

Challenges to Unconventional Gas Development, Technology Innovation, and Potential Opportunities for NG in the U.S. Transportation Sector





Marcellus Center for Outreach and Research (MCOR)

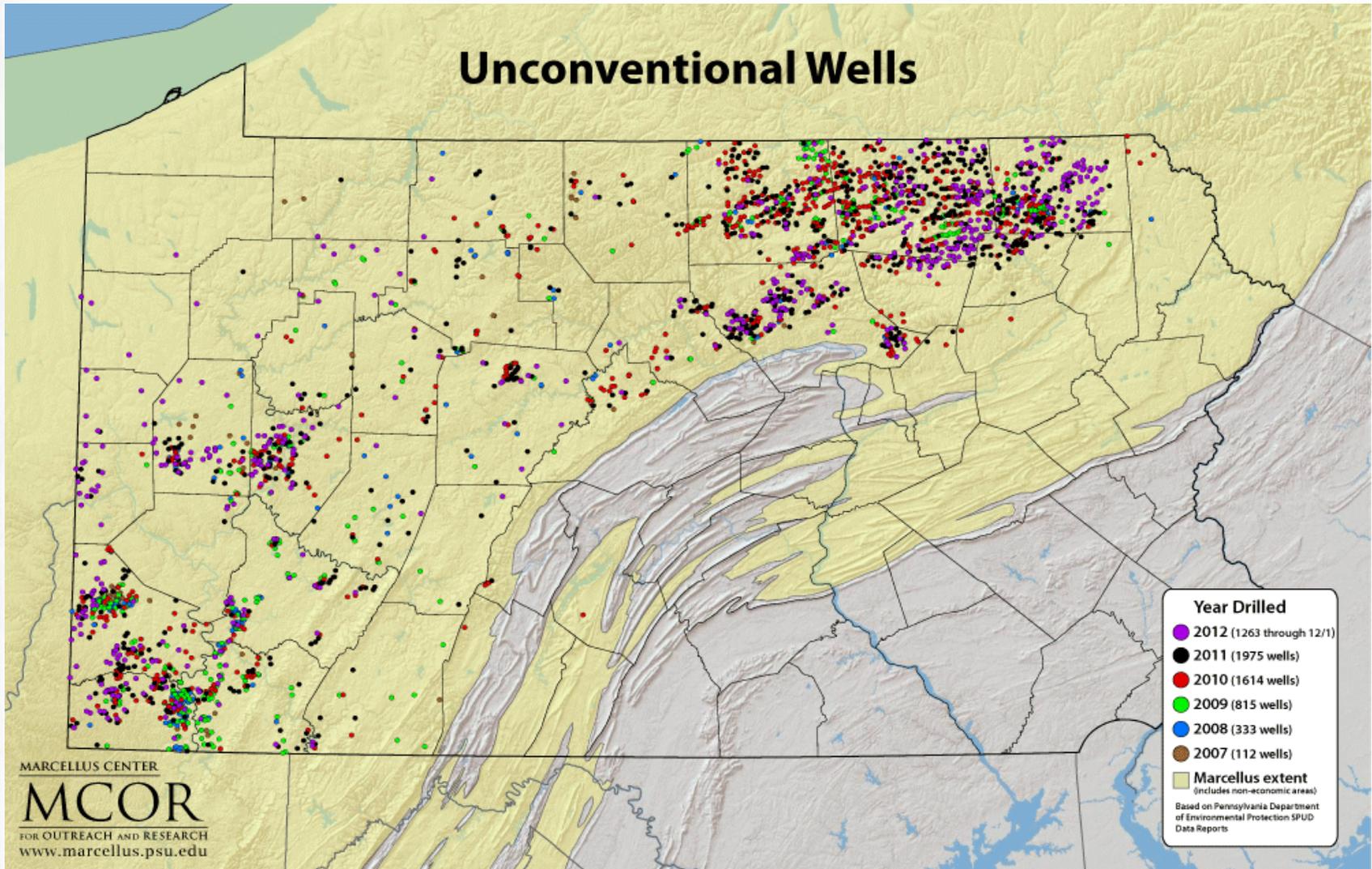
- Conduct research related to shale development in PA, the U.S., and globally
- Collaborative approach with other institutions, government agencies, NGOs, etc
- Research related to down hole technologies and above ground impacts--best management practices (BMPs)
- Outreach sessions to create greater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



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

Marcellus Wells Drilled (12/1/12)

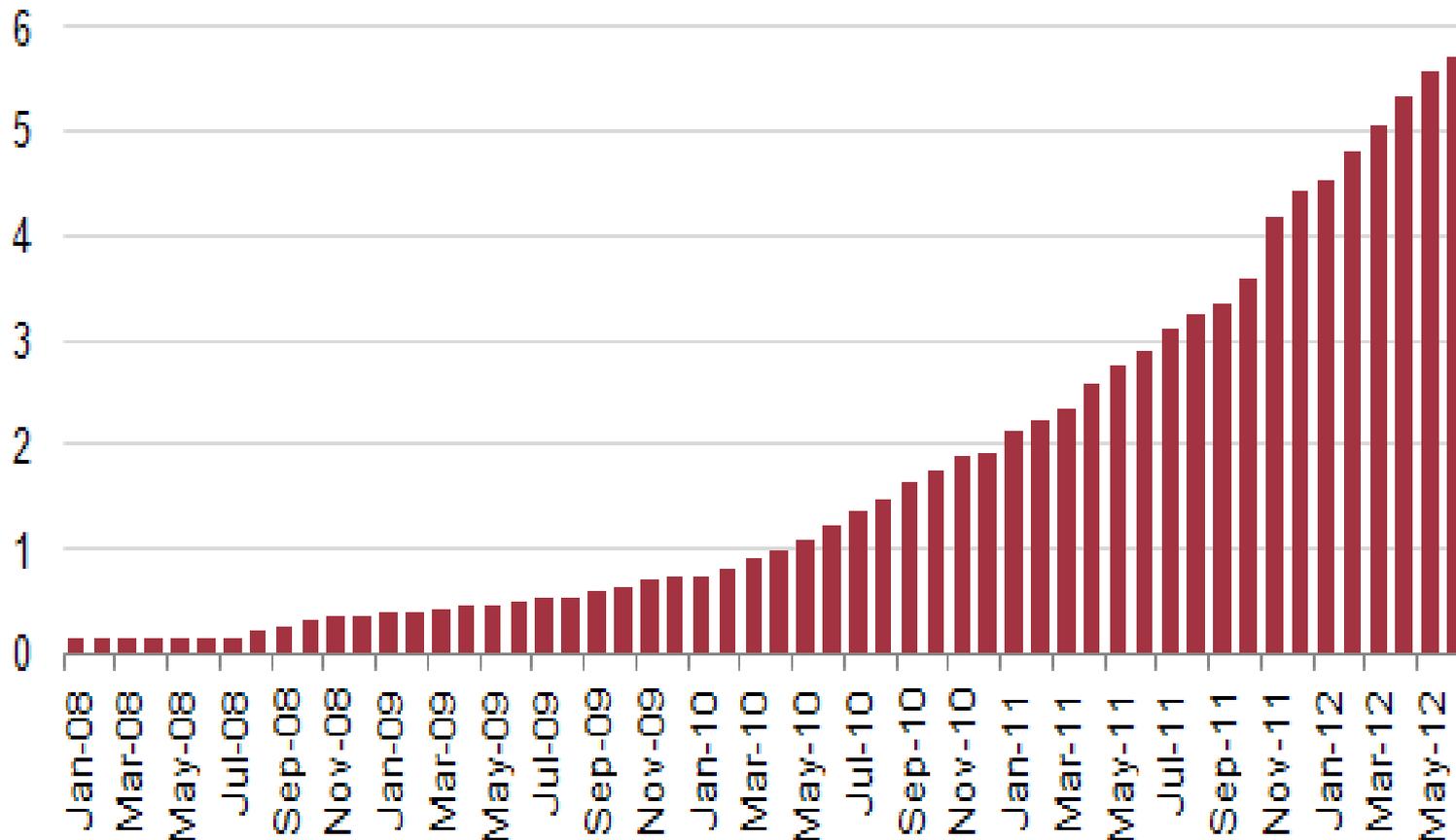


Marcellus NG Production

Estimated average monthly dry natural gas production in Pennsylvania,
January 2008 - June 2012

