# Shale and the Environment

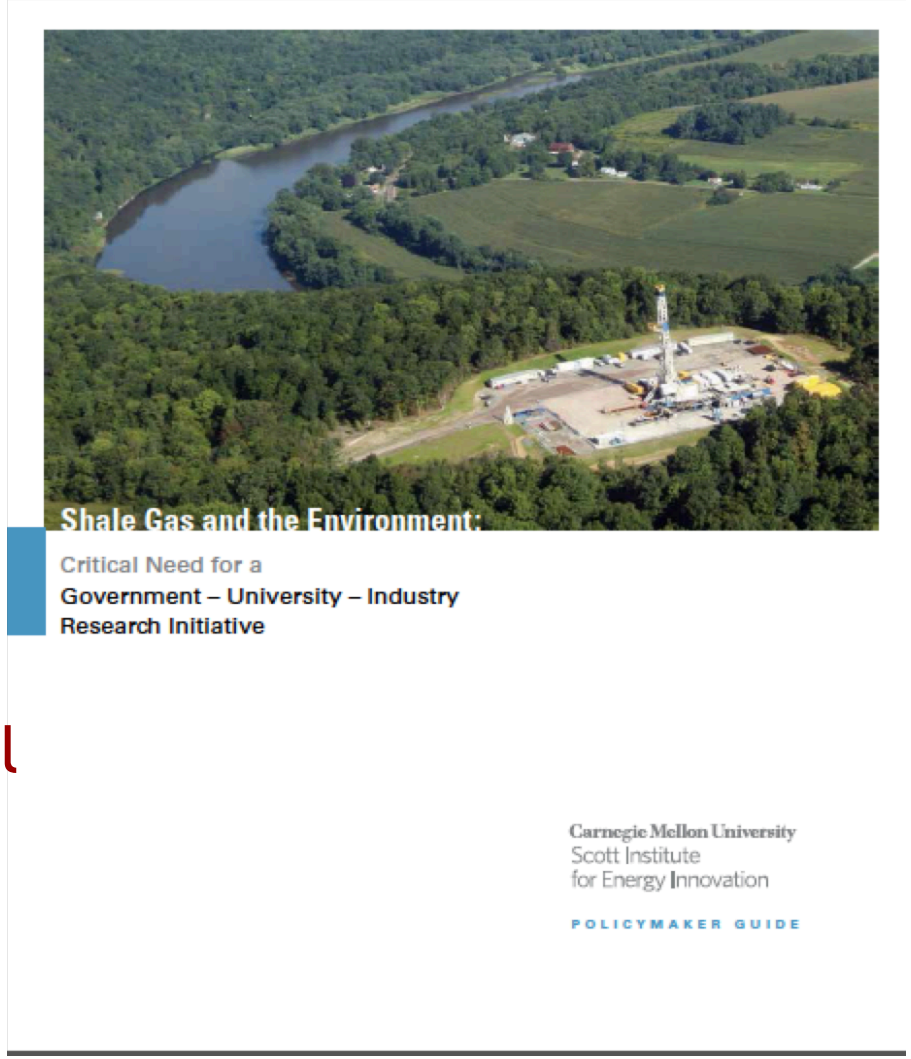
## Critical Need for a Government-University-Industry Research Initiative

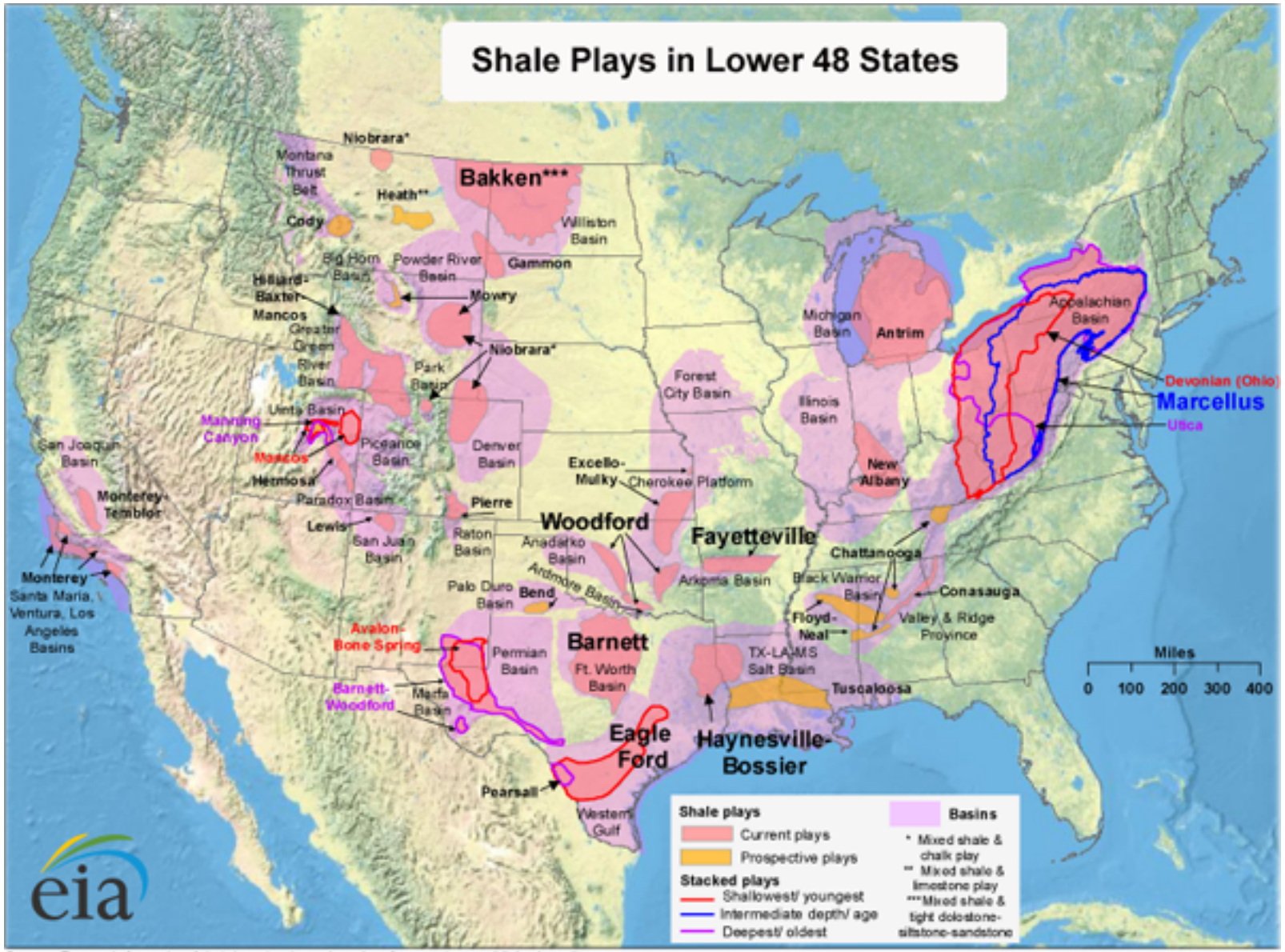
# Carnegie Mellon University
# Scott Institute for Energy Innovation

- Using and delivering the energy we already have far more efficiently
- Expanding the mix of energy sources in a way that is clean, reliable, affordable and sustainable
- Creating innovations in energy technologies, regulations and policies

