# Workshop Agenda

**MODERATORS:**

- Joseph Cavarretta, CAE, Executive Director, American Academy of Environmental Engineers
- C. Hunter Nolen, P.E., BCEE, President, Industrial Services Group, CDM Smith

**SCHEDULE:**

| | |
|---|---|
| 9:00 am | Introduction – Joseph Cavarretta, Executive Director, American Academy of Environmental Engineers |
| 9:15 am | General Introduction to Shale O&G Development and Environmental Challenges – C. Hunter Nolen, Pres., Industrial Service Group, CDM Smith |
| 9:45 am | Well Completion and Hydraulic Fracturing Methodology Explained – Kevin Rice, Baker Hughes Corporation |
| 10:15 am | BREAK |
| 10:30 am | Protection of Groundwater During Natural Gas Development – David Yoxtheimer, P.G., Penn State Marcellus Center for Outreach and Research |
| 11:15 am | Potential Relationships Between Deep Underground Injection and Earthquakes – William Leith, Ph.D., United States Geological Survey |
| 12:00 pm | LUNCH |
| 1:00 pm | An Operator's Perspective on Successful Development of Appalachian Shale O&G – Andrew Place, EQT Corporation |
| 1:45 pm | Industry Participation in EPA's Hydraulic Fracturing Study – Chris Hill, Chesapeake Energy Corporation |
| 2:30 pm | BREAK |
| 2:45 pm | Natural Gas Development in the Delaware River Basin – Carol Collier, Executive Director, Delaware River Basin Commission |
| 3:30 pm | Natural Gas Development and the NYC Water Supply – Kathryn Garcia, Chief Operating Officer, NYC Environmental Protection |
| 4:00 pm | Water Treatment Technologies and Key Considerations in Shale O&G Development – Bob Kimball, Technical Director Produced Water Treatment, CDM Smith |
| 4:30 pm | ADJOURN |

**BREAKFAST SESSION:** **May 15th,7:00-8:15 a.m. - Managing the Water Resource Impacts of Shale Gas – Tom Beauduy, Deputy Executive Directory and Council, Susquehanna River Basin Commission**



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# General Introduction to Shale O&G Development & Environmental Challenges

May 2012

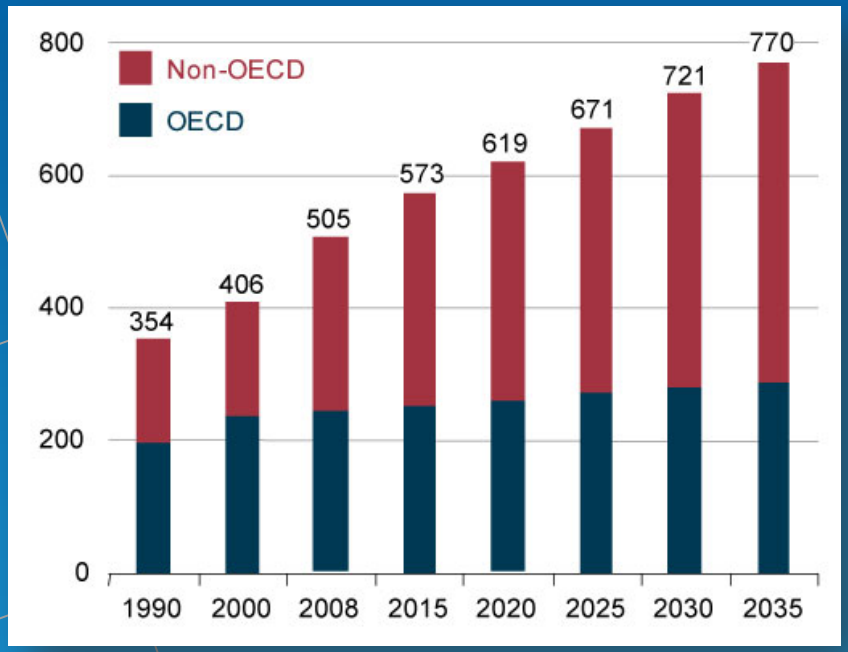
CDM Smith

# Presentation Outline

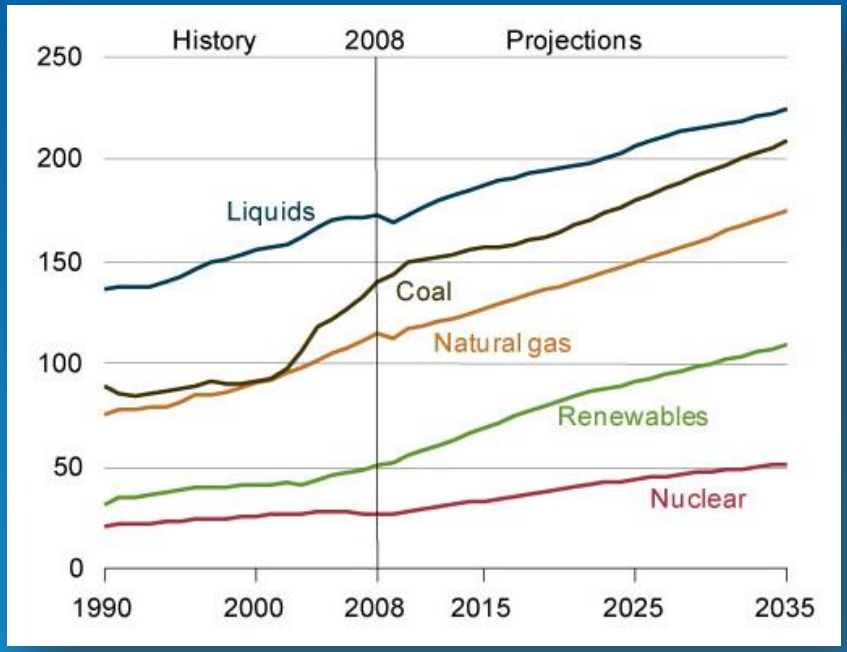
1) Summary of Shale Resource
2) Economic / Geopolitical Implications
3) Environmental Concerns
4) Water Management / Treatment
5) Energy Choices

# World Energy Consumption

## World Energy Consumption, 1990-2035 (quadrillion Btu)

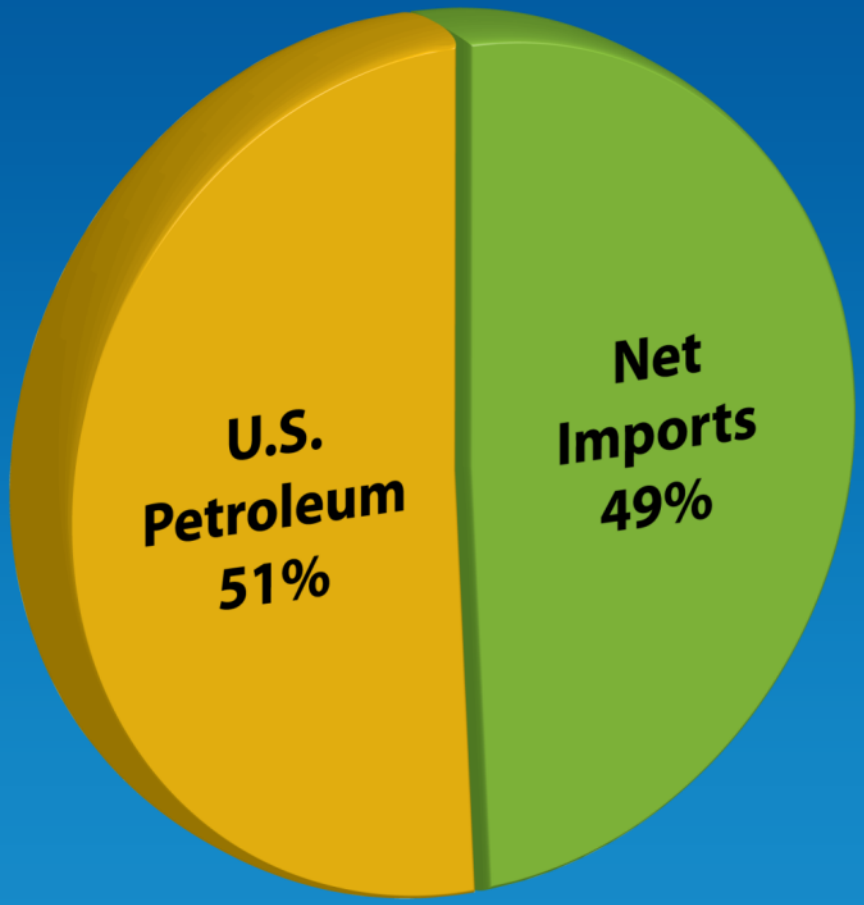



## World Energy Consumption by Fuel, 1990-2035 (quadrillion Btu)




*Source: U.S. Energy Information Administration, International Energy Outlook 2011*

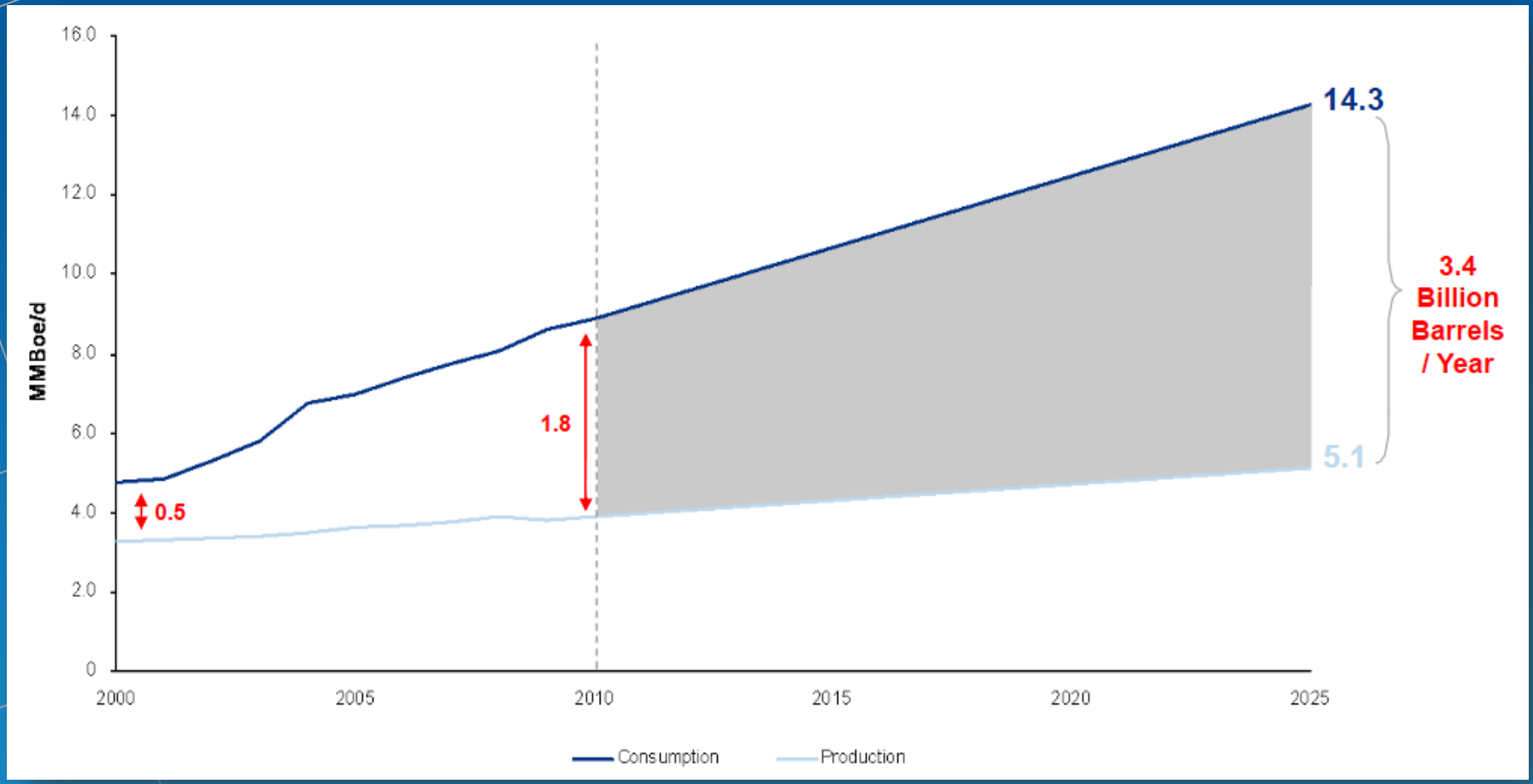
# Net Imports and Domestic Petroleum as Shares of U.S. Demand, 2010




