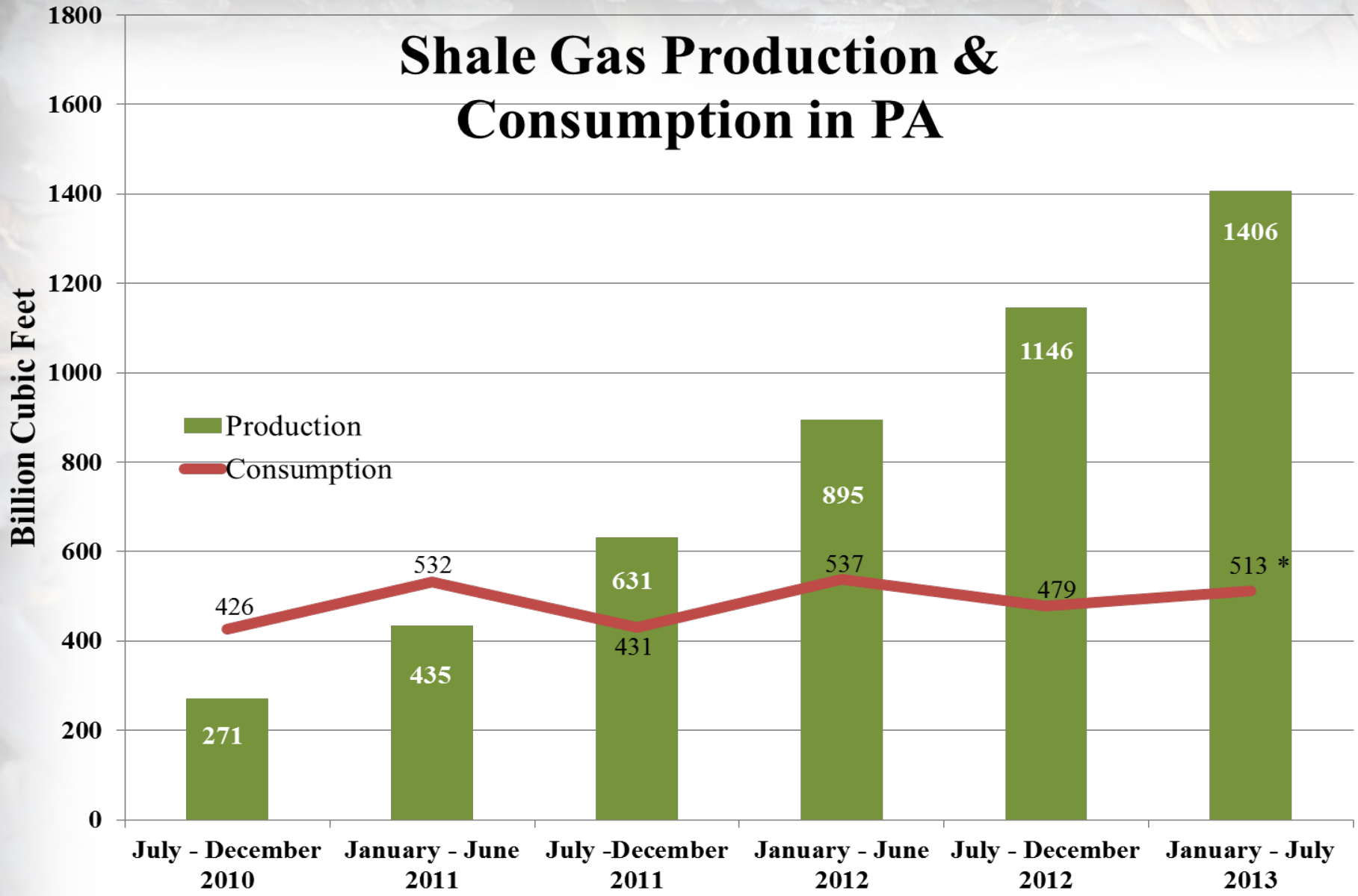

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PA Shale Economic Impacts

According to PA Department of Labor through 2012:

- Approximately new 20,000 jobs in "core-related" industries (direct jobs)
- Approximately 200,000 jobs supported partially by industry

As of 2012 PA collected:

- $402 MM in well impact fees
- Approximately $2 billion in taxes from 2006-2012

2012 PA Totals:

- ~$5.85 Billion in total revenues from gas sales
- ~$731 MM in royalties

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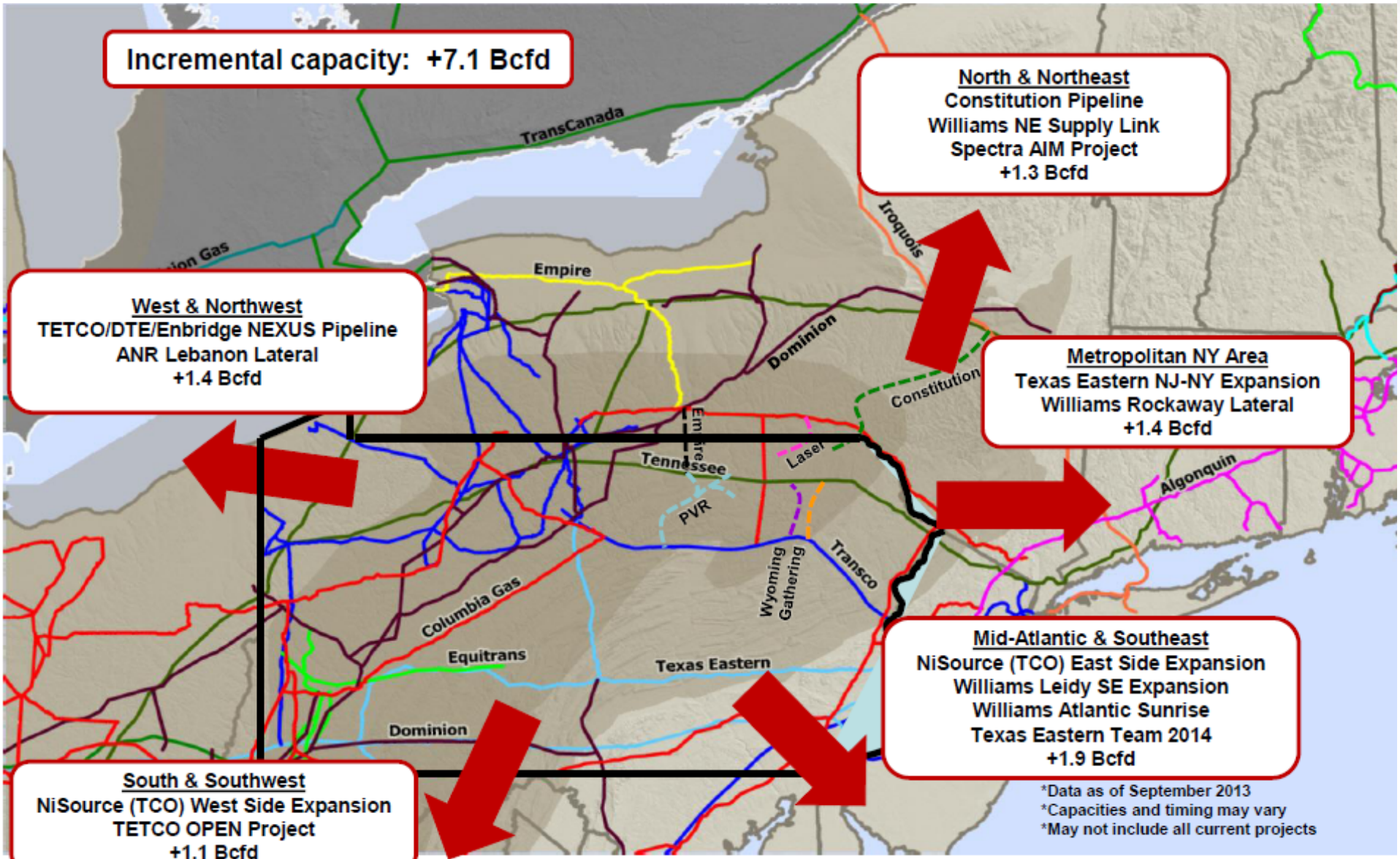
Marcellus - Proposed Infrastructure Projects through 2016



