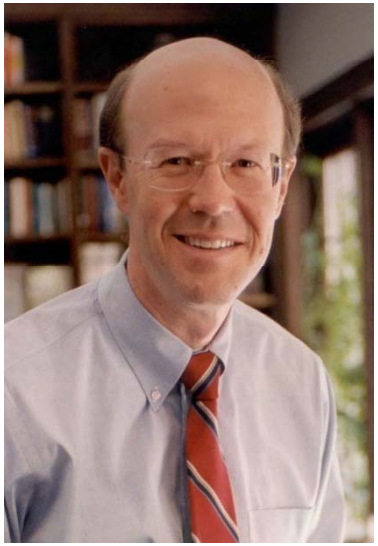


Response to Attacks on Hydraulic Fracturing
(A Proven Well Completion Technology for Shale Gas)

Commissioner Bob Anthony
Oklahoma Corporation Commission

Woodford Shale Summit
University of Oklahoma, Norman, Oklahoma

March 30, 2011
(Updated through December 2011)

http://www.occeweb.com/Comm/Anthony/Woodford%20Summit%2003302011v_final3.pdf

Energy Trends

FIGURE 4.—TRENDS IN THE MIX OF ENERGY SOURCES, UNITED STATES, 1850–2000

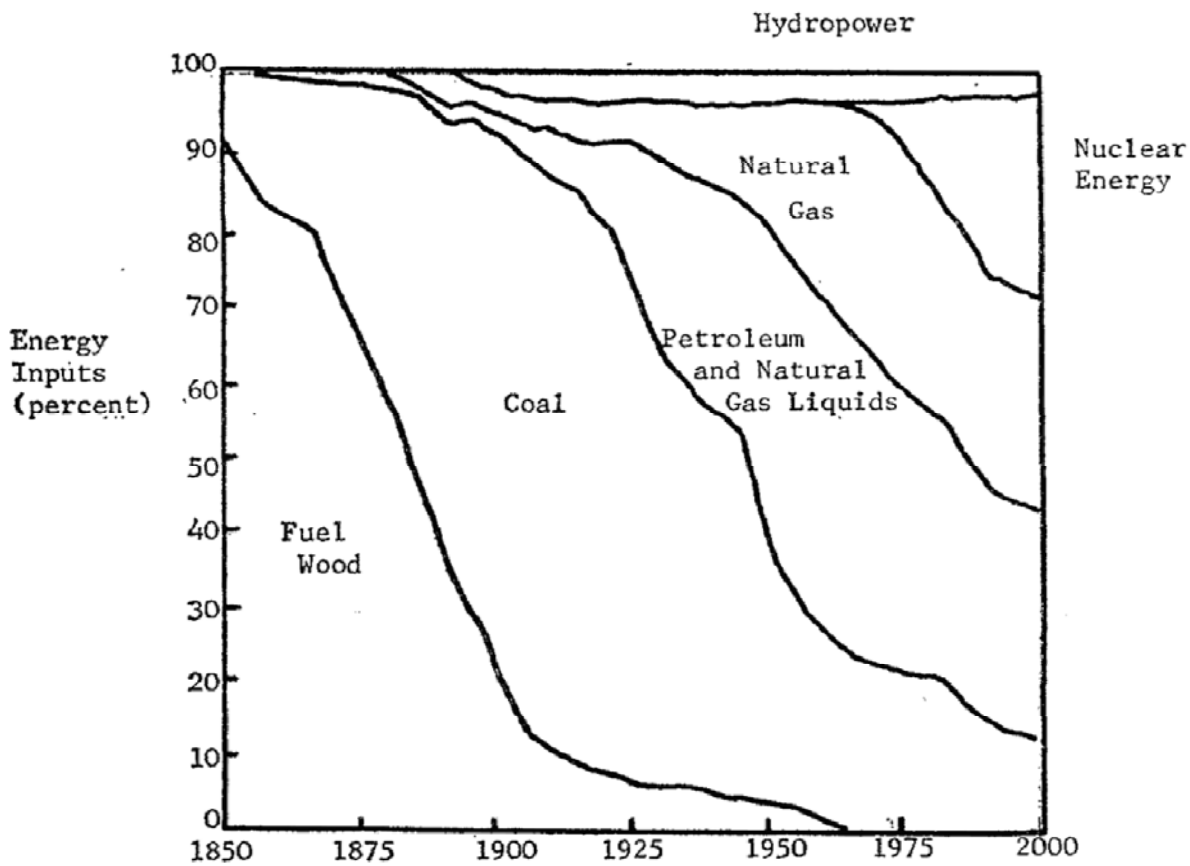
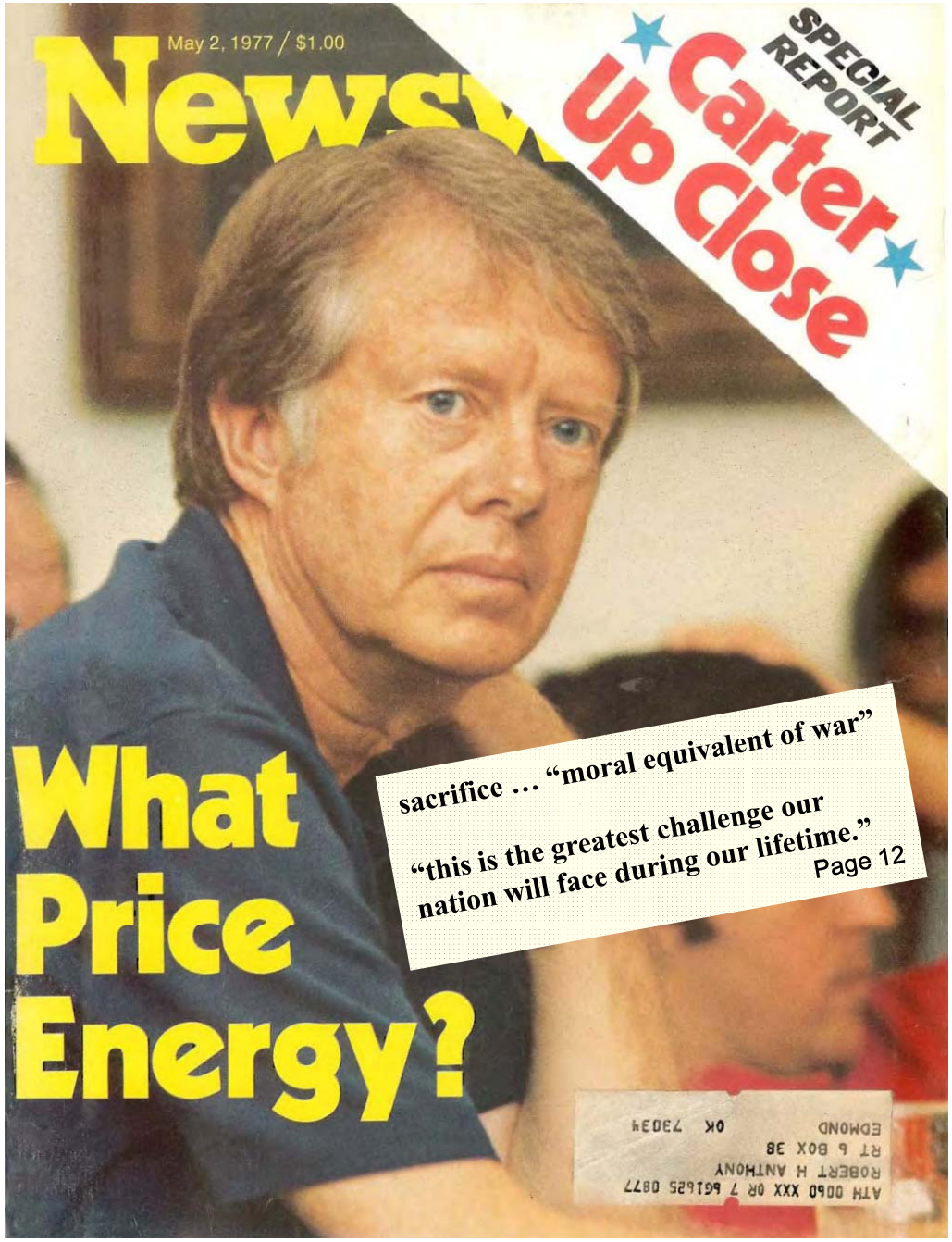


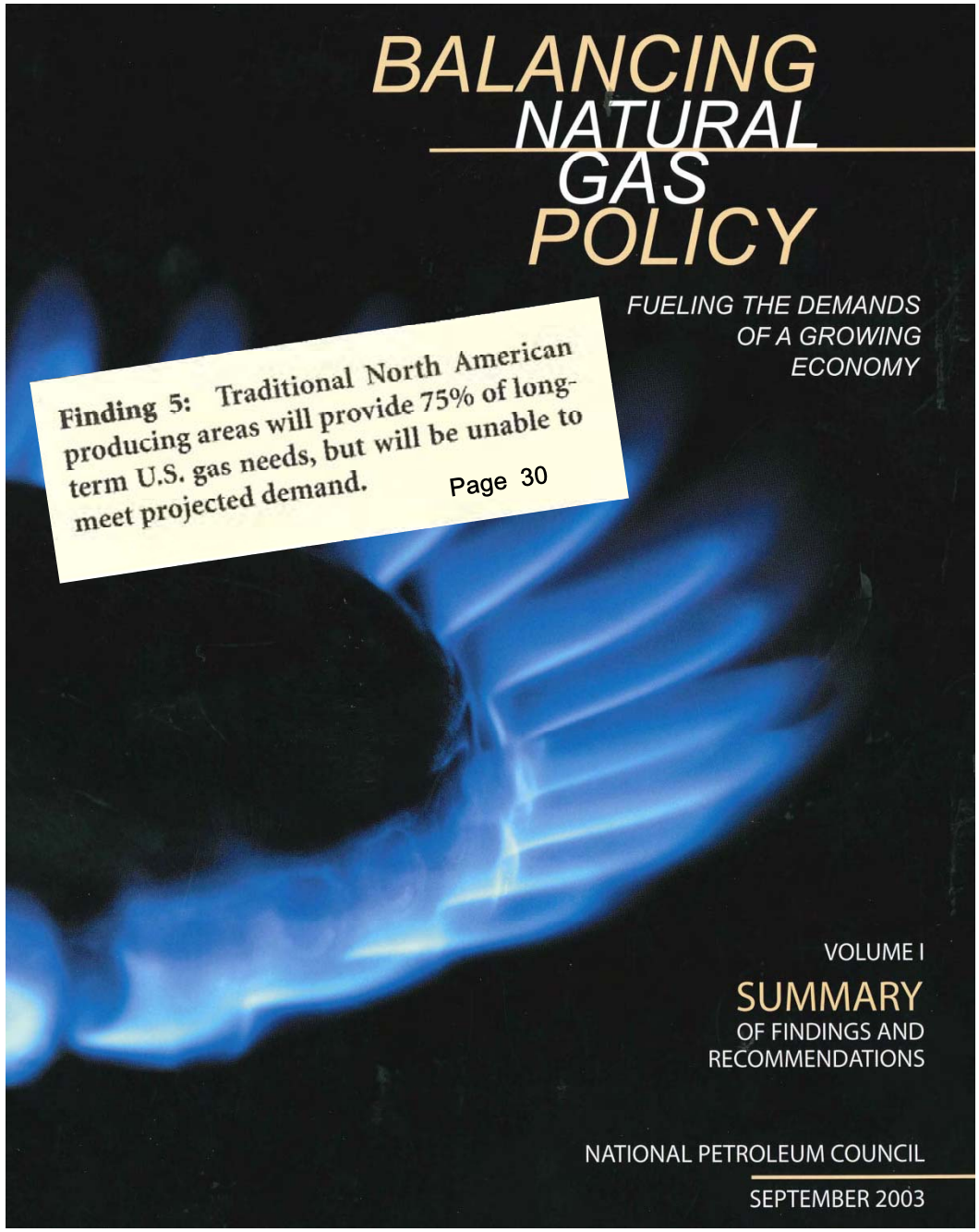
ILLUSTRATION ADAPTED FROM COOK, EARL. "THE FLOW OF ENERGY IN AN INDUSTRIAL SOCIETY," SCIENTIFIC AMERICAN, VOL. 224, NO. 3 (SEPTEMBER 1971), P. 137.

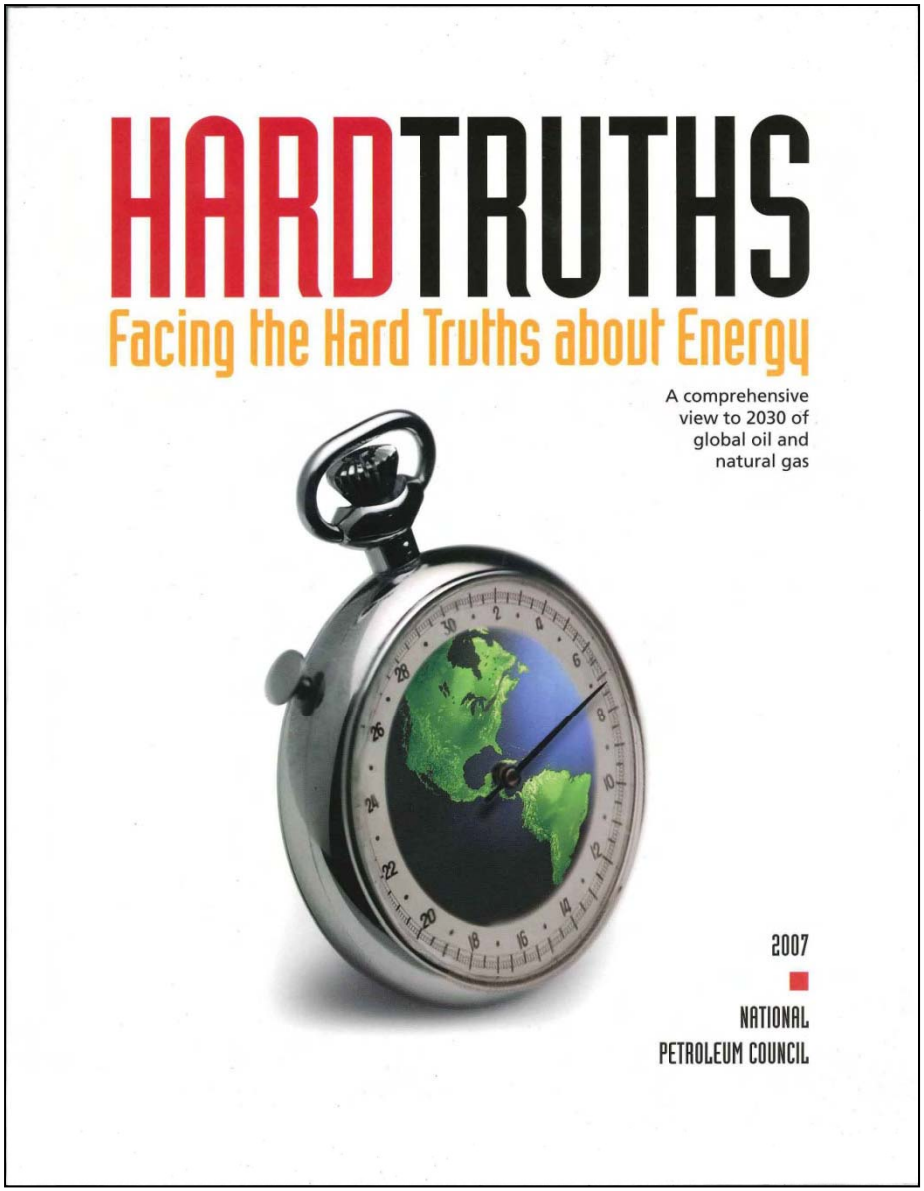


sacrifice … "moral equivalent of war"