*Source: U.S. Energy Information Administration, Monthly Energy Review, Table 3.3a (April 2011), preliminary data.*

# It's Not Going To Get Any Easier

(e.g., *Chinese Oil Production and Consumption)*




*Source: EIA and BP Statistical Review*



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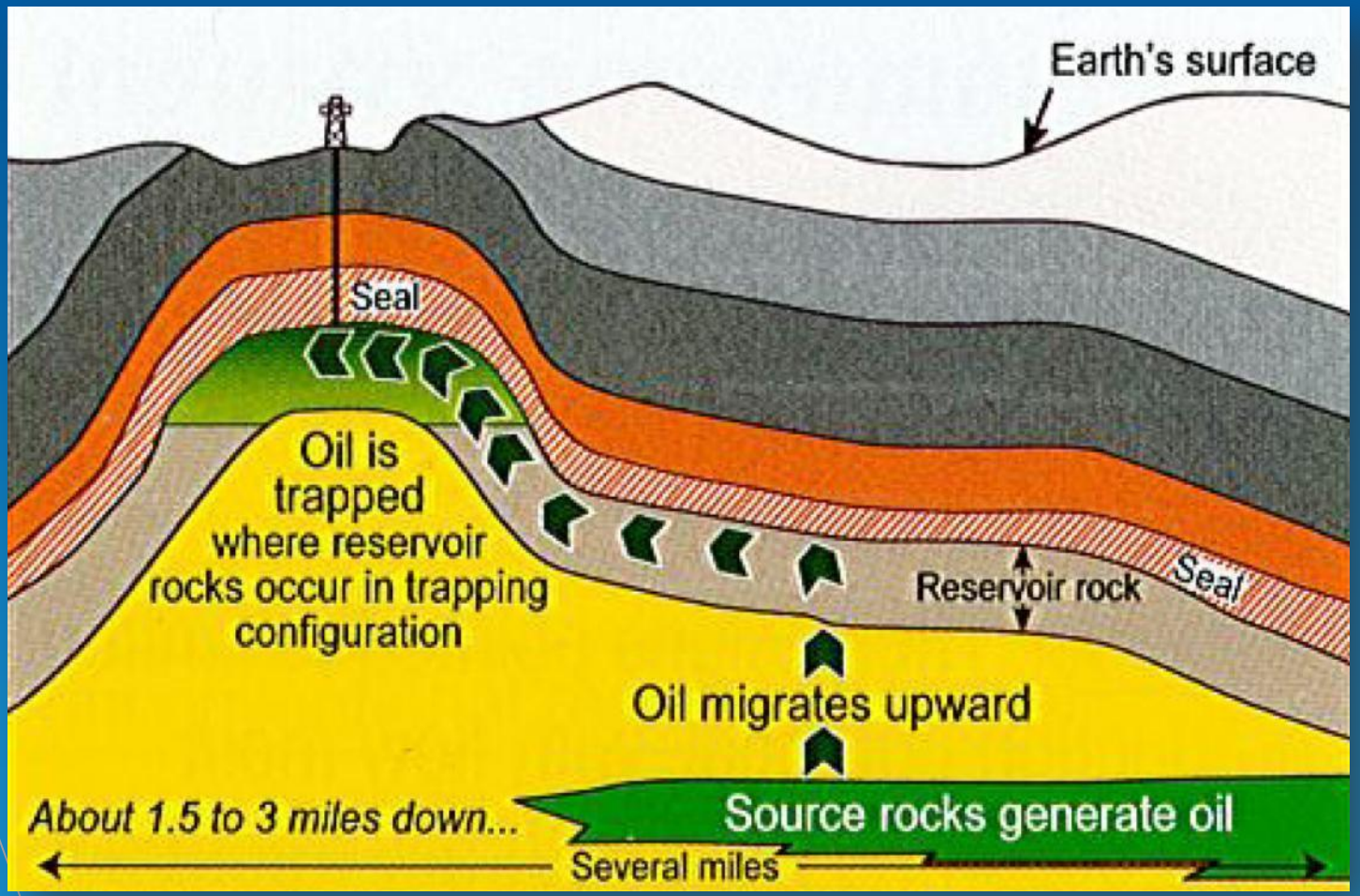
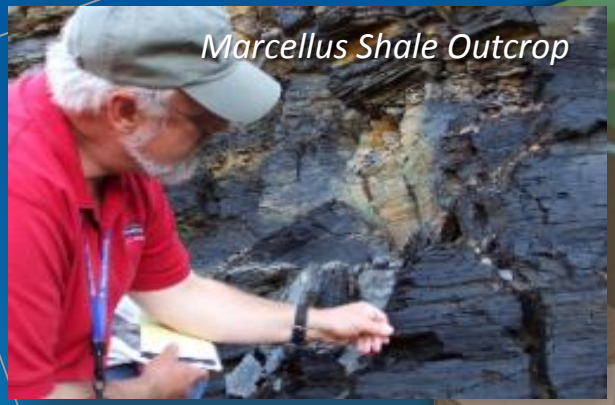
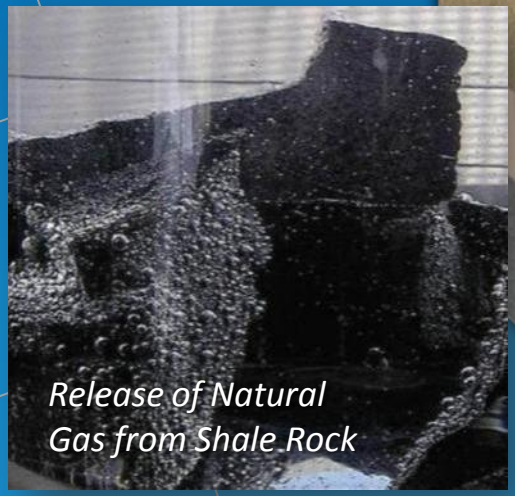
# Oil Migration & Entrapment, Conventional Model

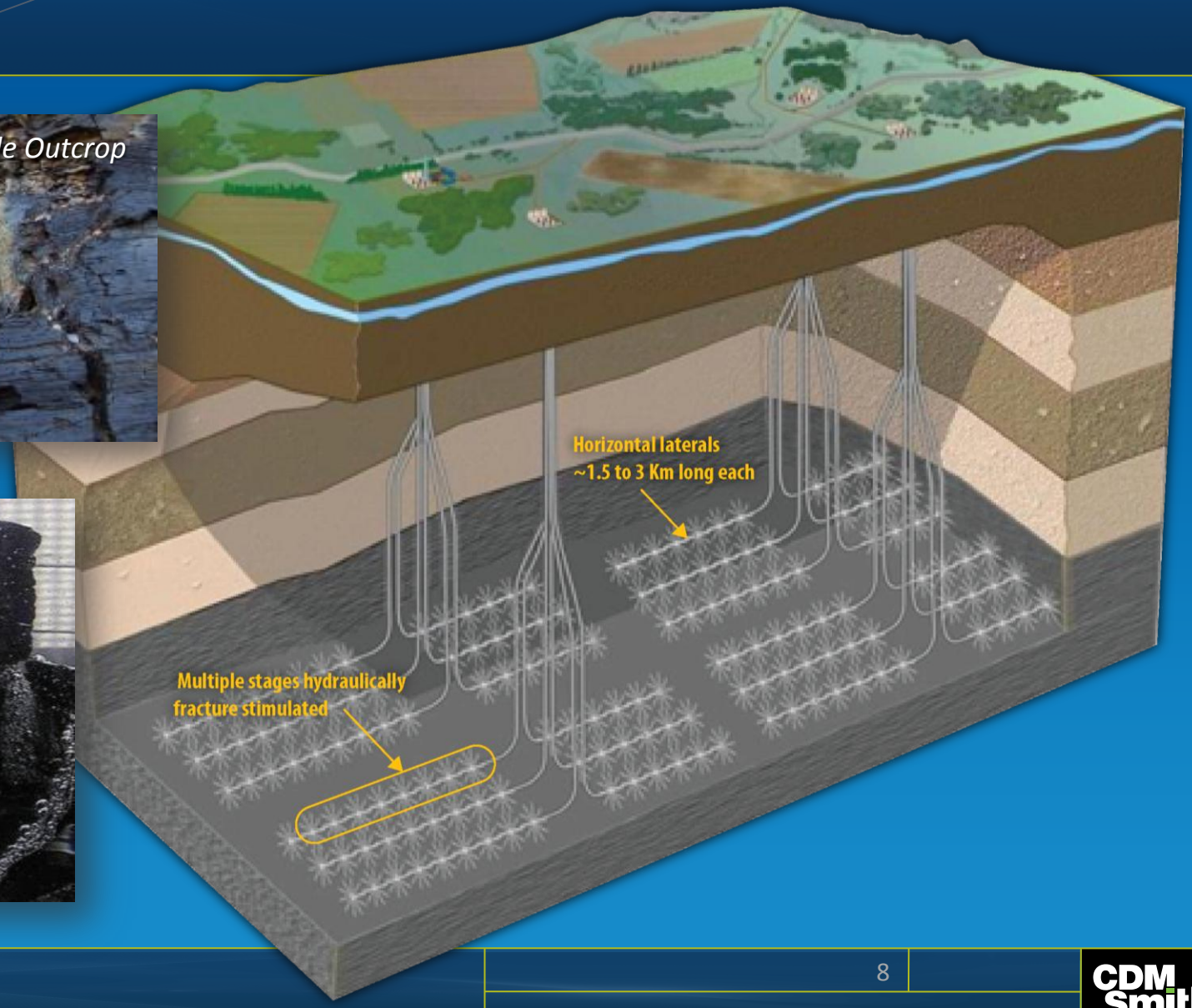



*Source: University of Texas at Austin, Bureau of Economic Geology, Annual Report, 2011*

# Horizontal Drilling and Hydraulic Fracturing




*Source: BNK Petroleum*

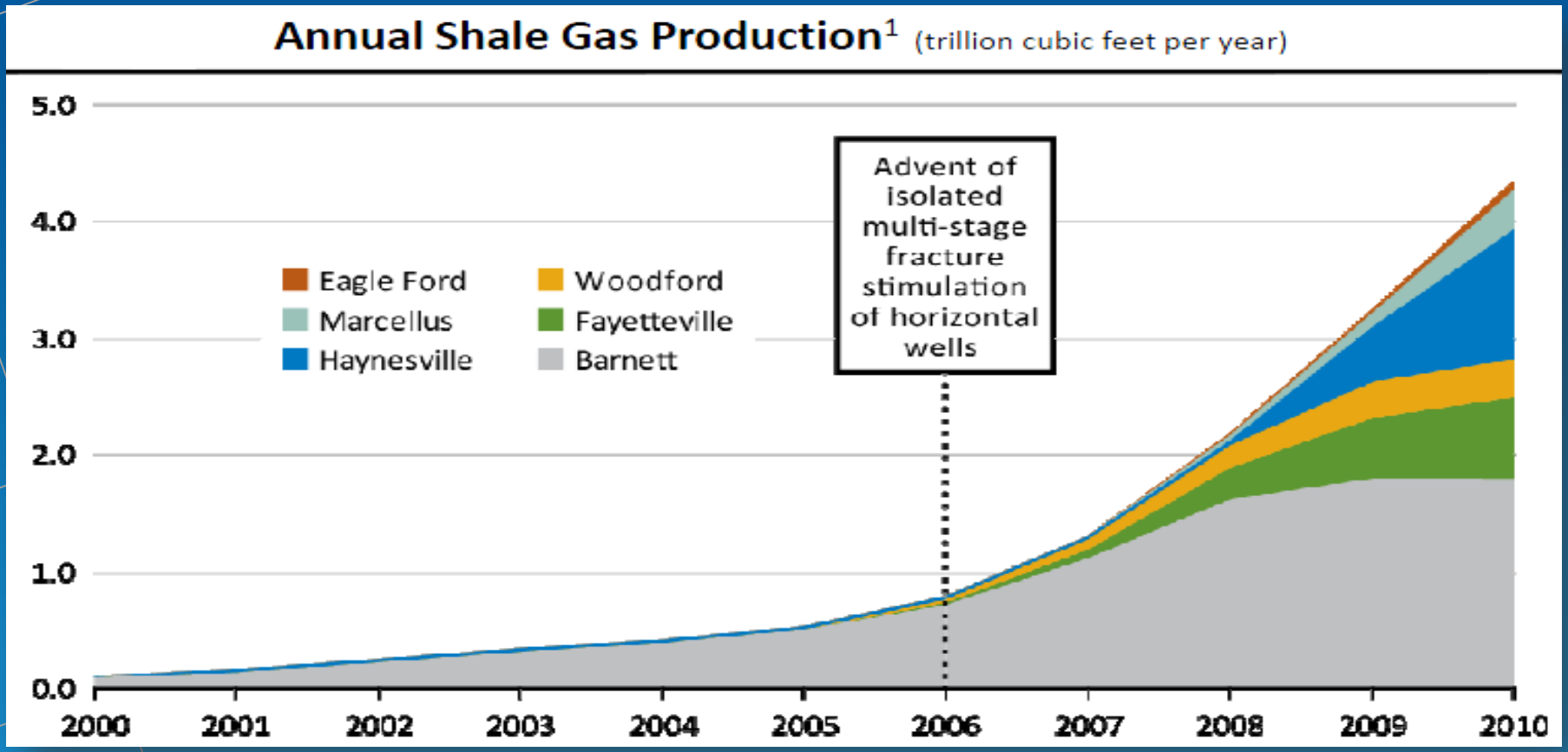
# History of Fracturing

| | |
|---|---|
| **Late 1800's** | Explosive fracturing |
| **1940's** | First hydraulic fractures |
| **1988** | Common practice (1 million performed to date) |
| **2006** | Advent of multistage fracturing of horizontal well |
| **2011** | 60% - 80% of all O&G wells are hydraulically fractured (35,000 per year and 2.5 million to date) |