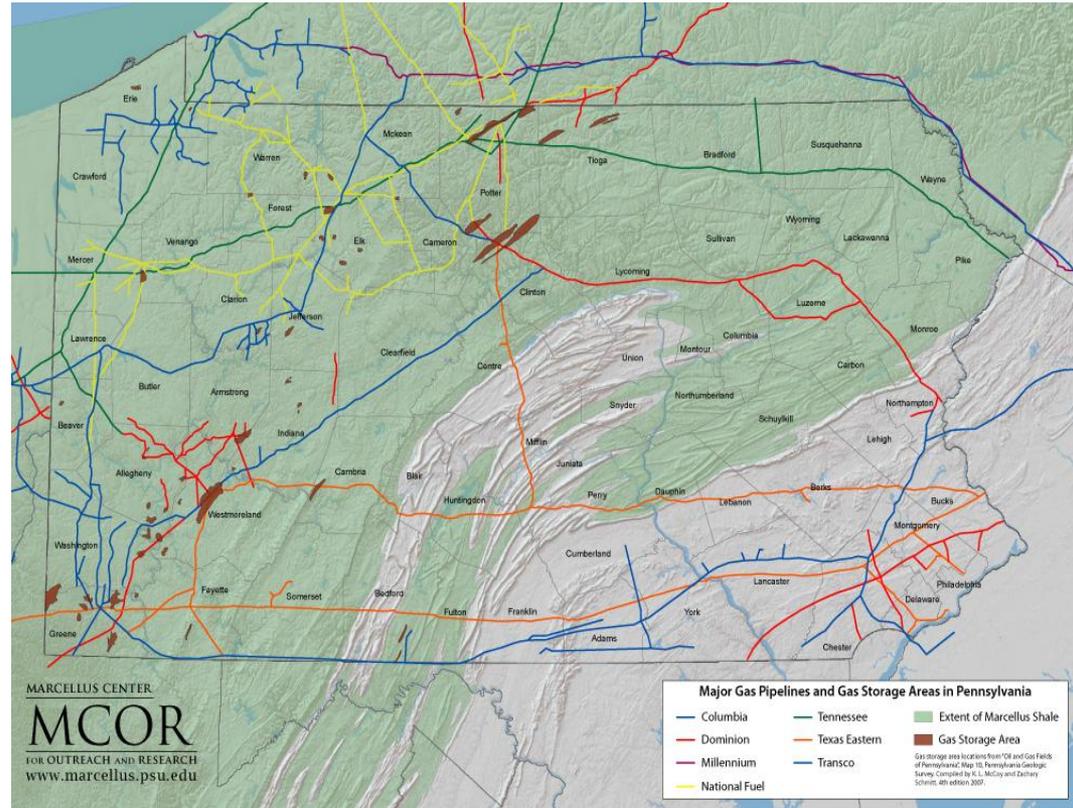


billion cubic feet per day



NE U.S. Production Changes

- Northeast U.S. is largest NG demand market in North America.
- Estimated increase of 9.5 bcf/d by 2017*
- Will displace pipeline flow by 5.5 bcf/d
- Region becoming net gas supplier to other regions of U.S.
 - South
 - Western markets
 - Eastern Canada



*Source: Bentek Energy Consultants

Shale Energy Production

- U.S. trending to an energy export nation
 - Sharp increases in energy production in North America
 - 2384 tcf potential gas resources*
 - Natural gas from shale(NGS) 45% of total
- Surpassing other nations globally
- Restarting refinery capacity on east coast
- Large benefit to rail industry
- Moving coal offshore to Europe –UK/Germany

*Source: Potential Gas Committee(2013)

New Energy Dynamics with NGS



- Production vs. utilization
- Adding value to the commodity?
- Large energy consumers
 - Industrial
 - Power
 - Domestic/Cross-border
 - Transportation
 - Petrochemicals
- New industrial renaissance?
 - “reshoring” of manufacturing
 - Manufacturing costs 15% cheaper than Germany or France
 - On par with China??
 - Increased investment in U.S.
- New workforce dynamics



US Industrial Renaissance

Chemical Industry Impact

- 17,000 direct jobs
- 395,000 indirect jobs
- \$80B capital investment next three years
- \$132.4B increase US economic output
- Clustered development –new U.S. region SW PA/OH/WV?

Ethylene Production Trend

- Capacity increase 30% increase (2011 to 2017)
- 5 new facilities (Dow, Shell, Chevron, Formosa, Sasol)
 - Also expanding and restarting capacity in Gulf locations
 - 10,000 construction jobs
 - Permitting 2 years, construction 3-4 years



Production of Electricity

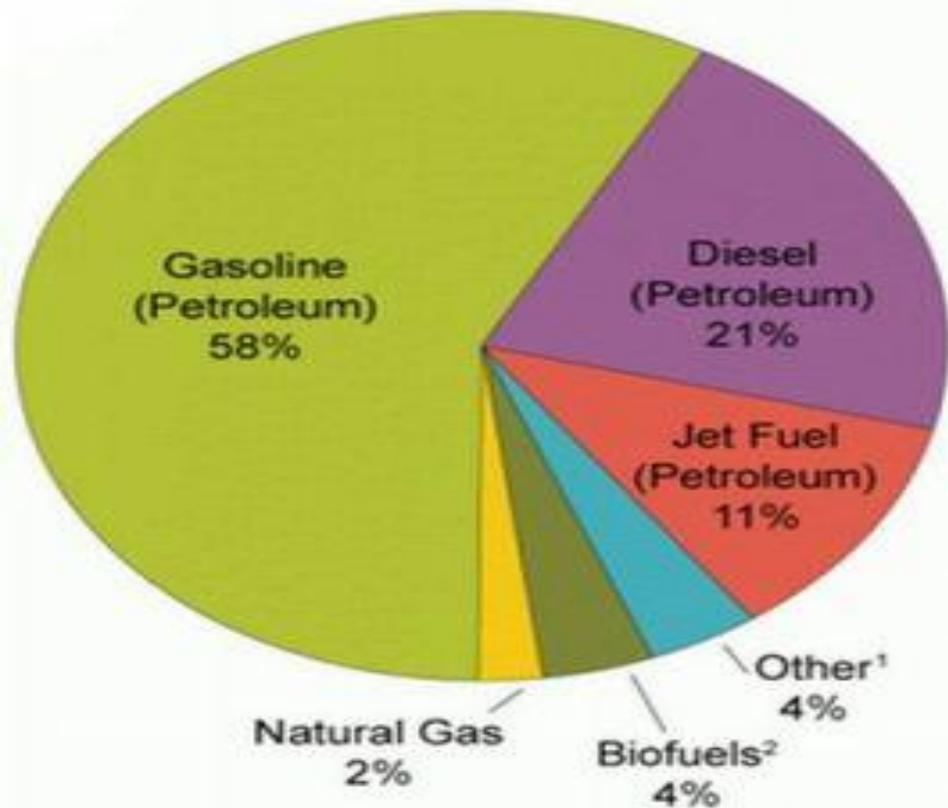
- Coal and NG trading spots for top U.S. power gen fuel
 - permanent??
 - 9 new natural gas power plants planned in Pennsylvania
 - 8,000 total megawatts
- 15% of coal gen offline by '16
- 20 yr low in CO2 emissions
 - mainly market driven
 - regulatory impacts
- New residential heat trends
 - 43% gas
 - 44% electric
- Greater onshore production
 - Reduced offshore extreme weather price impacts