Source: Range Resources

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Developing Shale Tech Trends

- Emerging technology followed by regulations
  - Closed loop systems w/tanks vs. open in-ground pits
  - Water recycling/remediation technologies
  - Stronger trend to "green completions" – reduced VOC and air emissions
  - Increased effort to monitor/eliminate methane leakage
- Evolving hydraulic fracturing technology
  - Fewer chemicals, changing water needs, LPG/CO2/other fracs
- Greening of the products and technologies used in the drilling/completion process
  - New chemistry –sourced from food industry
- Transparency – FracFocus.org

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Potential Regulatory Issues

- Water
  - Quality – can impaired waters be used?
  - Sourcing locations - quantity
  - Groundwater and watershed baselines, incl. TDS
- Waste streams
  - Water over lifecycle
  - Disposal wells(or not)
  - Drill cuttings/drilling muds
- NORM
- Air emissions/flaring/green completions
- Mitigation technologies

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Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies

- Five Penn State project coordinators

- Funded by the Center for Rural Pennsylvania (a legislative agency of the Pennsylvania General Assembly) and the Pennsylvania Water Resources Research Center at Penn State University

Objectives:

- Provide an unbiased and large scale study of water quality in private water wells both before and after the drilling of Marcellus gas wells nearby.

- Document both the enforcement of existing regulations and the utilization of voluntary measures by homeowners to protect water supplies.

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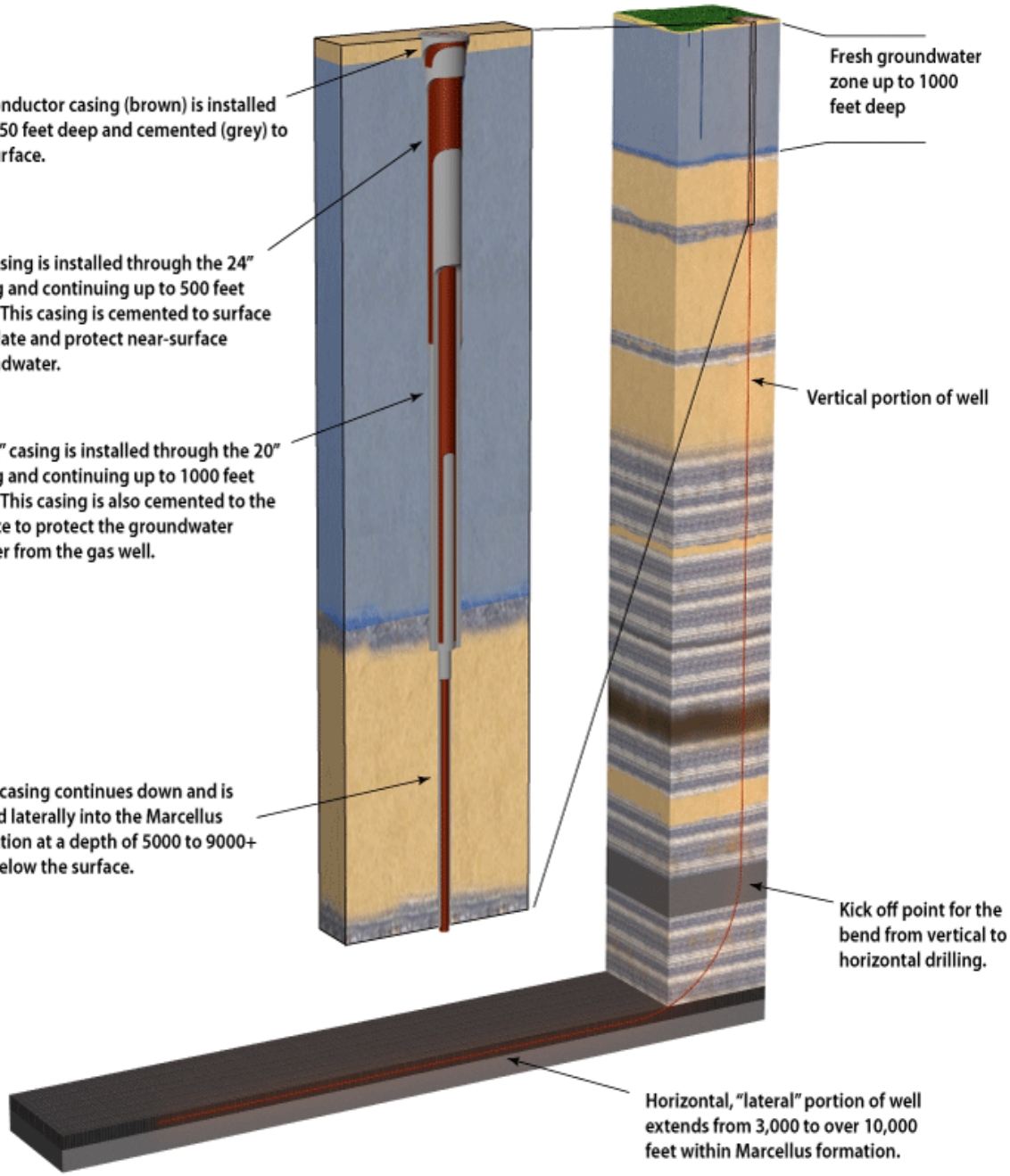