*Source: Baker Hughes*

# Shale Revolution Timeline

*U.S. Shale Gas Production Has Increased Six-Fold Since 2006*




**Shale gas has grown to over 15% of U.S. gas production[2] and is expected to grow to 45% by 2035.**

*1Source: EIA, Annual Energy Outlook 2011 Reference Case, 2Source: EIA*



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# U.S. Shale and Tight Gas Basins


*Source: EIA based on data from various published studies.*



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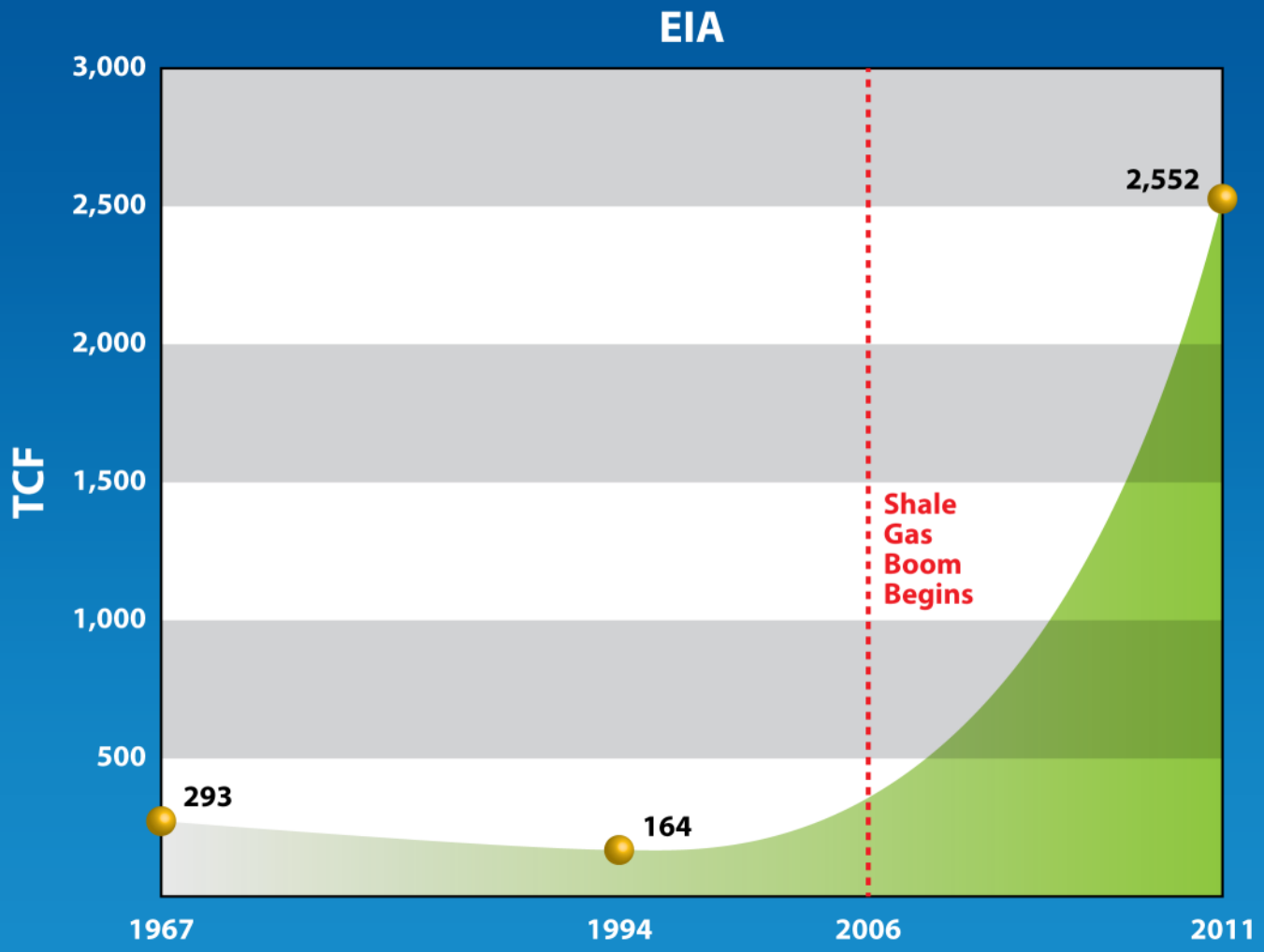
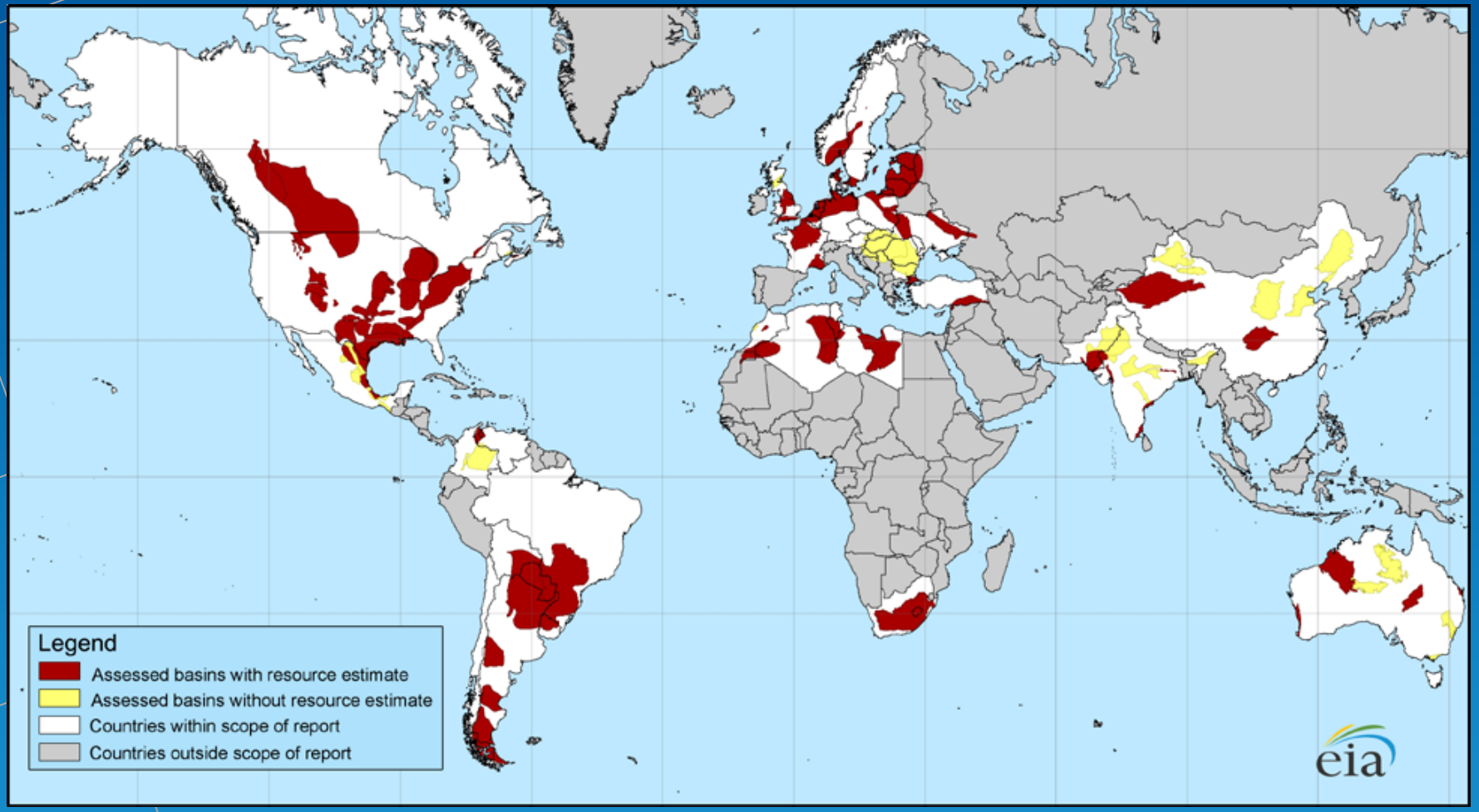
# Natural Gas U.S. Reserves Estimates




*Source: Power Magazine 2011*

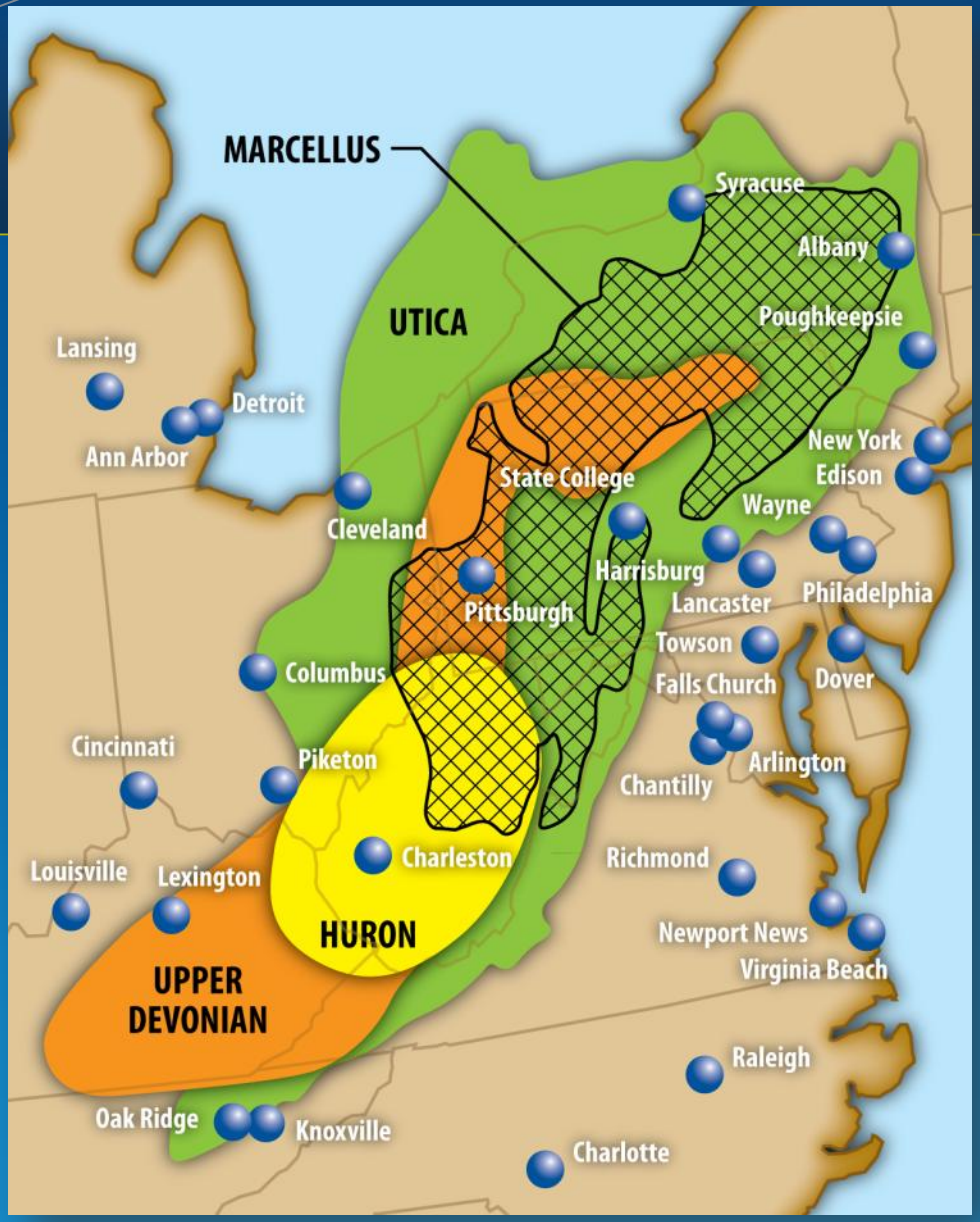
# Currently Known Global Shale Resources



# Marcellus Shale and Other Appalachian Formations

***500 – 1,500 trillion cubic feet (tcf) in place (50 - 500 tcf recoverable) in the Marcellus.***

***First gas well in U.S. – 1821, Devonian Shale, Fredonia, NY.***



# Magnitude of Supply

- A trillion cubic feet is enough gas to:
  - Heat 15 million homes for 1 year
  - Generate 100 billion kilowatt-hours of electricity
  - Fuel 12 million natural gas vehicles for one year
  - Marcellus alone ≃ 50 – 500 tcf
- 120 year supply in U.S.
- Lots of oil too (Utica, Eagle Ford, Bakken, etc.)


