

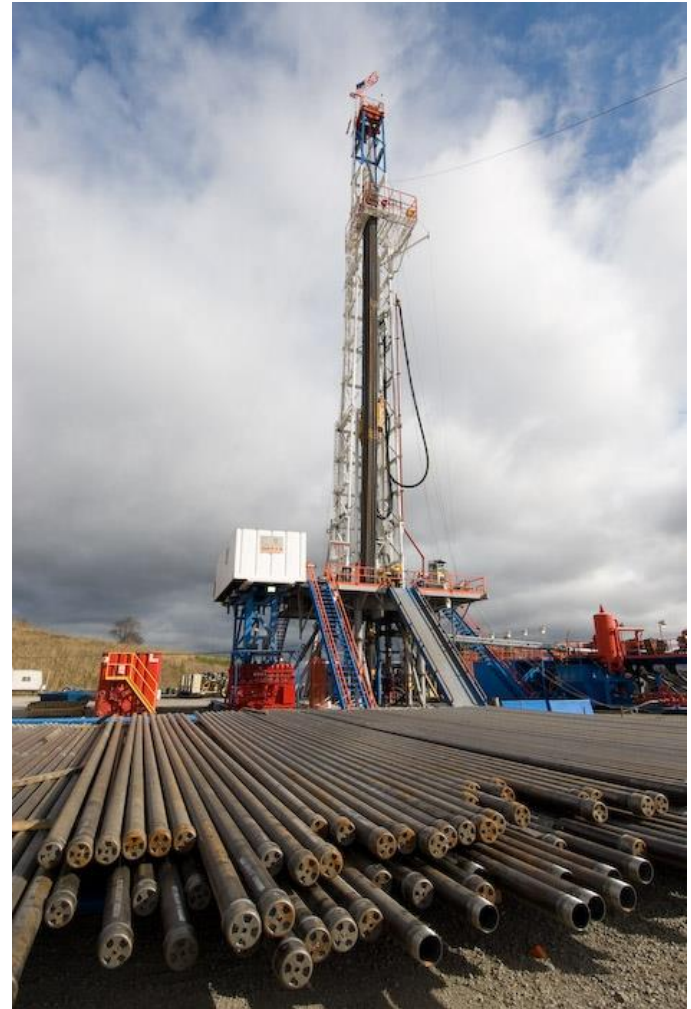
# Unconventional Shale Gas Development: *Convergence of Economics, Technology, and Policy*





# Marcellus Center for Outreach and Research

- Research
  - Down hole technical issues
  - Above ground risk(s)
    - Air emissions
    - Community impacts
  - Socio-economic
    - Agriculture, tourism
  - Environmental
  - Water – lifecycle impacts
  - Workforce
  - Business dev'l
  - Regulatory
  - Governance

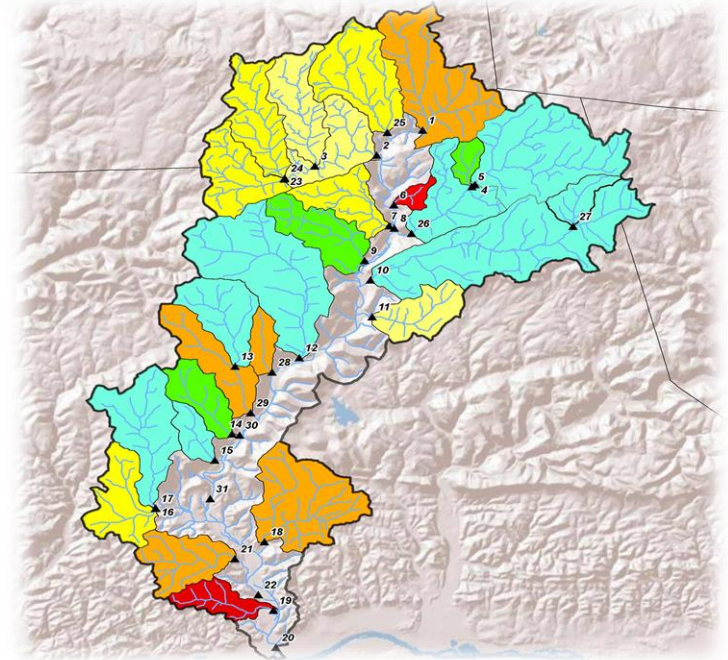


# Enhanced Groundwater Protection Research



# Impact of Shale Energy Production on Rural Drinking Water Supplies

- Importance of baseline testing before drilling
  - Performed by energy companies
  - Utilize state certified testing labs
  - “Monitor” wells at drill sites
- Testing of individual wells
  - Pre and post drilling
  - Pre and post hydraulic fracturing
- Ongoing monitoring of entire watersheds
  - Surface waters vs. groundwater
- Funding of studies
  - Public initiative for monitoring
  - Large scale
  - Unbiased
  - Document pre-existing status and adherence to current regulations
  - Observe potential change over time