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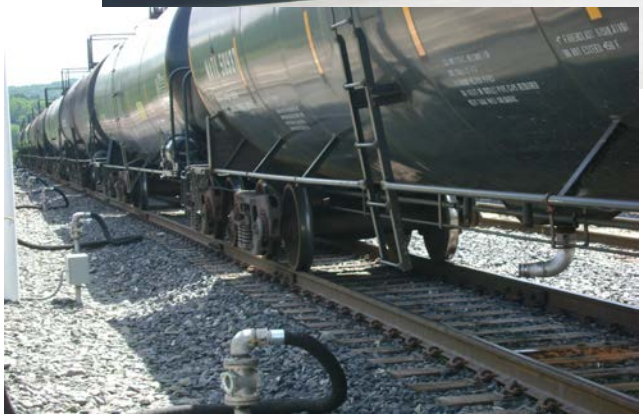
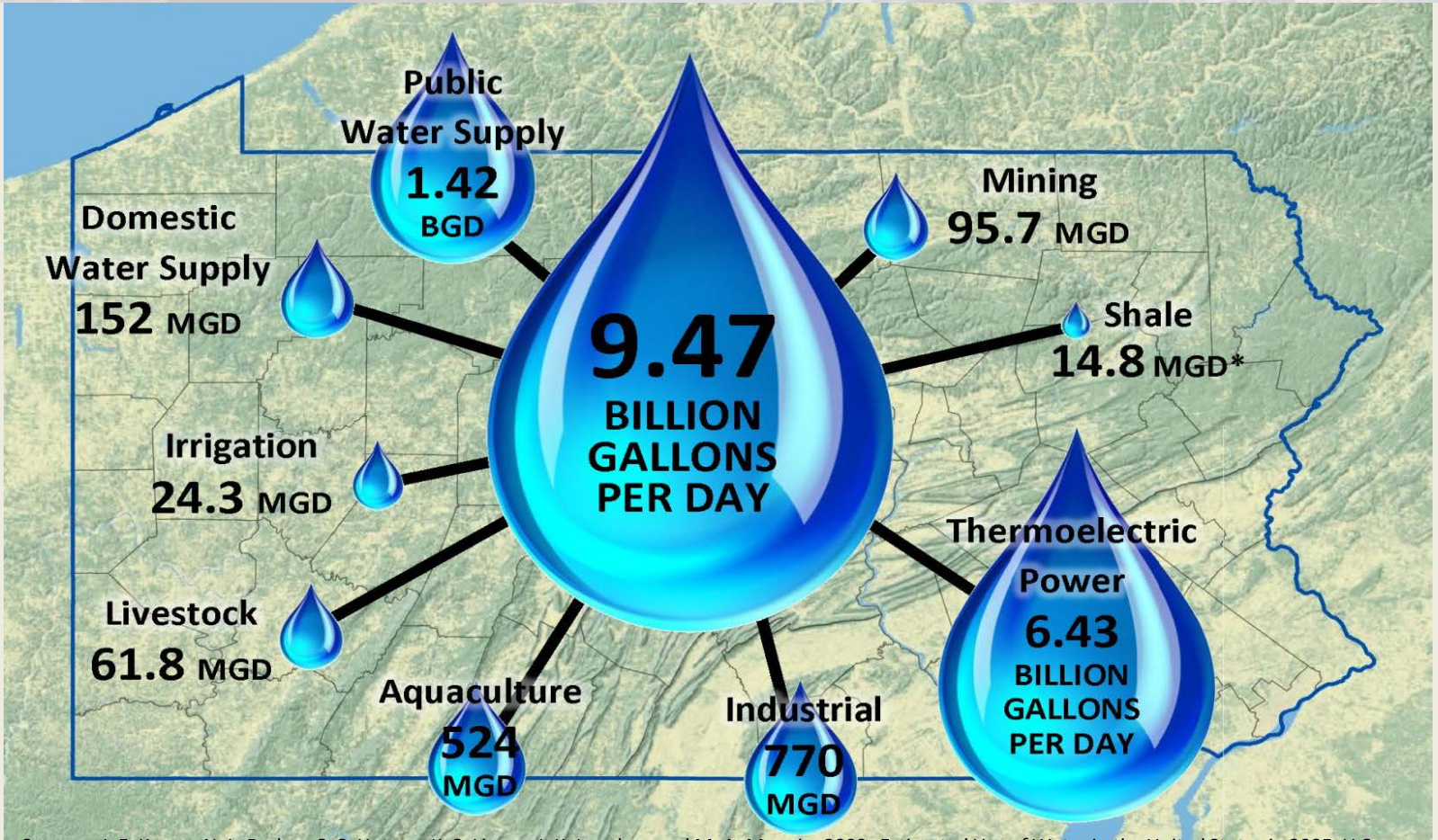
Water Usage and Sourcing