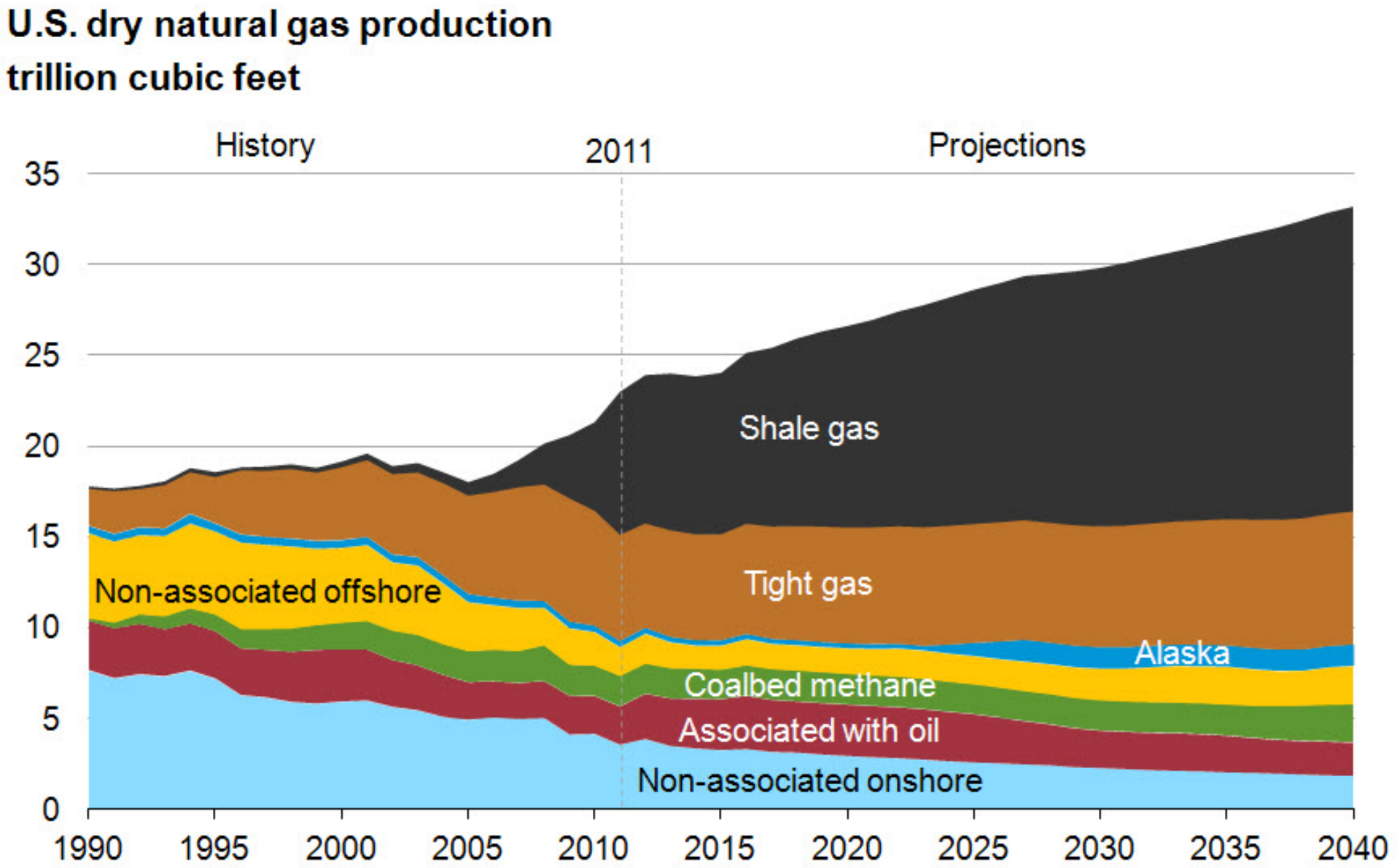
# Scott Institute Policymaker Guide

- Primer on shale gas
- Carnegie Mellon University research on shale gas and its potential impact on
  - water resources,
  - air quality
  - greenhouse gas emissions, and
  - economics of shale gas well abandonment
- Proposal for a government-university-industry research initiative





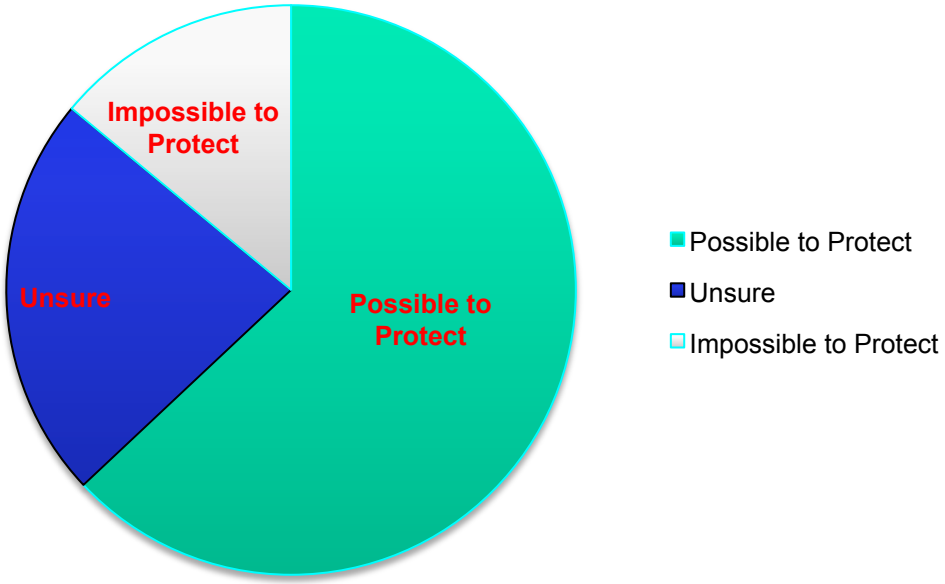

Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011




*Source:* U.S. Energy Information Administration, *Annual Energy Outlook 2013 Early Release*

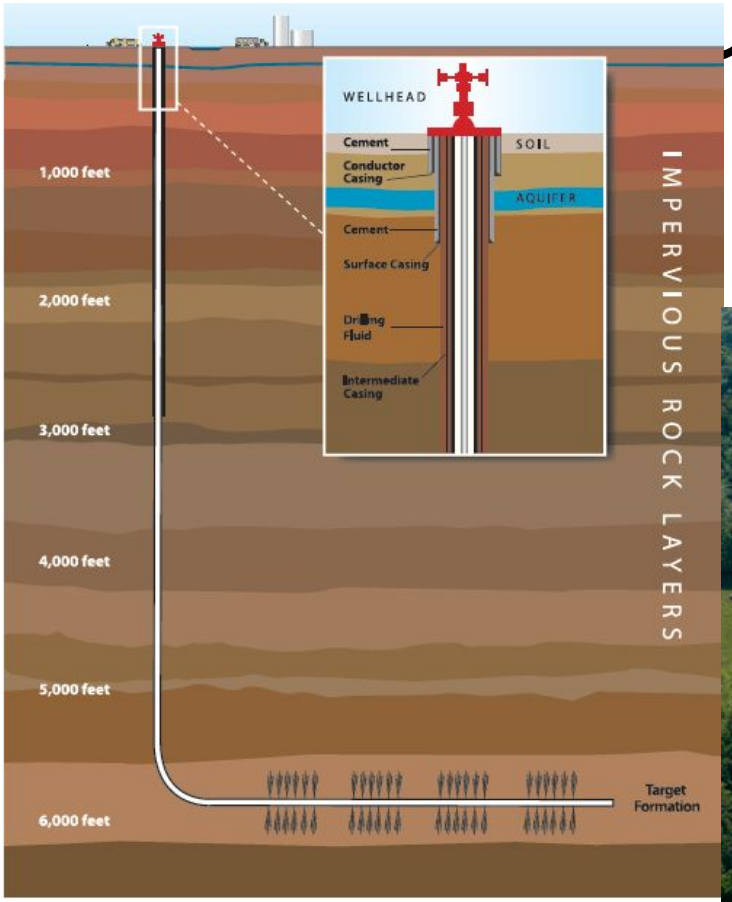
# Public Opinion and Shale Gas Development

- Rasmussen 2012 Poll
  - 57% of Americans favor use of hydraulic fracturing
  - Possible to Protect Environment?
    - 63% Possible to Protect
    - 23% Not Sure
    - 14% Impossible to Protect



# Jeanne VanBriesen, P.E., PhD
# Professor, Department of Civil and Environmental Engineering
# Director, Center for Water Quality in Urban Environmental Systems