MARCELLUS CENTER

**MCOR**

FOR OUTREACH AND RESEARCH

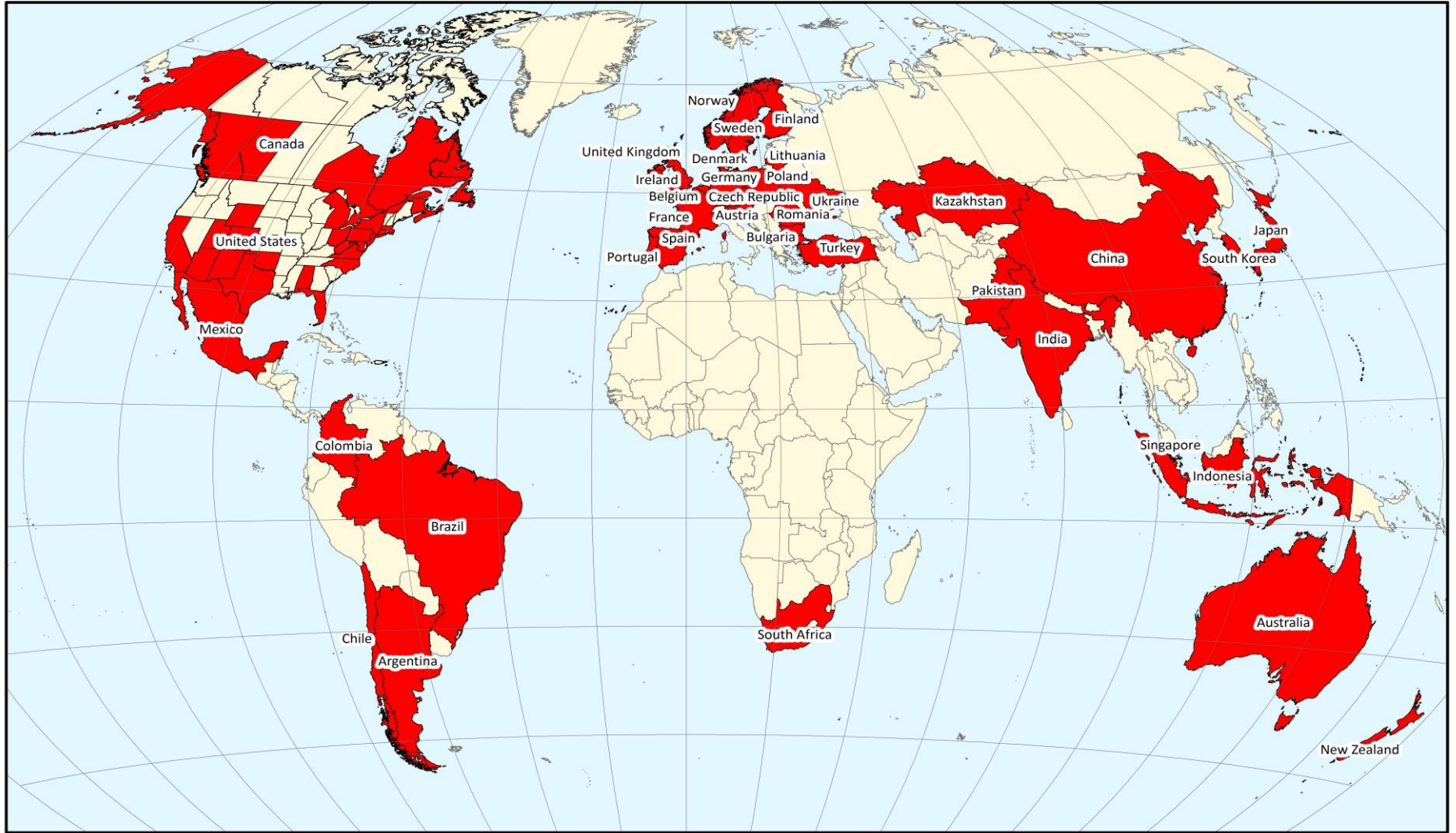


# Marcellus Center for Outreach and Research

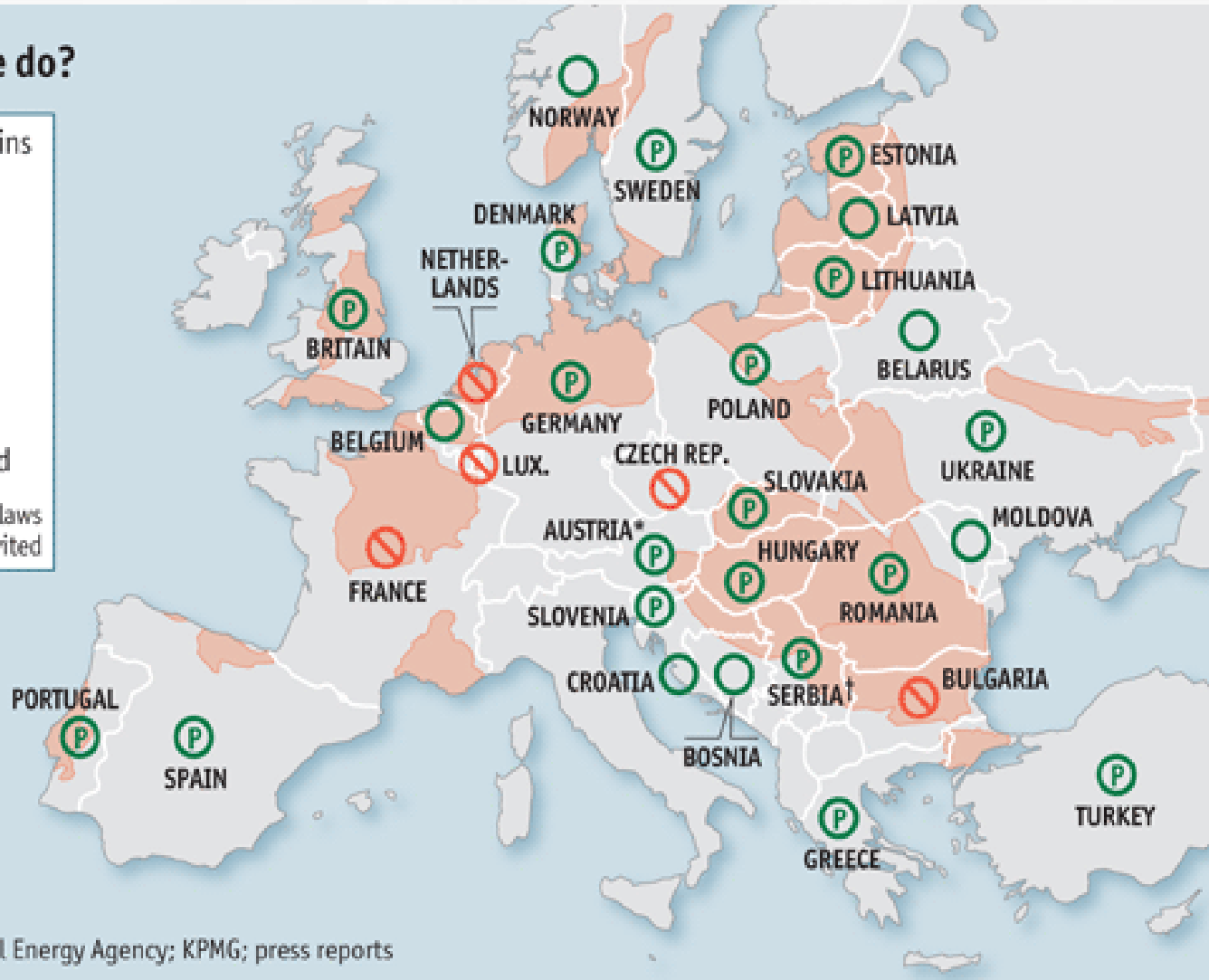
- Outreach
  - Stakeholder engagement
    - Elected officials
    - NGOs
    - Industry
    - Regulators (training)
    - “Social License”
    - General Public
      - 64% polled favor but...
  - Promotion of the science
    - Process
    - Technologies
    - Regulations
    - Global experiences
    - “Current moment”
    - Trends