Emerging Utilization



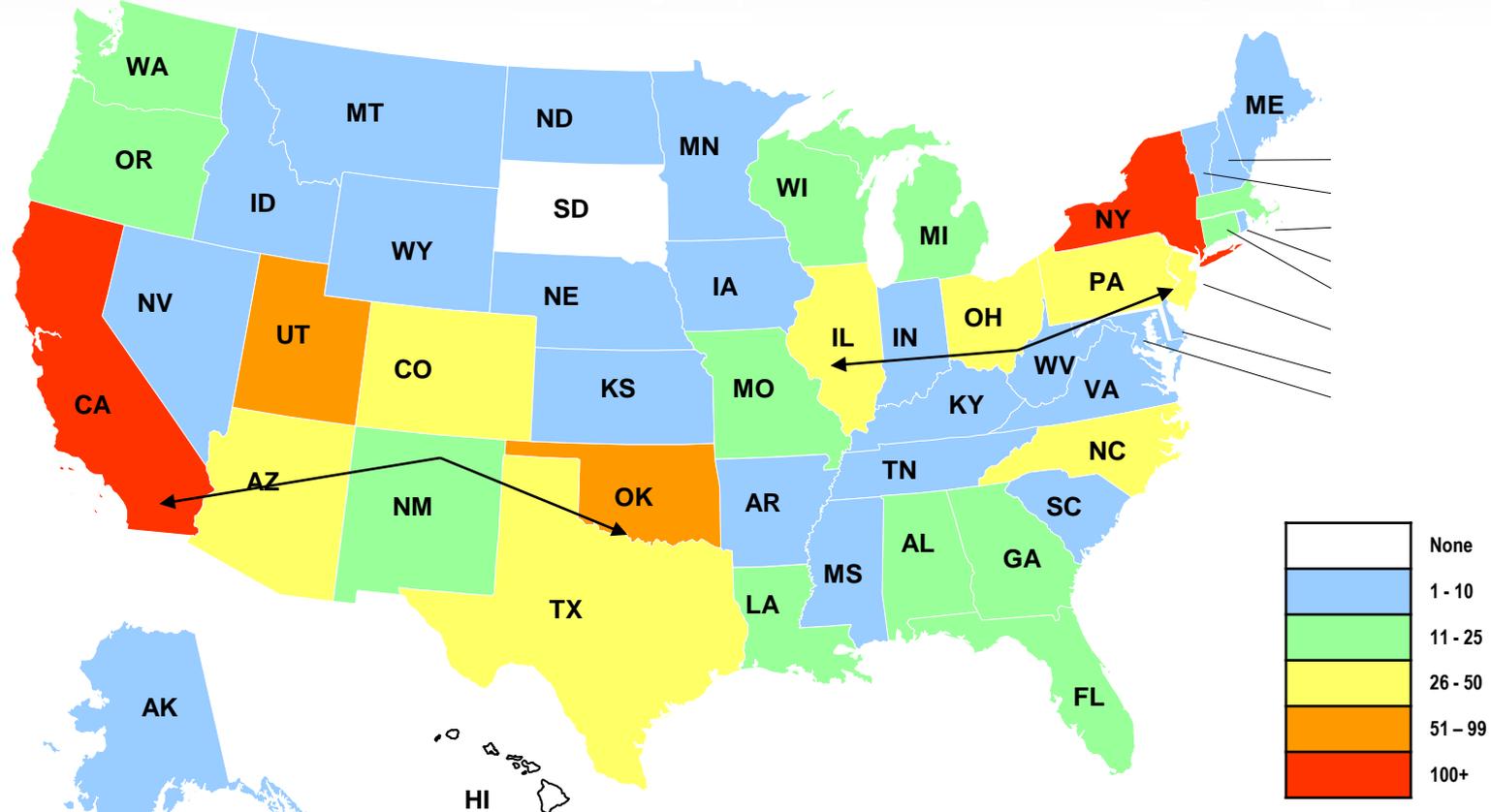
US Energy Used for Transportation



Source: EIA 2010

CNG Infrastructure

Number of Compressed Natural Gas Stations by State



Source: US Dept of Energy 2/14/2012

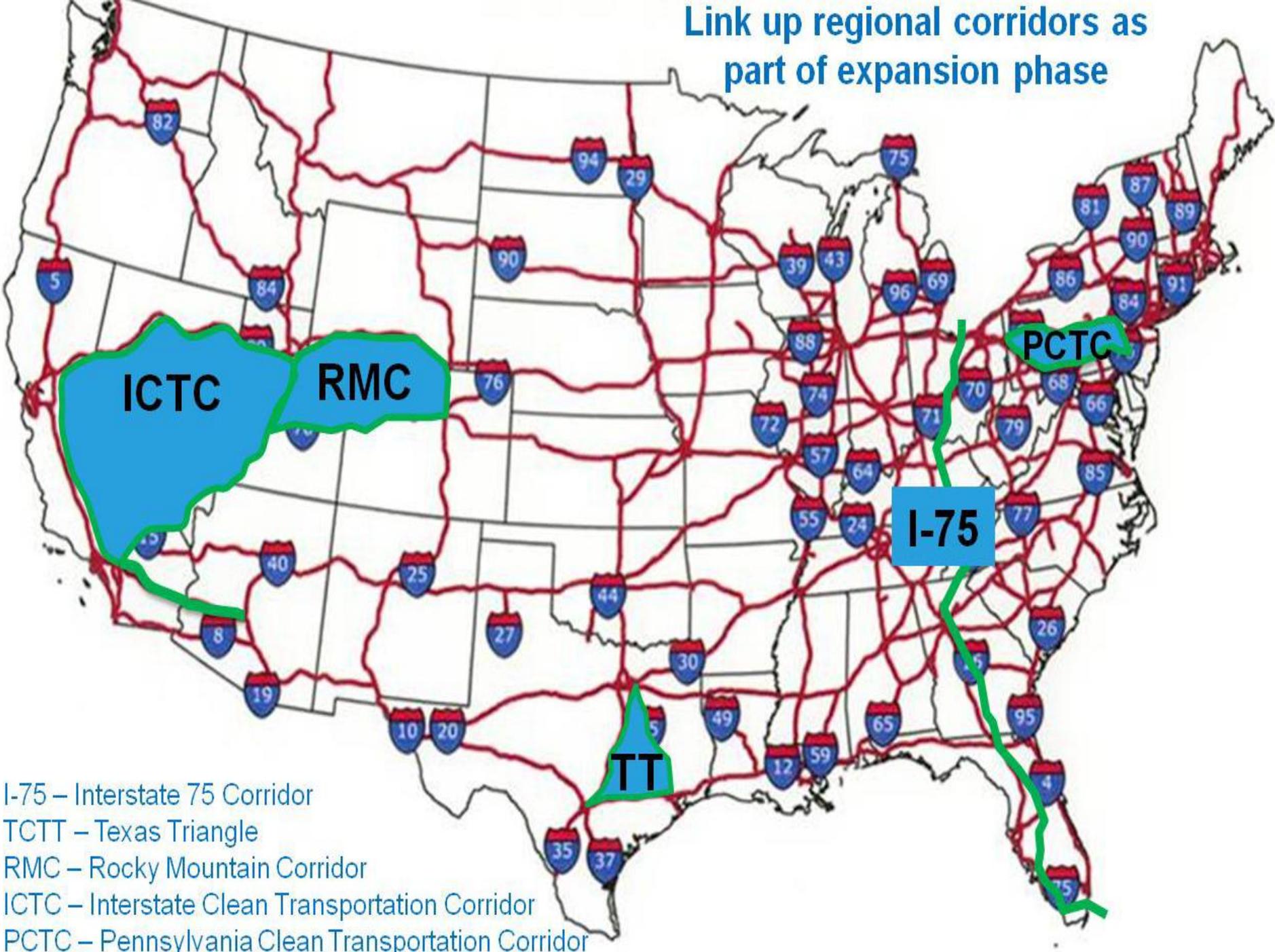
- The United States has approximately 960 Operational and 100 Planned CNG Service Stations
- For comparison there are 180,000 gas stations with half also selling diesel fuel
- CNG stations can be found in states with high populations (NY and CA) and in energy producing states.
- The industry forecasts the emergence of CNG corridors from CA to OK and IL to NY
- There are 57 Million homes heated by Natural gas – a potential CNG filling point with a compressor