# Shale Gas Extraction occurs near water, uses water and produces wastewater

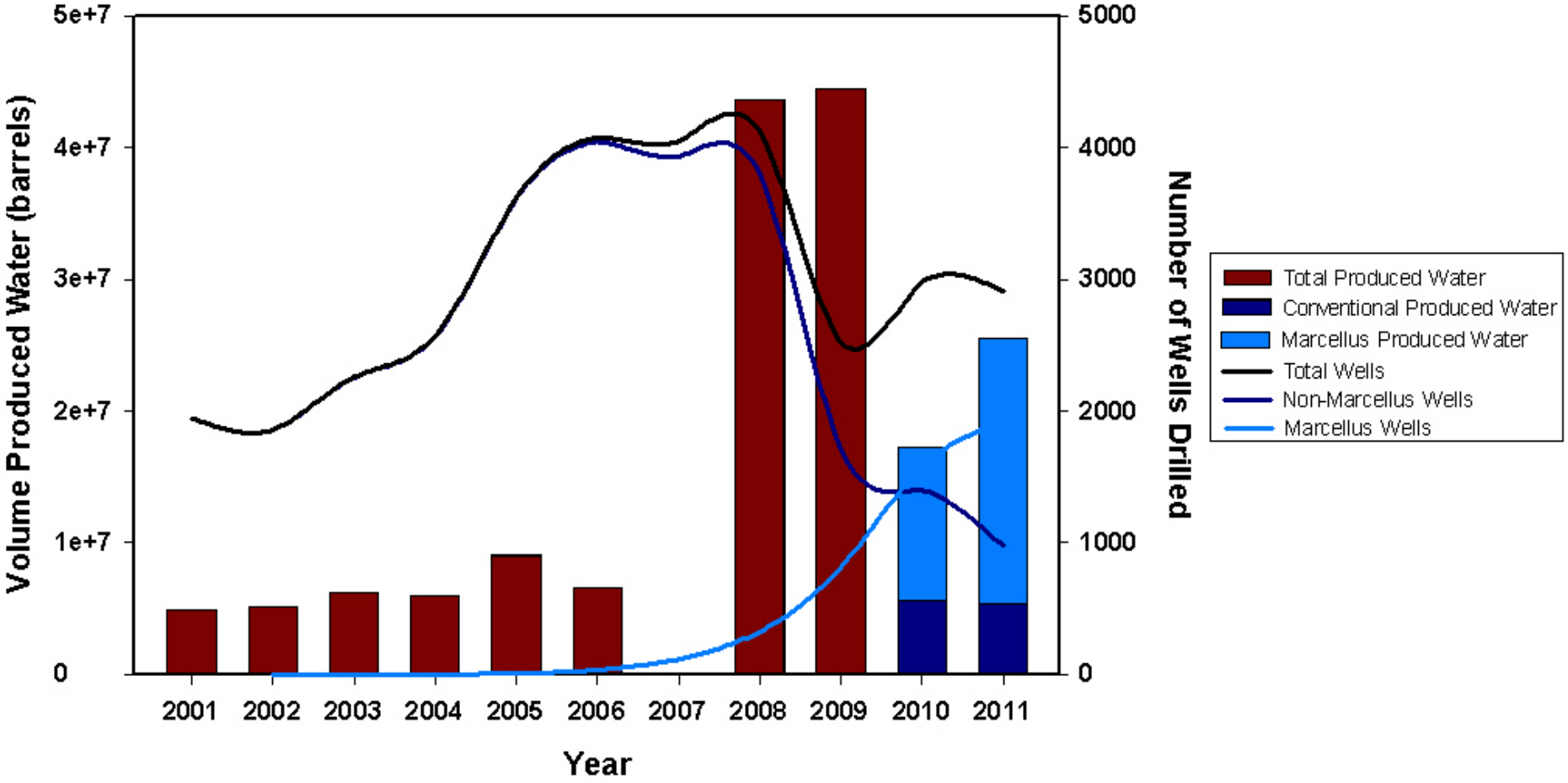



1. Protecting surface waters from spills of chemicals or wastewater.

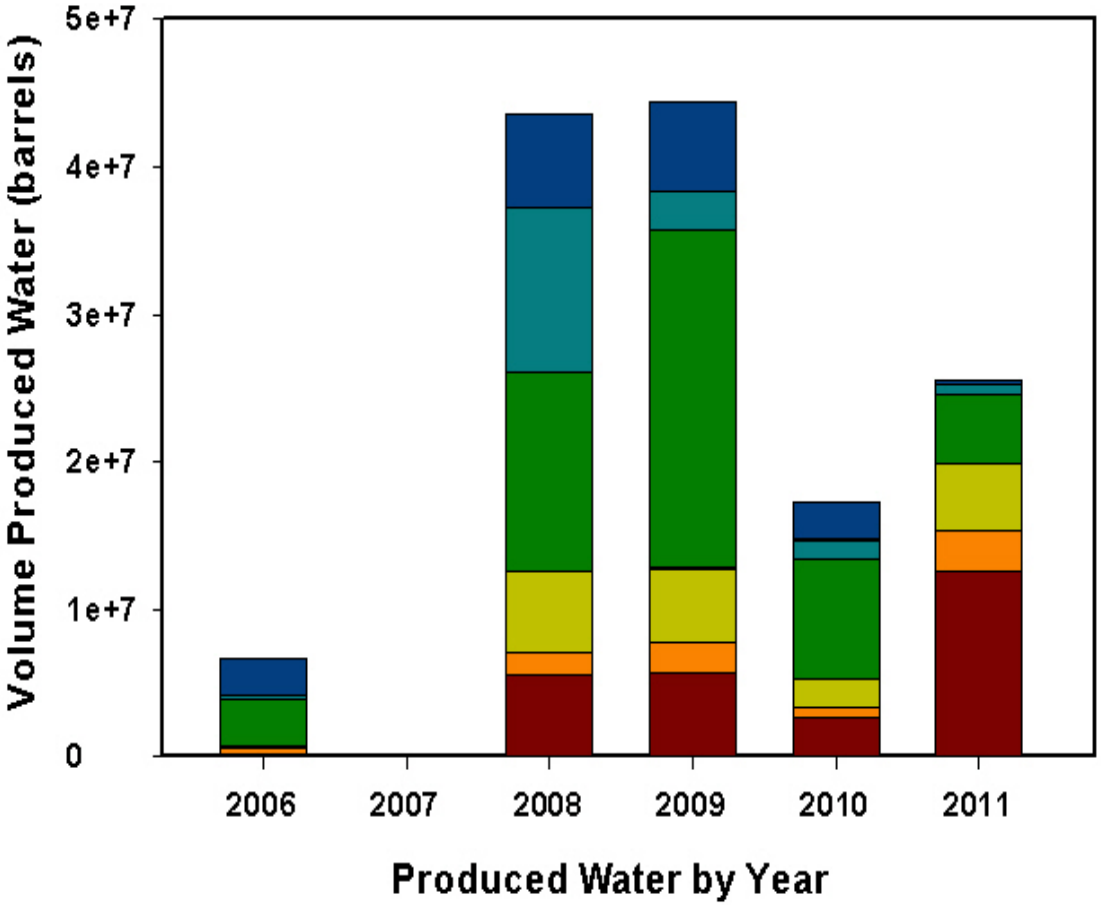
2. Isolating groundwater from drilling and hydraulic fracturing.


3. Managing water withdrawals and managing the treatment and disposal of produced waters to protect the environment.

# Produced water volumes requiring management significantly increased in response to increasing shale gas development in Pennsylvania



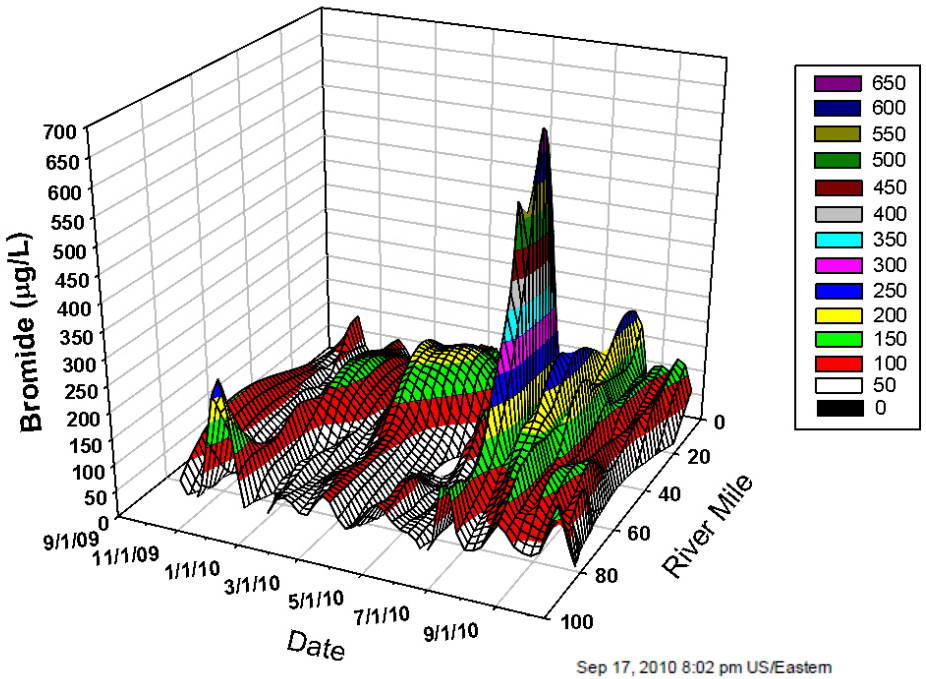
# Management options that result in partially treated produced water release to surface waters expanded in 2008 and 2009 in Pennsylvania




**.. . And affected the drinking water source for more than a million people**

- Reuse and storage within operations (not road spreading)
- Injection Well (UIC)
- Brine Treatment Plants (CWT) - Other
- Brine Treatment Plants (CWT) - Exempt
- Municipal Sewage Treatment Plants (POTW)
- Other (unspecified, road spreading, landfill)

# Management options that result in partially treated produced water release to surface waters expanded in 2008 and 2009 in Pennsylvania




**.. . And affected the drinking water source for more than a million people**

Sep 17, 2010 8:02 pm US/Eastern

## Researchers Concerned About Chemical In Mon River

Reporting
Mary Robb
Jackson

PITTSBURGH (KDKA) — The Monongahela River is the source for 13 different water companies.