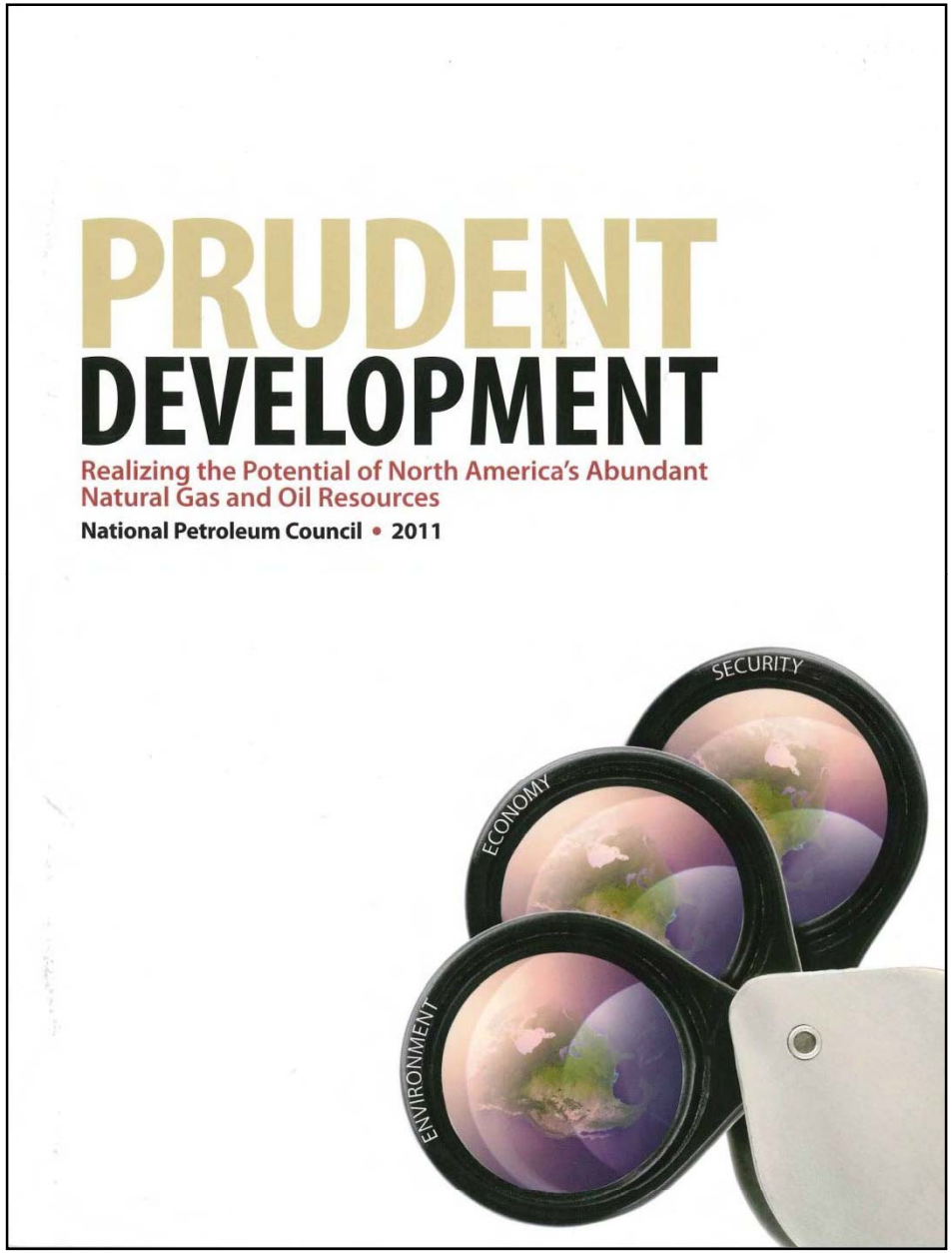
"this is the greatest challenge our nation will face during our lifetime."

Page 12


BALANCING
NATURAL
GAS
POLICY
FUELING THE DEMANDS
OF A GROWING
ECONOMY
Finding 5: Traditional North American producing areas will provide 75% of long-term U.S. gas needs, but will be unable to meet projected demand.
Page 30
VOLUME I
SUMMARY
OF FINDINGS AND
RECOMMENDATIONS
NATIONAL PETROLEUM COUNCIL
SEPTEMBER 2003



". . . nearly two-thirds of natural gas resources are concentrated in four countries, Russia, Qatar, Iran, and Saudi Arabia, which are projected to show the biggest growth in production." [p. 105]



". . . significant technology advances have unlocked vast natural gas and oil resources." [p. 7]

Shale Gas Will Rock the World

(Wall Street Journal, 5/10/2010)

Huge discoveries of natural gas promise to shake up the energy markets and geopolitics. And that's just for starters.

There's an energy revolution brewing right under our feet.

Over the past decade, a wave of drilling around the world has uncovered giant supplies of natural gas in shale rock. By some estimates, there's 1,000 trillion cubic feet recoverable in North America alone—enough to supply the nation's natural gas needs for the next 45 years. Europe may have nearly 200 trillion cubic feet of its own.

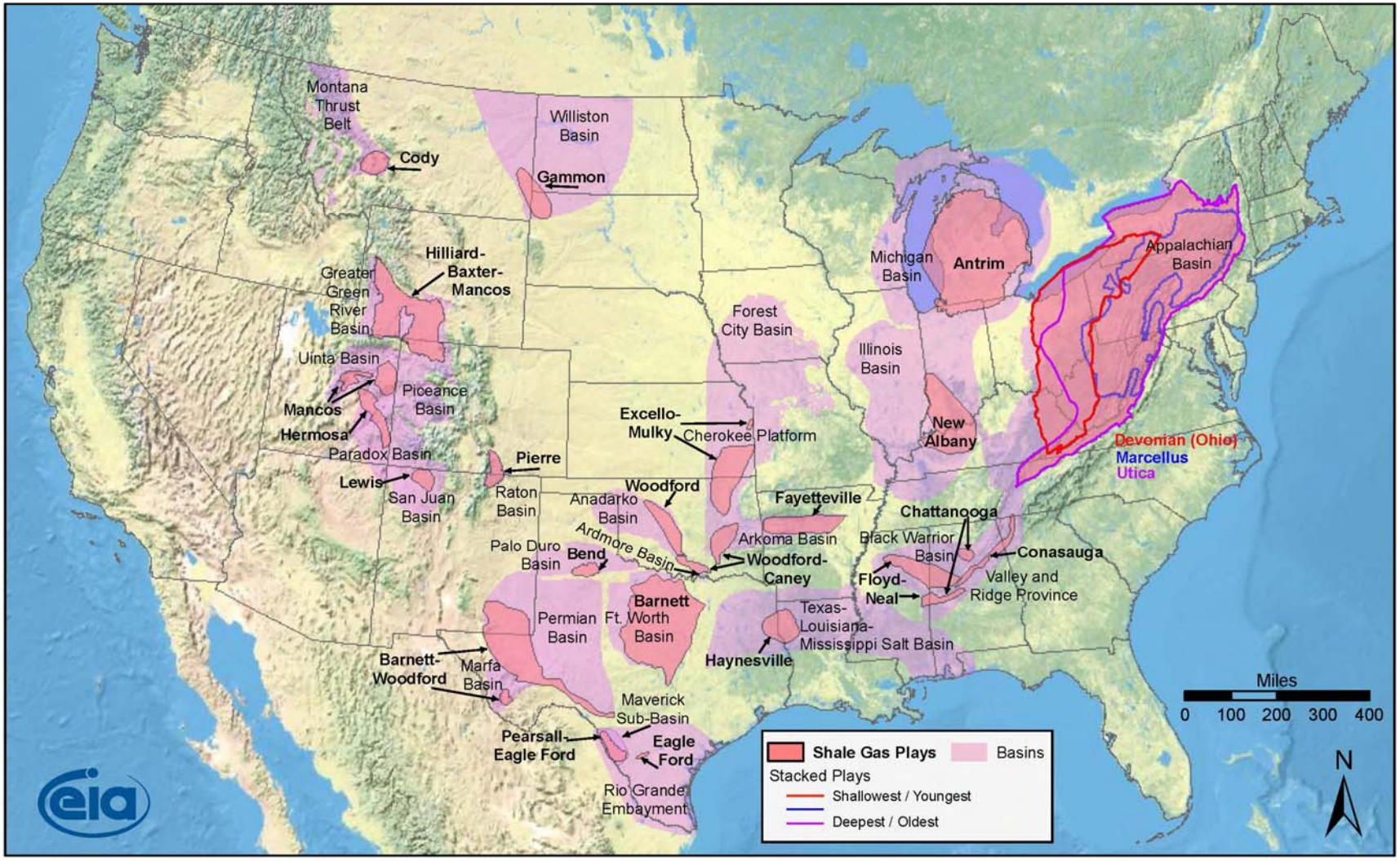
SPILL IN THE GULF

Obama Says He'll Push For Clean Energy Bill

Adding Up Costs of 'Fossil Fuel Addiction'
(*The New York Times*, June 23, 2010, p. A23)

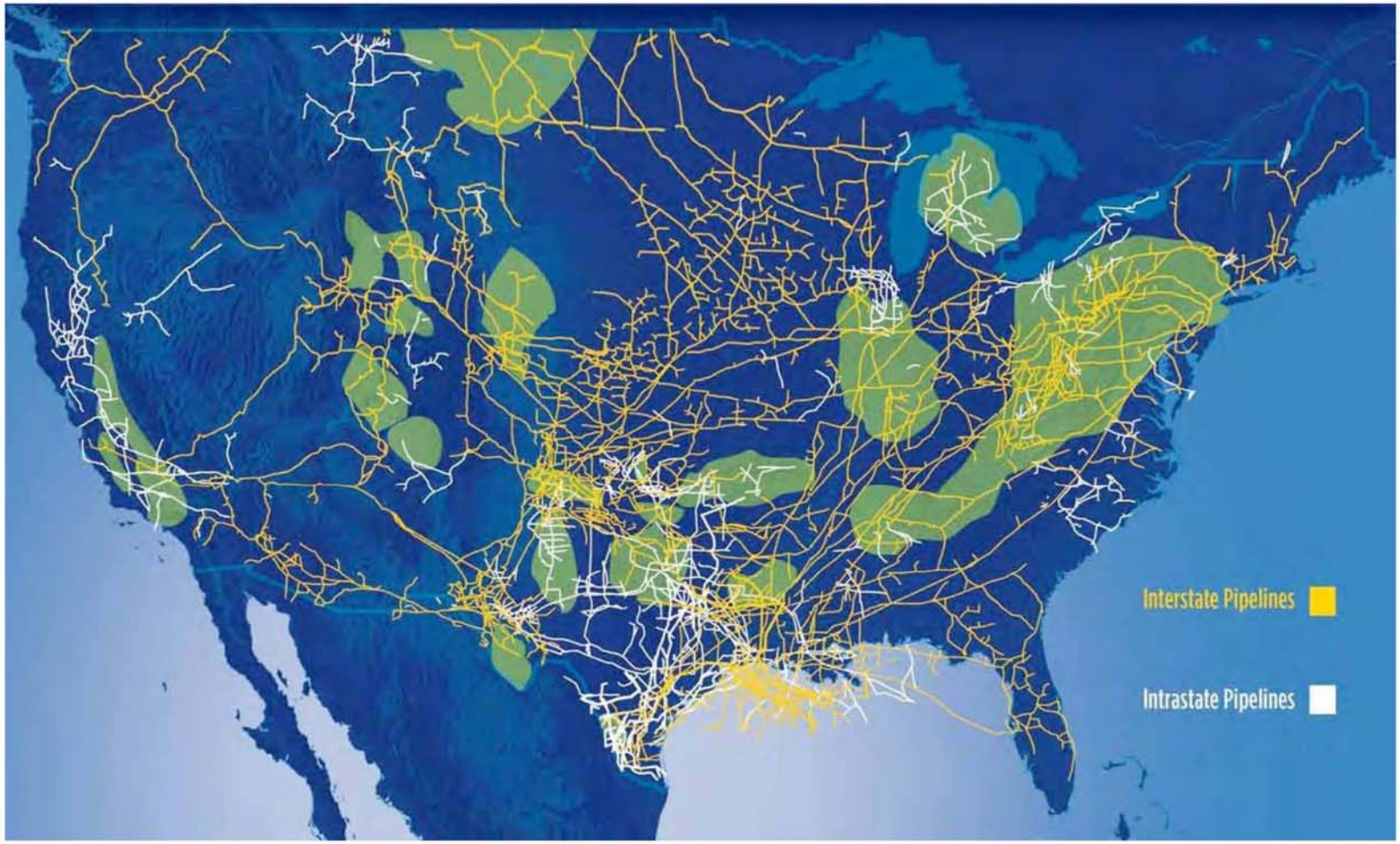
- Seeking to harness the deepening anger over the oil spill in the Gulf of Mexico to the advantage of his legislative agenda, Mr. Obama promised to find the lagging votes in the Senate to get the climate change and energy bill passed this year.
- "If we refuse to take into account the full cost of our **fossil fuel addiction** — if we don't factor in the environmental costs and national security costs and true economic costs — we will have missed our best chance to seize a clean energy future," Mr. Obama said. "The votes may not be there right now, but I intend to find them in the coming months."

Shale Gas Plays, Lower 48 States



Source: Energy Information Administration based on data from various published studies
Updated: May 28, 2009

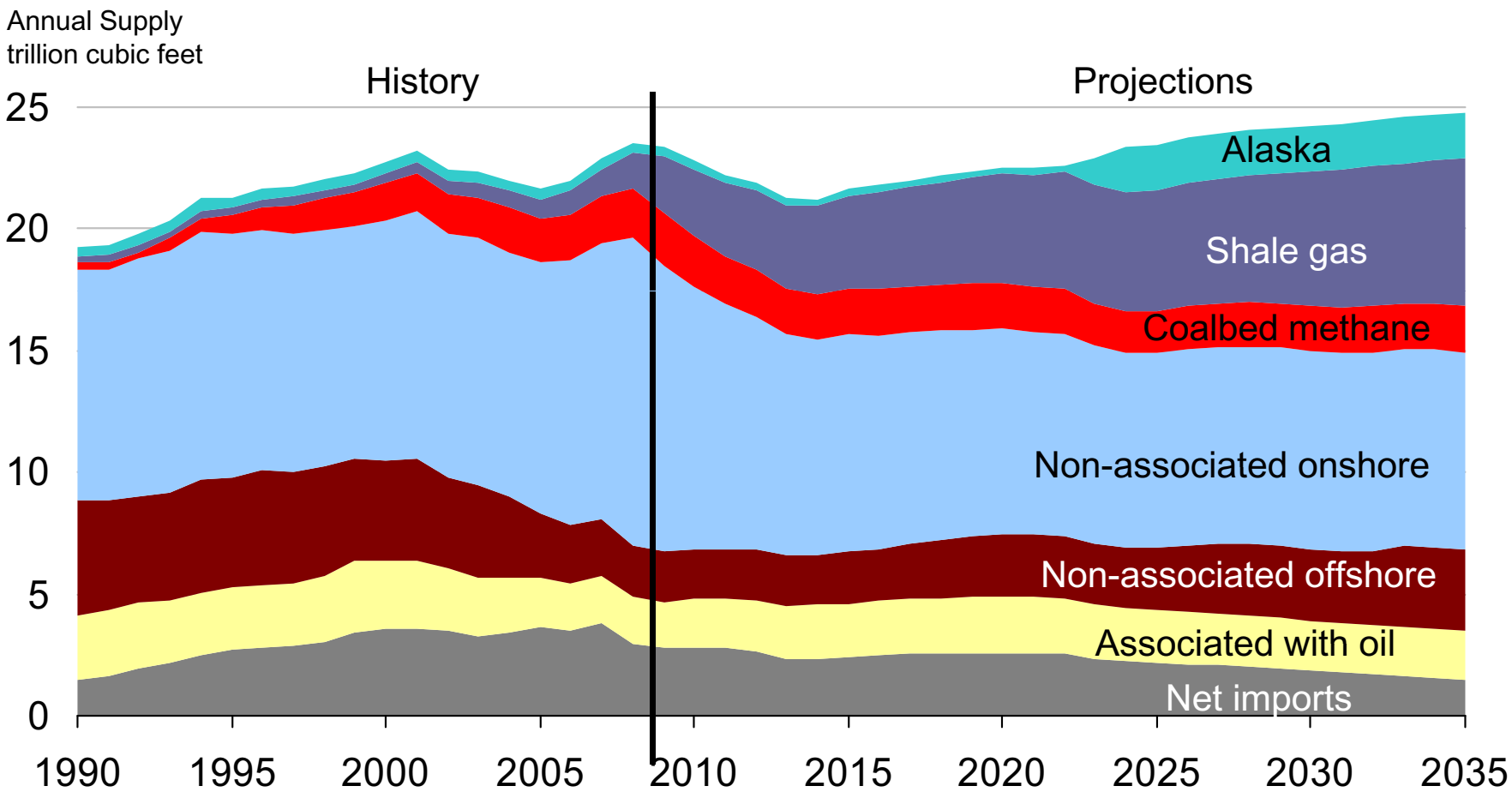
Shale Basins and the U.S. Pipeline Grid



Source: American Clean Skies Foundation.