- 16.5 million liters per well (ave.)
- 60 million liters used in PA Marcellus per day
  - 0.15% of all water withdrawals in PA daily
    - 40 billion liters/day for all uses
- Declining amount of water utilized for hydraulic fracturing is trucked
  - Strongly trending towards piped/rail water vs. trucks
- 75%+ is sourced from surface supply vs. wells
- Public transparency??





Sources: J. F. Kenny, N. L. Barber, S. S. Hutson, K. S. Linsey, J. K. Lovelace and M. A. Maupin. 2009. *Estimated Use of Water in the United States in 2005*, U.S. Geological Survey, Circular 1344

Graphic update based on *Pennsylvania Angler & Boater*. PA Fish & Boat Commission. January/February, 2011

*Shale estimate based on 1,200 wells per year at 4.5 million gallons per well = 14.8 mgd total water demand - ~3 mdg of water reuse

Penn State **Extension**

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Fluid Remediation/Disposal

- 1.75 billion liters of fluid recovered 1H ’12
- Approx. 10%-20% of fluid returns to surface in Marcellus
- Currently 90%+ of flowback and produced fluid is recycled
  - 89% infield recycling
  - 9% centralized plant recycling
  - 2% stored/disposal wells

Surface/Groundwater Protection

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Common Multi-well Pads

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Noise Abatement Techniques

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Five Important Questions

- Is there a regulatory protocol in place to start or develop from blank sheet?
- Layering of national level gov't w/local jurisdictional control –what is most effective, commercially viable, and predictable?
- Is the process guided by a longer term strategy, beyond just environmental, broadly to all energy sourcing & use?
- Is the public involved and at what level?
  - Ex: Norway and New York
- How can this process overcome/rebuild trust in governmental regulation/activity?