The drinking water comes out of taps in homes and businesses in the better part of southwestern Pennsylvania.

Now researchers at Carnegie Mellon University are raising concerns about the level of bromide in the Mon River – something they detected in July and August.

"Bromide itself is not a concern," says Dr. Jeanne VanBriesen, director of CMU's Water Quality In Urban Environmental Systems Center. "We're concerned that when the bromide gets into the drinking water plants there's a reaction that takes place."

# Unanswered Questions . . .

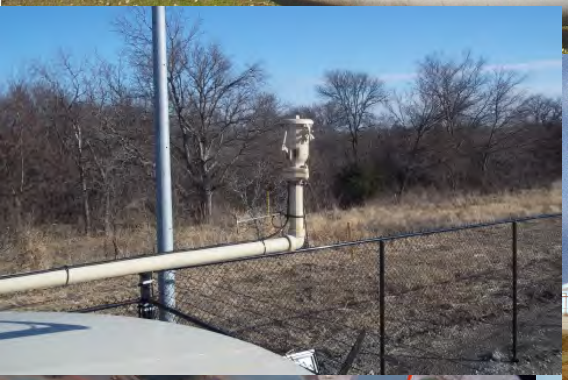
- How do changes in produced water quality over the life of a well affect management options and costs?
- How do decisions about produced water management change as development moves geographically and over time?
- What are the long term quantities of produced water expected from shale gas wells? When options for recycling end, what management options will dominate?
- Can reduced cost treatment technologies be developed?
- Can treatment technologies extract useful materials, making them more sustainable and cost effective?

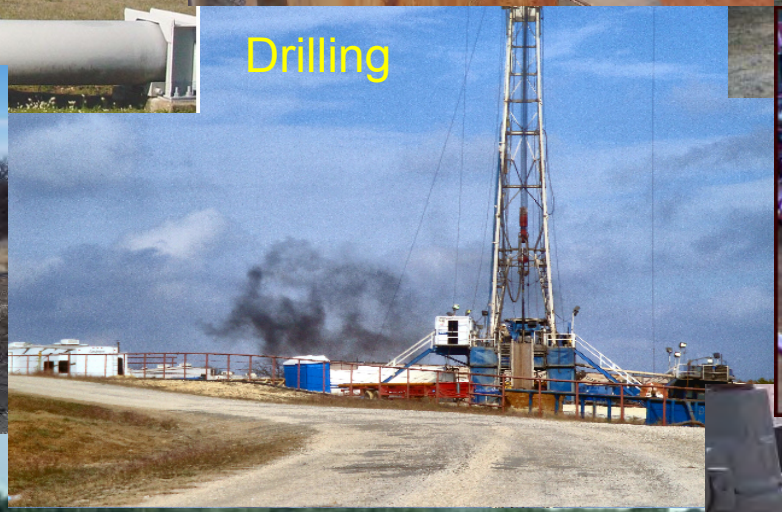
# Allen L. Robinson, PhD

**Raymond J. Lane Distinguished Professor**
**Professor and Head, Department of Mechanical Engineering**
**Professor, Engineering and Public Policy**
**Center for Atmospheric Particle Studies**