*Source: EIA*



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# ECONOMIC / GEOPOLITICAL IMPLICATIONS


*Source: Time Magazine Science,*
*"Could Shale Gas Power the World", Bryan Walsh*

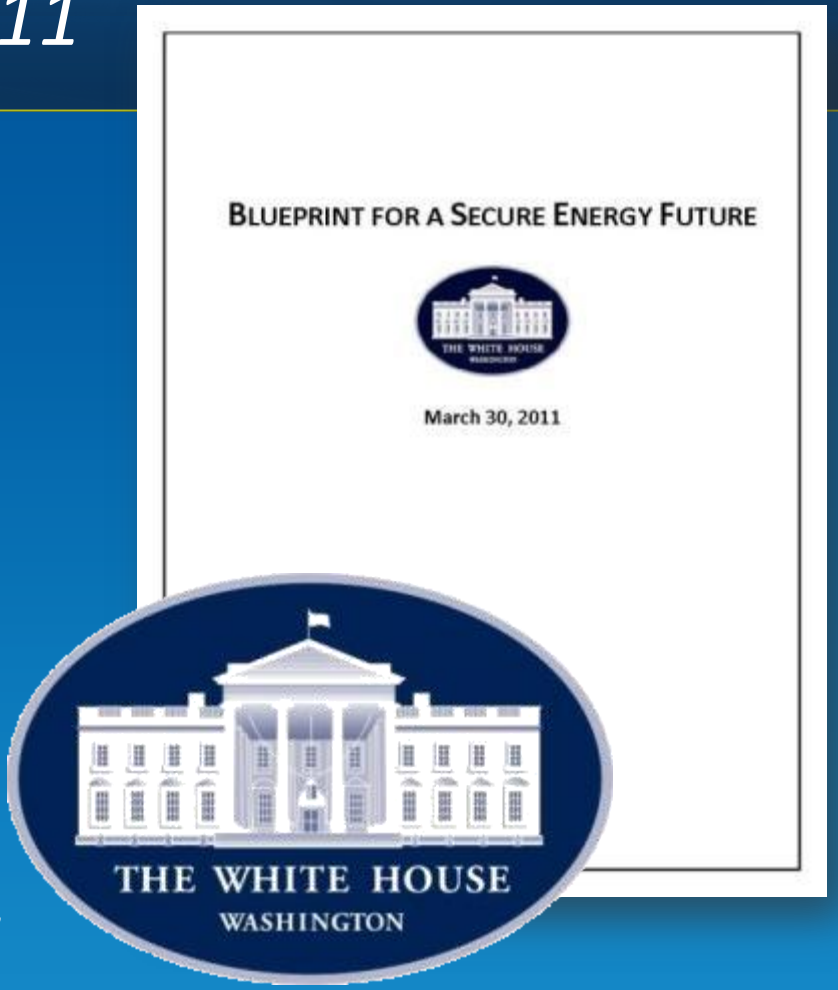
# Natural Gas Characteristics

- We have **lots of it.**
- **Cleanest combustion fuel available (half the $CO_2$ of coal).** But fugitive loss of $CH_4$ is **25x$CO_2$ potency for GHG**.
- **"Bridge" fuel** for transition to renewables, and **"leveling" fuel** for wind and solar.
- **Extensive transmission / distribution network** already in place.
- Underutilized gas power generation capacity can achieve **20 percent $CO_2$ emissions reduction** rapidly.
- Current **supply far exceeds demand.**

# Blueprint for a Secure Energy Future
## *White House, March 30, 2011*

- Three-point plan
  - Develop and secure America's energy supplies
  - Energy reduction
  - Innovate clean energy

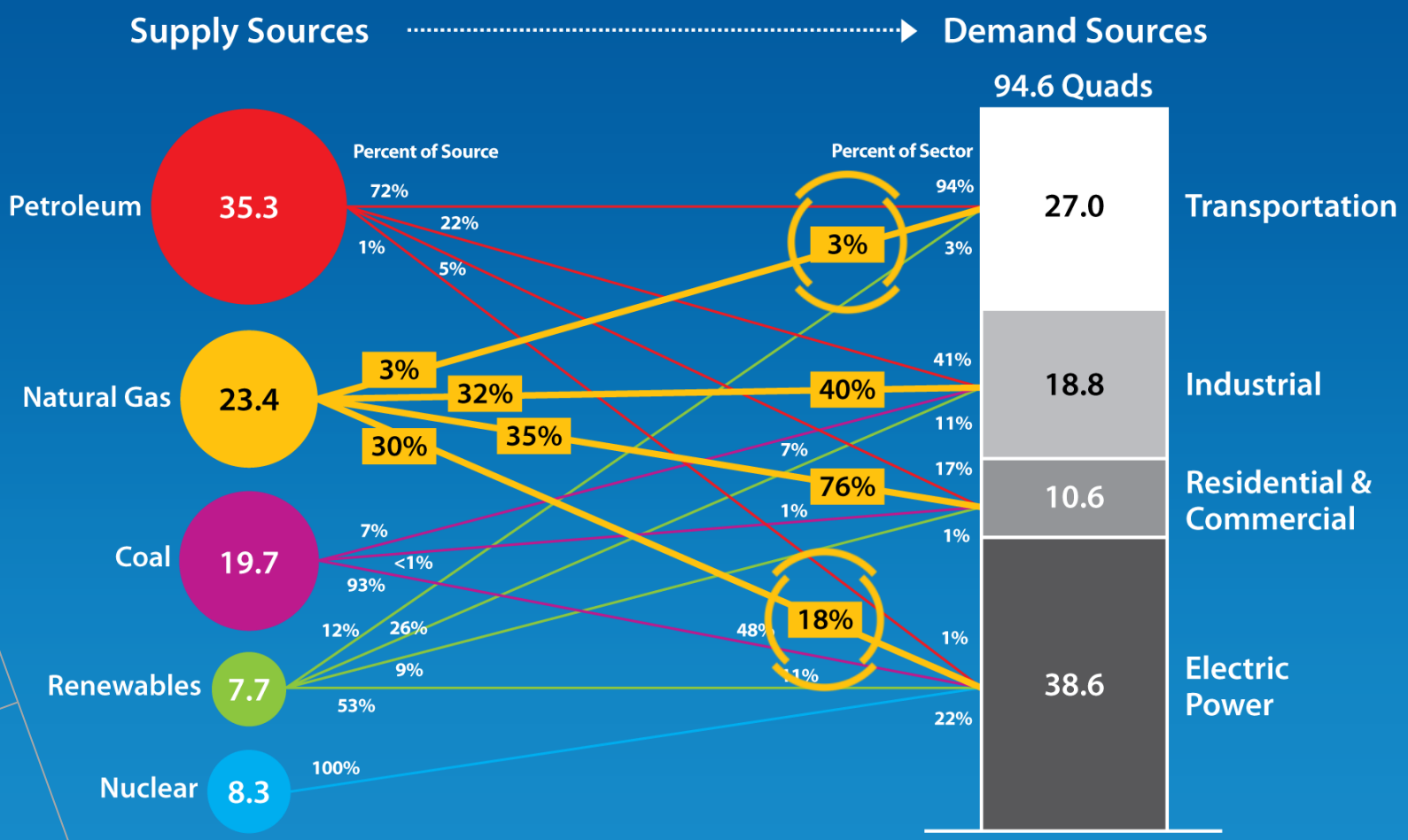
***"Natural gas and oil from shale formations…will play a critical role in domestic energy production in the coming decades."***



# Supply > Demand so Natural Gas is Affordable

- 1 barrel of oil = **$97.23** (May 10, 2012)
- 1 MMBtu of gas = $2.56 (May 10, 2012)
- 1 barrel of oil equivalent (BOE) = 5.8 MMBTU
- Price of 1 BOE of natural gas = **$14.85**

# Sources and Use of Primary Energy in the U.S. with Natural Gas Highlighted (quadrillion Btu), 2009




*Source: EIA, Annual Energy Outlook, 2009*



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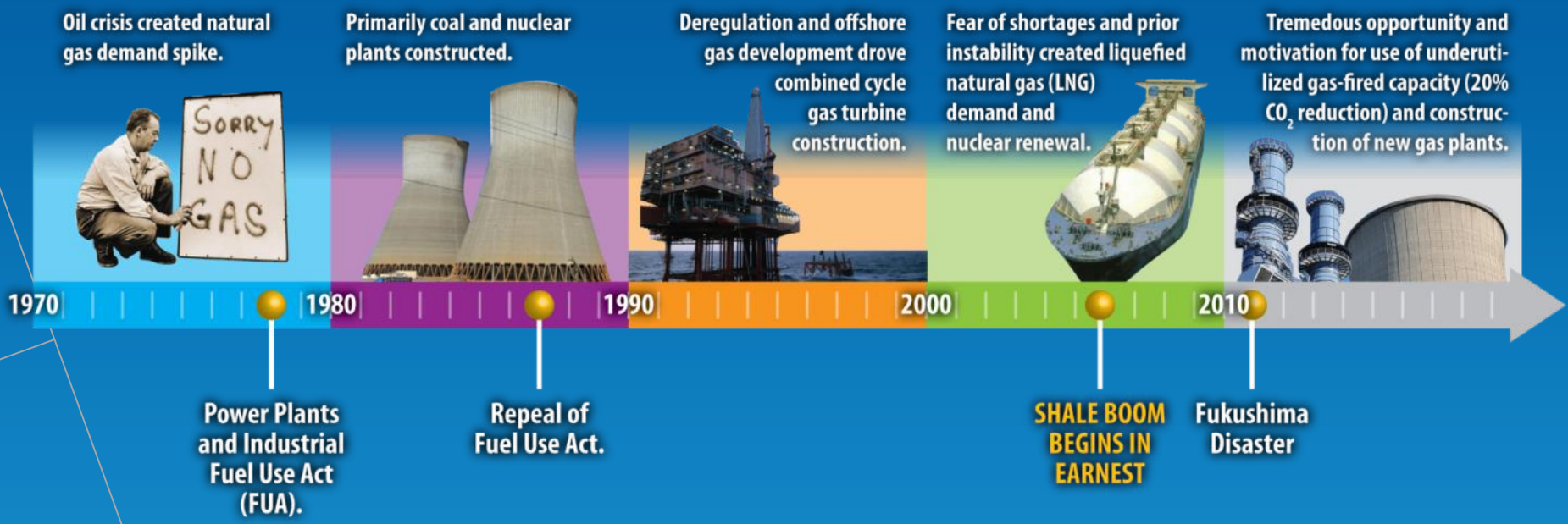
# Central Area Transit Authority, State College, PA
## *Natural Gas Transit Facility*