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www.marcellus.psu.edu
www.shaletec.org
www.naturalgas.psu.edu

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Workforce Assessment

- Assessment model by academics, industry, and gov't.
- The direct workforce to drill a single well (lifecycle)
  - **420** individuals working in **150** different occupations
- Each well requires
  - **13.09-13.29** FTE workers annually. Gas processing increases from roughly two to four FTE's for every 10 wells drilled
  - Multi-Well pads **83%** of 2011 wells drilled on a multi-well pad
- 75% of jobs will be technical positions
  - On the job training
  - Certificate or 2 year degrees

Source: Pennsylvania Marcellus Shale Workforce Needs Assessment
http://www.ShaleTEC.org/

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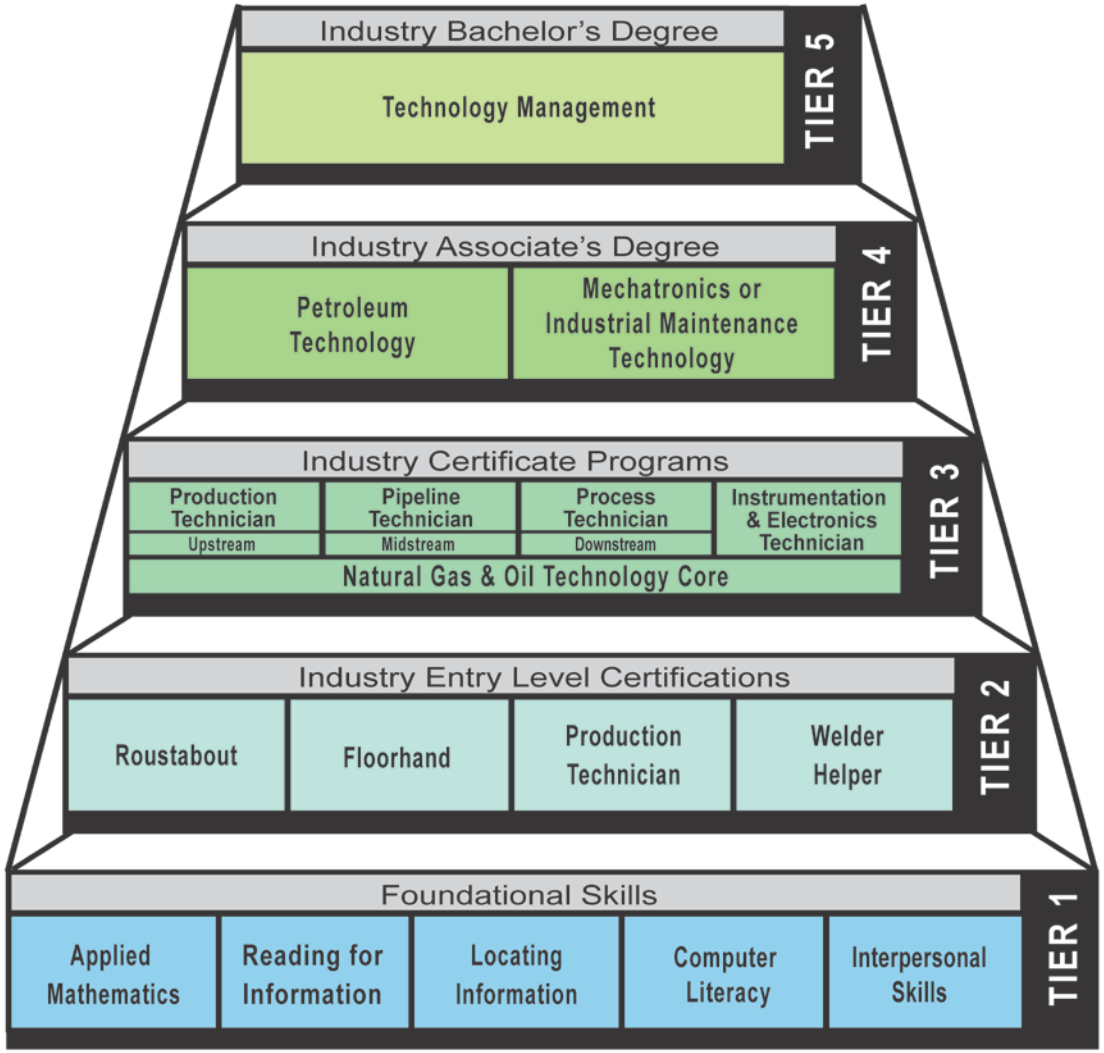
ShaleNET U.S.