Compressor stations

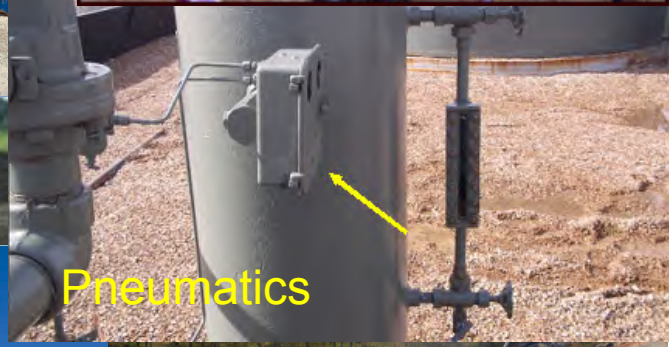

Condensate Tanks



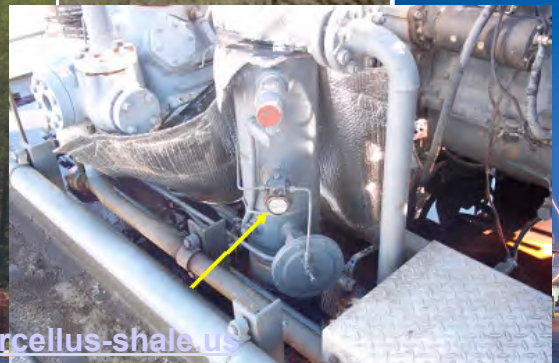

Drilling


Fracing


Fugitives


Pneumatics

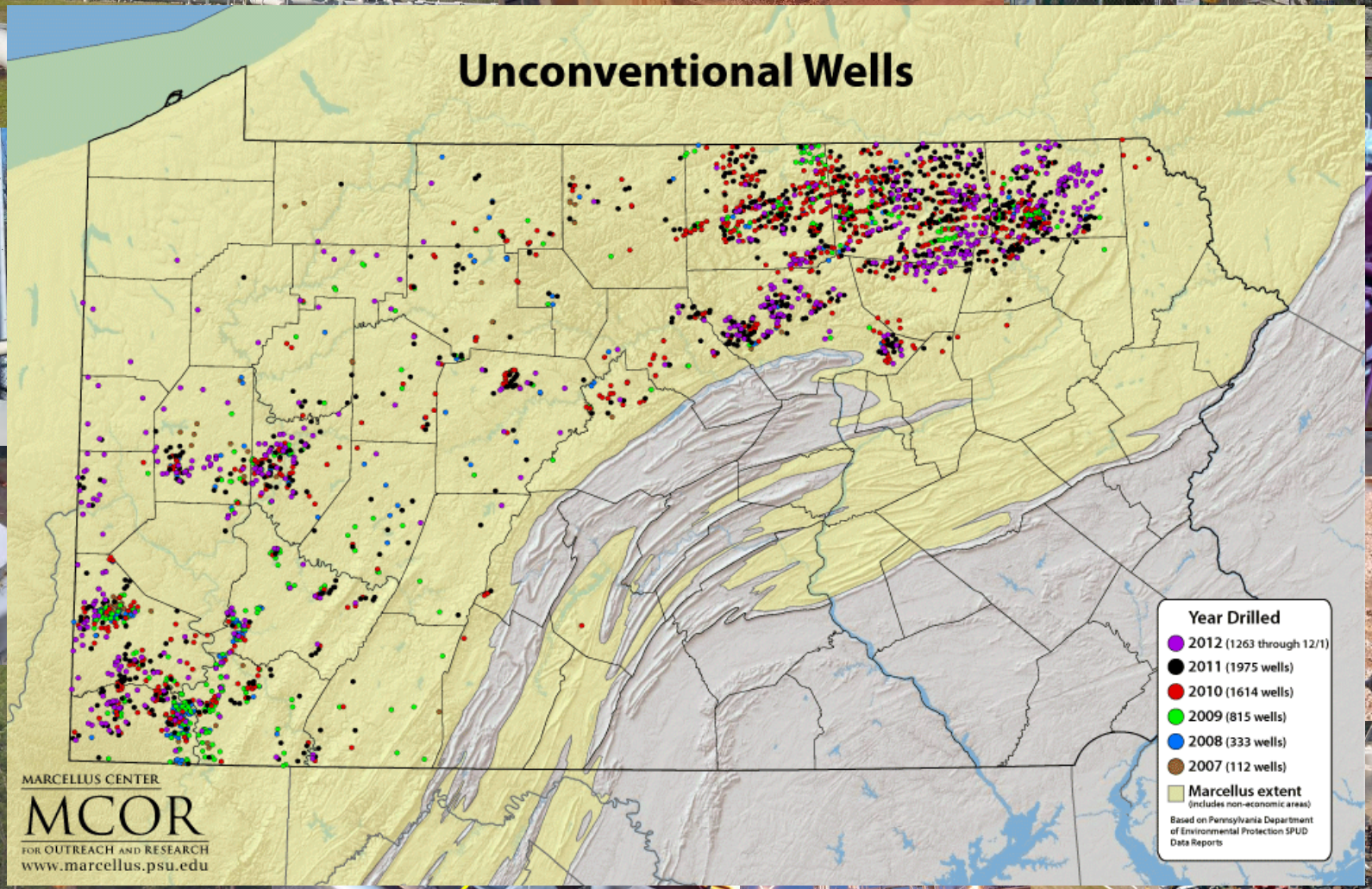

Flaring




marcellus-shale.us

http://www.marcellus-shale.us

# Complex mix of sources widely distributed in space (A very large chemical plant)



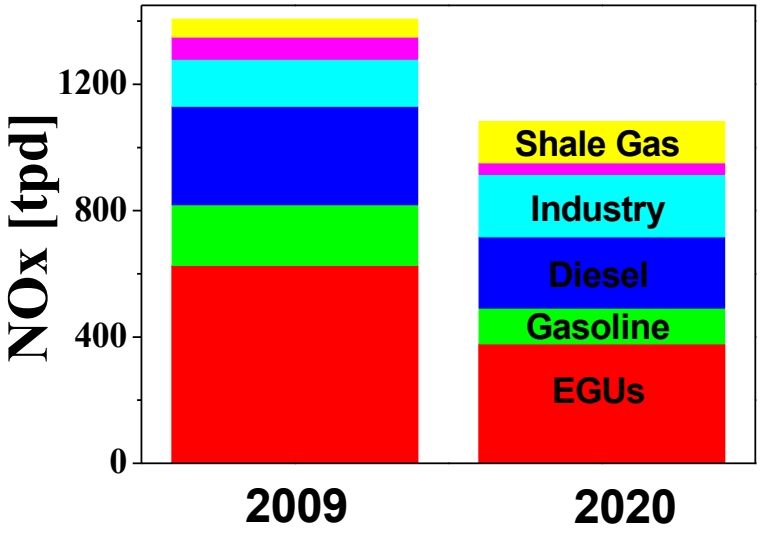

Flaring

http://www.marcellus-shale.us

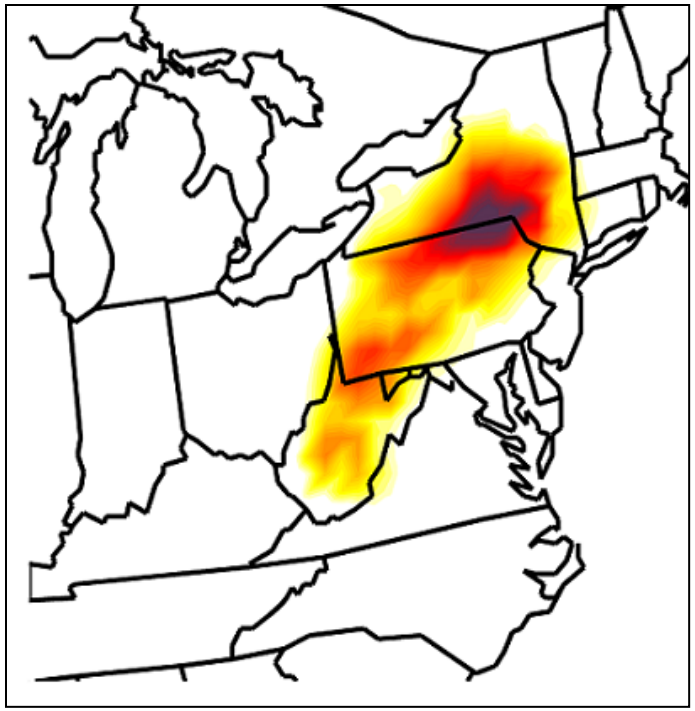
marcellus-shale.us

# Regional Air Quality Impacts

Marcellus Region NOx Emissions



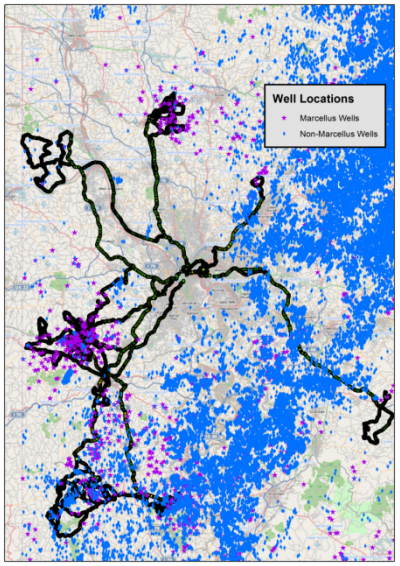

Predicted $O_3$ Impacts in 2020



Peak increase ~ 11 ppbv

(Roy et al. under review)

# What about local air quality impacts?




**Driving route around Marcellus sites near Pittsburgh**

**CMU Mobile Air Quality Laboratory mapping hot spots**
**"High emitter problem" – few sources with high emissions**

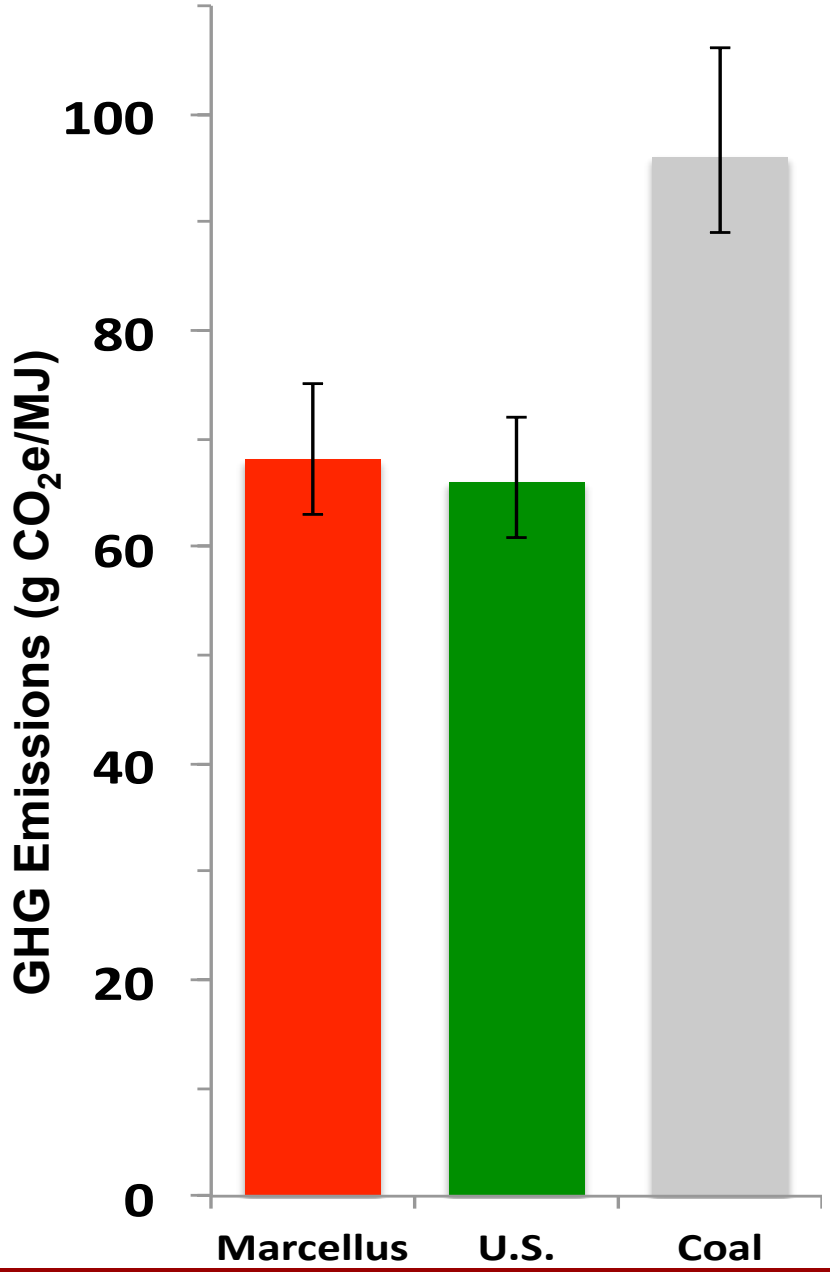
# Unanswered Questions . . .