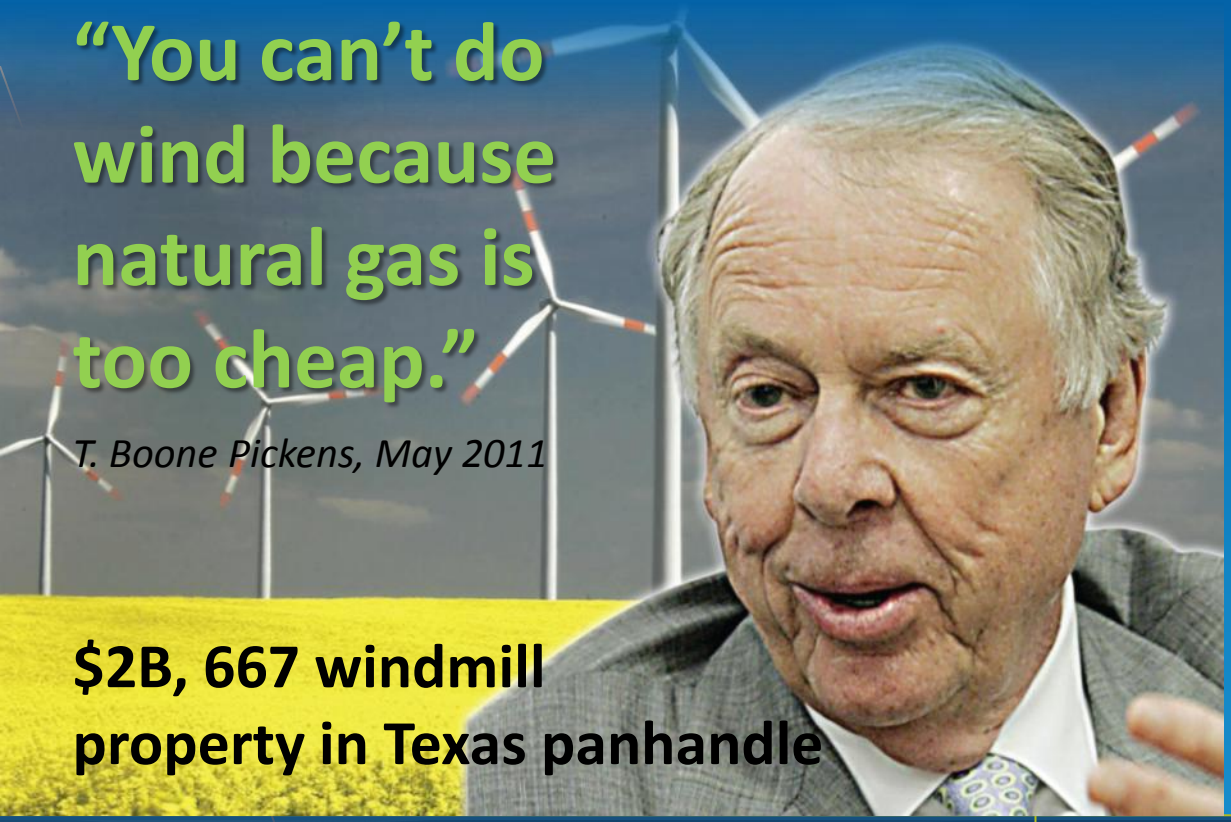
Many similar current and future projects in U.S. and abroad


# Recent History Natural Gas In U.S. Power Generation



# Looking for Some Cheap Windmills?

## T. Boone Pickens is Selling…



**“You can’t do wind because natural gas is too cheap.”**

*T. Boone Pickens, May 2011*

**$2B, 667 windmill property in Texas panhandle**

**“The need to spend enormous sums to build new long-distance transmission lines to move power from generating sites favorable for wind and sun to local centers may diminish with readily available low-cost gas**

*Maize et al,*
*Power Magazine, Sept 2011*

THE WALL STREET JOURNAL. | BUSINESS

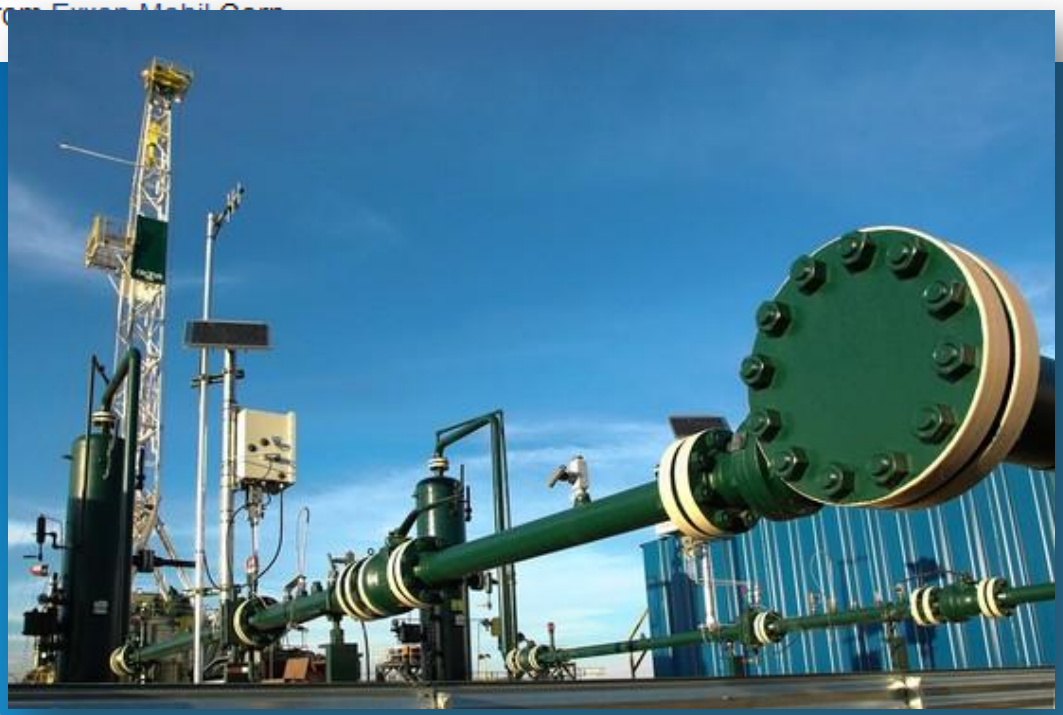
BUSINESS | DECEMBER 8, 2011

# Exxon Declares Gas King

*Abundant Fuel Expected to Dethrone Coal as Top U.S. Power Generator by 2025*

By TOM FOWLER

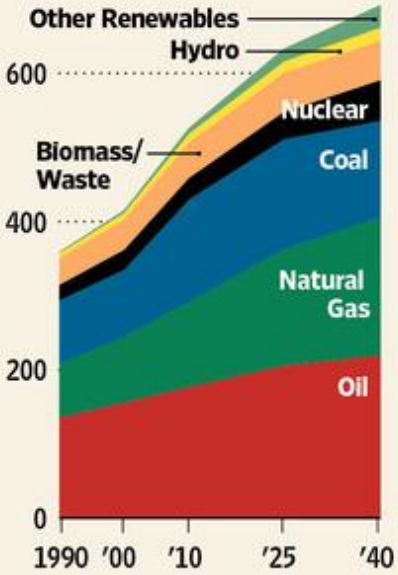
Natural gas will replace coal as the leading fuel for generating electricity in the U.S. by 2025, when it will also become the world's No. 2 overall fuel source thanks to its abundance and a drive for cleaner-burning energy, according to the latest long-term outlook fr



## Energetic Appetite

Global energy demand by fuel type

In quadrillions of BTUs*




*BTU: British thermal unit. A BTU is a standard unit of energy that can be used to measure any type of energy source. 1 quadrillion = 1 thousand trillion

Source: Exxon Mobil's Outlook for Energy

*Source: Wall Street Journal*

# Jobs / Taxes

- U.S. Reliance on Foreign O&G Equates to **$500 Billion in Wealth Transfer Annually**
- Barnett Shale Economic Impact Report estimated **$11 billion and 111,000 jobs annually** contributed to DFW area, plus **$275 million annually** in state severance taxes

- Marcellus peak drilling rate estimated at **3,000 wells annually** for decades. The Manhattan Institute estimates a typical Marcellus well generates:
  - **$5.5 million in purchases** by company, supplier, worker, and landowner
  - **$2 million in tax revenues**
  - **62 jobs**

# Jobs / Taxes (continued)

"The end to the moratorium on fracturing in New York could spur over **$11.4B** in economic output and create **15,000-18,000 jobs** in the state's southern tier and western New York alone"

*Manhattan Institute, 2011*

Over **600,000 jobs** created to date from the shale gas development industry

*Wall Street Journal, 2011*

# Projections for Chemical Industry Economic Boost from Shale Gas (Natural Gas and Ethane)

- **17,000** new knowledge-intensive jobs
- **395,000** additional jobs – suppliers and construction
- **$4.4B** more in federal, state, and local tax revenue annually (**$43.9 billion** over 10 years)
- **$16.2B** in capital investment for new capacity
- **$132B** in U.S. economic output (production, suppliers, and capital)

*Source: American Chemical Council, March 2011*

THE WALL STREET JOURNAL. | BUSINESS

DECEMBER 5, 2011

# Big Oil Heads Back Home

*Energy companies are shifting their focus away from the Middle East and toward the West—with profound implications for the companies, global politics and consumers*

By GUY CHAZAN

Jean-Francois Podevin

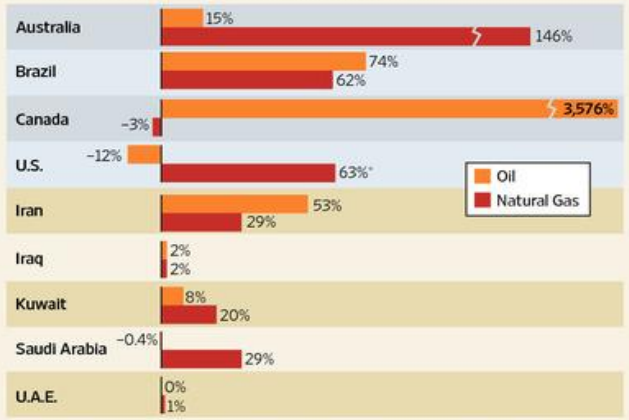
Big Oil is redrawing the energy map.

For decades, its main stomping grounds were in the developing world—exotic locales like the Persian Gulf and the desert sands of North Africa, the Niger Delta and the Caspian Sea. But in recent years, that geographical focus has undergone a radica
energy giants are in
supplies in rich, dev
shift that could have
implications for the i
politics and consum

## A Shift in the Energy Landscape

**The Middle East still has most of the leaders in proven oil reserves (2010, in billions of barrels)**


**But many of the biggest increases in oil and natural-gas reserves over the past decade have come outside the Middle East as unconventional technologies make more deposits accessible. Percentage changes for selected countries, 2000 to 2010 (except as noted):**




*1999-2009 data, the latest available Source: Energy Information Administration, Department of Energy

*Source: Wall Street Journal*



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# Shale Gas and U.S. National Security

*Baker Institute Policy Report, October 2011*

## ALTERNATIVE 1
### Extensive U.S. Development

- U.S. energy security
- Improved $CO_2$ footprint (power and transportation conversion)
- Seriously diminished Russian, Venezuelan, and Iranian geopolitical power
- U.S. economic enhancement
  - Employment
  - Currency stability (Less wealth transfer)
  - Lower energy cost

## ALTERNATIVE 2
### No Further Development

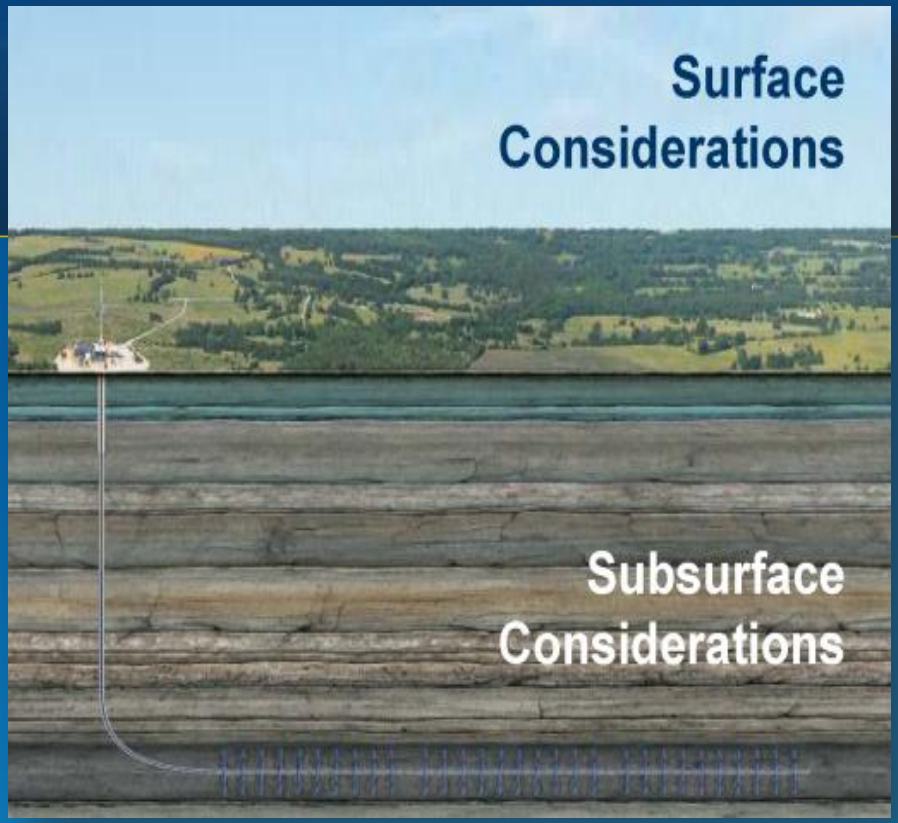
- Opposite of Alternative 1

## ALTERNATIVE 3
### No Northeast U.S. Development

- Generally diminishes Alternative 1
- Higher energy cost in northeast U.S.
- Lesser and shorter diminishment of Russian, Venezuelan, and Iranian geopolitical power