Stackable Credential Model



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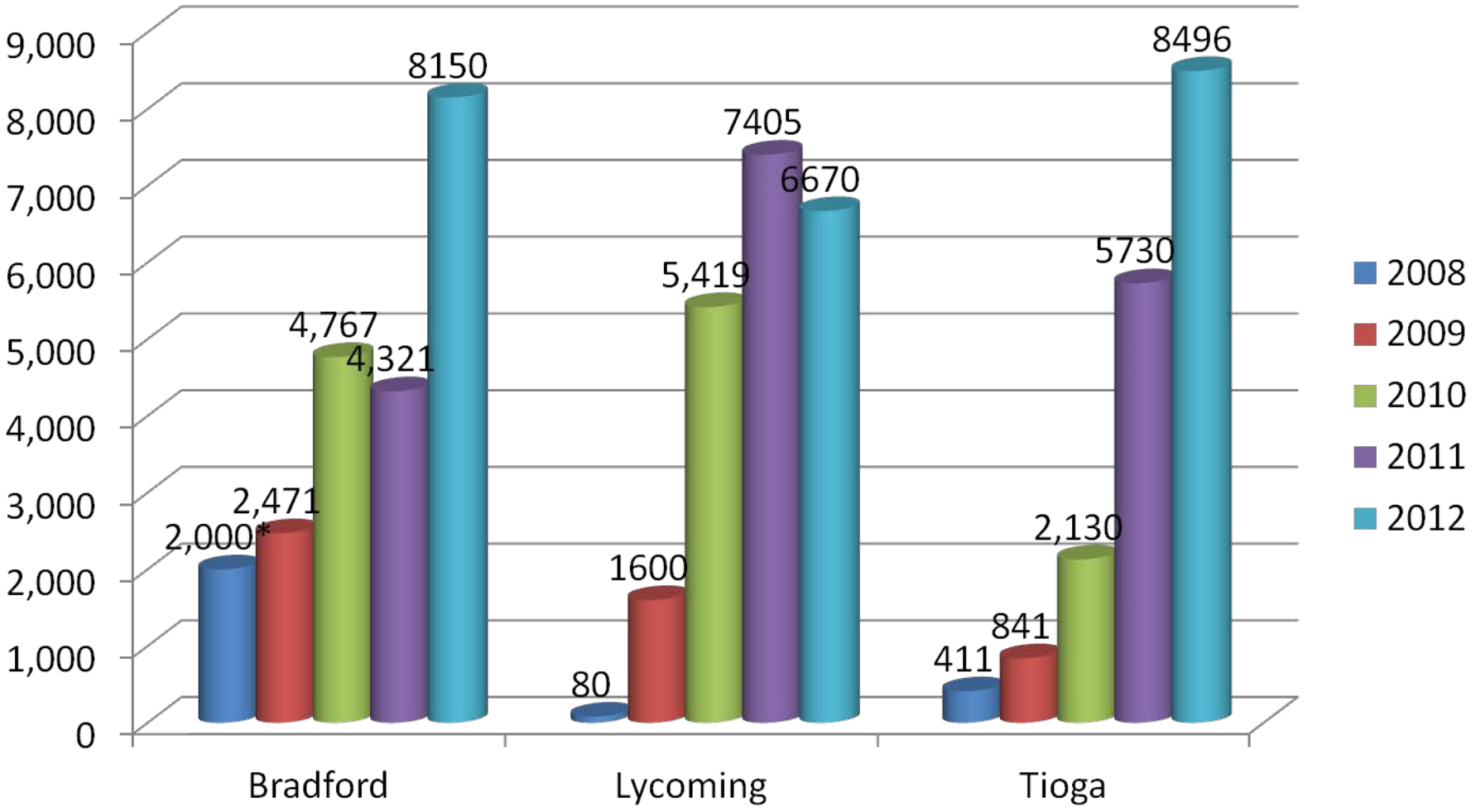
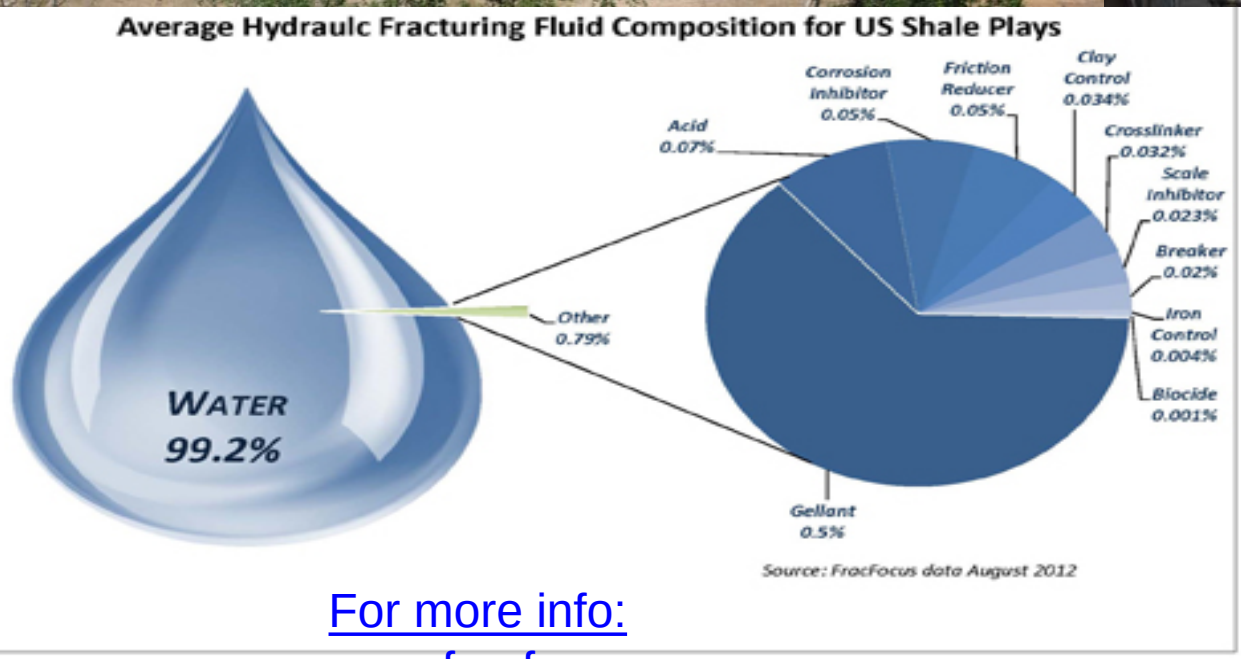
Rail Car Traffic



Shale Gas Development Water Use



For more info:

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Outreach Model(s)

- Confluence of academia, industry, government, eNGOs, foundations
- The role of the academic?
- How do you fund it?
- How to build and maintain credibility?

- MCOR
- ShaleTEC
- CSSD
- CSIRO
- Centre for Social Responsibility in Mining
- Others