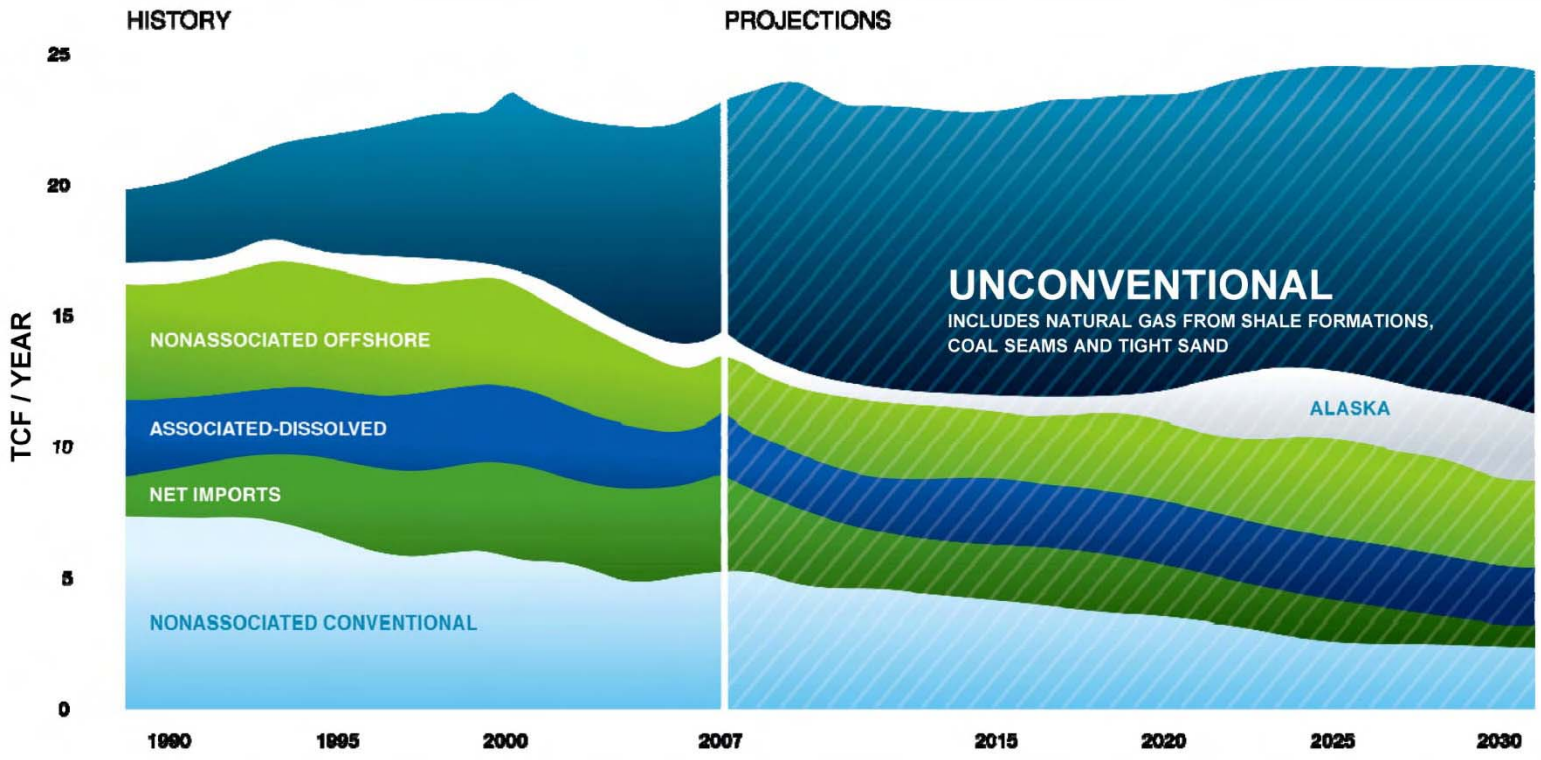
AGA American Gas Association

Shale gas and Alaska production offset declines in supply to meet consumption growth and lower import needs



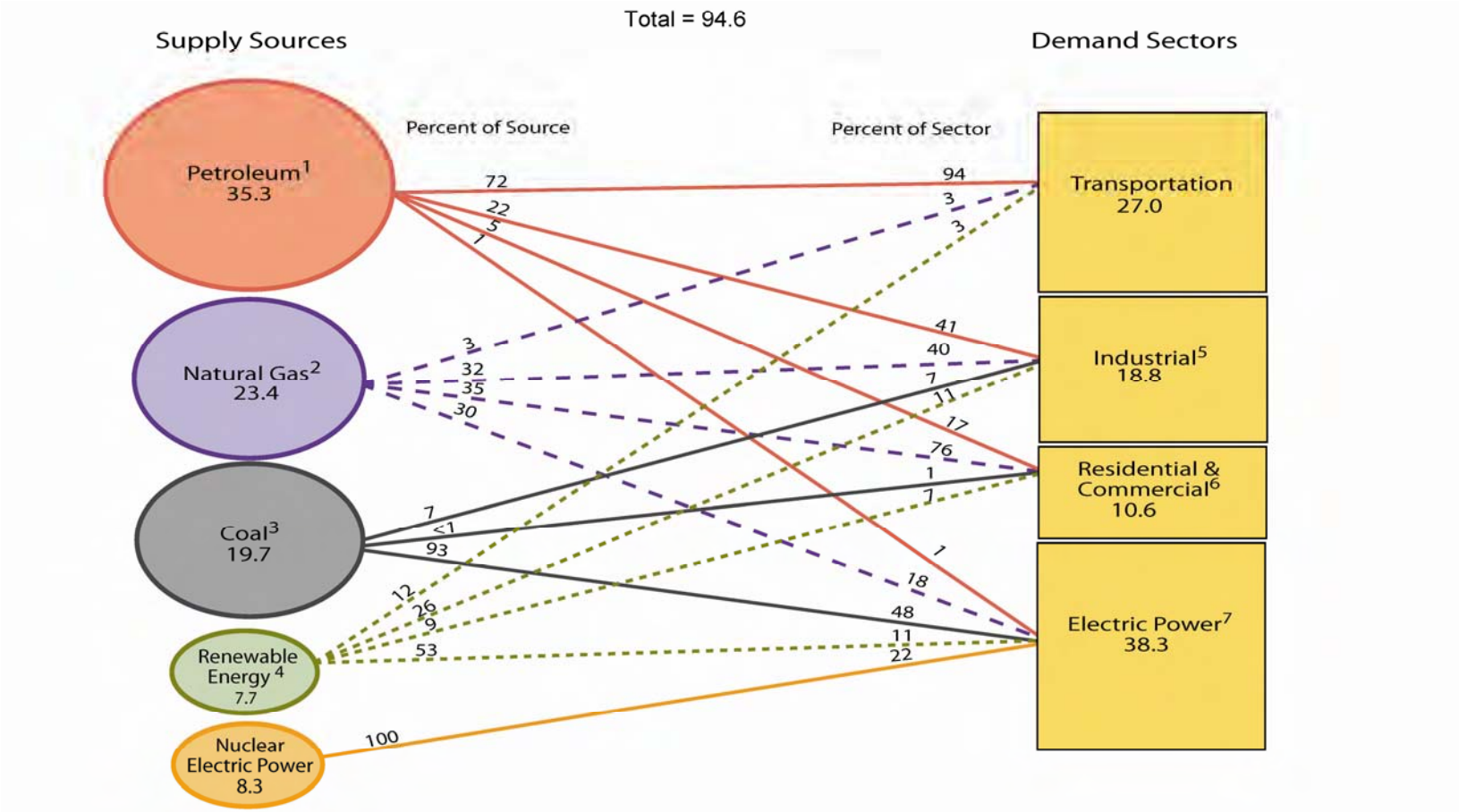
Source: EIA Annual Energy Outlook 2010

Unconventional Natural Gas: A Game Changer for the U.S.



U.S. Primary Energy Consumption by Source and Sector, 2009

(Quadrillion Btu)



[1] Does not include biofuels that have been blended with petroleum—biofuels are included in "Renewable Energy."
[2] Excludes supplemental gaseous fuels.
[3] Includes less than 0.1 quadrillion Btu of coal coke net exports.
[4] Conventional hydroelectric power, geothermal, solar/PV, wind, and biomass.
[5] Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
[6] Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[7] Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

Note: Sum of components may not equal total due to independent rounding.
Sources: U.S. Energy Information Administration, *Annual Energy Review 2009*, Tables 1.3, 2.1b-2.1f , 10.3, and 10.4.

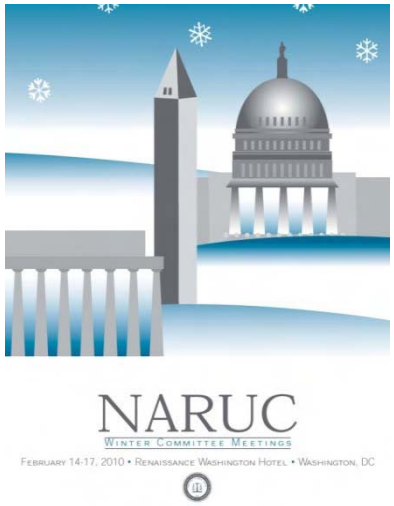
U.S. Energy Information Administration / Annual Energy Review 2009

Anthony 2010 Presentations / Input on Hydraulic Fracturing

- February 14 — NARUC, Washington, DC
  National Association of Regulatory Utility Commissioners
  http://www.narucmeetings.org/meeting%20programs/2010WinterProgram.pdf p.25
- May 18 — NECPUC, Brewster, MA
  New England Conference of Public Utilities Commissioners
  http://necpuc.org/Presentations/Bzdyra%20Anthony%20Bob%20100518.pdf
- July 20 — NARUC, Sacramento, CA
  National Association of Regulatory Utility Commissioners
  http://www.narucmeetings.org/Presentations/NARUC_Presentation_07202010v11.pdf
- August 10 — Wall Street, New York, NY
  Utility Commissioners / Wall Street Dialogue
- October 4 — EIPF, Amelia Island, FL
  Emerging Issues Policy Forum
- October 20 — OCGS, Oklahoma City, OK
  Oklahoma City Geological Society
  http://www.occeweb.com/Comm/Anthony/Hydraulic%20Fracturing.pdf
- December 9 — NPC, Washington, DC
  National Petroleum Council (CSC Meeting)

Anthony 2011 Presentations / Input on Hydraulic Fracturing

- January 4 — Fortune Club, Oklahoma City, OK
- January 24 — SPE, Houston, TX
  Society of Petroleum Engineers, Hydraulic Fracturing Technology Conference
- February 22 — COPAS, Oklahoma City, OK
  Council of Petroleum Accountants Societies
- March 30 — Woodford Shale Summit, Norman, OK
  Sponsored by the University of Oklahoma and
  Interstate Oil & Gas Compact Commission (IOGCC)
- April 8 — Yale Alumni in Energy Conference, New Haven, CT
  Sponsored by Yale University
- June 13 — EEI Annual Conference, Colorado Springs, CO
  Edison Electric Institute
- October 11 — EIPF, Amelia Island, FL
  Emerging Issues Policy Forum



2010 Winter NARUC Hydraulic Fracturing Panel

Hydraulic Fracturing - How to balance the need for new gas supplies with environmental uncertainties

Hydraulic fracturing releases natural gas by injecting highly pressurized water mixed with some sand and a small amount of chemicals through a deep well, lined with steel pipe and sealed with cement, into the ground to break shale rocks and release natural gas.

By enabling access to previously untapped shale basins, hydraulic fracturing has been projected to increase the nation's gas supply by over 35%. Yet, uncertainty about potentially adverse environmental impacts, including concerns about drinking and agricultural water contamination, have raised questions about potential unintended environmental consequences.

Moderator: ***Hon. Bob Anthony****-Chairman, Oklahoma Corporation Commission*

Panelists:

Hon. Barry Smitherman-Chairman, Public Utility Commission of Texas

Steve Heare-Dir, ***Drinking Water Protection Division****, Office of Groundwater & Drinking Water,* ***US EPA***

Bill Kappel, ***Hydrologist, Section Chief, US Geological Survey****, Water Science Center, Ithaca, NY*

Michael Bahorich -Executive Vice President and Technology Officer, Apache Corporation

Nancy Johnson-Dir, ***Environmental Science and Policy Analysis****, DOE Office of Oil and Natural Gas*

EPA Official: State Regulators Doing Fine On Hydrofracking

February 15, 2010, Dow Jones, Ian Talley

WASHINGTON (Dow Jones)--State regulators are doing a good job overseeing a key natural gas production technique called hydrofracking and there's no evidence the process causes water contamination, a senior federal environment official said Monday.

Environmentalists and some lawmakers are pressing to give the Environmental Protection Agency federal oversight of the process, concerned that the drilling technique is contaminating water suppliers.

State regulators and the natural gas industry have been fighting against federal regulation, saying it could prevent or delay development of trillions of cubic feet of new resources.

The process, which injects water, sand and a small amount of chemicals into natural gas reservoirs under high pressure, has opened new deposits to development, dramatically expanding estimates for domestic production.

"I have no information that states aren't doing a good job already," **Steve Heare, director of EPA's Drinking Water Protection Division** said on the sidelines of a state regulators conference here. He also said despite claims by environmental organizations, he hadn't seen any documented cases that the hydro-fracking process was contaminating water supplies.

In its 2011 budget, the EPA is seeking to spend $4 million to study the environmental impacts of the process.

Bill Kappel, a U.S. Geological Survey official, said contamination of water supplies is more likely to happen as companies process the waste water from hydrofracking. In some instances, municipal water systems that treat the water have reported higher levels of heavy metals and radioactivity.

"Treatment of the [waste] water hasn't caught up with the hydro-fracking technology," Kappel said.

But both re-injection of that waste water and water treatment at the surface is already regulated by the federal government under the Safe Drinking Water and Clean Water Acts.