## Penn State Marcellus Center for Outreach & Research Global Shale Initiatives

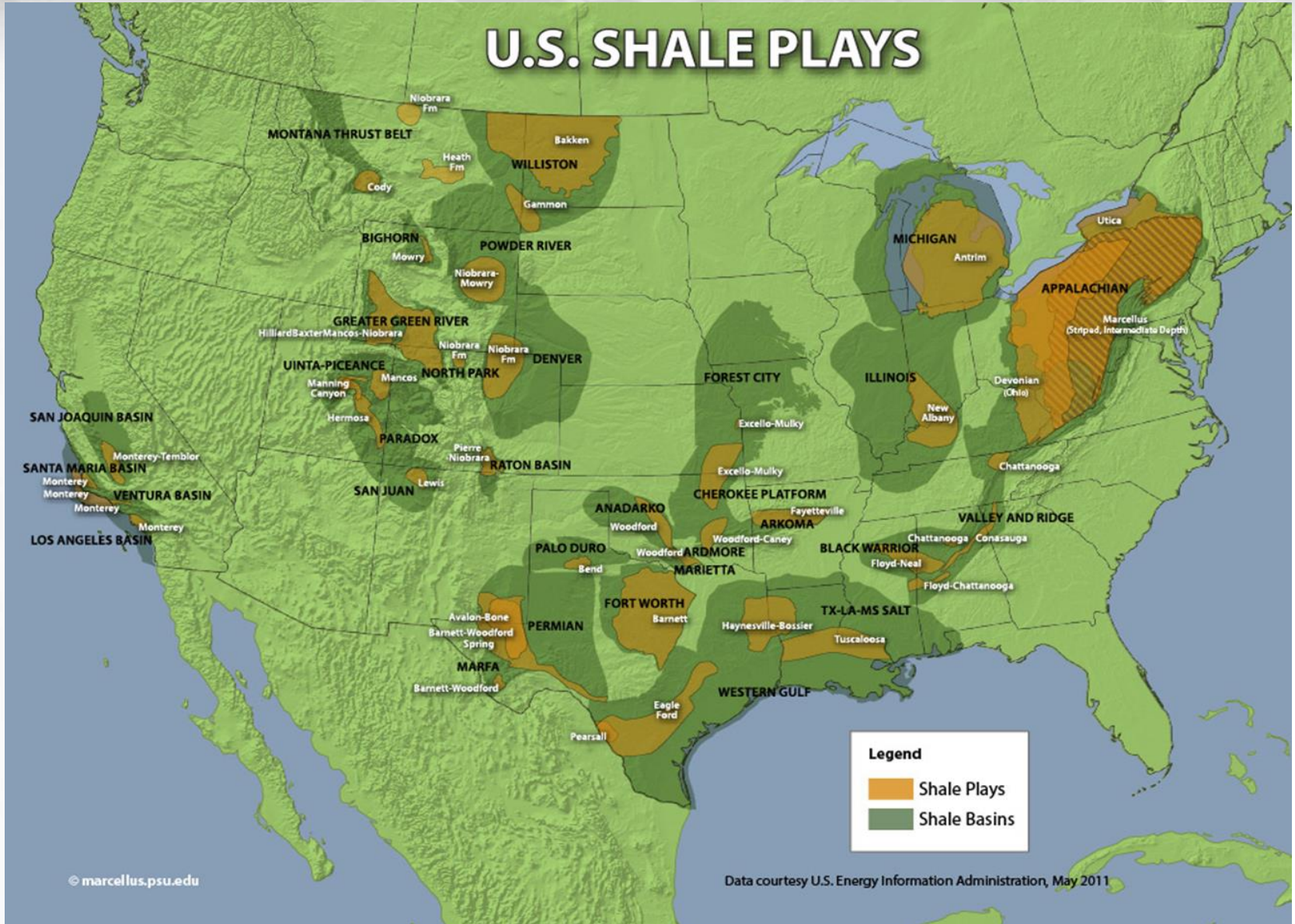


## What shale we do?



Sources: International Energy Agency; KPMG; press reports

# U.S. SHALE PLAYS



**Legend**

- Shale Plays
- Shale Basins

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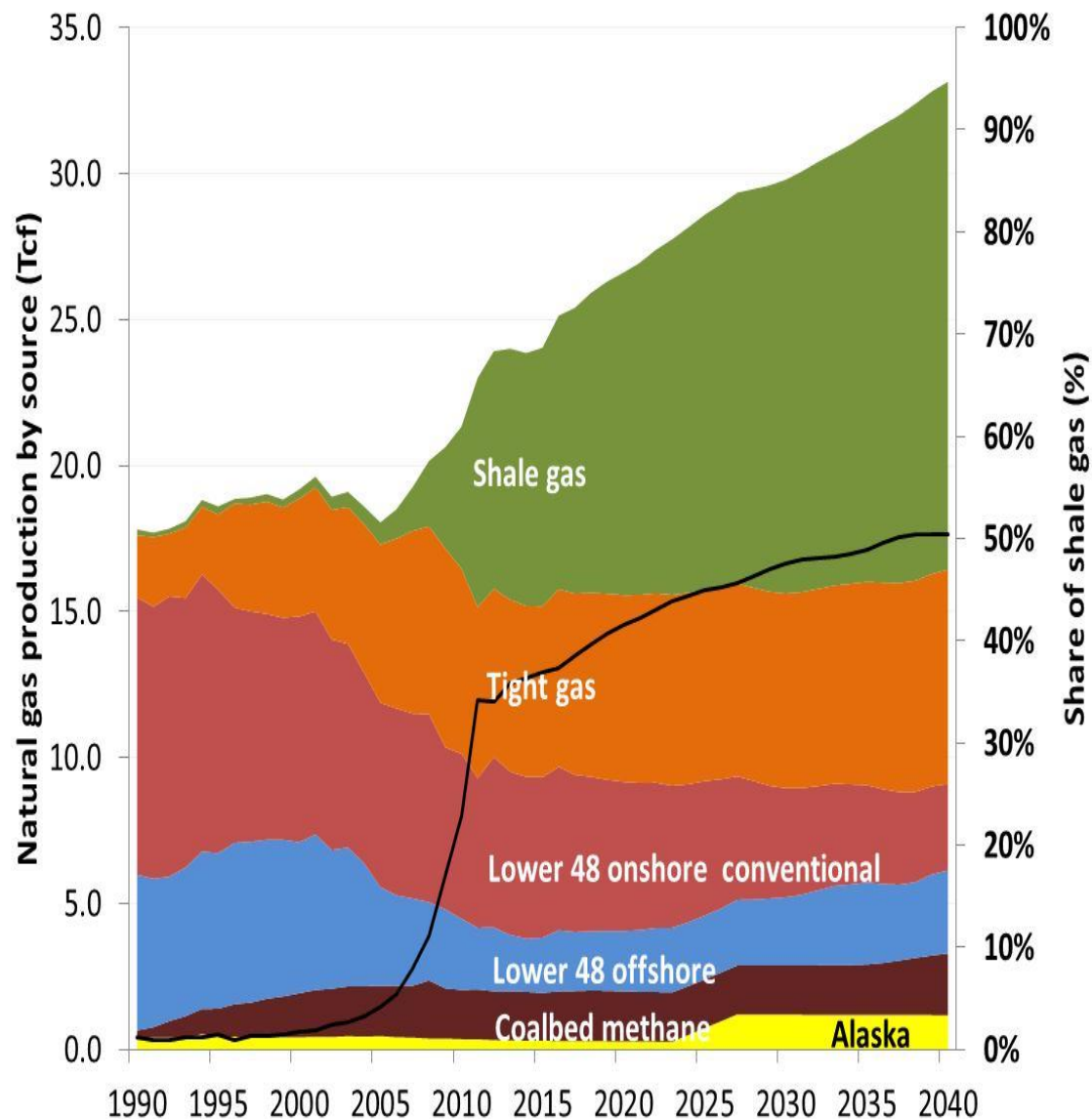
Data courtesy U.S. Energy Information Administration, May 2011



# 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
  - Geopolitical opportunity
    - Energy security
    - Balance of payments
  - \*\* A technical challenge is a broad understanding of the science in U.S.
- Possible vs. probable
  - Cars/food/fire/etc.
  - Well failure
  - Water contamination
    - Chemicals
    - Methane
  - Air emissions
  - Health
  - Gaps in research??