- What is the positive and negative marginal impact of shale gas development on regional and local air pollution? What is the spatial distribution of these benefits and costs?
- From a regulatory perspective, should each site be viewed as an individual source of air pollution emissions or a very large chemical plant or refinery distributed over a large area such as an air basin or valley?
- Are toxic air emissions such as diesel particulate matter and formaldehyde likely to create local problems?

W. Michael Griffin, PhD
Associate Research Professor
Engineering and Public Policy
Tepper School of Business
Co-Director, Green Design Institute

# Greenhouse Gas Emissions

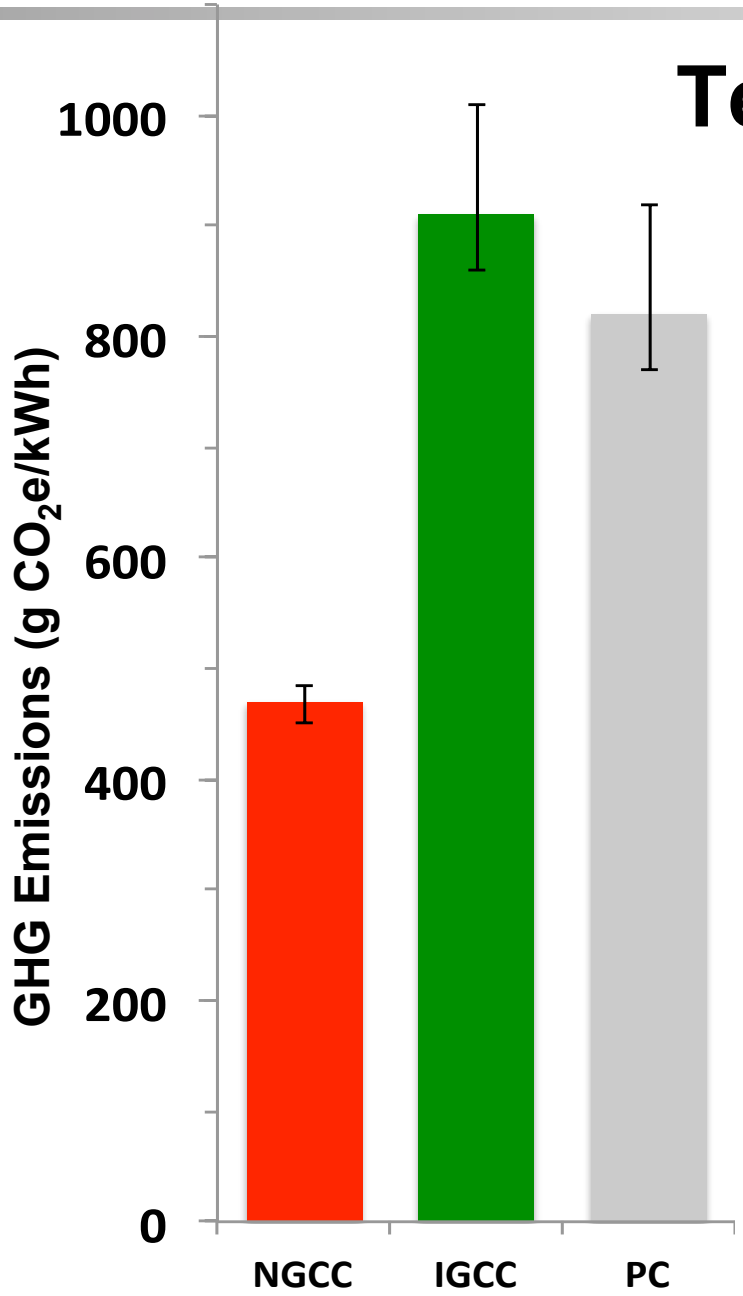
- Greenhouse Gas (GHG) emissions from unconventional gas is controversial
- Suggested as a transition fuel
- Methane is a potent GHG gas




# Fuel Comparisons

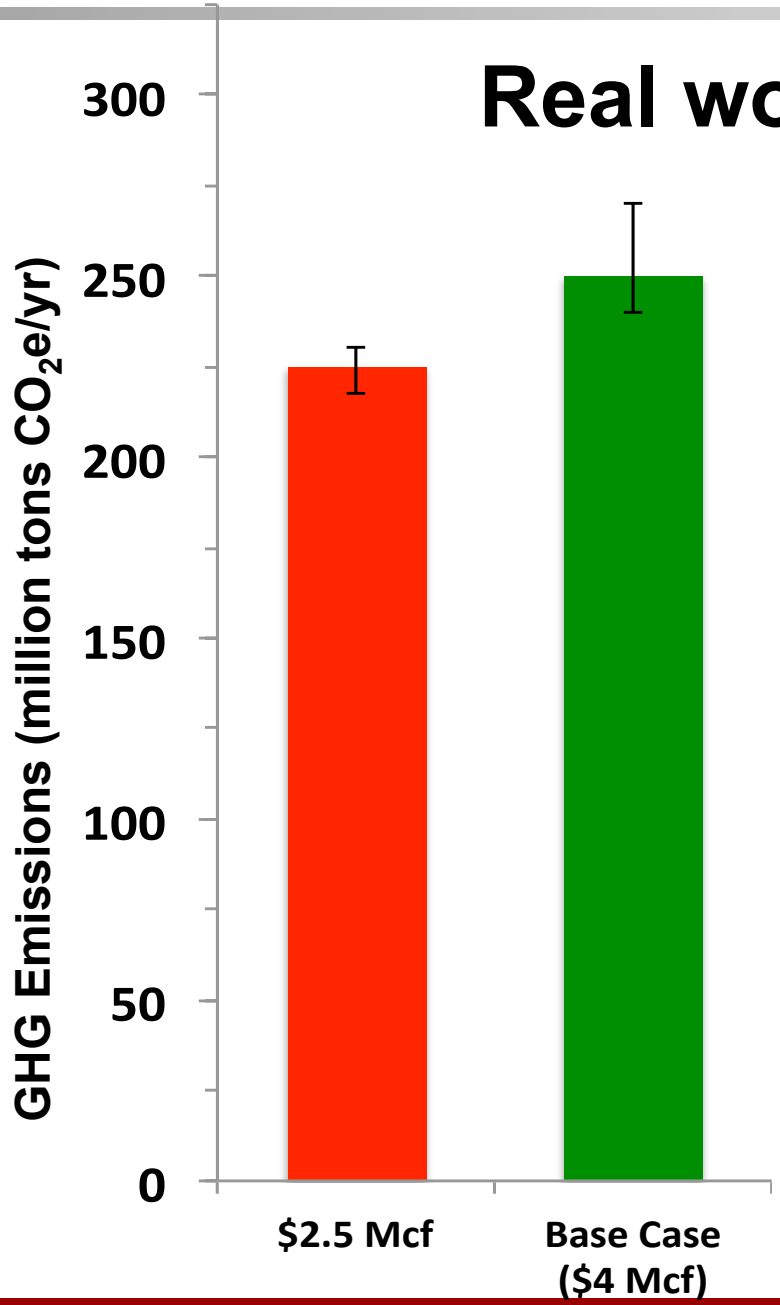
- Marcellus GHG emission slightly higher than US natural gas in 2009
- Natural gas emissions about 30% less than coal
- Inappropriate comparison however!