Although legislation in the House and Senate to bring greater federal oversight of the hydro-fracking process hasn't gained momentum, Heare said even if such proposals are approved, it wouldn't likely have a dramatic affect on regulation. States would still have the right under the Safe Drinking Water Act to use their own regulatory standards.

The National Association of Regulatory Utility Commissioners has pushed to maintain state's primacy in oversight of oil and gas activities.

Contrary to some press reports, Heare also noted that the EPA wasn't conducting any current investigations linking hydrofracking to water contaminations.

Companies such as Range Resources Corp. (RRC), EOG Resources Inc. (EOG), Devon Energy Corp. (DVN), Royal Dutch Shell PLC (RDSA) and Chesapeake Energy Corp. (CHK) say the process is multiplying their reserves. For example, the Marcellus deposit that lies under Pennsylvania, Virginia, Ohio and New York is estimated to hold more than 500 trillion cubic feet, compared to total conventional natural-gas resource estimates in the U.S. of around 378 trillion cubic feet, according to the U.S. Geological Survey.

http://online.wsj.com/article/BT-CO-201002150706628.html?mod=WSJ_latestheadlines

"Reservoir Stimulation" using Hydraulic Fracturing

What is Hydraulic Fracturing ?

- A method for creating a conductive fracture or crack in a subsurface formation to provide an easier path for fluids to flow to the well bore from the extremities of the well's drainage area

Why Frac ?

- To stimulate oil and/or gas production to increase Net Present Value (NPV) of a well through:
  - ✓ • Accelerating income through increasing production rates
  - ✓ • Reducing well life operating expenses
  - ✓ • Increasing total cumulative production (reserves)

Source: "**Hydraulic Fracturing**", Mohd Zaki bin Awang

Oklahoma

- 60 years of Hydraulic Fracturing (safer than nitroglycerin)
- 100,000 hydraulically fractured oil and gas wells
- No verified or documented instances of harm to groundwater from HF
- Cost per well: $10,000 to $2 million plus
- HF tailored to individual well characteristics

Fracturing effects on producing rate for 1.0 and .005 millidarcy reservoirs

(darcy is a measure of permeability)

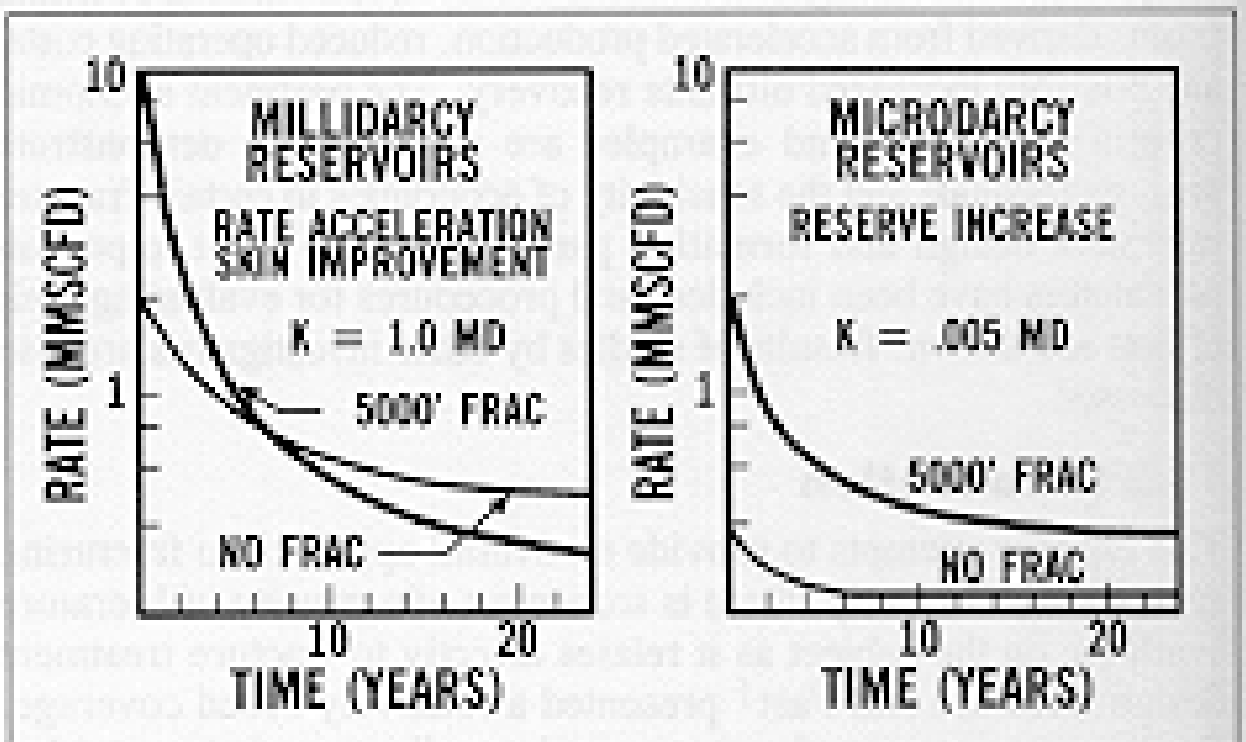


Fig. 17.4—Fracturing effects on producing rate for 1.0 and 0.005 md.

Source: "**Hydraulic Fracturing**", Mohd Zaki bin Awang

Hydraulic Fracturing on the Net

Wikipedia (http://en.wikipedia.org/wiki/Hydraulic_fracturing)

- The technique of hydraulic fracturing is used to increase or restore the rate at which fluids, such as oil, gas or water can be produced from a reservoir, including unconventional reservoirs such as shale rock or coal beds. **Environmental concerns** regarding hydrofracturing techniques include **potential for contamination of aquifers with fracturing chemicals or waste fluids**. On the other hand, hydraulic fracturing is applied to remediation of environmental waste spills.
- The process of hydraulic fracturing is used to enable the production of natural gas and oil from rock formations deep below the earth's surface (generally 5,000-20,000') that otherwise do not posses sufficient porosity and permeability to allow the natural gas and oil to flow up the borehole to be recovered at the surface of the earth. Creating conductive fractures in the rock is essential to produce hydrocarbons due to the extremely low natural permeability of shale reservoirs (measured in the microdarcy to nanodarcy range). The fracture provides a conductive path connecting a larger area of the reservoir to the well, thereby increasing the area from which natural gas and liquids can be recovered from the targeted formation.
- Hydraulic fracturing for stimulation of oil and natural gas wells was first used in the United States in 1947 It was first used commercially in 1949, and because of its success in increasing production from oil wells was quickly adopted, and is now used worldwide in tens of thousands of oil and natural gas wells annually.
- An estimated 90% of the natural gas wells in the U.S. rely on hydraulic fracturing to produce natural gas at economic rates.

Hydraulic Fracturing on the Net

Raising Environmental Issues

- Propublica - Buried Secrets: Gas Drilling's Environmental Threat
  http://www.propublica.org/series/buried-secrets-gas-drillings-environmental-threat
- Natural Resources Defense Council (NRDC)
  Incidents where hydraulic fracturing is a suspected cause of drinking water contamination
  http://switchboard.nrdc.org/blogs/amall/incidents_where_hydraulic_frac.html
- PBS "NOW" 3/26/2010 *Gasland*
  http://www.pbs.org/now/shows/613/
- *Gasland* documentary on HBO
  http://www.hbo.com/documentaries?cmpid=ABC449#/documentaries/gasland/index.html
- PBS "Need to Know", 8/27/2010 Pavilion, WY
  http://www.pbs.org/wnet/need-to-know/environment/the-price-of-gas-a-need-to-know-investigation/3170/

Rebuttal by Independent Petroleum Association of America (IPAA)

- *Gasland* Debunked
- *Gasland* "documentary targeting natural gas heavy on hyperbole, light on actual facts."
- *"GasLand:* politics at its worst, art at its most contrived, and contradictions of fact found around every bend of the river."
- Issue by Issue critique at:
  http://www.energyindepth.org/2010/06/debunking-gasland

EPA Investigation and Town Hall Hearing, Pavilion, Wyoming

Still image from the August 27 broadcast of the PBS Program *Need to Know* covering the EPA Investigation and Town Hall Meeting in Pavilion, Wyoming.
http://www.pbs.org/wnet/need-to-know/environment/the-price-of-gas-a-need-to-know-investigation/3170/

Gasland: Truth vs. Fiction

(http://www.hbo.com/documentaries?cmpid=ABC449#/documentaries/gasland/index.html)

Truth: The state agency that regulates natural gas drilling in Colorado found the flammable water was caused by naturally occurring methane gas, not Hydraulic Fracturing, according to the oil and gas industry-funded website energyindepth.org.

Gasland: Colorado Oil and Gas Conservation Commission (COGCC) Investigation Report

(http://cogcc.state.co.us/library/GASLAND%20DOC.pdf)

- Issued 10/29/2010
- *"Finally, it should be understood that the COGCC Director, Dave Neslin, offered to speak with Gasland's producer, Josh Fox, on camera during the filming of the movie. Because the issues are technical and complex and arouse concerns in many people, Director Neslin asked that he be allowed to review any material from the interview that would be included in the final film. Unfortunately, Mr. Fox declined. Such a discussion might have prevented the inaccuracies noted above."*
- None of the contamination situations described in the film were determined to have been caused by Hydraulic Fracturing.
- All but one were determined to have been caused by naturally occurring biogenic methane deposits (e.g. coal beds)
- The exception was caused by improper cementing of surface casing. Enforcement Order 1V-276 was approved in 2004 and assessed a substantial fine against the operator.

www.earthjustice.org/ny

(Founded in 1971 as the Sierra Club Legal Defense Fund)

EPA Hydraulic Fracturing (HF) Study

Chronology

- Federal Safe Water Drinking Act of 1974 exempted HF from underground injection control ("UIC") regulation.
- The 1997 11th circuit opinion in *LEAF v. EPA*, 118 F.3d 1467, subjected HF of coal bed methane to UIC regulation based on statutory interpretation.
- 2004 EPA Study of HF in Coal Bed Methane analyzed 200 peer reviewed studies and concluded that HF did not adversely impact underground sources of drinking water.
- Energy Policy Act of 2005 Amendment subjected diesel based HF to UIC regulation and continues remainder of HF exemptions.
- 2010 Congress asked the EPA to study HF and report by 2012.
  http://yosemite.epa.gov/sab/sabproduct.nsf/0/3B745430D624ED3B852576D400514B76?OpenDocument
- EPA's Research and Development (R&D) organization developed a scoping document – March 2010.
- Reviewed by Augmented Environmental Engineering Committee of EPA's Science Advisory Board - April 2010.
- Committee Report issued - May 19, 2010.
- Science Advisory Board reviewed Committee Report - June 2010.
- Science Advisory Board issued report to EPA R&D – June 24, 2010.
  http://yosemite.epa.gov/sab/sabproduct.nsf/0/CC09DE2B8B4755718525774D0044F929/$File/EPA-SAB-10-009-unsigned.pdf
- EPA Ground Water and Ecosystems Restoration Research Center (Ada, OK) will produce final research plan – about September 2010 – and the study will be initiated by December 2010.
- Study results to be issued late 2012.

Scope

- Short-term research should be directed to study sources and pathways of potential impacts of hydraulic fracturing on water resources, especially drinking water resources.
- Use a lifecycle framework to identify the most important research questions.
- Careful compilation and review of all available data and knowledge available in peer-reviewed. literature, in industry, in professional and non- governmental organizations, and government agencies.
- Water resources should be the central theme.
- Emphasize environmental concerns that are specific to hydraulic fracturing rather than concerns that are common to all oil and gas production activities.

Sources: EPA Web site & Dr. Robert W. Puls, Technical Lead, EPA Hydraulic Fracturing Study, Presentation to IOGCC

MIT Report: The Future of Natural Gas (June 2010)

http://web.mit.edu/mitei/research/studies/report-natural-gas.pdf

- Approximately 400 Tcf of Shale Gas could be economically developed with a gas price at or below $6/MMBtu at the well-head.
- "feast or famine" expectations for U.S. natural gas supply, associated with price swings and policy changes, have often led to costly investment decisions in the past.
- With over 20,000 shale wells drilled in the last 10 years, the environmental record of shale gas development is for the most part a good one.
- One must recognize the inherent risks of the oil and gas business and the damage that can be caused by just one poor operation; the industry must continuously strive to mitigate risk and address public concerns.
- **The environmental impacts of shale development are manageable but challenging.**
- The protection of freshwater aquifers from fracture fluids has been a primary objective of oil and gas field regulation for many years. Good oil-field practice and existing legislation should be sufficient to manage this risk.
- Water supply and disposal issues, where they exist, could be addressed by requiring collaboration between operators on a regional basis to create integrated water usage and disposal plans. In addition, complete transparency about the contents of fracture fluids, which are for the most part benign, and the replacement of any potentially toxic components where they exist, could help to alleviate public concern.

Library of Congress
Congressional Research Service
Unconventional Gas Shales: Development, Technology, and Policy Issues

http://assets.opencrs.com/rpts/R40894_20091030.pdf

Congressional Research Service

Unconventional Gas Shales: Development, Technology, and Policy Issues

Anthony Andrews, Coordinator
Specialist in Energy and Energy Infrastructure Policy

Peter Folger
Specialist in Energy and Natural Resources Policy

Marc Humphries
Analyst in Energy Policy

Claudia Copeland
Specialist in Resources and Environmental Policy

Mary Tiemann
Specialist in Environmental Policy

Robert Meltz
Legislative Attorney

Cynthia Brougher
Legislative Attorney

October 30, 2009

Congressional Research Service
7-5700
www.crs.gov
R40894

CRS Report for Congress
Prepared for Members and Committees of Congress

Fracturing Risks to Groundwater

An environmental concern raised by hydraulic fracturing is the possibility of introducing contaminants into aquifers. Hydraulic fracturing does induce new fractures into shale, and can propagate fractures thousands of feet along the bedding plane of a shale formation. The potential for propagating fractures to an overlying aquifer may depend on the depth separating the two.

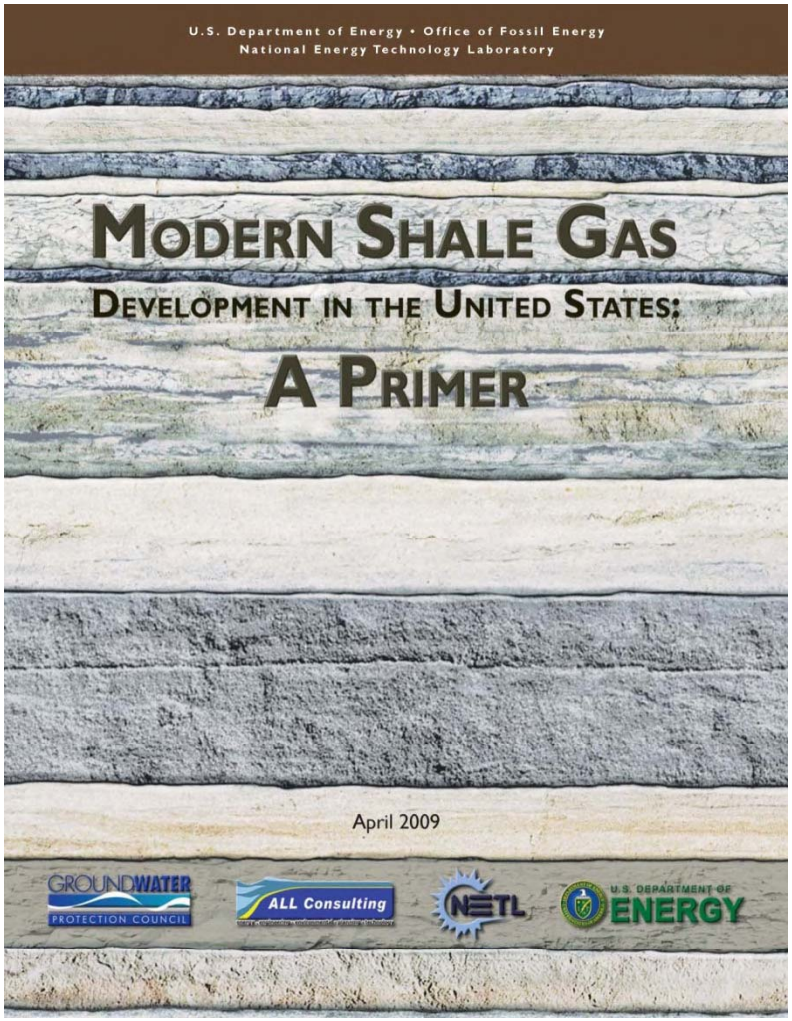
However, engineers designing and conducting frac jobs have a strong **incentive to limit** the fractures to the height of the gas-producing shale zones. Any fracture propagated to an overlying aquifer could allow water to flow down into the gas-producing portion of the shale, which could significantly hamper gas production.