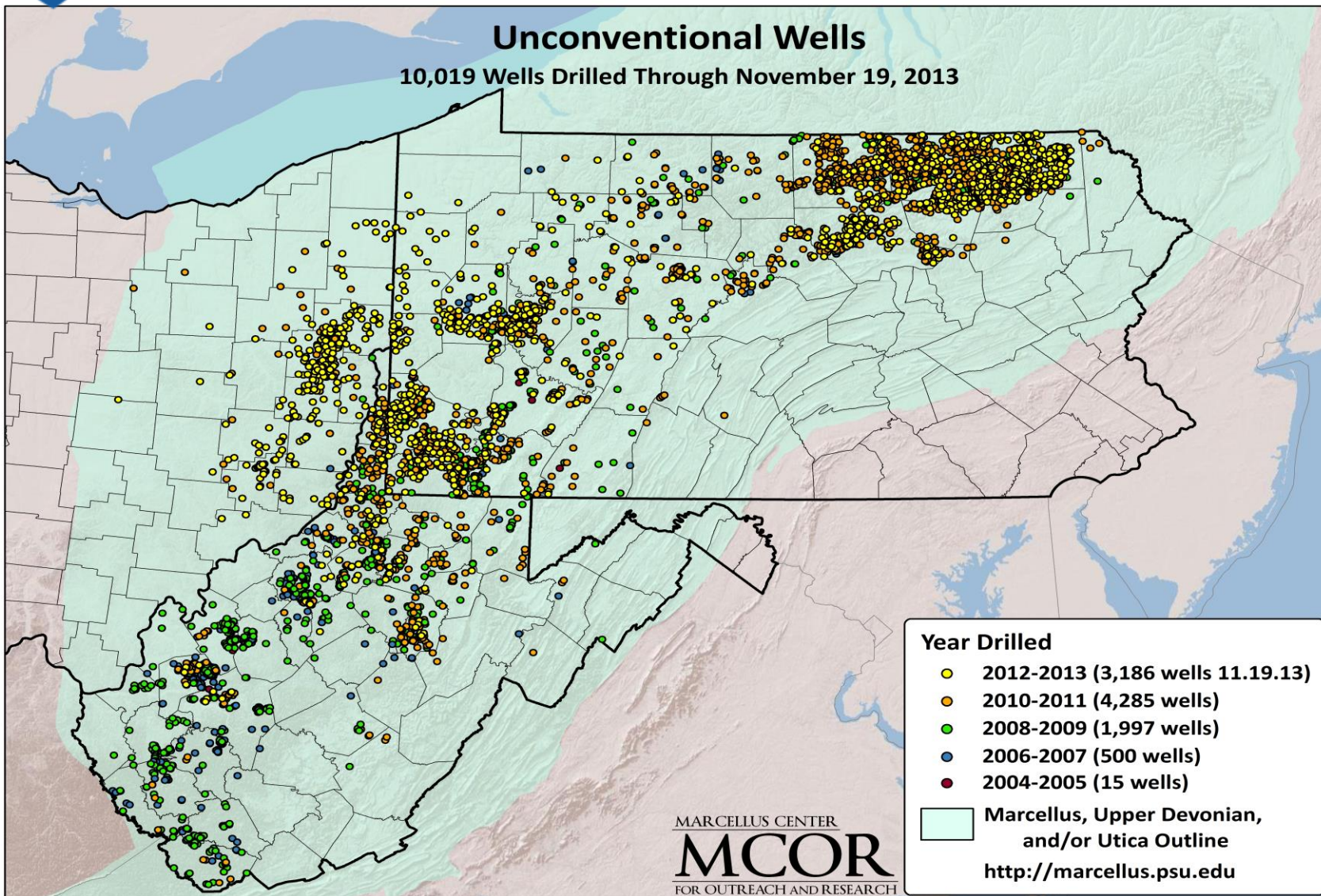
# U.S. Natural Gas Production



- 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
  - 70%??



# Unconventional Development in NE U.S.





Marcellus

# Natural gas production

million cubic feet/day

16,000

14,000

12,000

10,000

8,000

6,000

4,000

2,000

0

2007

2008

2009

2010

2011

2012

2013

2014

**Gas +419**  
million cubic feet/day  
month over month



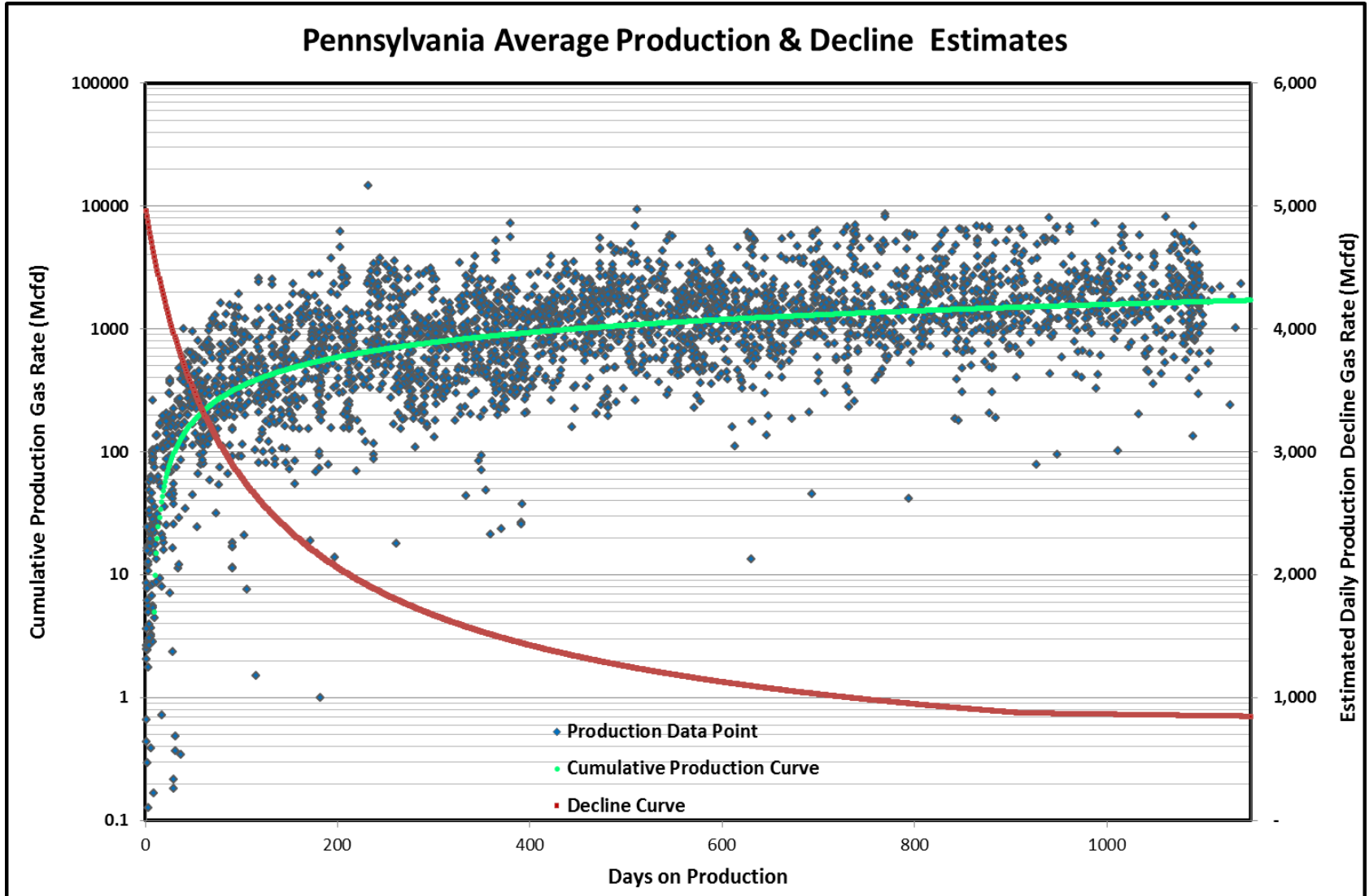
# NE U.S. Production Changes

- 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 will become net gas supplier to other regions of U.S.
  - South
  - Western markets
  - Eastern Canada