Utilization –New Technologies

- Compressed Natural Gas (CNG)
- Liquefied Natural Gas (LNG)
- Vehicle Conversion
- Gas to Liquids (GTL)
 - Gasoline/diesel
 - R&D
 - New fuel formulations
 - New engine technologies
- Co-fueling
 - Diesel/Natural Gas
 - Electric/Natural Gas
- Investment opportunity



Link up regional corridors as part of expansion phase



ICTC

RMC

TT

I-75

PCTC

I-75 – Interstate 75 Corridor

TCTT – Texas Triangle

RMC – Rocky Mountain Corridor

ICTC – Interstate Clean Transportation Corridor

PCTC – Pennsylvania Clean Transportation Corridor

Cross-Section of Typical Horizontal Marcellus Well

24" conductor casing (brown) is installed up to 50 feet deep and cemented (grey) to the surface.

20" casing is installed through the 24" casing and continuing up to 500 feet deep. This casing is cemented to surface to isolate and protect near-surface groundwater.

13 3/8" casing is installed through the 20" casing and continuing up to 1000 feet deep. This casing is also cemented to the surface to protect the groundwater aquifer from the gas well.

5 1/2" casing continues down and is turned laterally into the Marcellus formation at a depth of 5000 to 9000+ feet below the surface.

Fresh groundwater zone up to 1000 feet deep

Vertical portion of well

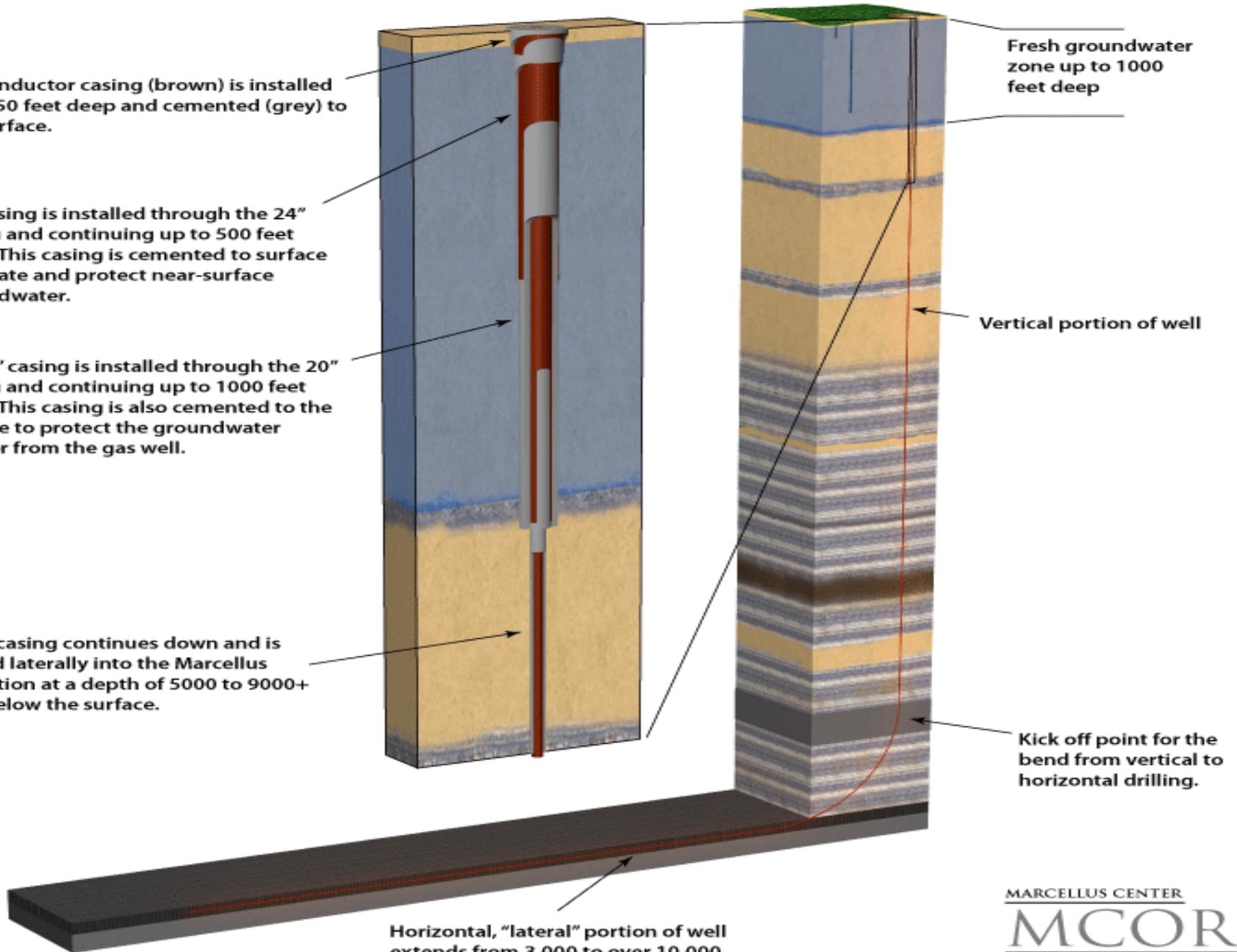
Kick off point for the bend from vertical to horizontal drilling.

Horizontal, "lateral" portion of well extends from 3,000 to over 10,000 feet within Marcellus formation.