# Technology Comparison




- Natural Gas Combined Cycle (NGCC) plant generates a kWH of electricity 45 to 50% less greenhouse emissions, than an Integrated Gasification Combined Cycle (IGCC) or Pulverized Coal (PC) plant

# Real world experience




- 2010 Electricity Reliability Council of Texas (ERCOT) dispatch of electricity assets
- Base case $4 gas
- Cheap Gas ($2.5 Mcf) GHG emissions reduced by 10%
- Gas price exceeds the base case emissions increase

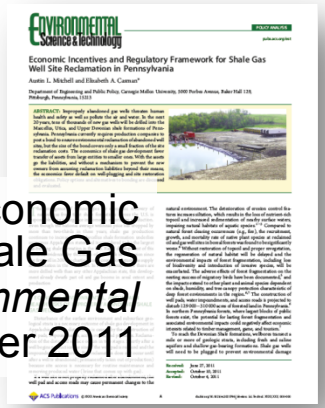
# Conclusions

- Marcellus natural gas emits the same amount of GHG as average US gas
- Using advanced technology natural gas electricity generation can reduce GHG emissions
- Real world – operations of the grid and price competition between natural gas and coal will limit the emissions reduction but are still substantial

# Unanswered Questions

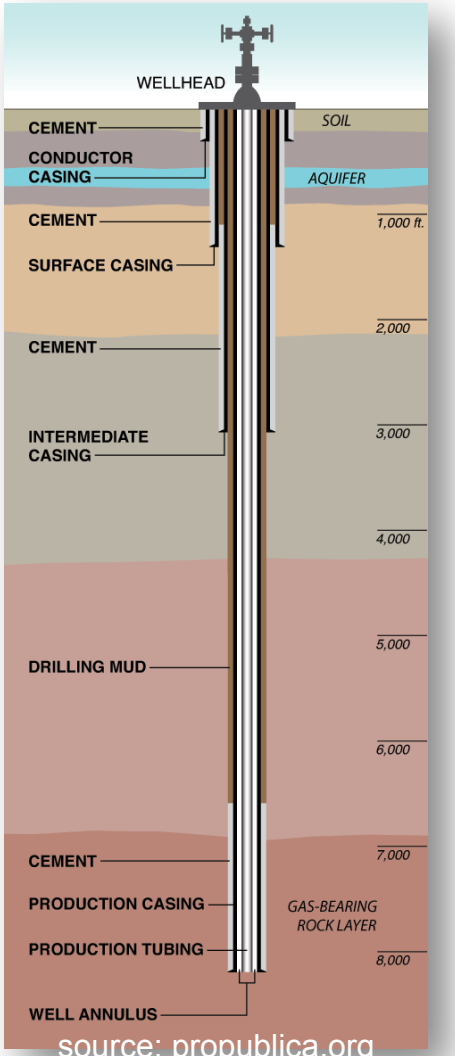
- What are the eventual production volumes (ultimate recoveries) of Marcellus shale wells?
- What will the impact be of the most common industry practices related to flaring and venting at Marcellus wells (e.g., “green completions” which capture methane and VOC compounds during well completions instead of venting and flaring)?
- What are the greenhouse gas emissions from shale plays other than Marcellus?
- Regional environmental variability and reservoir heterogeneity must be evaluated.
- What is the overall methane leakage rate from the entire natural gas system?

# Austin Mitchell
# Economics of Plugging and Abandonment



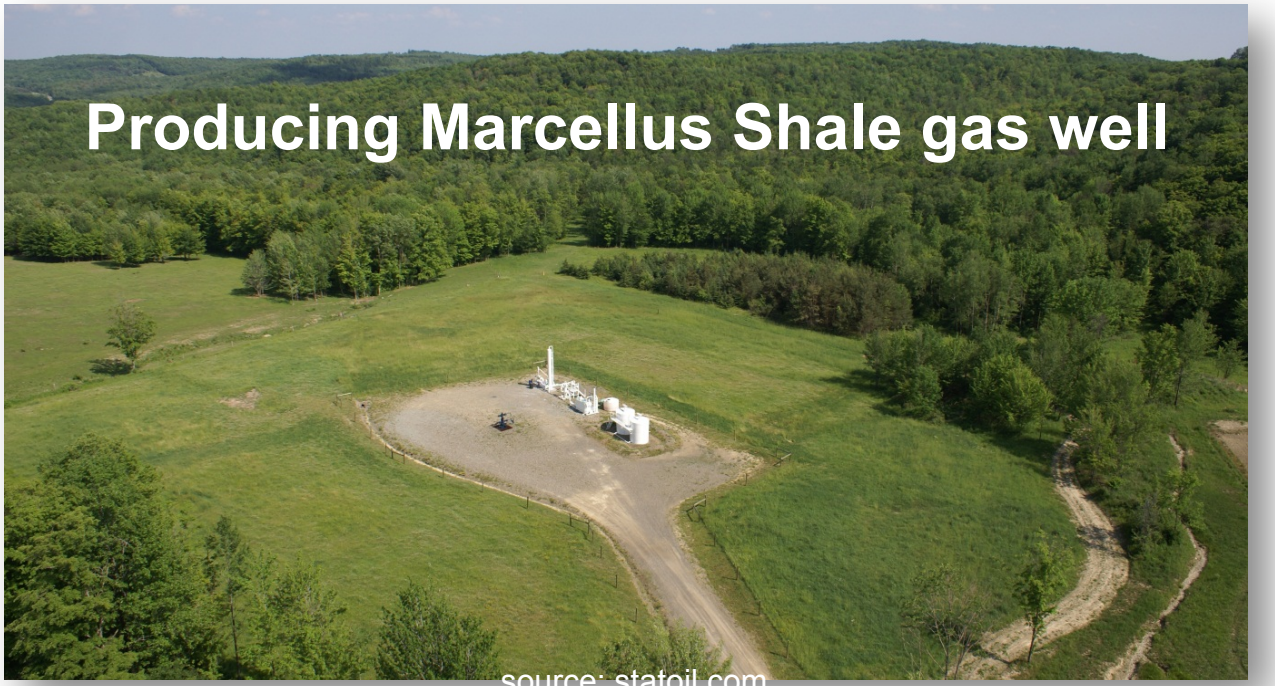

Austin L. Mitchell, Elizabeth A. Casman, Economic Incentives and Regulatory Framework for Shale Gas Well Site Reclamation in Pennsylvania, *Environmental Science & Technology*, November 2011