Another potential issue could be groundwater contamination from poorly constructed water wells.

Contaminated surface water unrelated to drilling could also contaminate an improperly cased or constructed water well. For example, a leaky septic system, or improper disposal of domestic refuse such as car batteries or used oil, could leak from the surface into the water well.

Gas Shale Primer
(DOE Office of Fossil Energy)

Http://fossil.energy.gov/programs/oilgas/publications/naturalgas_general/Shale_Gas_Primer_2009.pdf



IOGCC on Hydraulic Fracturing

INTERSTATE Oil & Gas COMPACT COMMISSION

http://www.iogcc.com/hydraulic-fracturing

ABOUT US | WHAT WE DO | MEMBER STATES | ISSUES | NEWS | PUBLICATIONS | EVENTS

Issues

Hydraulic Fracturing

Hydraulic fracturing is a technique used to allow oil and natural gas to move more freely from the rock pores where they are trapped to a producing well that can bring them to the surface. The technology was developed in the late 1940s and has been continuously improved and applied since that time. The process of hydraulic fracturing plays a major role in the development of virtually all unconventional oil and natural gas resources

State Regulation

Hydraulic fracturing is regulated by the states. IOGCC member states each have comprehensive laws and regulations to provide for safe operations and to protect drinking water sources, and have trained personnel to effectively regulate oil and gas exploration and production.

On March 5, 2009, the IOGCC hosted two briefings on Capitol Hill to explain state regulation of oil and natural gas. The presentation included an explanation of hydraulic fracturing and how existing state regulations prevent contamination of drinking water resources during hydraulic fracturing operations.

Is Hydraulic Fracturing Safe?

In 2004, the U.S. Environmental Protection Agency completed a study of the environmental risks associated with the hydraulic fracturing of coal bed methane wells. The EPA concluded that the injection of hydraulic fracturing fluids poses little or no threat to underground sources of drinking water.

Although thousands of wells are fractured annually, the EPA did not find a single incident of the contamination of drinking water wells by hydraulic fracturing fluid injection. Additionally, IOGCC member states have all stated that there have been no cases where hydraulic fracturing has been verified to have contaminated drinking water.

Resolutions

» **IOGCC Resolution** 09.011 on Hydraulic Fracturing (January 2009)
» **State Resolutions** on Hydraulic Fracturing (2009)

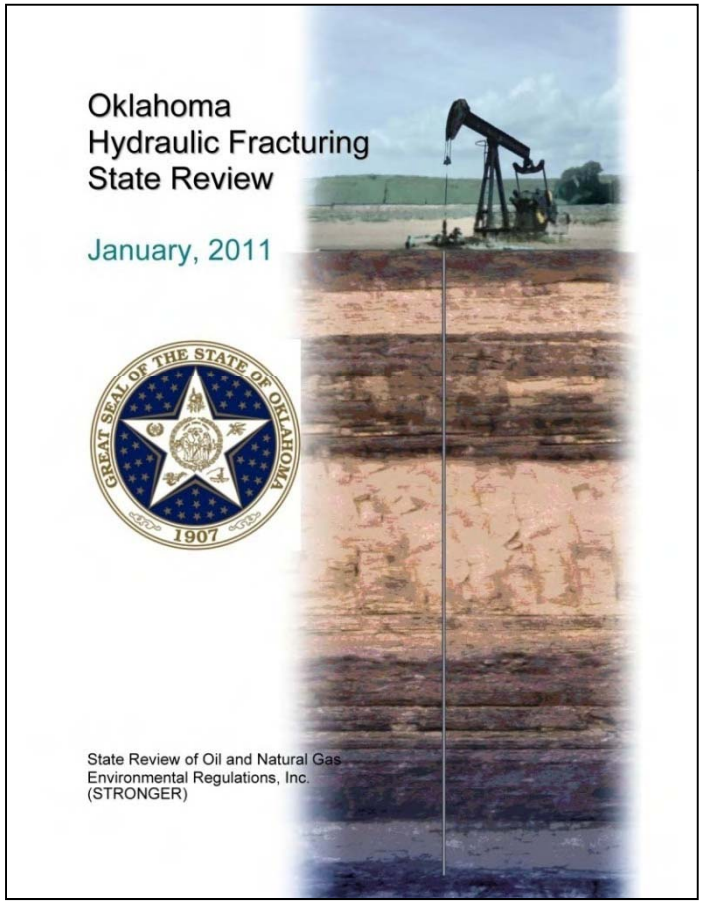
Expert Insight

» **Statements:** Remarks on Hydraulic Fracturing from State Regulatory Officials (June 2009)
» **White Paper:** History of Litigation Concerning Hydraulic Fracturing To Produce Coalbed Methane (S. Marvin Rogers, 2009)

» **EPA Study:** Study to Evaluate the Impacts to USDWs by Hydraulic Fracturing of Coalbed Methane Reservoirs (2004)

(State Review of Oil and Natural Gas Environmental Regulations, Inc.)
http://www.strongerinc.org/

- Key issues identified during Hydraulic Fracturing reviews vary from state to state:
  - Discharges to streams in PA
  - Urban drilling in OH
  - Recycling pits in OK
  - Groundwater withdrawals in LA
- States have acted to address their key issues



Edison Electric Institute Report on Emerging Natural Gas Issues

June 2011

http://www.eei.org/ourissues/ElectricityGeneration/Documents/Fracking%20June%202011_Web.pdf

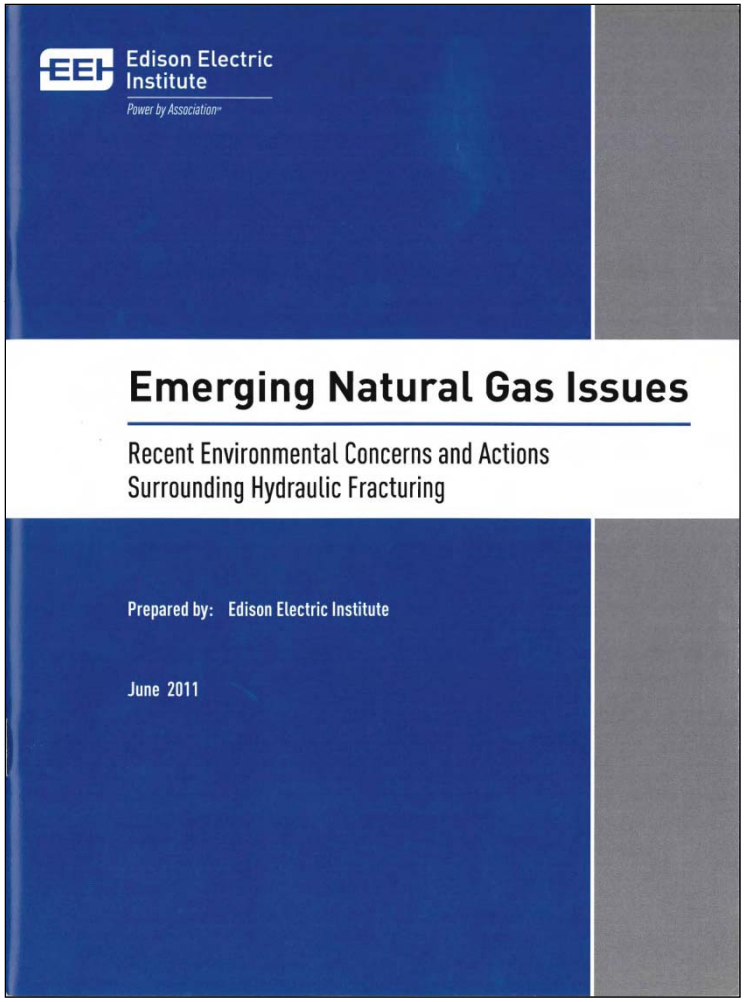
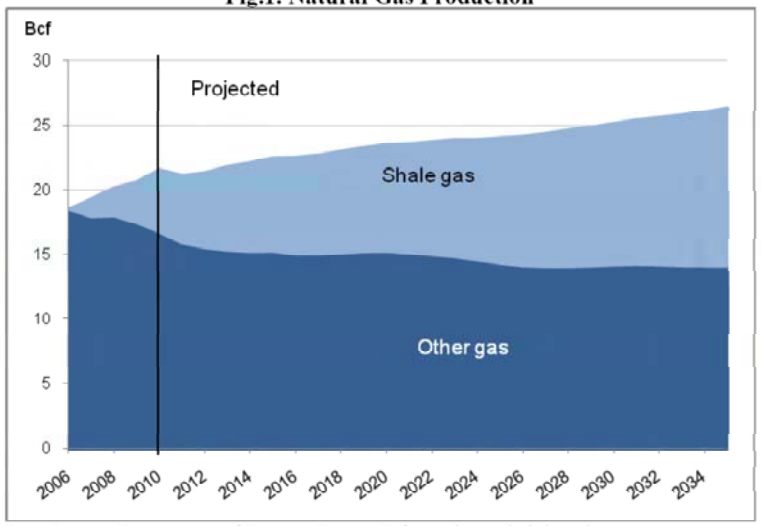


Fig.1. Natural Gas Production



Data Source: Department of Energy, Energy Information Administration

"Shale gas is an abundant resource and has been rendered cost effective by the combination of two production technologies: horizontal drilling and hydraulic fracturing*. The latter uses high pressure to inject fluids into the wells to create fissures in the shale rock, thereby releasing the gas that it contains. The composition of those fluids is at the forefront of the concerns since small, but potentially harmful amounts of toxic substances are used. The main issues currently under scrutiny are the possibility of surface and water tables contamination and the recycling and/or treatment of the wastewater. Some recent studies have also raised concerns about the ability of natural gas to help reduce greenhouse gas emissions."*

Hydro Fracking done to water wells in New England, et al.

WATER WELL FRACKING RESOURCES

(different drillers use their own proprietary chemical mixtures)

American Well Water Trust--What is Hydro Fracking
http://www.agwt.org/info/pdfs/hydrofrackingwells.pdf

Goodwin Well & Water (North Turner, ME)
http://www.goodwinwellandwater.com/hydrofac/index.html

Cushing and Sons (Keene, New Hampshire)
http://www.cushingandsons.com/wells.html

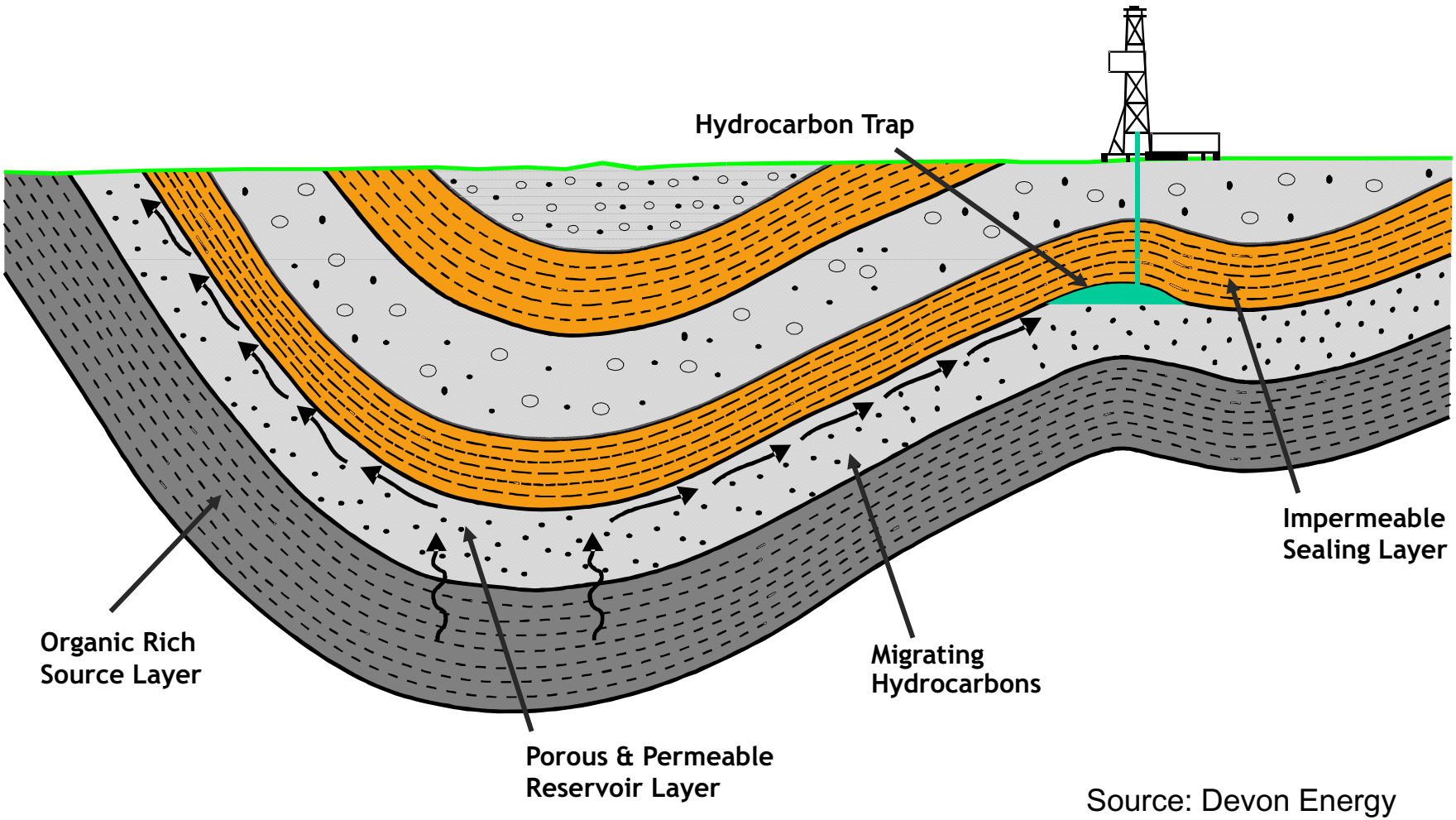
Northeast Water Wells (Hudson, New Hampshire)
http://www.wellguy.com/Hydrofrac1.html

Schrader Well Drilling (Carbon, Indiana)
http://www.schraderwells.com/Hydrofracking.html