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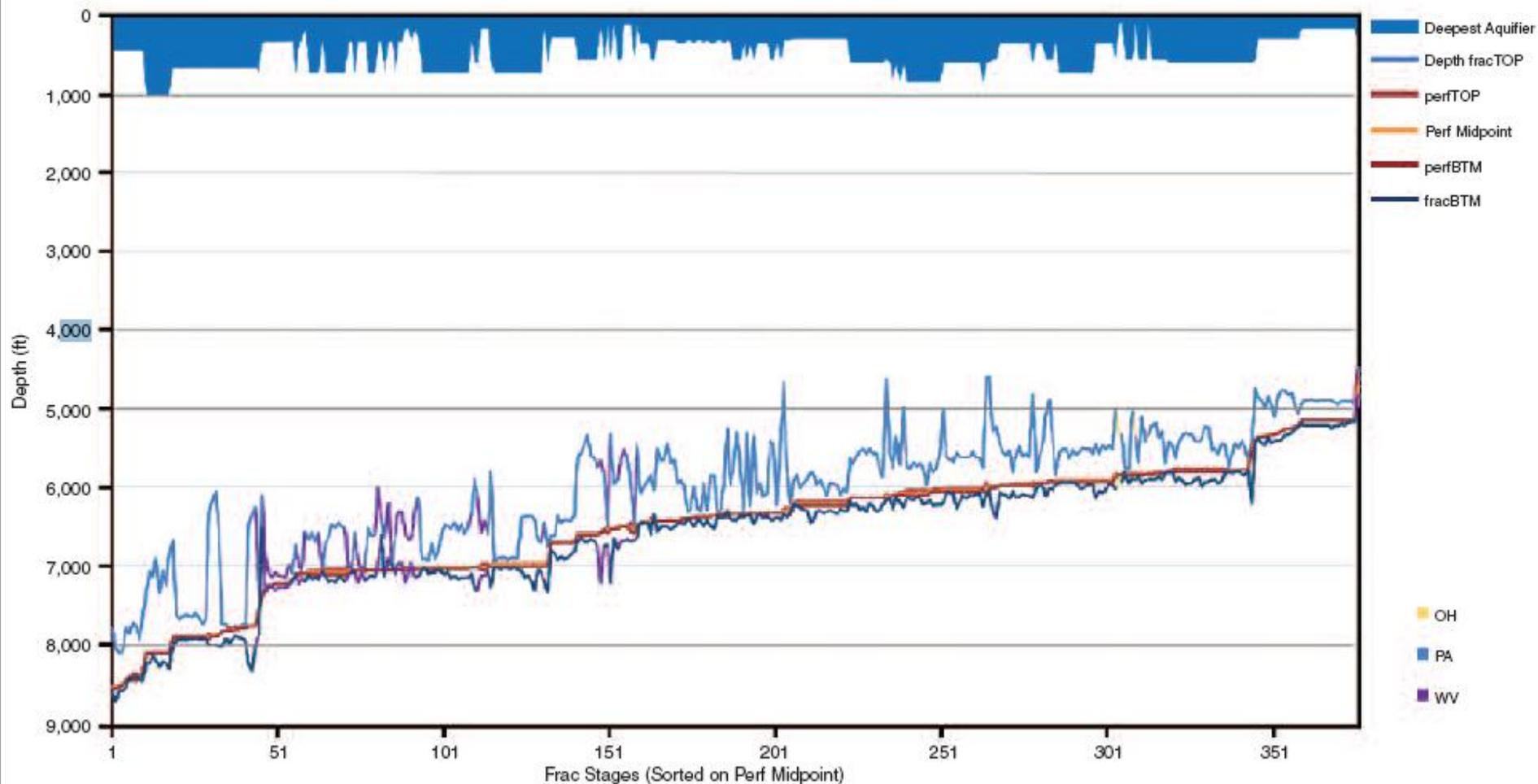
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www.marcellus.psu.edu



Height-Depth of Fracturing Based on Microseismic Data

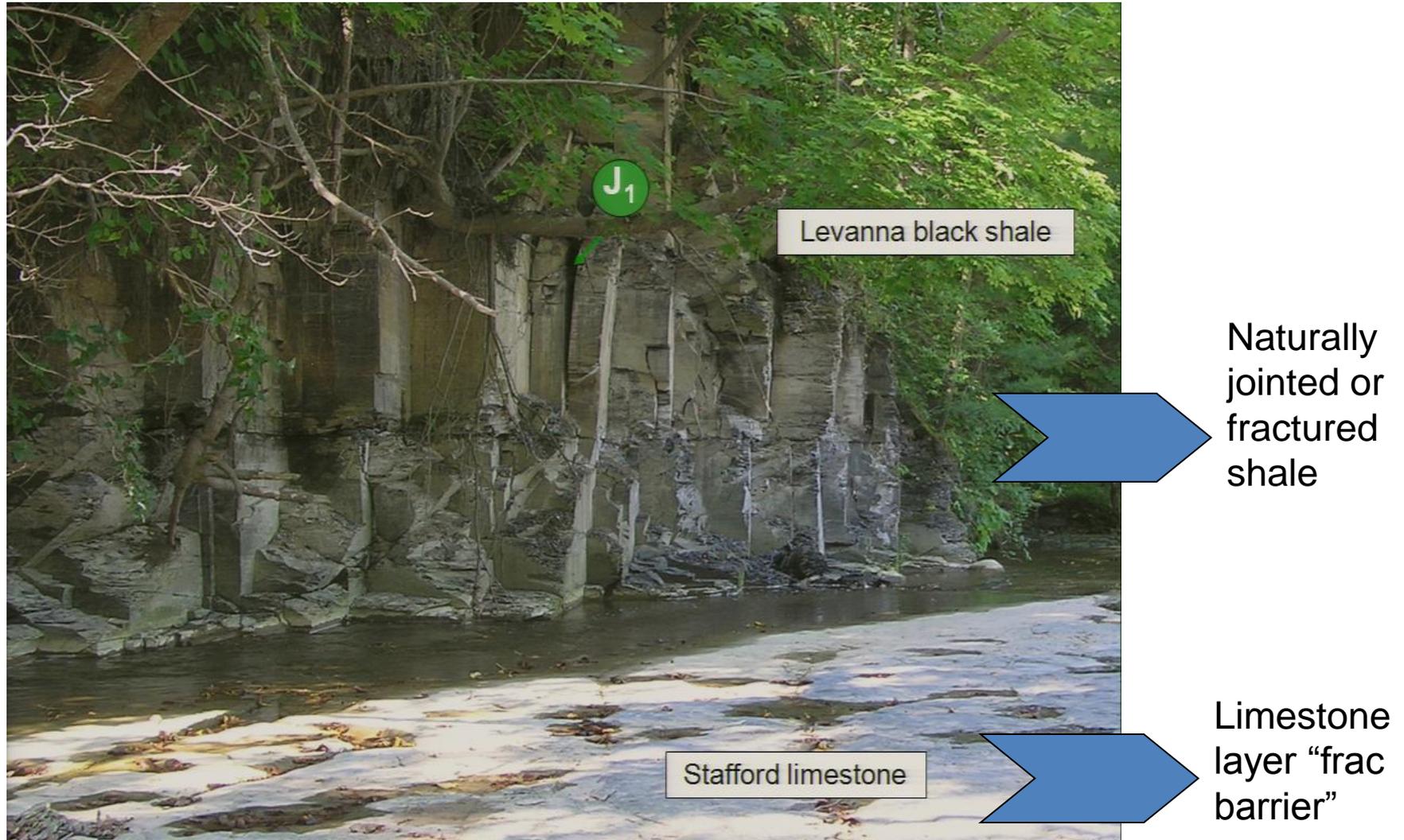
Marcellus Shale Mapped Fracture Treatments (TVD)



“Frac Barriers” of Onondaga Ls. below & Tully Ls. above. Marcellus Sh. thousands of meters below fresh water aquifers. Induced fractures cannot extend upwards because of overburden stress and horsepower limitations.