# ENVIRONMENTAL CONCERNS

# Environmental Concerns




## SURFACE

- Air Emissions
- Water Resources / Quality
- Land Impacts
  - Drilling Locations
    - Pit Construction; Chemical Storage; Erosion Control
  - Infrastructure
    - Roads; Compressors; Pipelines; Water Treatment Facilities
  - Truck Traffic and Road Damage

## SUBSURFACE

- Protecting Underground Water Resources
- Seismic Events

*Source: Southwestern Energy*

# Onshore Exploration and Production Regulatory Framework

**FEDERAL**

- U.S. EPA – CWA, SDWA, CAA, NEPA, and OPA
- 2011 U.S. EPA National Enforcement Initiative (NEI) for energy extraction activities
- Bureau of Land Mgmt. (BLM) – BLM lands
- U.S. Forest Service (USFS) – USFS lands
- Hydraulic fracturing not regulated at federal level "regulated at state and local level"

**STATE**

- Permitting agencies
- Environmental regulatory agencies
- Many have "primacy" for federal regulations
- Much variation between states

**REGULATIONS IN FLUX**

**LOCAL / REGIONAL**

- Cities, counties, tribes, and regional water authorities

**INDEPENDENTS**

- Ground Water Protection Council (VIC implementation review)
- Interstate Oil and Gas Compact Commission (IOGCC)
- State Review of Oil and Natural Gas Environmental Regulations (STRONGER)

# WATER MANAGEMENT / TREATMENT

# Hydraulic Fracturing

## The Shale Development Solution and Environmental Controversy

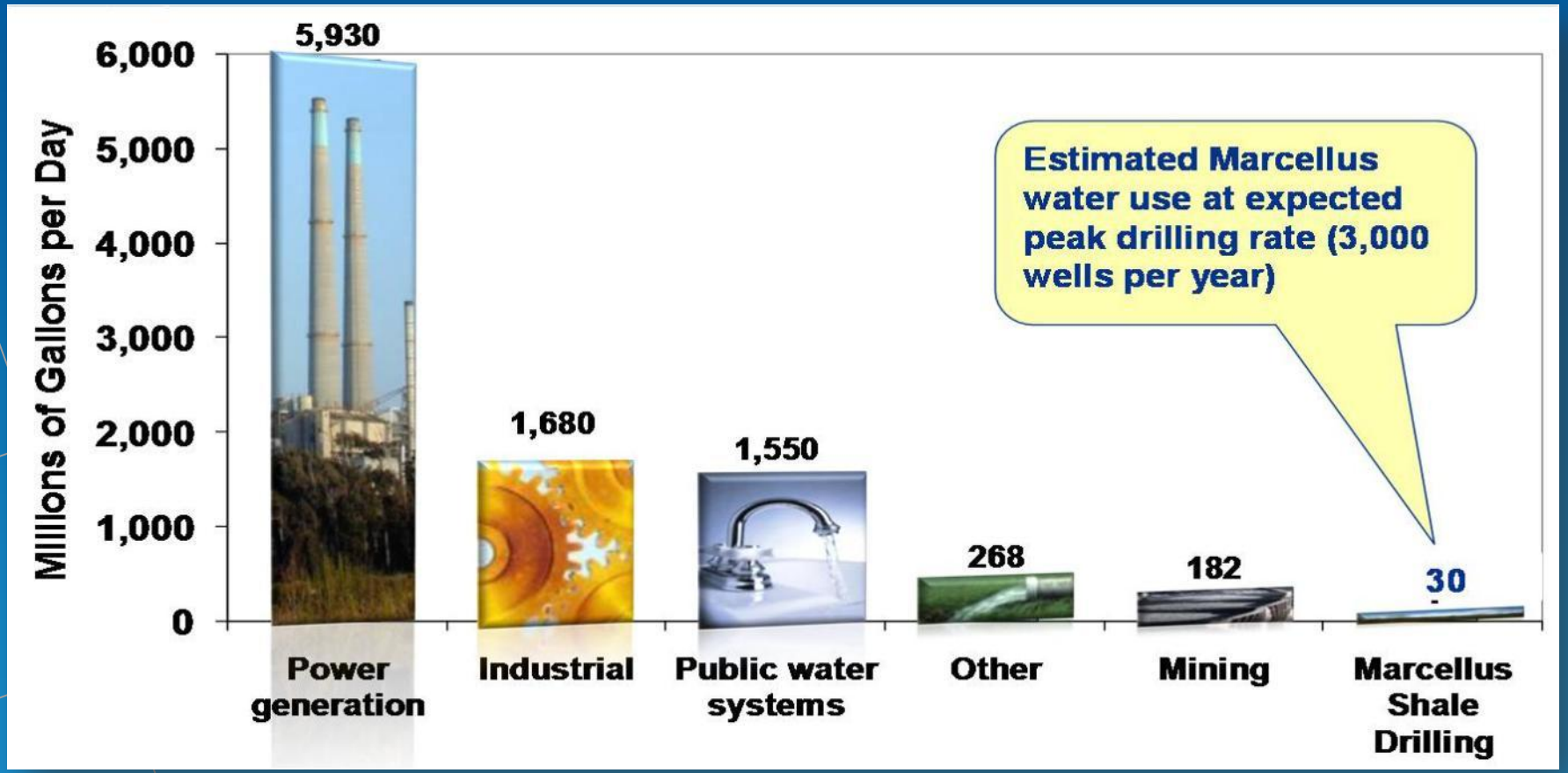
- Frac Water Volume: 2 to 6 million gallons per well
- Additional components include biocides, corrosion inhibitors, $O_2$ scavengers, proppant, etc.
- 20-40% frac "flow back" water recovery requires collection, handling, and disposal / treatment / reuse


*Source: ALL Consulting. Handbook on Coal Bed Methane Produced Water: Management and Beneficial Use Alternatives, July 2003.*

# Shale Development and Water

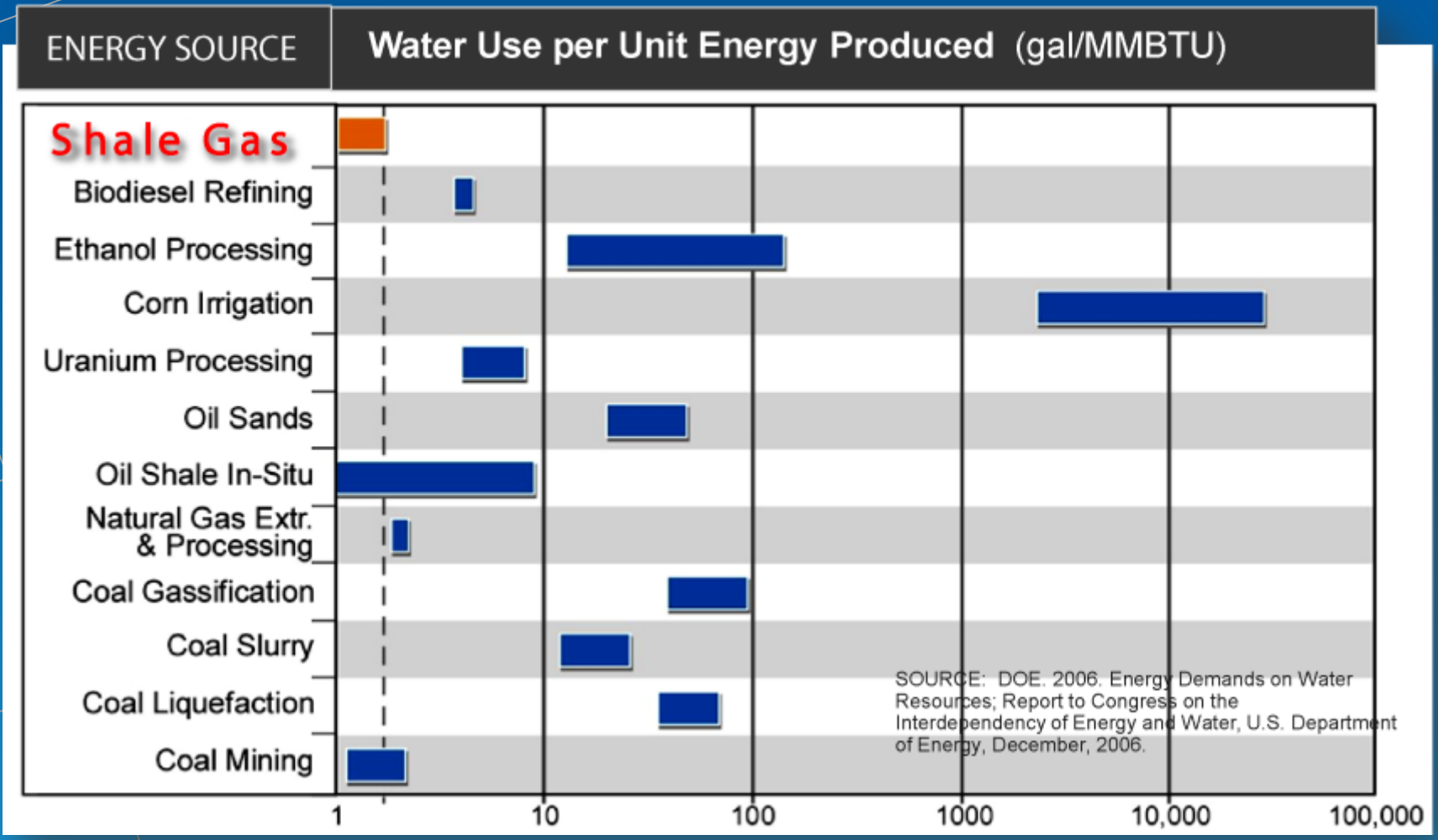
- Source it
- Transport it
- Store it
- Treat it
- Re-use it
- Dispose of it
- Protect it
  (quality and quantity)
  - Surface water
  - Ground water
- **PLAN IT**

# Shale Gas Water Use Requirements




*Source: USGS Pennsylvania Water Consumption*

# Shale Gas:
# Water Use Efficiency vs. Other Energy Sources

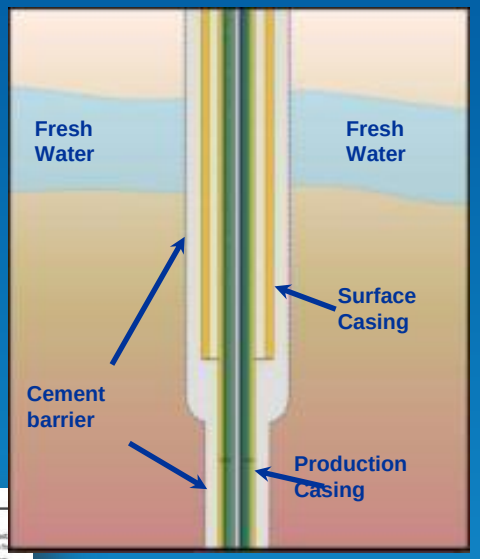



*Source: GSI Environmental, Houston, Texas, 2010*

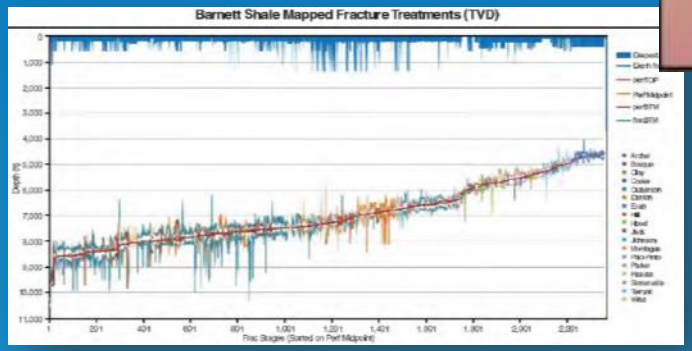
# Groundwater and Surface Water Concerns