Lusier Drilling (Oconto Falls, WI)
http://www.luisierdrilling.com/hydro.html

Natural Gas

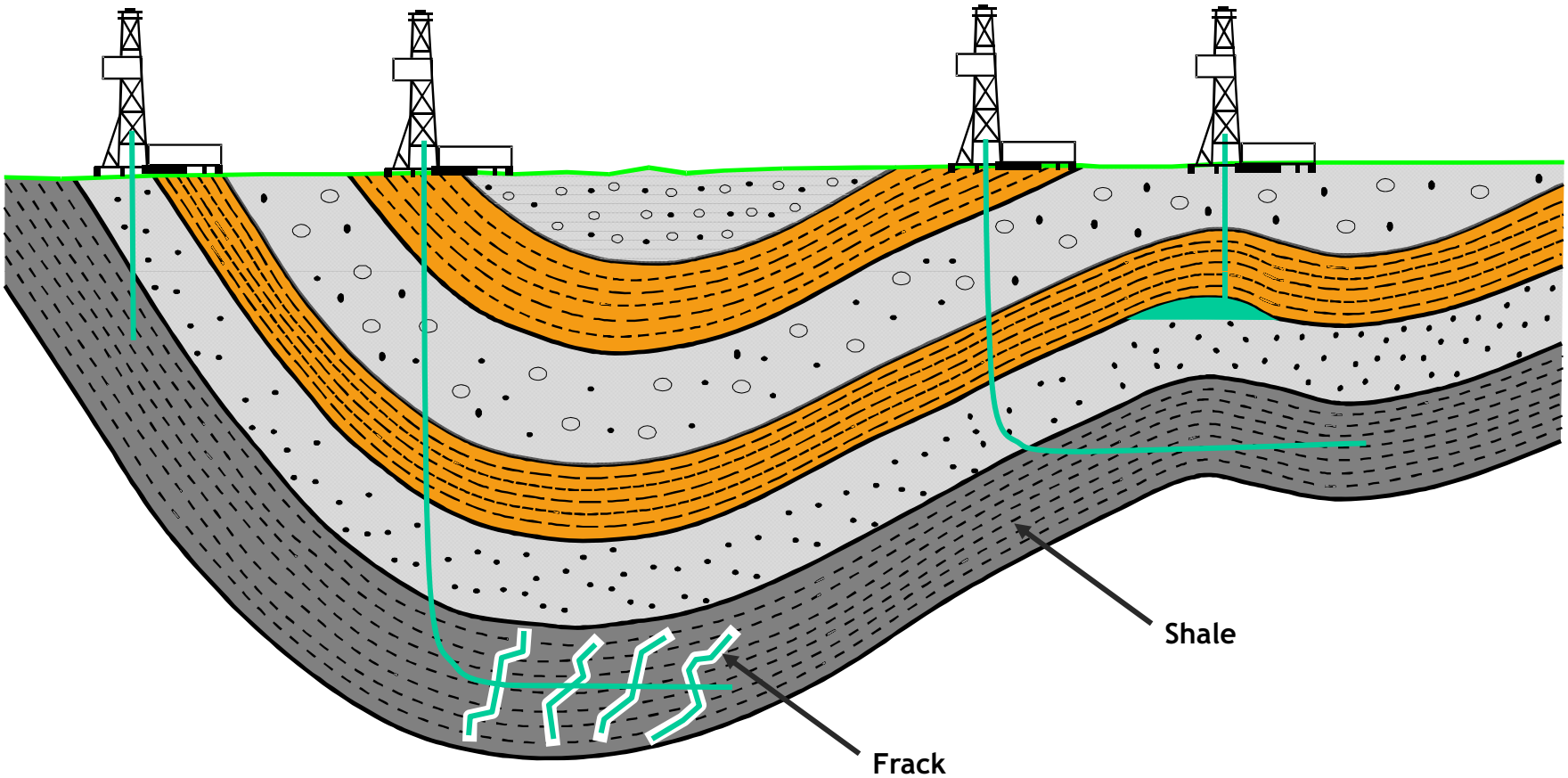
Traps vs. Shales



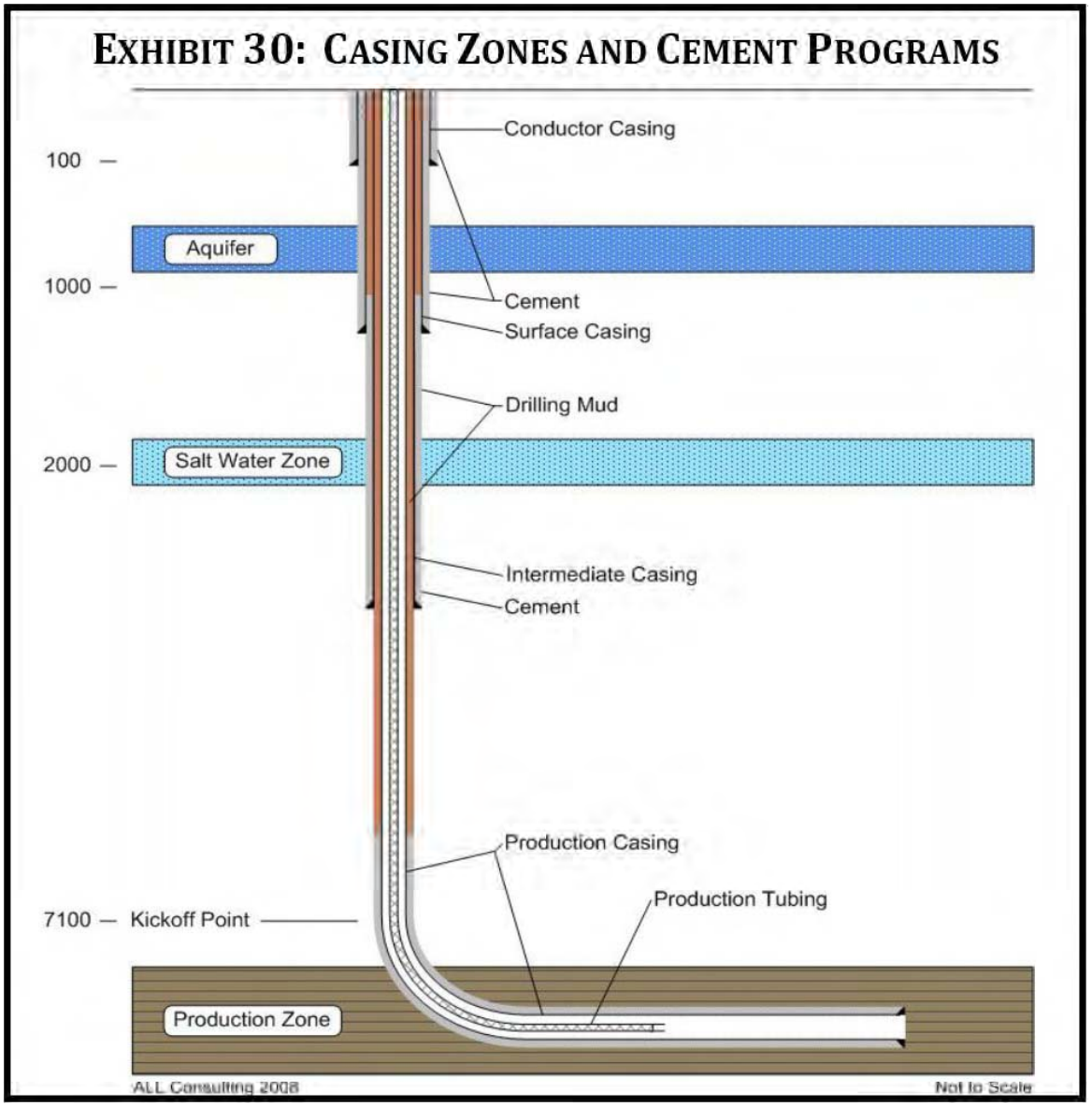
Source: Devon Energy

Natural Gas

Traps vs. Shales



Source: Devon Energy



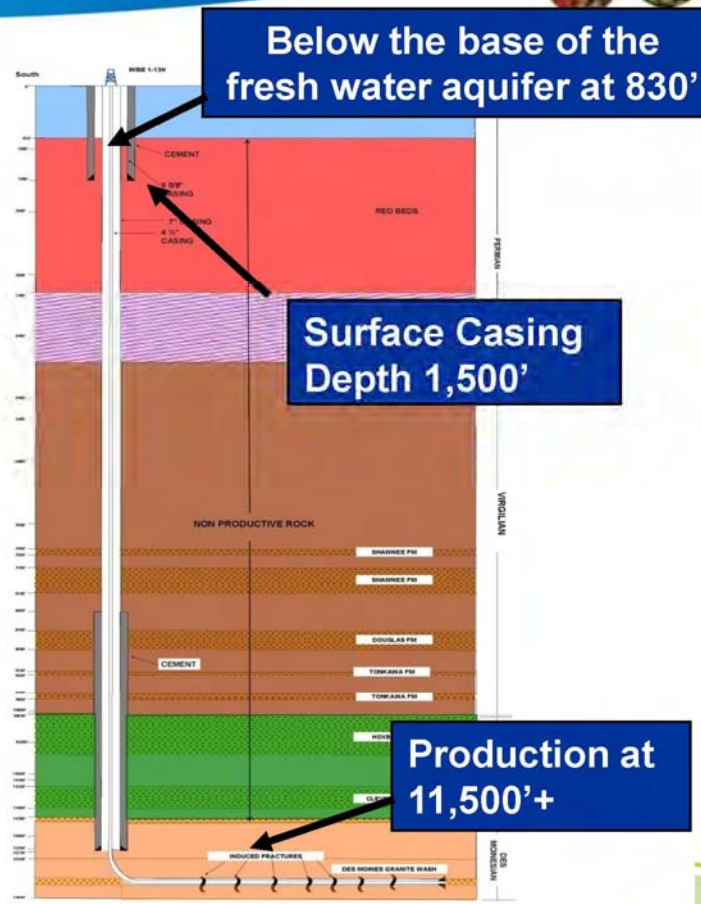
Source:"Modern Shale Gas, A Primer", p. 52

NARUC – Winter Meeting 2009

Fresh Water Aquifers Protected by Cement, Steel, and Thousands of Feet of Rock

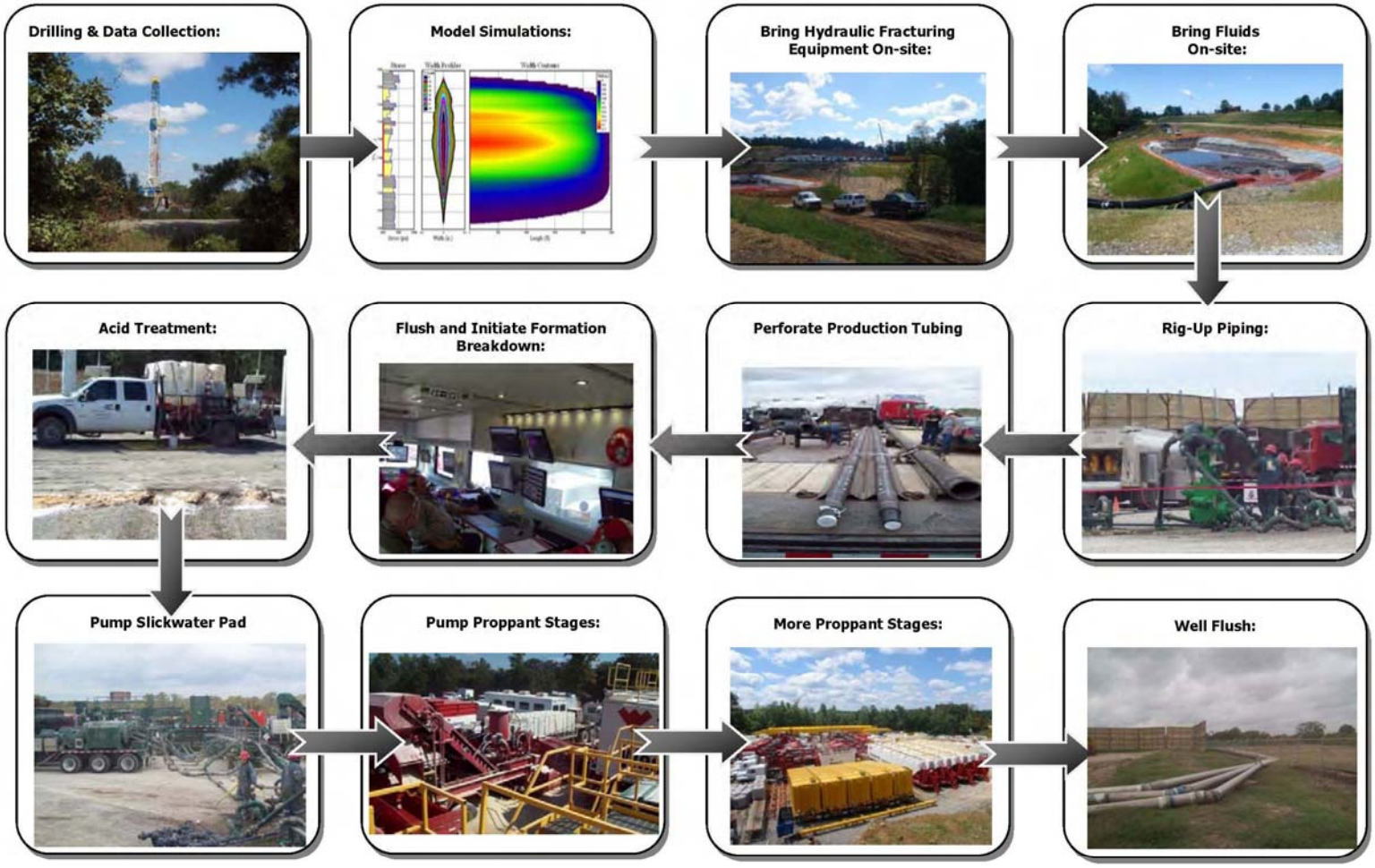
- The fracing process takes place <u>2 miles</u> below the base of the fresh water aquifer

Cross section of a Haynesville well bore



Source: "Natural Gas – the Clean Energy Bridge", NARUC 2009 Winter Meeting, Tom Price, Chesapeake Energy

Process Flow of a Hydraulic Fracturing Job



Source: "Evaluating the Environmental Implications of Hydraulic Fracturing in Shale Gas Reservoirs", ALL Consulting, 2008. http://www.all-llc.com/publicdownloads/ArthurHydrFracPaperFINAL.pdf