# Plugging and abandonment…



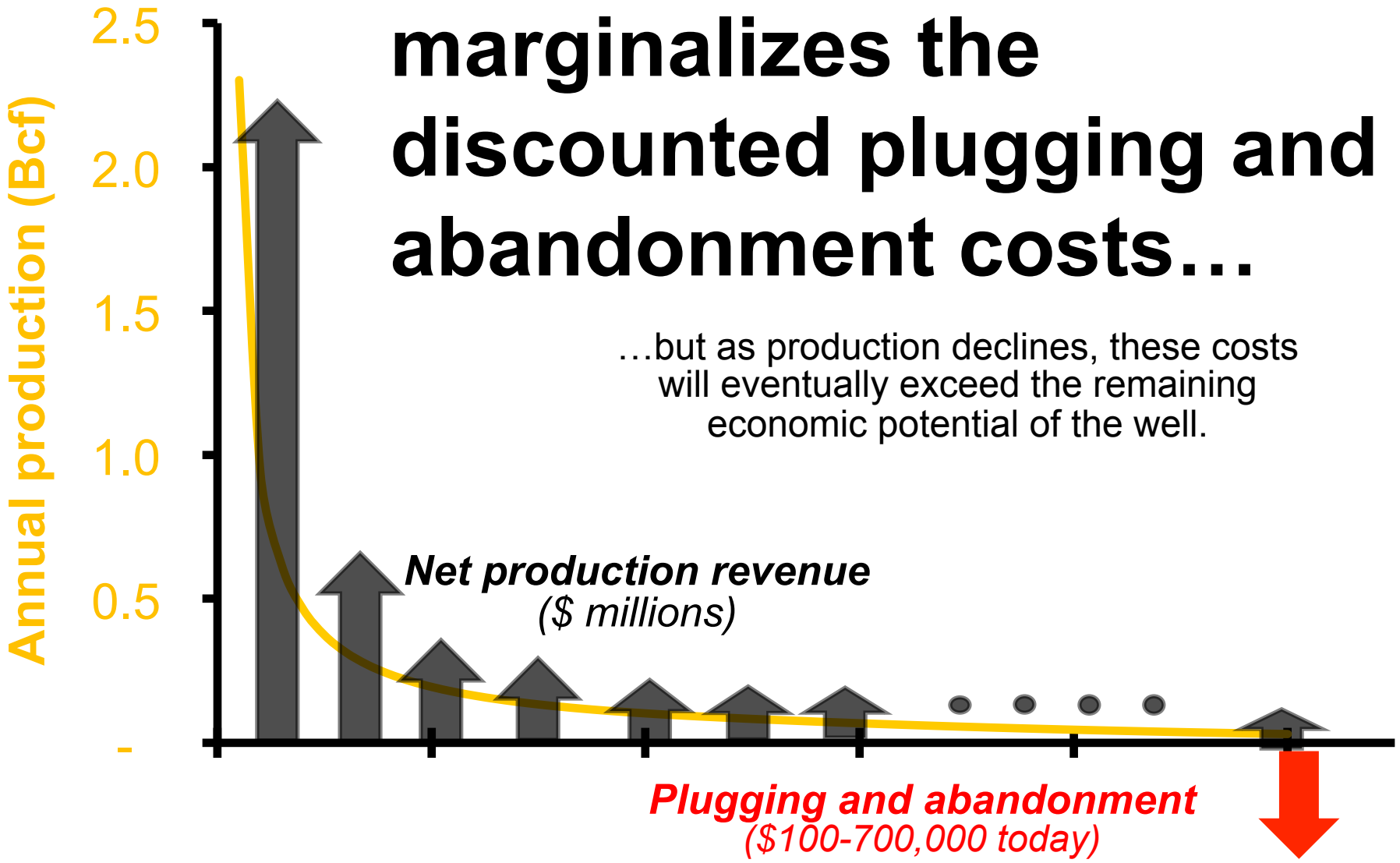

source: propublica.org

1) **Permanently isolate groundwater:** pull production casing, insert cement plugs
2) **Reclamation of well pad:** remove equipment and gravel, replace topsoil, re-vegetate land




source: statoil.com

# Near-term accounting marginalizes the discounted plugging and abandonment costs…



# Pennsylvania's well bonds cover a small fraction of actual plugging and abandonment costs…

**$10,000 per well, capped at $600,000 per operator**



PA oil & gas production

***Developing Pennsylvania's shale gas will require tens of thousands of new wells and hundreds of thousands of acres of land…***

***…and this means tens of billions in unfunded environmental liabilities.***

1859 1940's Today Future

# Unanswered questions about plugging and abandonment?

- What changes in current environmental policy and implementation could minimize a future orphan shale gas well problem in Western Pennsylvania?

- What is the long-term reliability of cement plugs and casing in abandoned wells? What water and/or air monitoring would be required to efficiently identify problems?

# Recommendation

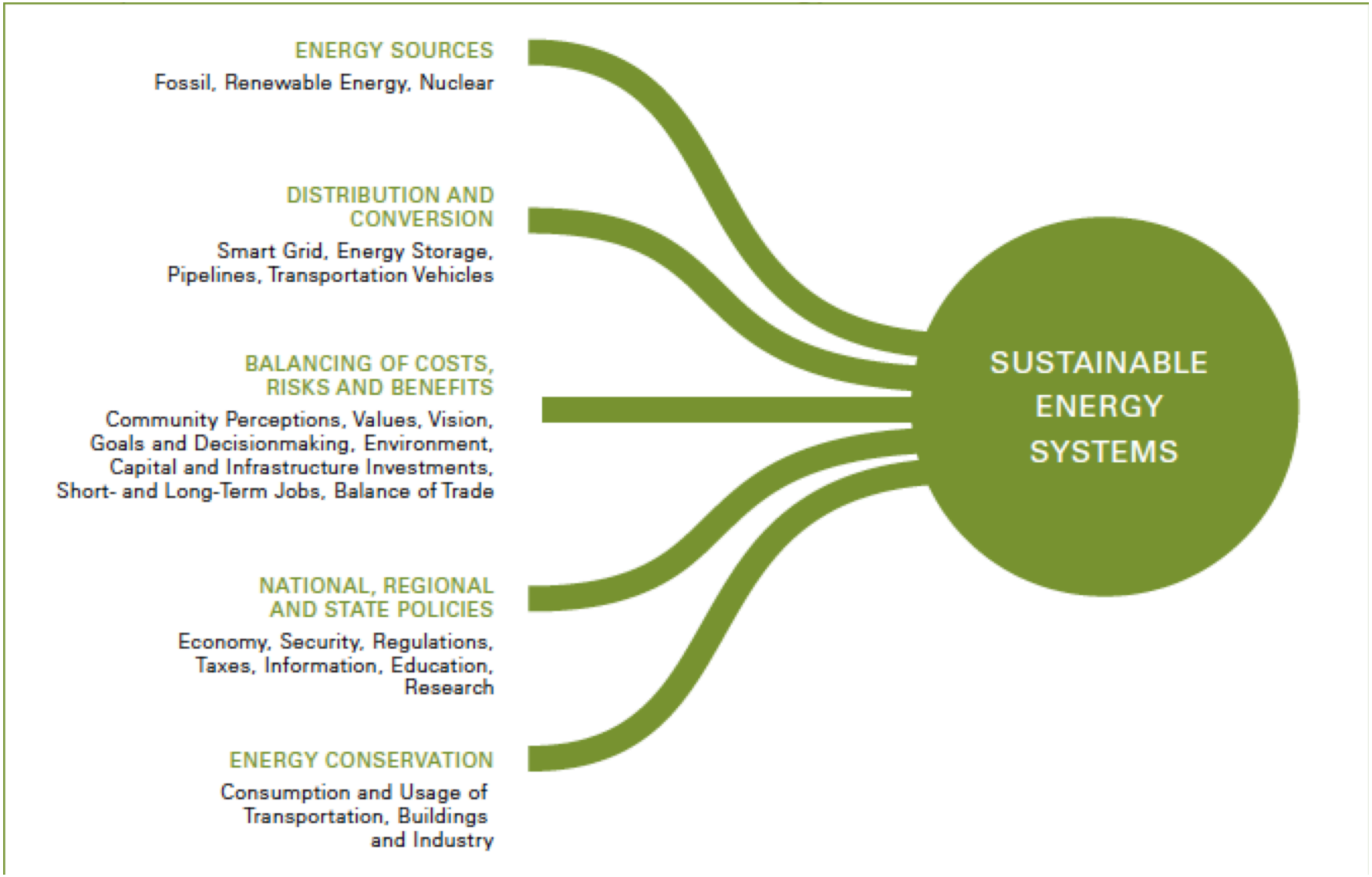
# Critical Need for a Government-University-Industry Research Initiative

- Federal, state and/or regional governments government–university–industry initiative to
  - engage in broad environmental monitoring, coupled with research, to understand the meaning of collected data, and
  - develop support tools to enable data-informed decisions regarding development of shale resources
  - provide information to the public that is unbiased and informed by science and engineering.

# Why is Government-University-Industry Shale Gas Research Initiative Needed?

- Insufficient research is in place to assess the impact of shale gas operations as illustrated by unanswered questions in this presentation.
  - Monitoring is one example. In Pennsylvania, there are 100 surface water monitoring stations for 86,000 miles of rivers and streams and 4,000 lakes, reservoirs and ponds.
- Initiative provides a “firewall” between the funding of research and the research priorities, activities and results.
- Research conducted by universities may not align well with policymaker information and priority-setting needs due to the requirement for systems approach. (see figure)
- Industry initiation and leadership is key to successful government-university-industry initiatives.

# Energy System Components



# How Will the Initiative Work?

1. **Develop Prioritized Research Agenda**: Solicit sponsor views, but independent board will develop the criteria for determining and prioritizing research questions.
2. **Prioritize Proposals for Support:** Rank research proposals through anonymous committee of experts based on merit and approved research agenda.
3. **Monitor Funded Research:** Incorporate site visits by initiative staff and expert reviewers.
4. **Communicate Research Results to Policymakers:** Release report to public with policymaker summary and briefings including unresolved critiques of reseach.
5. **Policymaker Feedback to Initiative Board:** Adjust research priorities and products based on policymaker needs.

# Future Scott Institute Activities

- Shale Gas: Implications for America's Regional Manufacturing Economies: April 4 2013 Symposium in Pittsburgh
    - Industrial Development
    - Natural Gas for Transportation
    - Environmental Impacts
    - Free and open to public: register at Scott Institute Website (www.cmu.edu/energy)
- Petrochemical Mid- and Down-Stream Industry Manufacturing Renaissance Roadmap: January 2014
- Next  Policymaker Guide: Integrating Renewable Energy into the Grid: May 2013

# For More Information

Carnegie Mellon University

Scott Institute for Energy Innovation

www.cmu.edu/energy

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