## Surface Activities

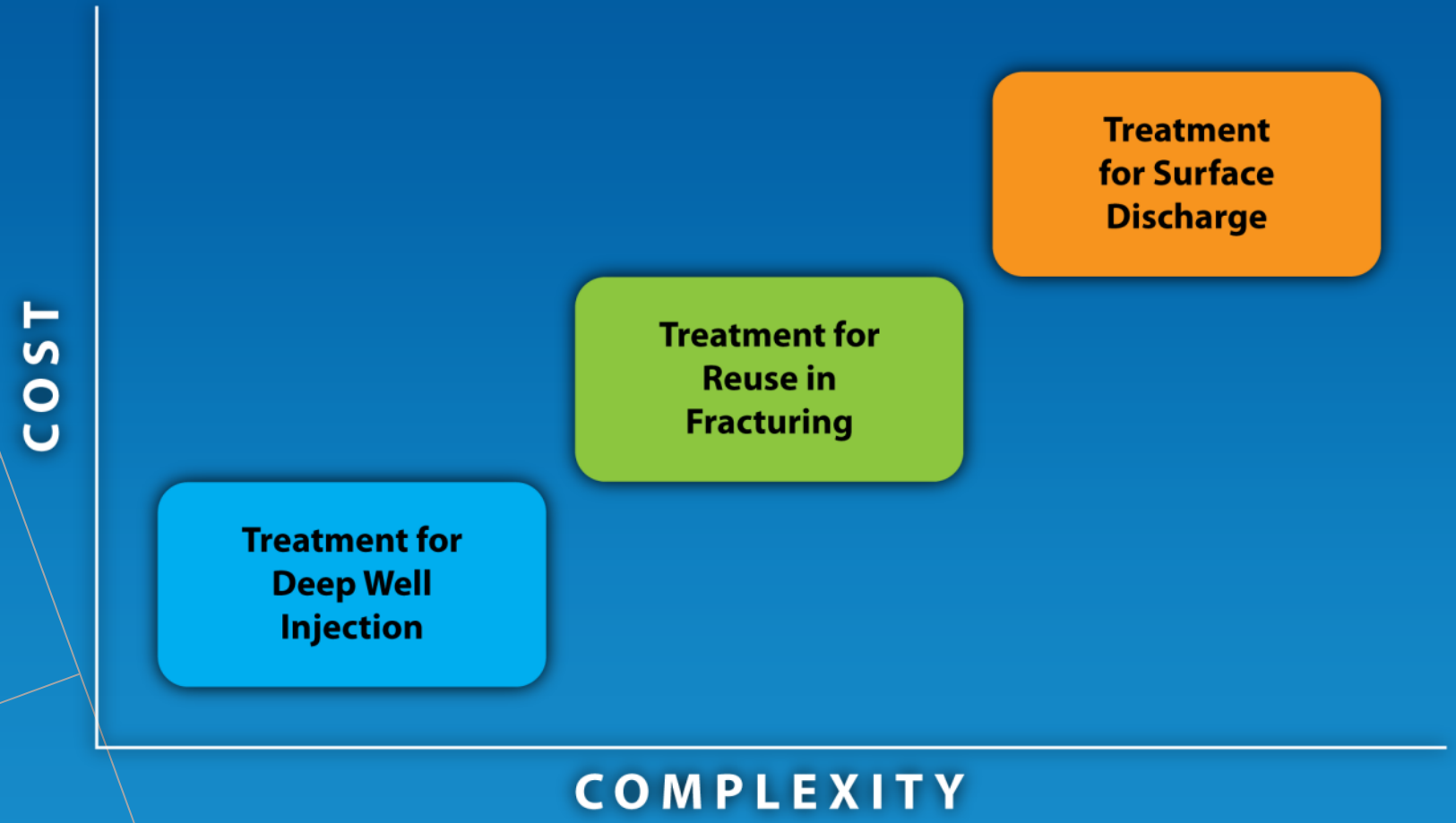
## Well Completion




## Fracturing?

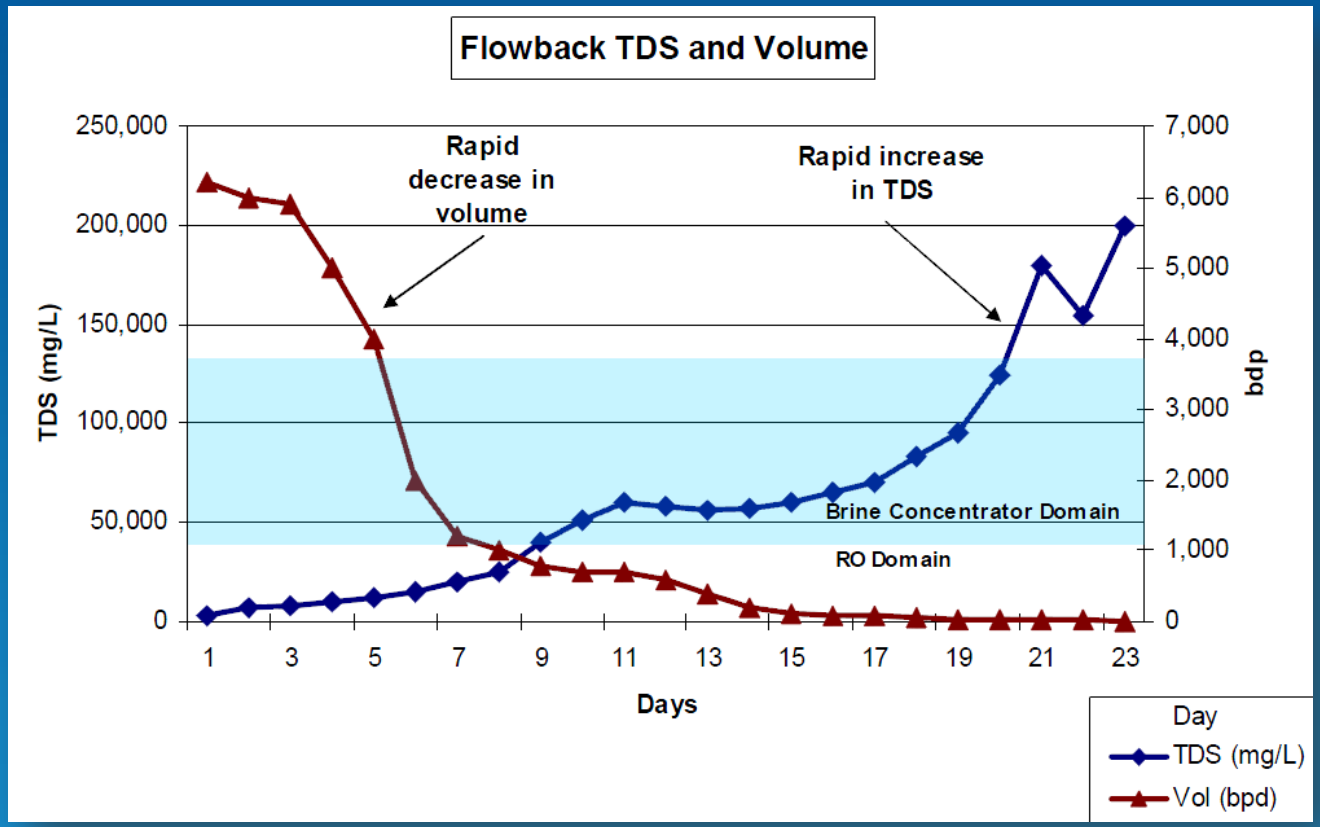


# Shale O&G Water Treatment



# Marcellus Flow back Characteristics

As frac water spends an increasing amount of time in the ground it transitions from fresh water to salty brine, dissolving salt compounds in the earth. Over time, volume decreases and TDS increases.




*Source: Siemens AG 2009*

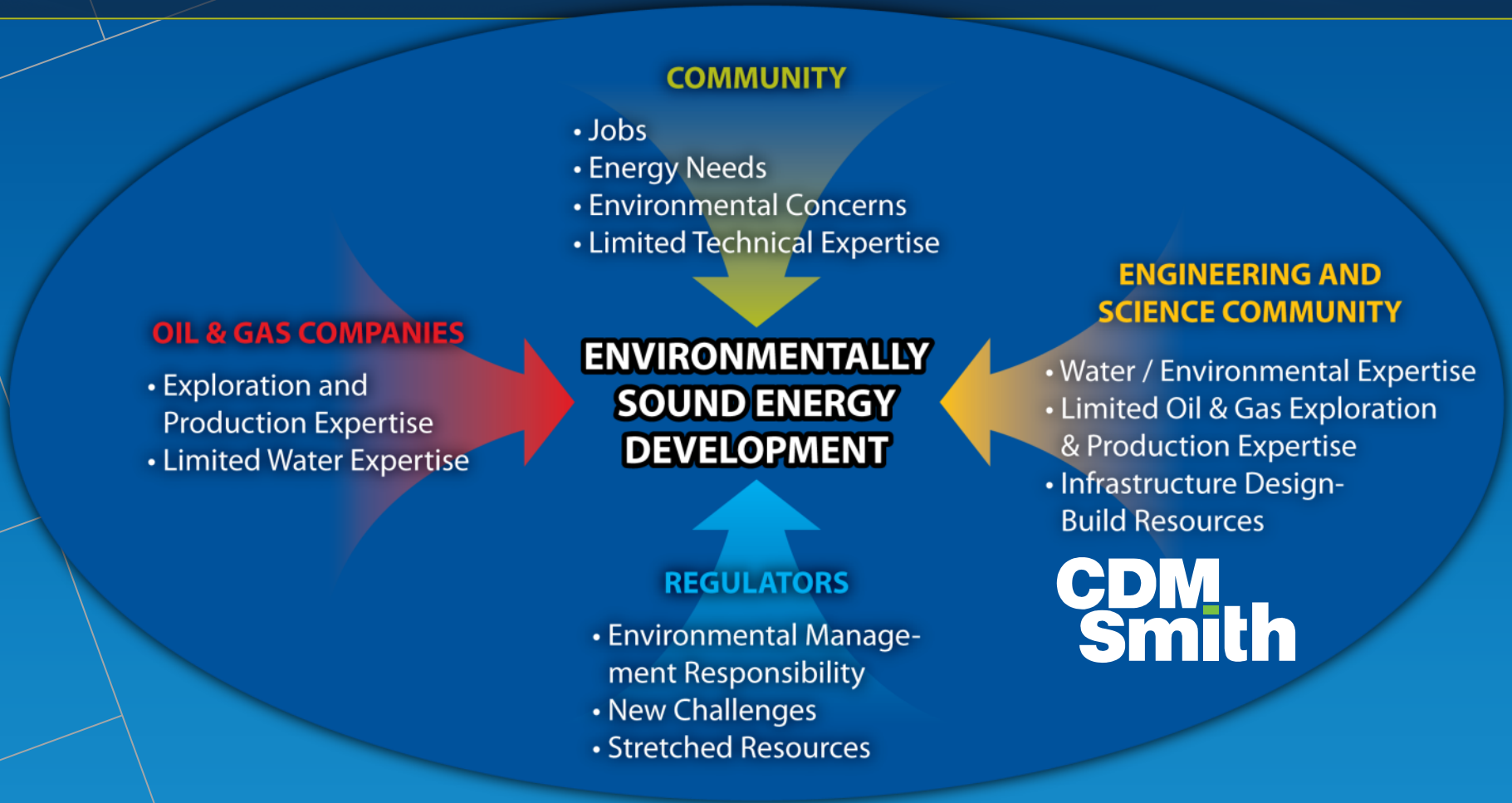
# Other Major Treatment Challenges

- Water balance changes over life of a field
- Water quality variations
  - Geography
  - Temporally
- Mobile vs. centralized treatment planning / decision