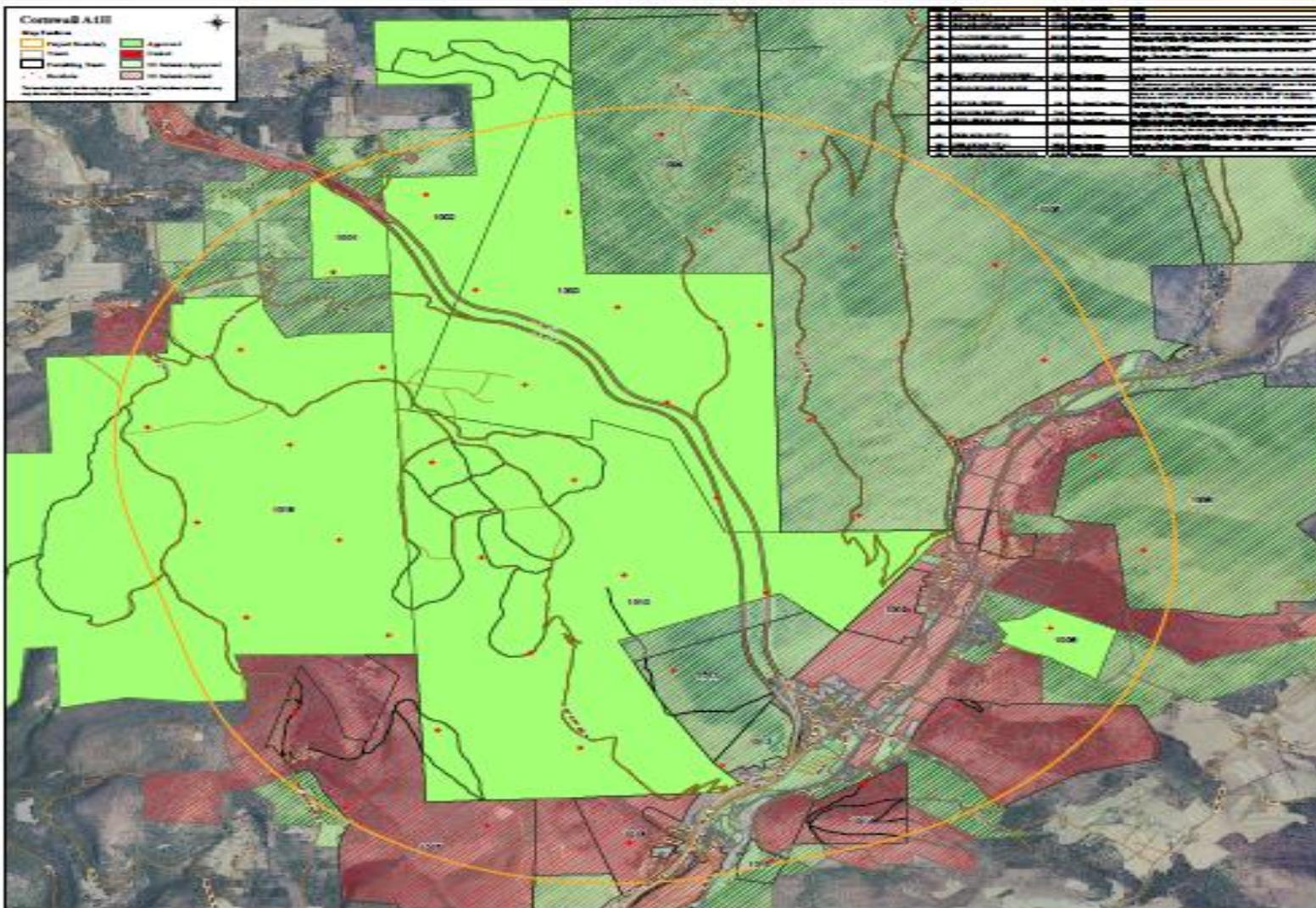
Source: Pinnacle

Natural Shale Fractures and Seals





Fixed Array Micro Seismic



Source: T. Engelder, PSU

Pennsylvania Chapter 78 Well Construction Standards

- Goal – prevent methane migration and protect water supplies
- Update well construction, casing and cementing standards
- Expanded well completion reporting requirements, including disclosure of hydraulic fracturing chemicals
- Revised well plugging standards
- Evolving technology and regulations greatly mitigating risk
- Transparency

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.