Water Usage

EXHIBIT 37: ESTIMATED WATER NEEDS FOR DRILLING AND FRACTURING WELLS IN SELECT SHALE GAS PLAYS

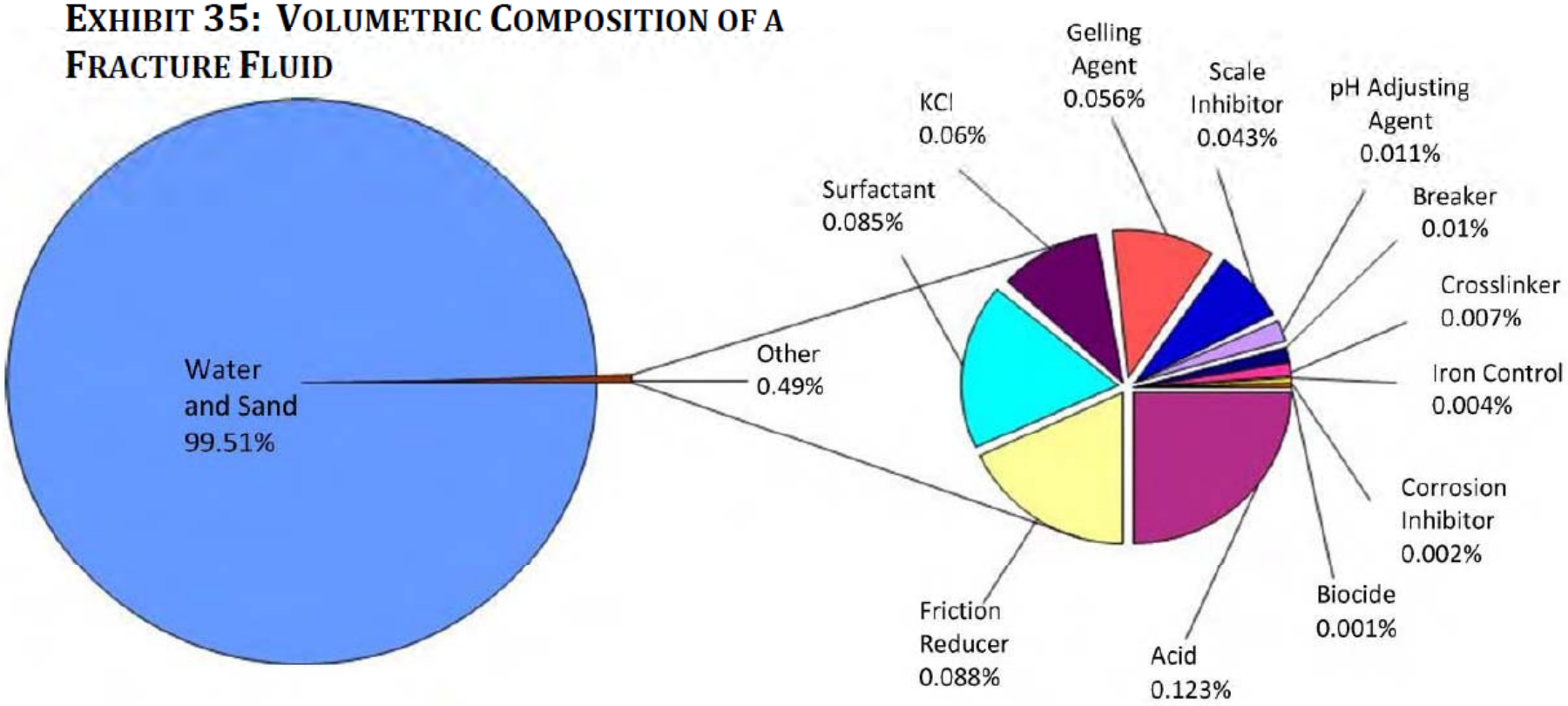
Shale Gas Play	Volume of Drilling Water per well (gal)	Volume of Fracturing Water per well (gal)	Total Volumes of Water per well (gal)
Barnett Shale	400,000	2,300,000	2,700,000
Fayetteville Shale	60,000*	2,900,000	3,060,000
Haynesville Shale	1,000,000	2,700,000	3,700,000
Marcellus Shale	80,000*	3,800,000	3,880,000

* Drilling performed with an air "mist" and/or water-based or oil-based muds for deep horizontal well completions.

Note: These volumes are approximate and may vary substantially between wells.

Source: "Modern Shale Gas, A Primer", p. 64

EXHIBIT 35: VOLUMETRIC COMPOSITION OF A FRACTURE FLUID



Source: "Modern Shale Gas, A Primer", p. 62

Typical Deep Shale Fracturing Mixture

More than 99% of the fracturing mixture is comprised of freshwater and sand. The remainder is additives; the main components are listed below.

FRACTURING FLUID ADDITIVES, MAIN COMPOUNDS AND COMMON USES

Additive Type	Main Compound	Purpose	Common Use of Main Compound
Acid	Hydrochloric acid or muriatic acid	Helps dissolve minerals and initiate cracks in the rock	Swimming pool chemical and cleaner
Antibacterial agents	Glutaraldehyde	Eliminates bacteria in the water that produce corrosive by-products	Disinfectant; sterilizer for medical and dental equipment
Breaker	Ammonium Persulfate	Allows a delayed break down of the gel	Used in hair coloring, as a disinfectant, and in the manufacture of common household plastics
Corrosion inhibitor	Formamide	Prevents the corrosion of the well casing	Used in pharmaceuticals, acrylic fibers and plastics
Crosslinker	Borate salts	Maintains fluid viscosity as temperature increases	Used in laundry detergents, hand soaps and cosmetics
Friction reducer	Petroleum distillate	"Slicks" the water to minimize friction	Used in cosmetics including hair, make-up, nail and skin products
Gel	Guar gum or hydroxyethyl cellulose	Thickens the water in order to suspend the sand	Thickener used in cosmetics, baked goods, ice cream, toothpaste, sauces and salad dressings
Iron control	Citric acid	Prevents precipitation of metal oxides	Food additive; food and beverages; lemon juice ~7% citric acid
Clay stabilizer	Potassium chloride	Creates a brine carrier fluid that prohibits fluid interaction with formation clays	Used in low-sodium table salt substitute, medicines and IV fluids
pH adjusting agent	Sodium or potassium carbonate	Maintains the effectiveness of other components, such as crosslinkers	Used in laundry detergents, soap, water softener and dishwasher detergents
Proppant	Silica, quartz sand	Allows the fractures to remain open so the gas can escape	Drinking water filtration, play sand, concrete and brick mortar
Scale inhibitor	Ethylene glycol	Prevents scale deposits in the pipe	Used in household cleansers, de-icer, paints and caulk
Surfactant	Isopropanol	Used to reduce the surface tension of the fracturing fluids to improve liquid recovery from the well after the frac	Used in glass cleaner, multi-surface cleansers, antiperspirant, deodorants and hair color
Water	Water	Used to expand fracture and deliver proppant (sand)	Landscaping, manufacturing

Source: Chesapeake Marcellus Hydraulic Fracturing Fact Sheet, March 2010

Ground Water Protection Council to Develop and Implement a State-Based System Disclosing Chemicals Used in Hydraulic Fracturing

GWPC Board Supports Complete Public Disclosure of Chemical Compositions Per Well

RESOLUTION 10-1: REGARDING THE AVAILABILITY OF INFORMATION ABOUT THE CHEMICAL CONSTITUENTS USED IN THE PRACTICE OF HYDRAULIC FRACTURING

WHEREAS, the practice of hydraulic fracturing typically involves the use of an engineered fluid system that contains chemical additives; and

WHEREAS, it is in the best interest of the public that information concerning the individual chemical constituents used in hydraulic fracturing be made available through the states; and

WHEREAS, the experience and capability exists within the Ground Water Protection Council and its member states to develop electronic systems to gather, store and disseminate information about the chemicals used in hydraulic fracturing;

NOW THEREFORE BE IT RESOLVED THAT, the GWPC, in concert with other state representative organizations, intends to develop and implement a system to enhance access to state and other pertinent information concerning chemicals used in hydraulic fracturing.

Pittsburgh, PA, September 27, 2010

FracFocus.org

(GWPC and IOGCC)

Home / Welcome / Publications / News & Updates / Links

Frac Focus
Chemical Disclosure Registry

HYDRAULIC FRACTURING HOW IT WORKS | GROUNDWATER PROTECTION | CHEMICAL USE | REGULATIONS BY STATE | FIND A WELL BY STATE | FREQUENT QUESTIONS

Groundwater
PROTECTION & WATER USAGE

Pure, clean groundwater. Nothing can replace it. This is why fresh-water aquifers are protected through strictly regulated exploration and production practices.

ABOUT GROUNDWATER PROTECTION >

Groundwater Protection

- Hydraulic Fracturing Water Usage
- Groundwater & Aquifers
- Groundwater Quality & Testing
- Well Construction & Groundwater Protection
- Fluid Flow in the Subsurface (Darcy's Law)

HYDRAULIC FRACTURING WATER USAGE

Hydraulic fracturing requires large quantities of water.

Oil and natural gas producers have developed multiple ways to obtain the water necessary for wells that are hydraulically fraced.

Building ponds and reservoirs to capture rain, recycling water and contracting with public works and farmers are some of the innovative ways the industry is obtaining, monitoring and regulating water usage in areas.

Read more

HOW CASING PROTECTS GROUNDWATER

Casing is a process that is regulated by the state for each hydraulically fractured well site.

Well casing acts as a protective barrier between hydraulic fracturing fluid, oil and natural gas that flows through the well and the fresh water aquifers. The process involves sealing the drilling well bore in multiple layers of cylindrical steel pipes encased in multiple layers of cement.

The casing layers extend underground with the Surface casing reaching anywhere from 50-1,500 feet below freshwater aquifers. Production casing can extend from 5,000-10,000 feet underground.

Looking for information about a *well site near you?*

Search for nearby well sites that have been hydraulically fractured to see what chemicals were used in the process.

Hydraulic Fracturing Installation

Source: Halliburton Presentation to OCC – March 2010

Weatherford

PALFINGER CRANE
PK 32080

Fracturing Technologies

Coleman
Mach

Pressure 1
10541
Pressure 2
10345
Annulus
2999
Surf Press
15
REC
Start Job
Tag Event
Reset Totals
Job Setup
Stg Time Remaining
8.94
Job Time Remaining
410.32
Stage
1
Prop SGU 2.65
Blender SGU 1.00
Inline SGU 1.00
Fluid SGU 1.00
Viscosity DAS 0
Pressure Warning
OVER PRESSURE
Clean Rate
21.4
Clean Total
108
Slurry Rate
20.8
Slurry Total
105.1
Slurry Stg Total
104
Clean Stg Total
107
Stg Target Vol
292
Stg Vol Remaining
187
Job Target Vol.
8663
RPM Prop Total
0
CAS
Suction Rate
0
Total
0
Truck Side
10152
Transfer Total
0
Target
0.00
Ratiometric
0.00
Blender Density
0.00
3" dens
0.01
Blender Prop Total
0
3" total
102

Flowback Water Sources for Recycling are Variable

Sample	#1	#2	#3	#4	#5	#6	#7	#8	*#9*	#10	#11
Specific Gravity	1.026	1.036	1.019	1.012	1.07	1.1	1.17	1.105	1.066	1.02	
pH	7.92	7.51	7.91	6.61	6.72	6.68	6.05	7.11	7.04	6.83	
Bicarbonate	1,010	717	1,190	259	183	193	76	366	366	839	94
Chloride	19,400	29,400	10,000	6,290	59,700	87,700	153,000	96,400	58,300	11,500	19,730
Sulfate	34	0	88	67	0	0	0	670	479	0	3,100
Calcium	630	1,058	294	476	7,283	10,210	20,100	4,131	2,573	282	451
Magnesium	199	265	145	49.6	599	840	1690	544	344	40.7	1,330
Barium	49.4	94.8	6.42	6.24	278	213	657	1.06	5.1	97.4	
Strontium	107	179	44.7	74.3	2,087	2,353	5,049	178	112	45.3	
Total Iron	4.73	25.7	8.03	14	27.4	2.89	67.6	26.4	33.8	63.4	0
Aluminum	0.17	0.21	0.91	0.38	0.18	0	0.1	0.17	0.78	1.12	
Silica	33.8		40.7							33.2	
Boron	28.2	27.1	26.7	8.82	45.1	73.1	80.4	94.5	65.7	4.79	4.5
Potassium	192	273	78.7	85.8	977	1,559	2,273	2,232	1,439	135	
Sodium	10,960	16,450	5,985	3,261	26,780	39,990	61,400	54,960	32,600	7,048	11,307
TDS	**33,300**	**49,300**	**18,200**	**10,800**	**98,600**	**144,000**	**252,000**	**160,000**	**97,700**	**20,200**	**36,092**
TSS	57	246	50	30	10	12	32	120	13,762	1,004	
TOC	89	64	133	180	218	70	143	266	235	344	
				fbw	fbw	pw	pw	pw	fbw		

Woodford | Marcellus | Bakken | Piceance | GOM Sea water

Source: Halliburton Presentation to OCC – March 2010

What's The Problem With Flowback Water?

- Can pick up contaminants down hole such as:
  - Barium, Calcium Bicarbonate, Iron, Magnesium Sulfate, Sodium Chloride, Strontium
- Possibly comes back with:
  - Organic materials (bacteria from rock, chemicals from job)
  - Polymer from friction reducer
  - Residual Hydrocarbons
  - Suspended solids (clay, iron oxides, silica)

Source: Halliburton Presentation to OCC – March 2010

Weatherford
CAUTION

EMPOWERING OKLAHOMA

Oklahoma Corporation Commission

ENERGY•TRANSPORTATION•UTILITIES

- Agency established by Constitution at statehood (1907)
- 3 Commissioners, elected statewide, daily meetings
- 15,000 Commission Orders issued in 2009
- 440 Employees
- The OCC has broad regulatory powers over:
  - oil and gas drilling, production and pollution abatement
  - public utilities (telephone, electric and natural gas)
  - trucking
  - railroad crossings
  - petroleum storage tanks and fueling stations
  - pipeline safety

Oklahoma Oil and Gas Industry

- Active wells (drilled, not plugged)
  44,000 natural gas
  84,000 oil
  10,500 injection/disposal
  138,500 Total active wells
- ~310,000 plugged and abandoned wells
- ~450,000 wells drilled in Oklahoma history
- 100,000+ hydraulically fractured oil and gas wells
- 2,660 active operators of oil and gas wells
- ~40,000 miles of pipelines under commission jurisdiction

(*Well Data is as of year end 2010; updated 3/23/2011, as supplied by OCC Oil and Gas Division)*

- $160.4 billion 2010 Gross State Product

(Source: OSU Business School Outlook 2011 Estimate)

	Oklahoma Oil Production		Oklahoma Natural Gas Production		
2007	60,952,000 bbls	$4.2 billion	1,783,682	MMcf	$11.1 billion
2008	64,065,000 bbls	$6.2 billion	1,886,710	MMcf	$13.8 billion
2009	67,017,000 bbls	$3.8 billion	1,857,777	MMcf	$6.6 billion
2010	69,515,000 bbls	$5.2 billion	1,827,360	MMcf	$8.5 billion

(Source: U.S. Energy Information Administration, Oklahoma Tax Commission, updated 8/10/2011)

Oklahoma Corporation Commission
Oil and Gas Inspection and Enforcement

		FY 2007	FY 2008	FY 2009	FY 2010	FY2011
Inspections	Well Site	67,666	74,873	73,661	58,434	52,237
	UIC	9,870	9,865	9,844	8,280	6,188
	Total	77,536	84,738	83,505	66,714	58,425
Complaints	Pollution	1,377	1,201	1,079	926	933
	Other	1,939	1,928	1,731	1,689	1,725
Fines ($)*	Assessed	$395,386	$245,750	$450,400	$127,800	$235,500
	Collected	$316,736	$227,250	$294,600	$97,650	$199,250

*These numbers are for cases filed in the fiscal year and reflect assessments and collections through June 30.

UIC = Underground Injection Control - EPA program for Class 2 Wells

Updated 8/10/2011

Federal Regulation of the oil and gas industry includes:

- MMS: Minerals Management Service (outer continental shelf)
- OSHA: Occupational Safety and Health Administration
- CWA: Clean Water Act
- SDWA: Safe Drinking Water Act
- CAA: Clean Air Act
- NEPA: National Environmental Policy Act
- ESA: Endangered Species Act
- CERCLA: Comprehensive Environmental Response, Compensation, and Liability Act
- SARA: Superfund Amendments and Reauthorization Act

States and state agencies may adopt their own standards; however, these must be at least as protective as the federal standards they replace, and may even be more protective in order to address local conditions.