\*Source: Bentek Energy Consultants

# PA Production Declines





# 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

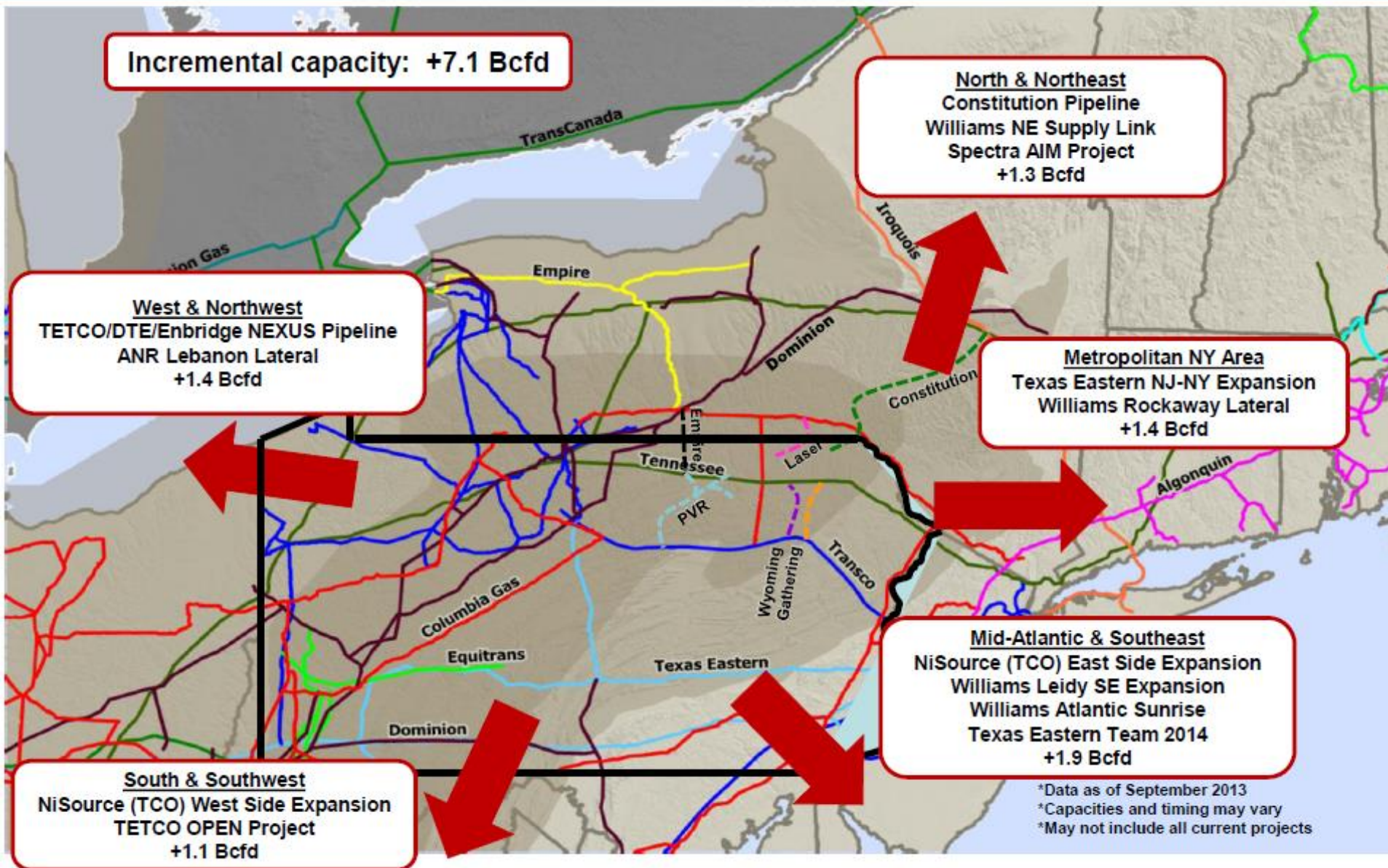
As of 4Q 2012 PA collected:

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

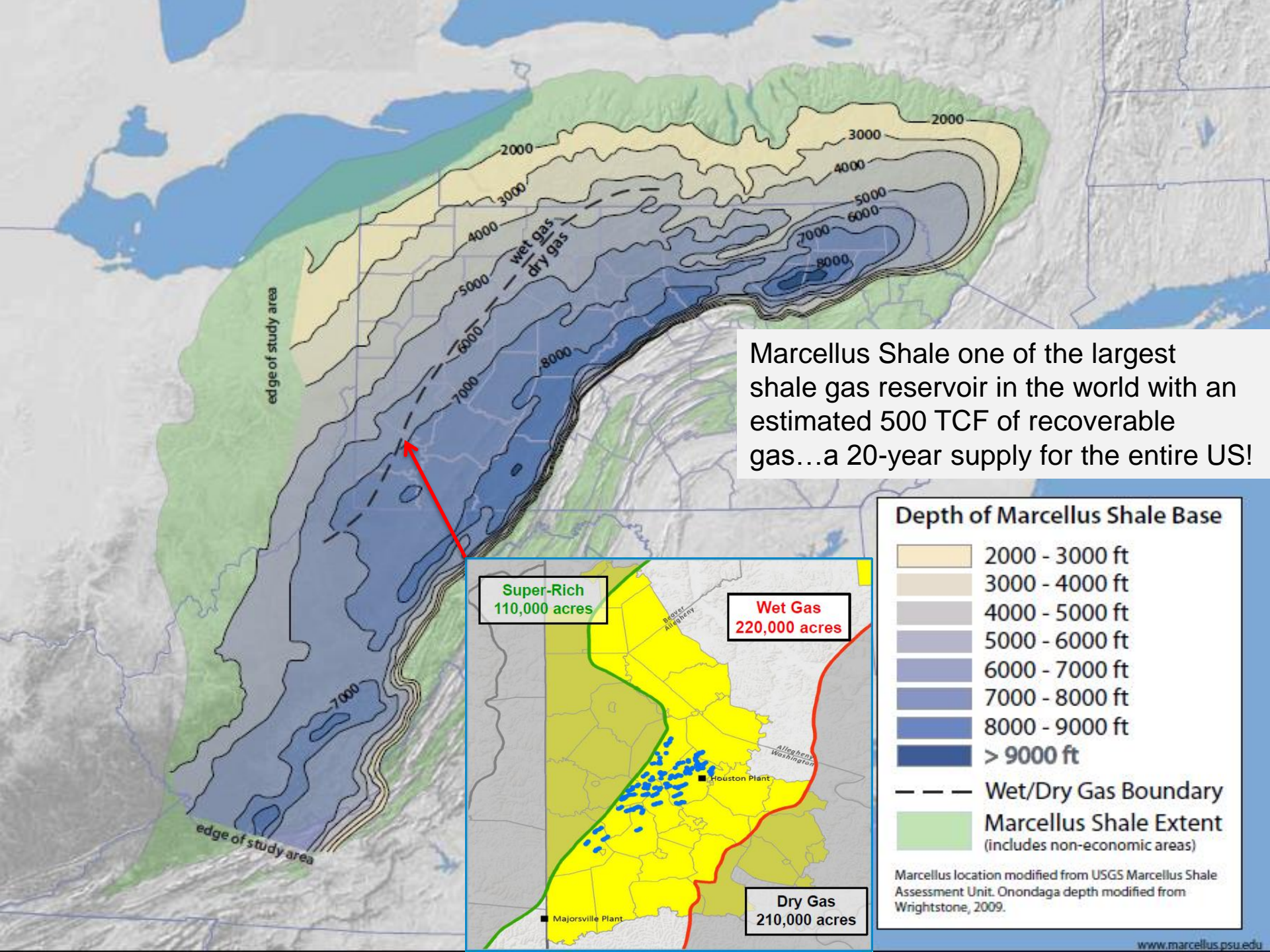
2012 PA Totals:

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

# Marcellus - Proposed Infrastructure Projects through 2016







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!