# Treatment Technologies – Treatment Options

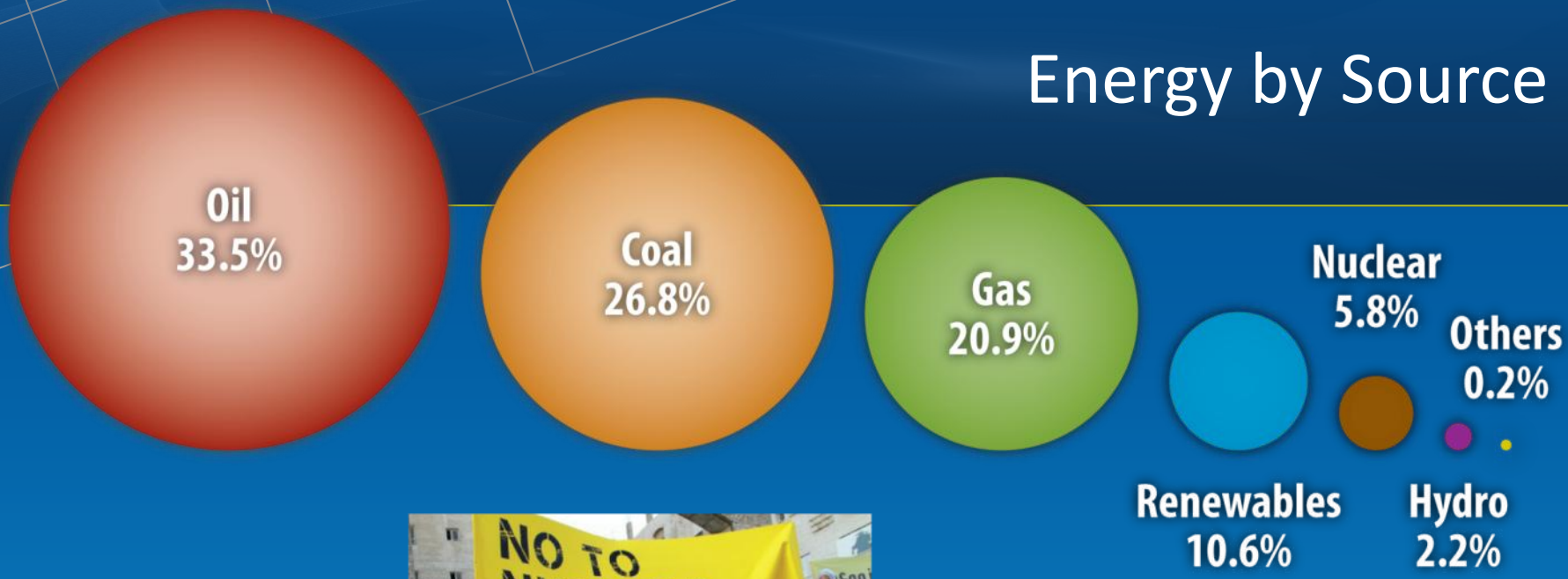
| Technology | Bact. | CH3OH | O/G | DRO | GRO | TA | HCO3- | TH | Ca | Mg | Fe | Ba | St | SO4 | Cl | TDS | TSS | Polymers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| API Separators | | | X | | | | | | | | | | | | | | | |
| Dissolved Gas Flotation | | | | X | X | | | | | | | | | | | | | |
| Activated Carbon | | | X | X | X | | | | | | | | | | | | | X |
| Nut Shell Filters | | | X | | | | | | | | | | | | | | | |
| Organo-clay Adsorbents | | | X | | | | | | | | | | | | | | | |
| Chemical Oxidation | X | | | | | | | | | | X | | | | | | | X |
| UV Disinfection | X | | | | | | | | | | | | | | | | | |
| Biological Processes | | | X | X | X | | | | | | | | | | | | | |
| Air Stripper | | | | | X | X | X | | | | | | | | | | | |
| Chemical Precipitation | | | | | | | | X | X | X | X | X | X | X | | | | |
| Lime/Soda Softening | X | | | | | X | X | X | X | X | X | | | | | | | |
| Clarifiers | | | | | | | | | | | | | | | | | X | |
| Settling Ponds | | | | | | | | | | | | | | | | | X | |
| Ion Exchange | | | | | | | | X | X | X | X | X | X | X | X | X | | |
| Multi- Media Filtration | | | | | | | | | | | | | | | | | X | |
| Membrane Filtration | X | | | | | | | | | | | | | | | | X | |
| Greensand Filters | X | | | | | | | | | | X | | | | | | | |
| Cartridge Filters | | | | | | | | | | | | | | | | | X | |
| Reverse Osmosis | | | | | | X | X | X | X | X | | | | X | X | X | | |
| Evaporation | | | | | | | | X | X | X | X | X | X | X | X | X | | |
| Steam Stripping | | X | | X | X | | | | | | | | | | | | | |
| Acidification | | | | | | X | X | | | | | | | | | | | |

# O&G / Water Knowledge Convergence



# ENERGY CHOICES

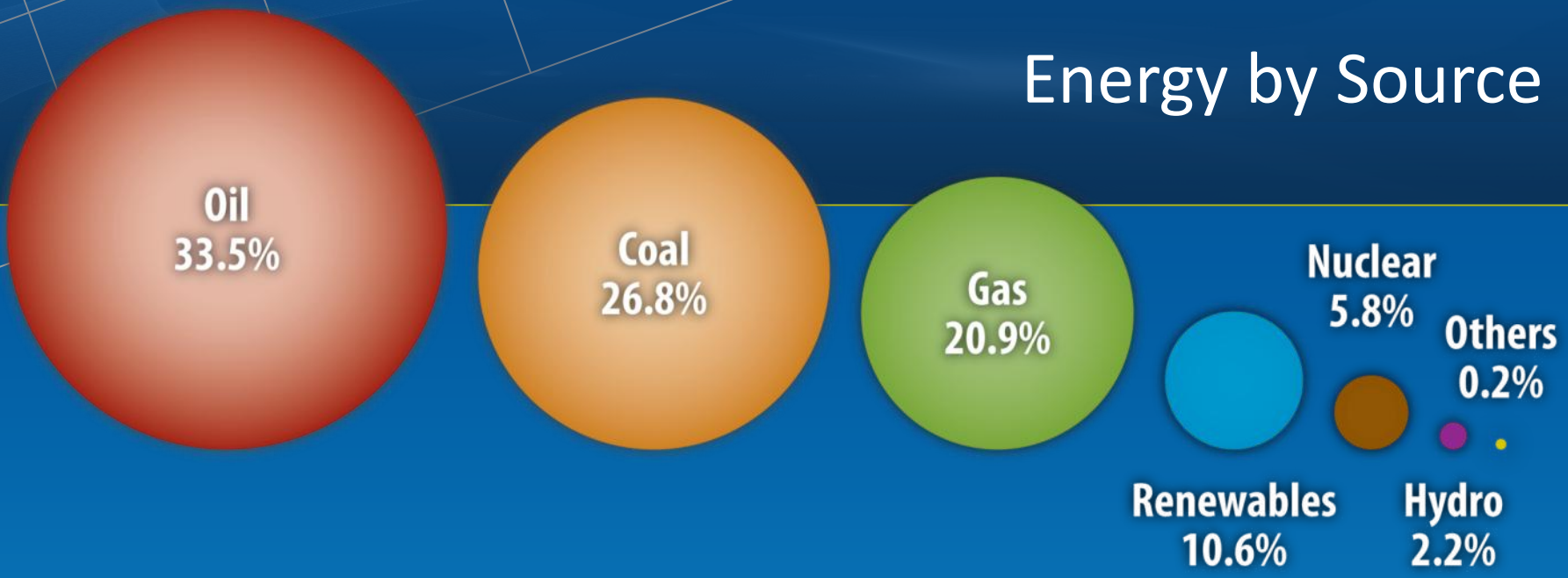
# Energy by Source







# Energy by Source




**"There are very few energy resources large enough to cope with modern global energy demand. Any technologies able to satisfy these demands will unavoidably interfere with natural dynamic systems.**

**A scenario in which available energy resources fail to provide a basis for the energy infrastructure will be a scenario with drastic reductions in economic output and one in which living standards will fall back to much lower levels."**

*Klaus Lackner, Issues in Environmental Science and Technology, Royal Society of Chemistry 2010*

# Tone of Shale Gas Media Coverage

| | Negative | Neutral | Positive |
|---|---|---|---|
| National Newspapers | 64% | 25% | 12% |
| Local Newspapers | 65% | 23% | 12% |
| National Television & Radio | 64% | 19% | 18% |
| Local Television | 70% | 27% | 3% |
| Online News | 63% | 30% | 7% |

**"The great enemy of the truth is very often not a lie – deliberate, contrived, and dishonest – but the myth – persistent, persuasive, and unrealistic."**

*John F. Kennedy*

*Source: The University of Texas at Austin (Energy Institute), Separating Fact from Fiction in Shale Gas Development Report*

# No-Development Case – France
## *(Ban on Hydraulic Fracturing)*


**France wants gas, they just want it to come from somebody else's backyard.**

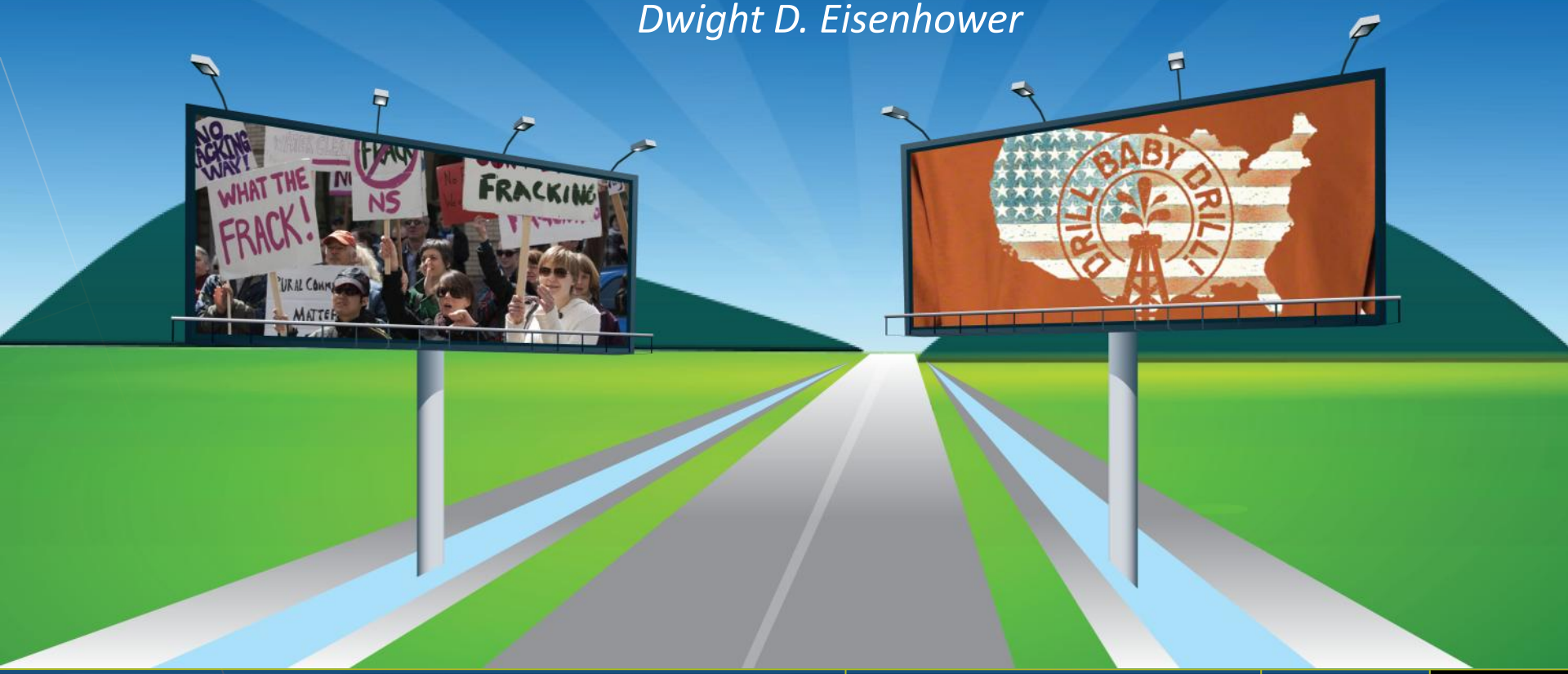
**IS THIS WHAT WE WANT TOO?**

*Source: U.S. EIA (market) and Oil & Gas Journal, Dec. 6, 2010*

# The Road to the Future…

**"The road to the future is paved in the middle. Too far to the left or too far to the right is in the gutter."**

*Dwight D. Eisenhower*






CDM Smith

# Questions and Answers


**C. Hunter Nolen, P.E., BCEE**
President, Industrial Services Group

CDM Smith

1777 N.E. Loop 410, Suite 500
San Antonio, Texas 78217
210-826-3200 (office)
713-858-2372 (cell)
nolench@cdmsmith.com (email)