MERGE U.S. Electric Generation Deployment

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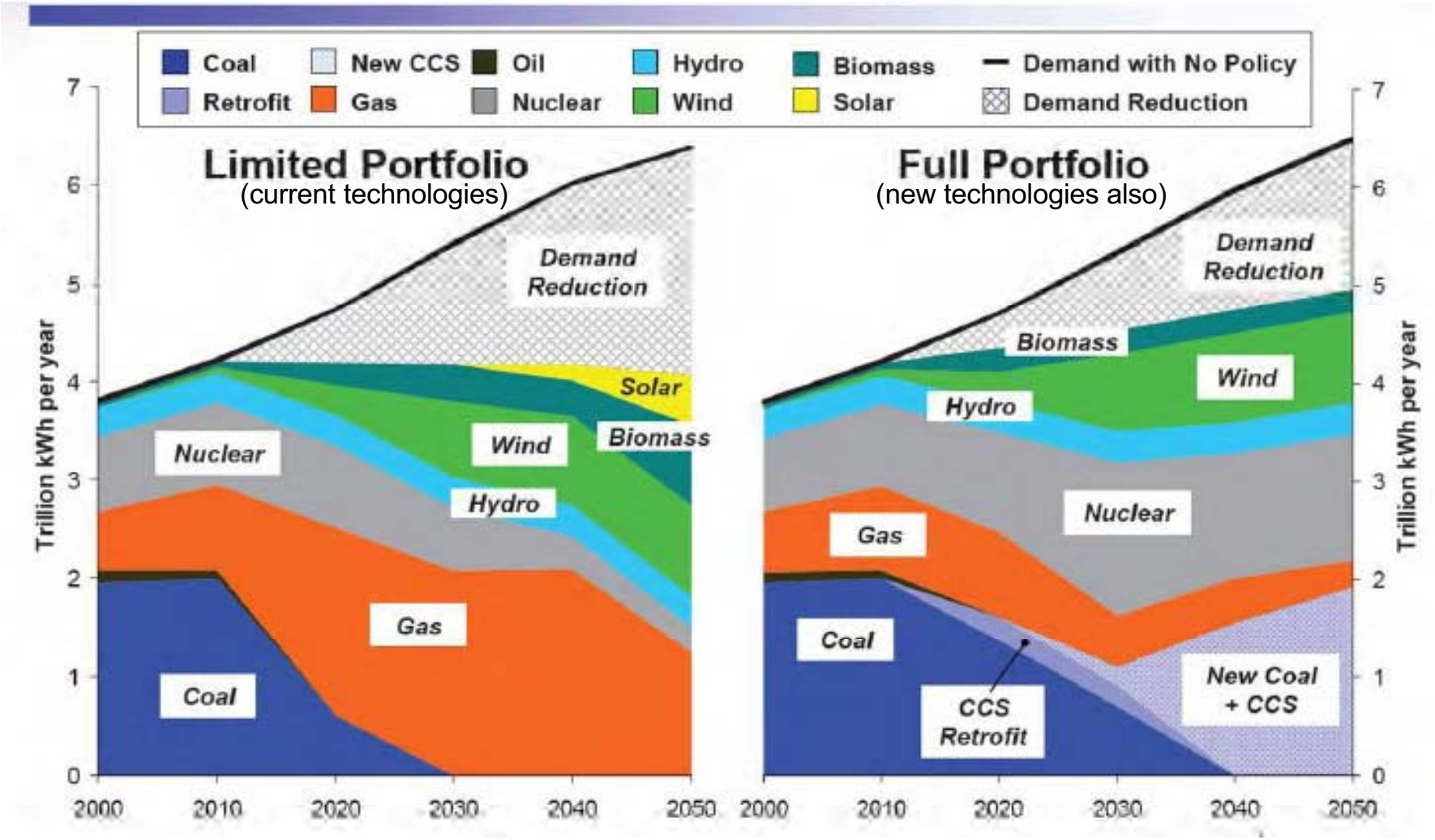
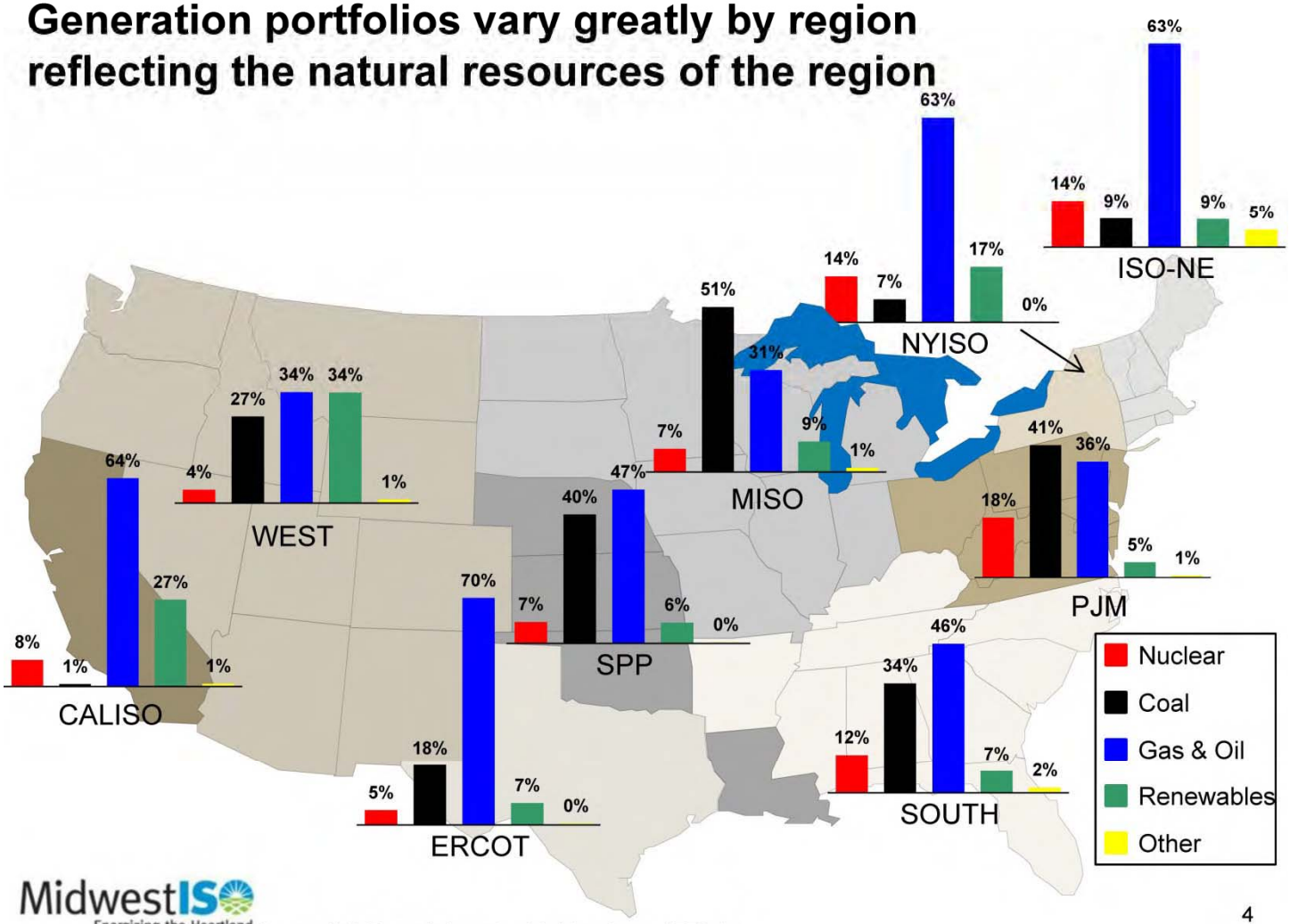


MERGE is a general equilibrium econometric model used to analyze impacts of significant CO_2 emission reductions.

Generation portfolios vary greatly by region reflecting the natural resources of the region

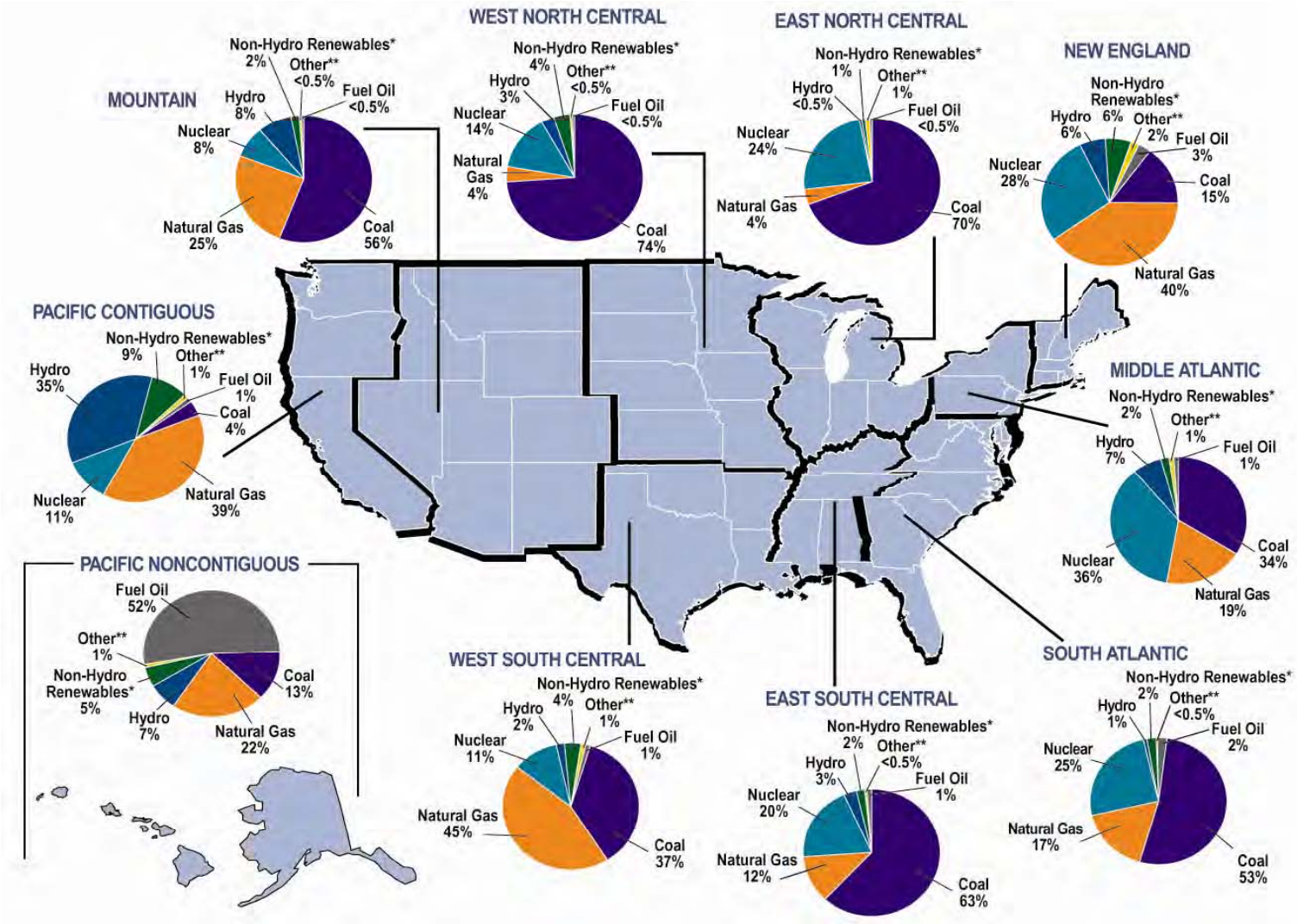


MidwestISO Energizing the Heartland

Source: U.S. Energy Information Administration and RTO data

4

Different Regions of the Country
Different Fuel Mixes to Generate Electricity



*Includes generation by agricultural waste, landfill gas recovery, municipal solid waste, wood, geothermal, non-wood waste, wind, and solar.

** Includes generation by tires, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Sum of components may not add to 100% due to independent rounding.

Source: U.S. Department of Energy, Energy Information Administration, Power Plant Operations Report (EIA-923); 2008 preliminary generation data.

January 2010

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The Madness of New York

(Wall Street Journal, 12/16/2010, p. A22)

New York State urgently needs more jobs and new tax revenue, so naturally its political class has decided to reject one of the best economic opportunities in decades.

American was suddenly able to extract, cost-effectively, huge amounts of natural gas from tightly packed shale rocks.

Instead, New York has imposed a de facto drilling moratorium because of dubious environmental fears.

No wonder the once great Empire state can't pay its bills and keeps losing taxpayers to places that want their citizens to prosper.

EPA vs. Texas

- Environmental Protection Agency (EPA) orders Range Resources to locate and stop the source of a natural gas seep in Parker County
- Texas Railroad Commission (RRC) says incident under investigation since August, 2010 and EPA actions are premature
- RRC calls EPA intervention “Washington politics of the worst kind”
- RRC states that the “public is poorly served” if this is another EPA action designed to reach pre-determined conclusions and to generate headlines rather than conduct a successful environmental investigation
- Range Resources reports water well drilling in the area abandoned in 2005 due to methane contamination from natural sources
- On March 22, 2011, the Texas Railroad Commission ("RRC") formally determined that Range Resources was not responsible for methane contamination in drinking water wells in the Barnett Shale, allowing Range to continue to operate its wells

State Regulation is better than EPA Regulation

- Geology differs among/within states, not one size fits all
- Water availability is a local issue and is best allocated by state/local authorities
- Local knowledge of specific aquifers and producing gas formations
- States can adopt rules for specific geographic areas--field rules
- States can adopt, amend rules quickly to respond to changing circumstances, technology
- State Inspectors live in the area and can react more quickly
- Historically, EPA has focused on surface water, not groundwater
- EPA traditionally grants primacy for inspection/enforcement to states

NARUC Resolution Supporting State Regulation of Hydraulic Fracturing

WHEREAS, The National Association of Regulatory Utility Commissioners has observed with great concern the current debate in Congress over the appropriate method for regulating the use of hydraulic fracturing to complete oil and gas wells; *and*

WHEREAS, Hydraulic fracturing is a proven technology with a long history of environmentally safe use in the completion of oil and gas wells; *and*

WHEREAS, The oil and gas producing States regulate hydraulic fracturing as a component of their regulatory programs for the drilling, completion, operation, and plugging of oil and gas wells; *and*

WHEREAS, The reservoirs that produce oil and gas are highly variable geologically and separated geographically across the oil and gas producing States such that State regulatory agencies are best suited by local expertise and experience to effectively regulate hydraulic fracturing; *and*

WHEREAS, State regulatory agencies are the most appropriate regulatory bodies to provide oversight and protection of hydrologically and environmentally sensitive localities as they relate to hydraulic fracturing; *and*

WHEREAS, The regulation of hydraulic fracturing under the federal Safe Drinking Water Act would add burdensome and unnecessary regulatory requirements to the drilling and completion of oil and gas wells, thereby increasing costs of producing domestic natural gas resources without any ancillary benefit to public health, safety or the environment; *and*

WHEREAS, The increased cost of producing domestic natural gas resources will reduce domestic supplies of natural gas, increase utility prices, and other costs to consumers, reduce tax and royalty revenues for local, State, and federal governments; and increase the nation's dependence on foreign energy imports; *and*

WHEREAS, The Interstate Oil and Gas Compact Commission (IOGCC) conducted a survey of oil and gas producing States, which found that there were no known cases of ground water contamination associated with hydraulic fracturing, and set forth its opposition to federal regulation of hydraulic fracturing under the underground injection control program in Resolution 09.011, dated January 7, 2009, "Urging Congress Not to Remove Exemption of Hydraulic Fracturing from Provisions of the Safe Drinking Water Act;" *now, therefore be it*

RESOLVED, That the Board of Directors of the National Association of Regulatory Utility Commissioners, convened at its 2009 Summer Committee Meetings in Seattle, Washington, supports continued jurisdiction of the States to conserve and properly regulate oil and gas production in their unique geological and geographical circumstances.

Sponsored by the Committee on Gas, Adopted by the NARUC Board of Directors, July 22, 2009