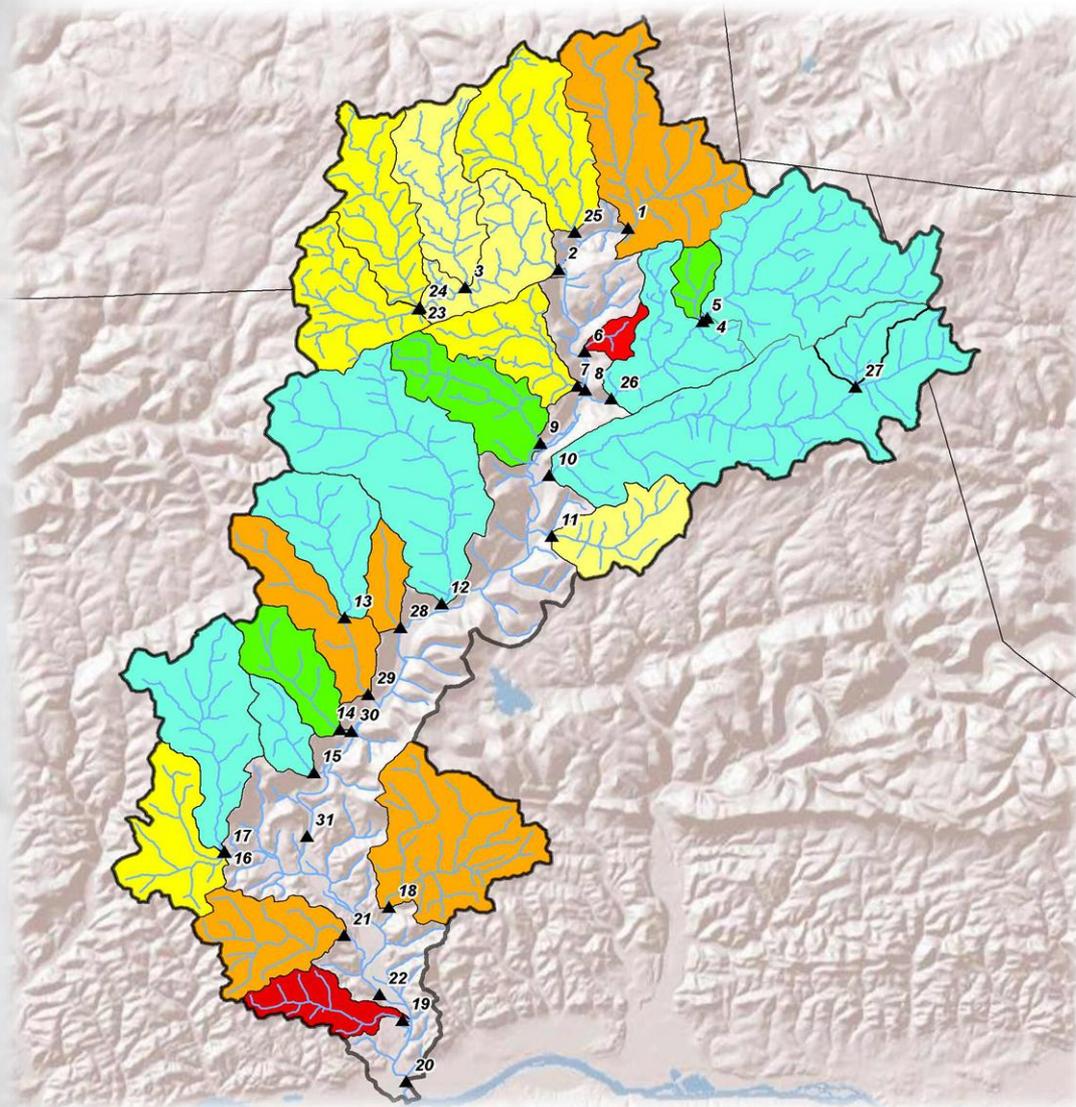


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Full Watershed Assessments for Total Dissolved Solids (TDS) Impacts



Site	Trib	ROE
9	Frozen	10
14	Wolf Upper	12
5	Hounds	14
4	Rock Upper	28
15	Daugherty	28
13	Trout Upper	30
12	Grays	32
10	Pleasant	34
16	Hogeland	38
26	Rock Lower	42
27	North Pleasant	44
30	Wolf Lower	44
17	Stoney	59
3	Salt	61
24	Brion	62
11	Slacks	65
23	Roar Head	72
25	Mill (head)	74
7	Red	78
2	Roar Roar	79
28	Hagerman	92
21	Beautys	102
29	Trout Lower	104
18	Mill (mouth)	106
6	Dutchman	191
19	Bottle	202



Evolving Regs – Chapter 95

- Limits the discharge of Total Dissolved Solids (TDS) from new or expanded facilities that take oil and gas wastewater – move to drinking water standards.
- Does not allow for new discharges that exceed 250 mg/l for chlorides and also removes radium
- Increases the use of recycled water, promotes the development of alternative forms of disposal
- Promotes the use of alternative sources of water for fracturing fluid
 - Acid Mine Drainage (AMD)
 - Treated public and industrial waste water

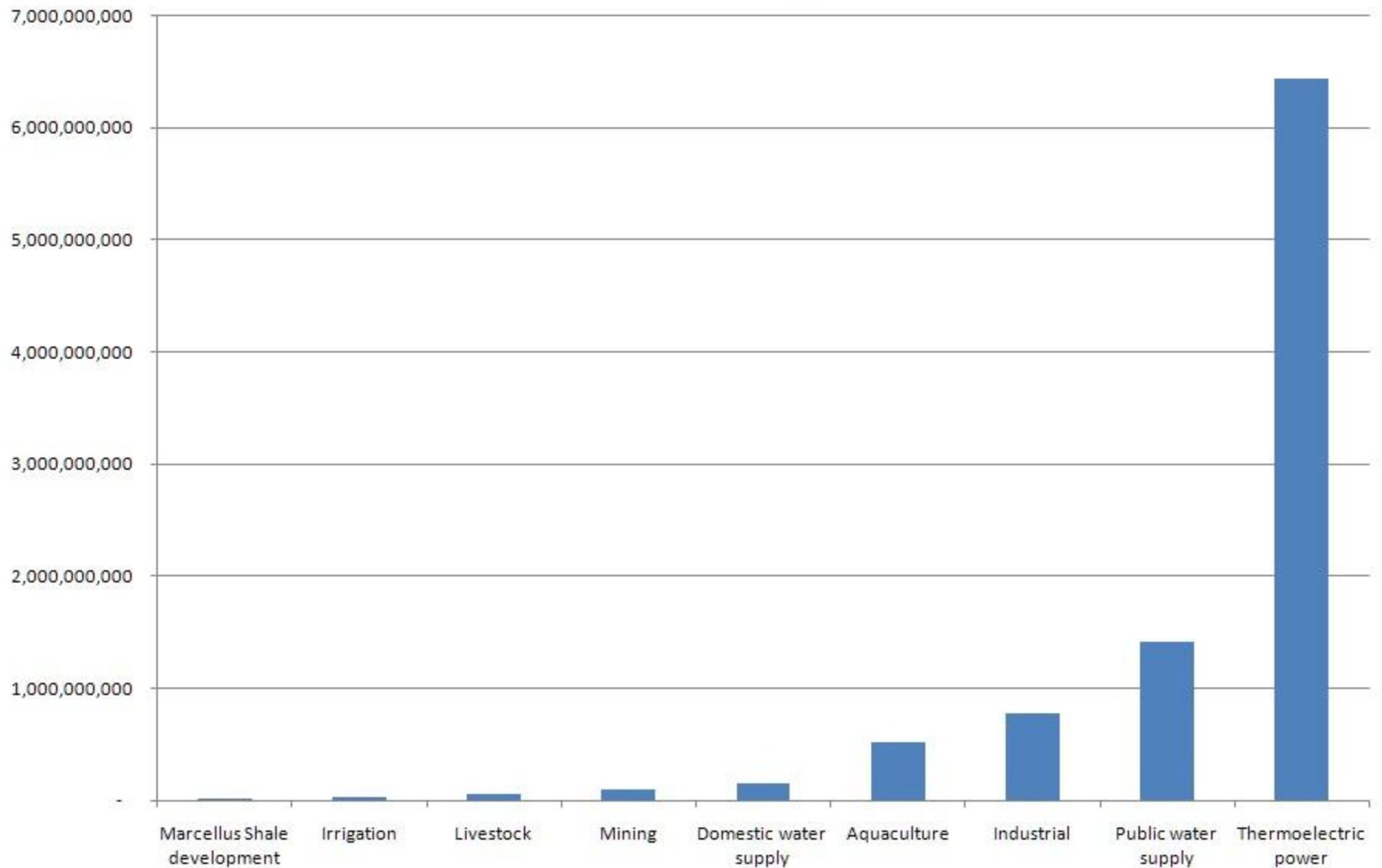


Water Usage and Sourcing

- 16.5 million liters per well (ave)
- 40 million liters used in PA Marcellus per day
 - 0.1% of all water withdrawals in PA daily
 - 40 billion liters/day for all uses
- 75% of water utilized for hydraulic fracturing is trucked
 - Strongly trending towards rail/piped water vs. trucks
- 75%+ is sourced from surface supply vs. wells
 - Costs from municipal well sources is \$5-16/3800L



Pennsylvania Surface and Groundwater Withdrawals by Industry Gallons Per Day





Fluid Remediation/Disposal

- 1.75 billion liters of fluid recovered 1H '12
- 90% recycling of flowback and produced
- Approx. 10%-20% of fluid returns to surface in Marcellus
- Currently 98% of flowback is recycled
 - 89% infield recycling
 - 9% centralized plant recycling
 - 1.6% stored
 - 0.3% disposal wells

Water Storage Tech Trends

- Vertical storage units – more storage, less footprint
- Closed loop systems
- Transportable and can be reused
- Piped to location for hydraulic fracturing
 - Greatly reduces truck traffic
- Redundant systems for spill prevention