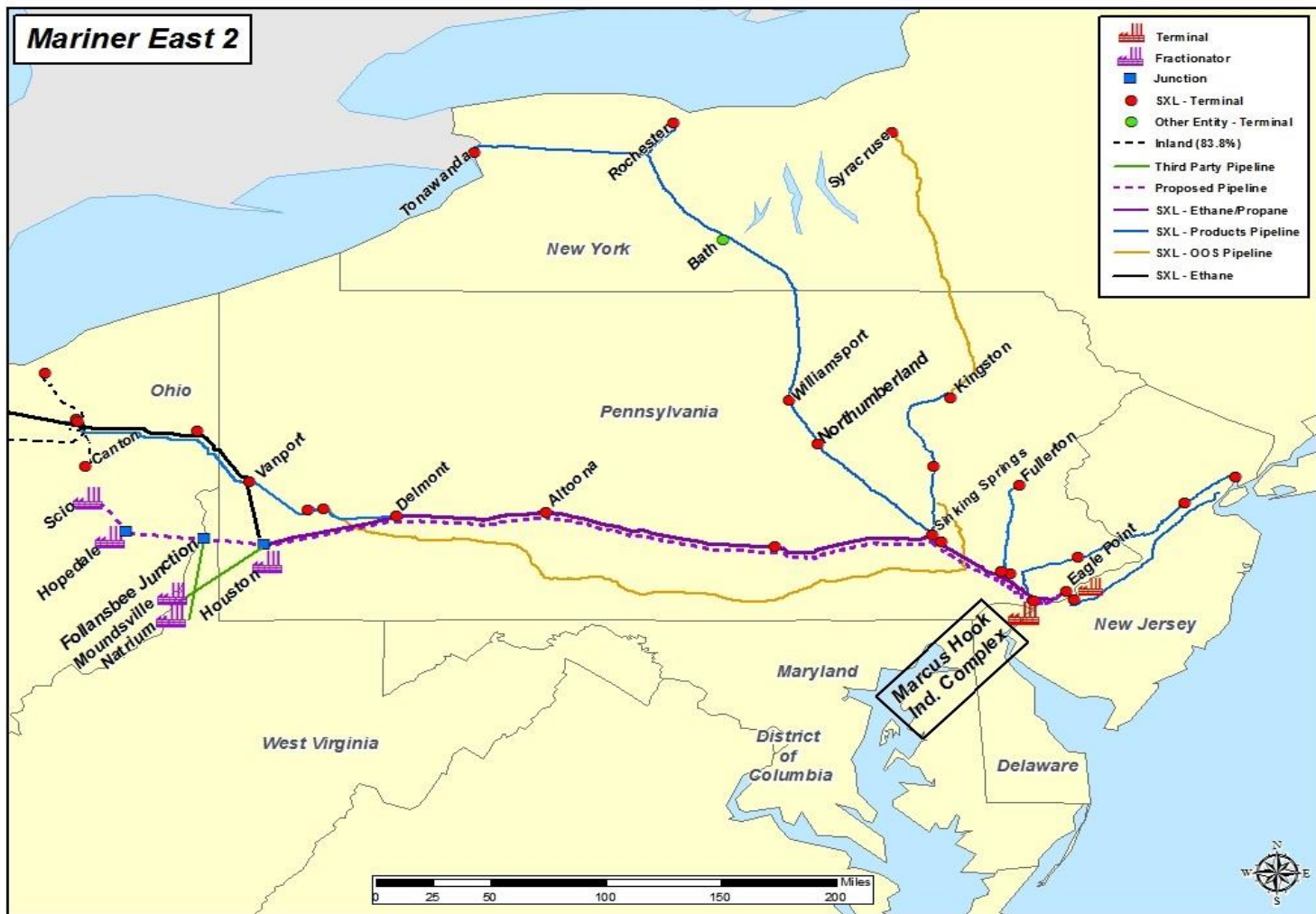
**Depth of Marcellus Shale Base**

|  |                |
|--|----------------|
|  | 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.

# NGL Gathering Capacity Demand

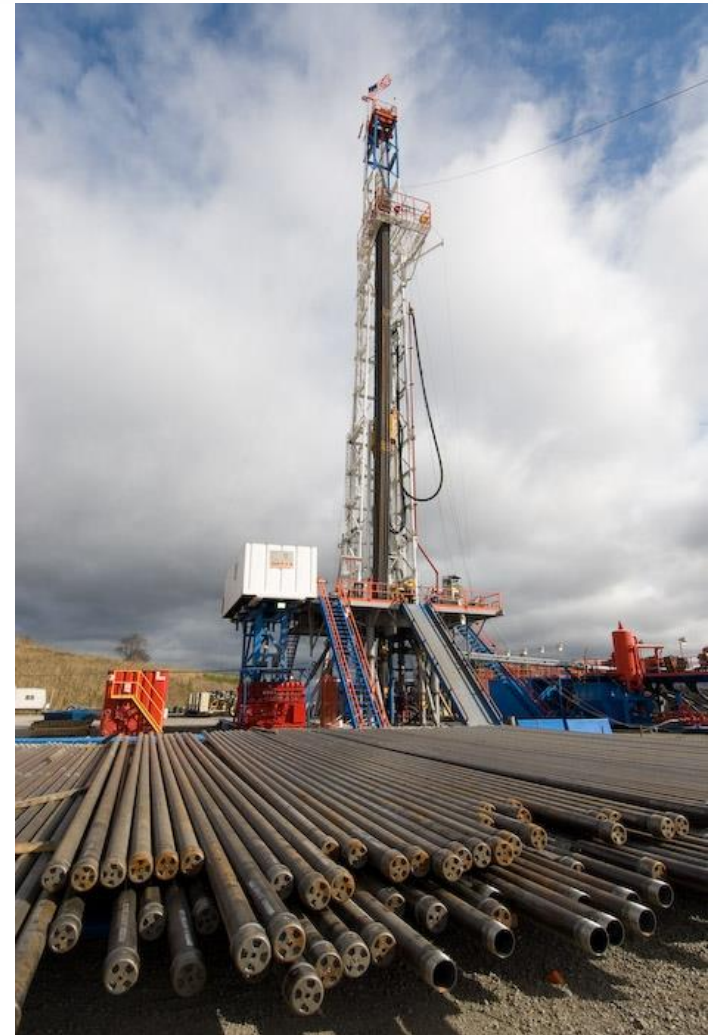


MarinerEastPhase2\_Vapor\_120110



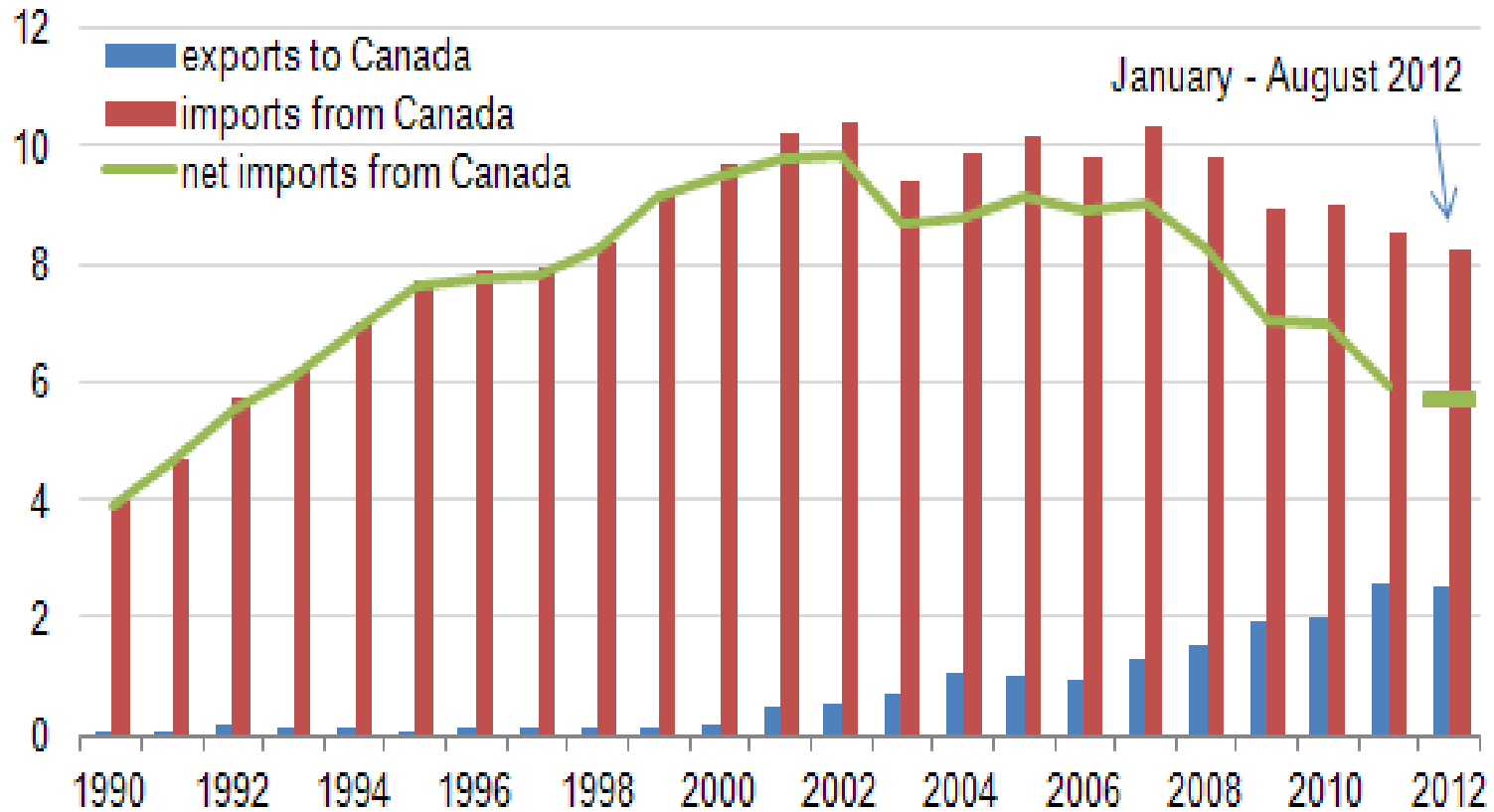
# LNG Export

- Emerging capacity to export the commodity
  - 4 permits issued for Gulf Coast
  - Alaska permitted again??
  - Western/Eastern Canada
  - Cove Point approved 9/11/13
  - 8.5 bcf/d current. Future??
- Economics favorable?
  - Long term contracts vs. spot pricing
  - Competitive environment - Africa, Australia, Canada, Qatar
- Federal agency review
  - Completed
  - Approval process??
  - Political will??
- End markets
  - Europe
  - Asia



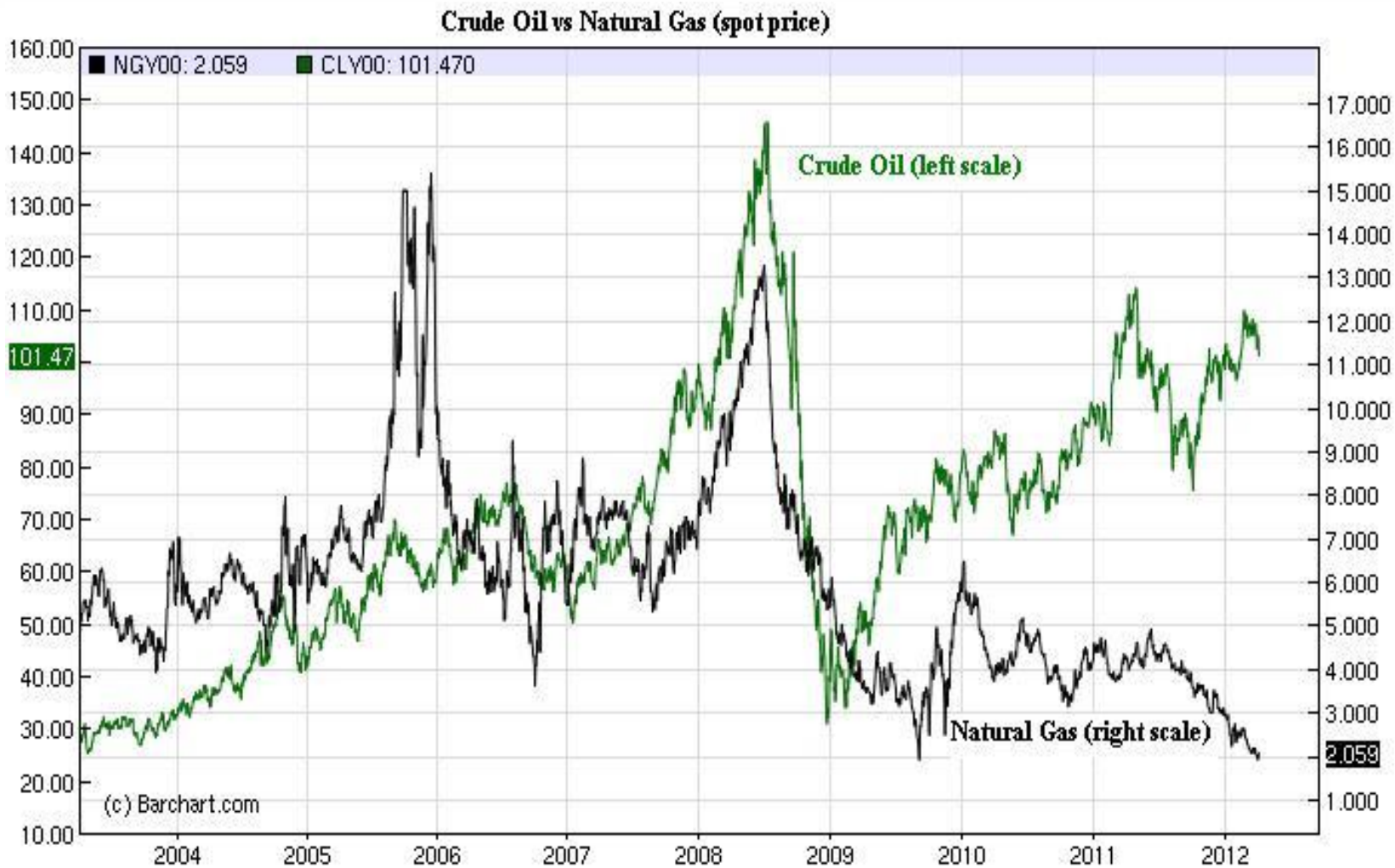
# Canadian Imports/Exports

U.S. natural gas net imports from Canada  
billion cubic feet per day





# U.S. Energy Pricing





# New Energy Dynamics with NGS



- Production vs. utilization
- Adding value to the commodity?
- Large energy consumers
  - Industrial
  - Power
  - Domestic/Cross-border
  - Transportation
  - Petrochemicals/Fertilizer
- New industrial renaissance?
  - “reshoring” of manufacturing
  - Manufacturing costs 15% cheaper than Germany or France
  - Implications for Asian trade?
  - Increased investment in U.S.
- Chemical Industry
  - 17,000 direct jobs, 395,000 indirect jobs
  - \$100B capital investment w/\$132.4B increase US economic output
- Ethylene Production
  - Capacity increase 30% increase (2011 to 2017)
  - 5 new facilities (Dow, Shell, Chevron, Formosa, Sasol)