Surface/Groundwater Protections





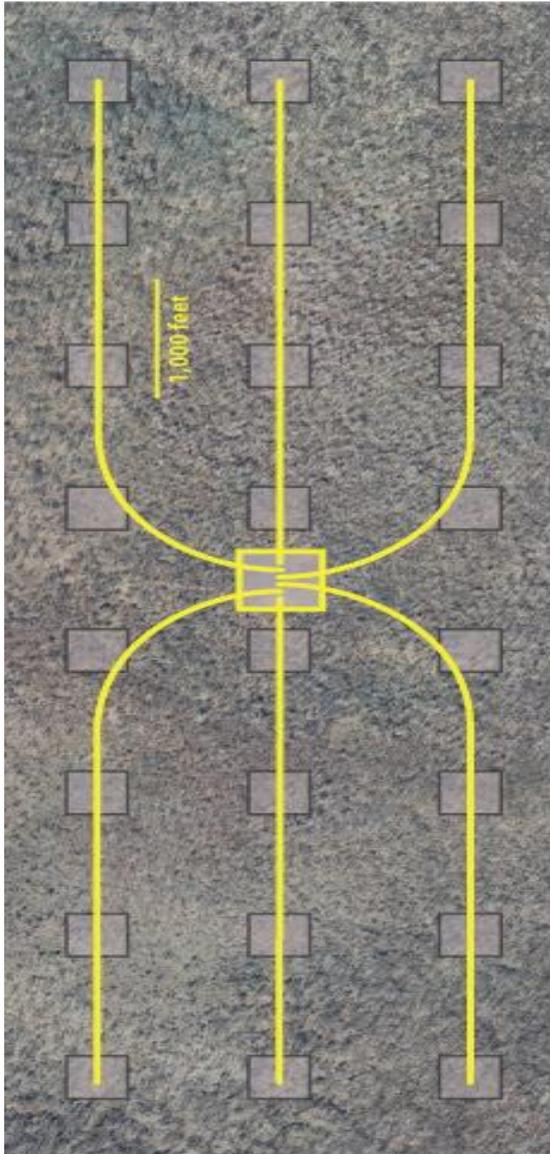
Hydraulic Fracturing Process and Impacts



Common NGS 6-Well Pad



Horizontal Drilling Patterns



- Smaller overall footprint
 - 2% land disturbance vs. vertical ~19%
 - One drilling pad
 - Fewer roads, pipeline connections
- Drilling Unit
 - 1-2 square mile

Noise Abatement Techniques





Drill Cuttings Management

- Current common “disposal” is with landfill as cover material
- Researching beneficial reuse
 - As proppant material
 - Road base
 - Pad stabilization
 - Construction
- Typically remediated and treated
- Emerging technology





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.msetc.org/>

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ShaleNET Formation

- Formed in July 2010
- Partnership between:
 - *Westmoreland County Community College*
 - *Pennsylvania College of Technology*
 - *Allegheny Conference*
 - *PA Independent Oil & Gas Assoc. (PIOGA)*
- First major initiative – U.S. DOL ShaleNET grant for \$4.9 million





ShaleNET Outcomes

- ShaleNET now consists of over 20 authorized training partners in PA, OH, WV, and NY
- Standardized curriculum for Roustabouts, Floorhands, Production Technicians, CDL, and Welder Helper
- Talent Match System integration
- Impacts (through March 2013):
 - Participants served: 10K+ (includes certifications)
 - Completing training activities and education: 2,367
 - Newly employed: 1,134

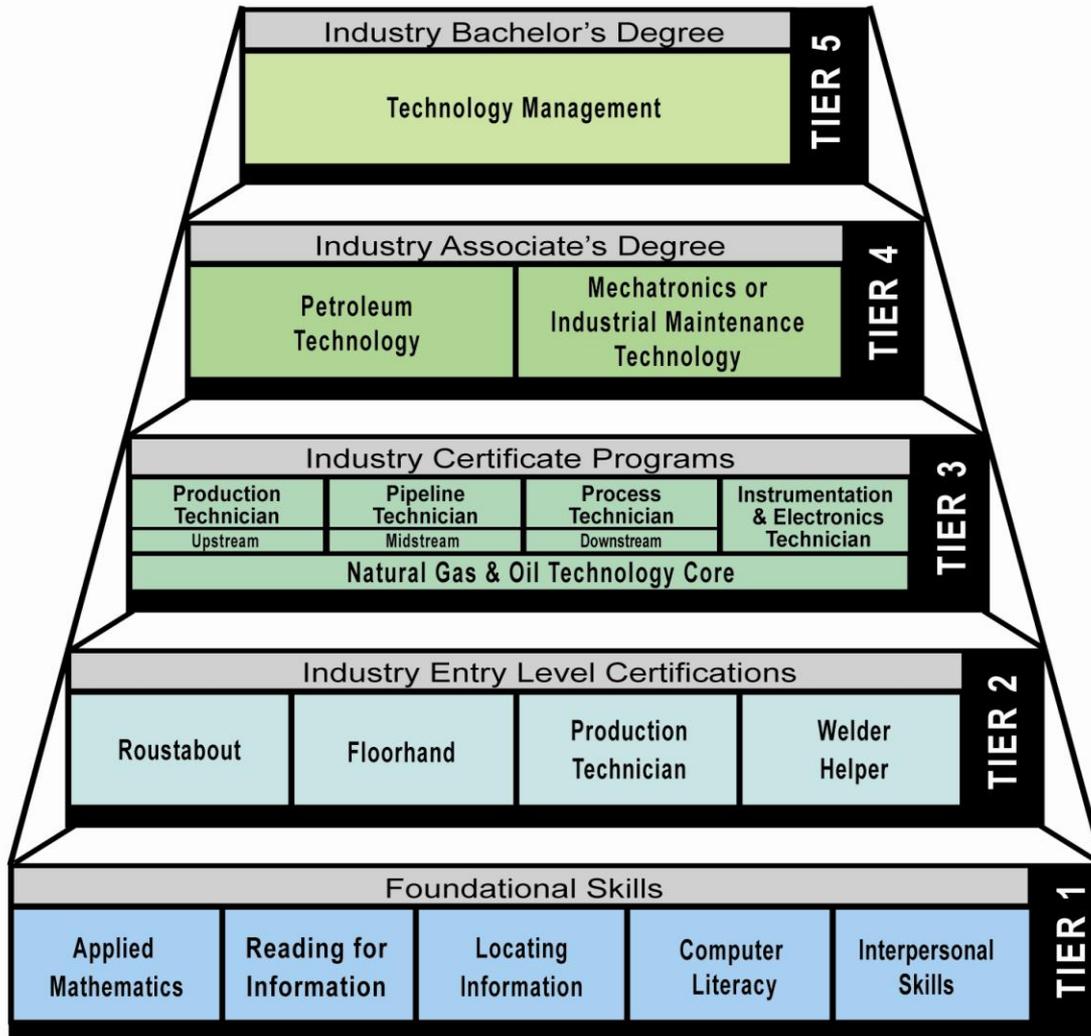
ShaleNET U.S.

- ShaleNET U.S. Grant awarded Oct. 1, 2012
 - \$15M Federal grant
 - *Pennsylvania College of Technology (PA)*
 - *Westmoreland County Community College (PA)*
 - *Navarro College (TX)*
 - *Stark College (OH)*
- Objective: *To develop and implement standardized stackable certificate and associate degree programs to serve upstream, midstream, downstream, and the instrumentation and electronics components of the oil and natural gas industry.*



ShaleNET U.S.

Stackable Credential Model





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



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