# Power Gen Trends

- 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



- New Federal emphasis on transportation
  - Legislative efforts to promote investment
  - Public/private initiative on infrastructure
  - Auto industry interest
  - Conversion of fleets



## Pennsylvania Wilds

*Design Guide Supplement  
for Oil & Gas Best Practices*



## Landscape Solutions

Planning efforts should pay special attention to views from the roadways and the experience of driving across the countryside. Transportation management plans may help reduce the amount of traffic on and damage to scenic roads. The preservation of views from the road can be accomplished by understanding how people look at the landscape around them. Carefully obscuring natural gas industrial development from view may even make its presence less disturbing to those who live in or travel through northern Pennsylvania.

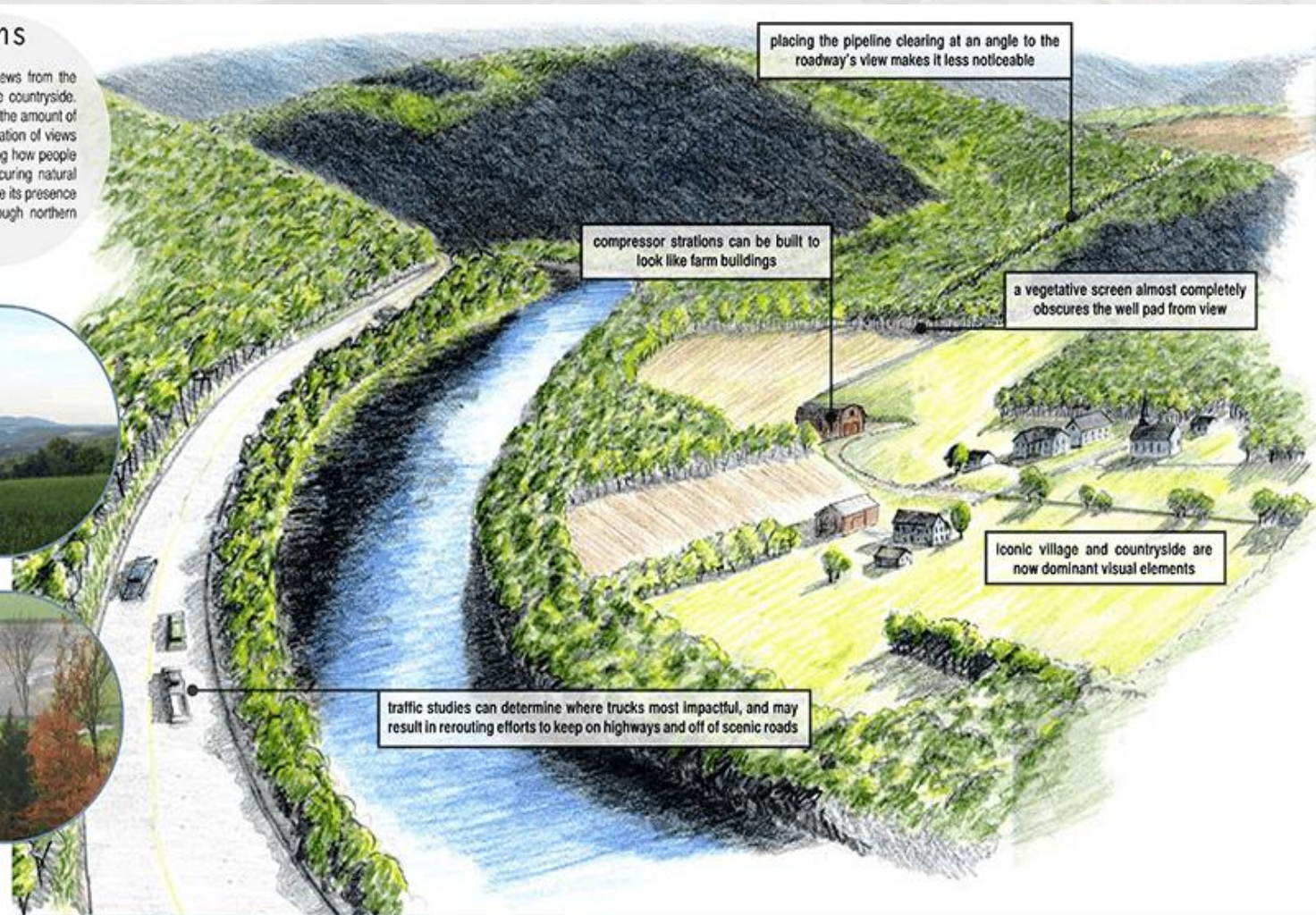
### Visual Preference

Visual preference refers to the way people look at and perceive the landscape around them. Elements that may usually be considered unattractive can sometimes be 'hidden in plain sight' simply by adjusting their orientation to the road.



### Vegetative Screens

In rural areas, trees and plant life are a common sight across the countryside. Planting trees or placing vegetation between roadways and natural gas development activities, such as well pads, may hide them from the view from the road.



# improved scenario

# Noise Abatement Techniques





# Key Issues In Compliance Assurance

- Trained & knowledgeable inspectors
  - Political will to develop and defend
  - Regulatory protocols suitable for regional geology
  - Emerging technology
  - Transparent process
  - Public trust
  - Academic ownership, eNGO buy-in
- Understanding the “true risks” from perceived
- Documenting the baseline data early
- Determining the gaps
  - Air emissions
  - Human health
  - Research to match science to emerging technology
  - Promote emerging BMPs

# Fluid Remediation/Disposal

**Approx. 10%-20% of fluid returns to surface in Marcellus**

**During 2013 in Pennsylvania ~90% of shale gas flowback and produced water was recycled and 10% disposed of via injection wells**

## **Flowback management options**

- Direct reuse (blending)
- On-site treatment w/reuse
- Off-site treatment w/reuse
- Off-site treatment and disposal
- UIC well disposal

## **Treatment technologies include**

- Chemical precipitation
- Electrocoagulation
- Evaporation (MVR)
- Filtration





# 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

# Summary



- Extensive shale energy drilling is occurring in North America, China, Poland, and moving forward in other areas
- New technology continues to improve the safety, well yields, and reduce environmental issues
- “Footprint” of the process is reduced with new equipment and engineering techniques

# Summary cont'd




- Best management practices learned in North America being applied globally
- Matched with progressive regulatory protocols
- More efficient water handling –less trucks
- Shorter drilling timeframes
- Better long term planning once geology is understood
- Becoming less impactful to communities





[www.marcellus.psu.edu](http://www.marcellus.psu.edu)  
[www.shaletec.org](http://www.shaletec.org)  
[www.naturalgas.psu.edu](http://www.naturalgas.psu.edu)



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