IOGCC Shale Gas Task Force

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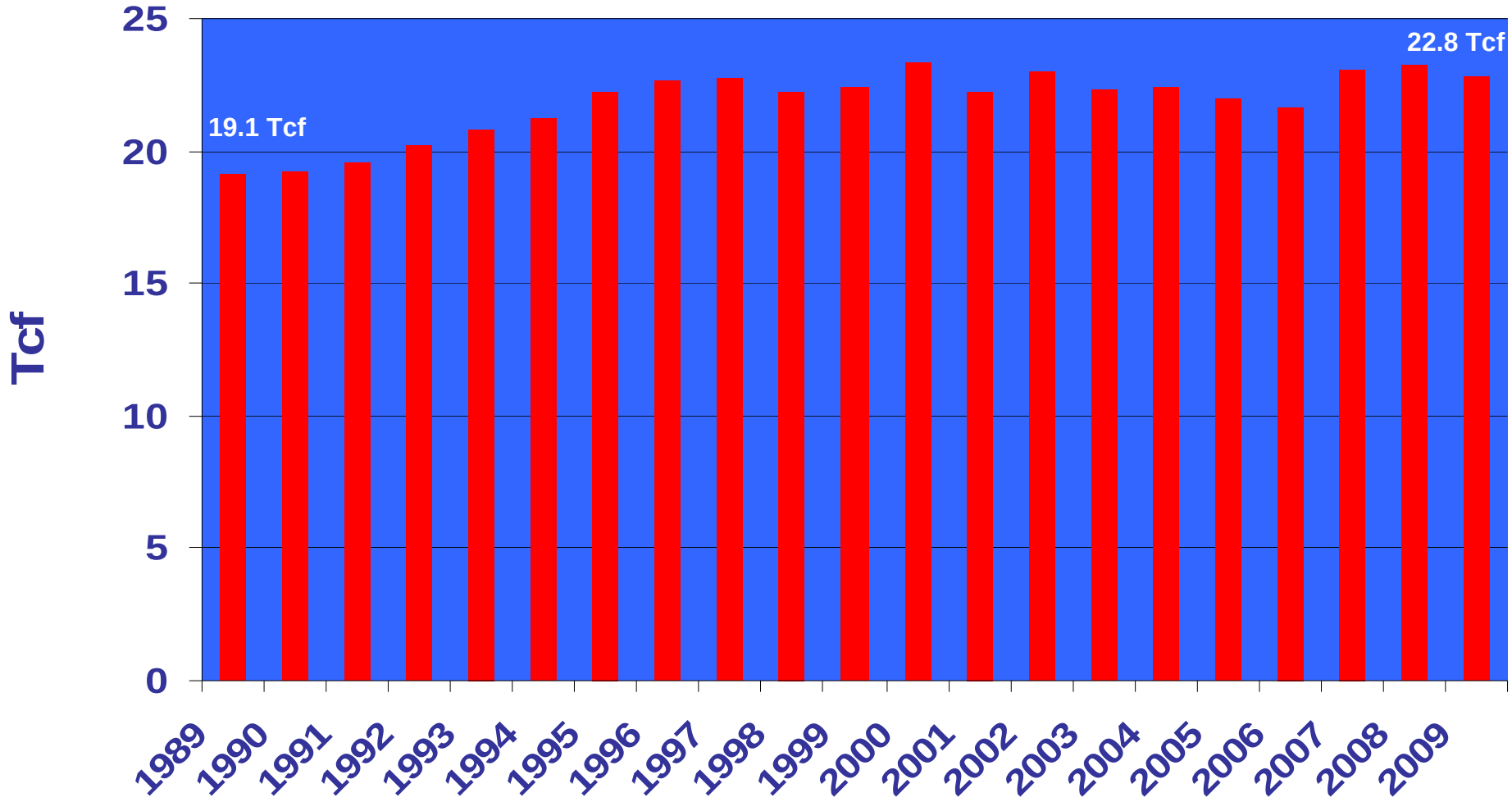
Overview of Shale Play Development

- Natural gas production from hydrocarbon rich shale formations is one of the most rapidly expanding trends in domestic production.
- As traditional sources of natural gas continue to be depleted, new sources of supply, such as shale gas, must be developed in order to continue to meet the energy demands.
- Hydraulic fracturing and horizontal drilling have allowed previously unrecoverable sources of gas to be developed in an economical and environmental safe manner.
- Because it is located in both traditional and non-traditional production locations, shale gas development presents unique economic opportunities to maximize each state's resources in a manner that is environmentally safe.
- The development of natural resources expands the economy of local communities by creating jobs and providing residents increased capital through royalty payments.
- State governments benefit from increased natural gas production through increased tax revenues.
- Because of its role in alternative energy strategies and reducing greenhouse gas emissions, natural gas use is expedited to continue to rise.

U.S. Natural Gas Consumption from 1989 to 2009

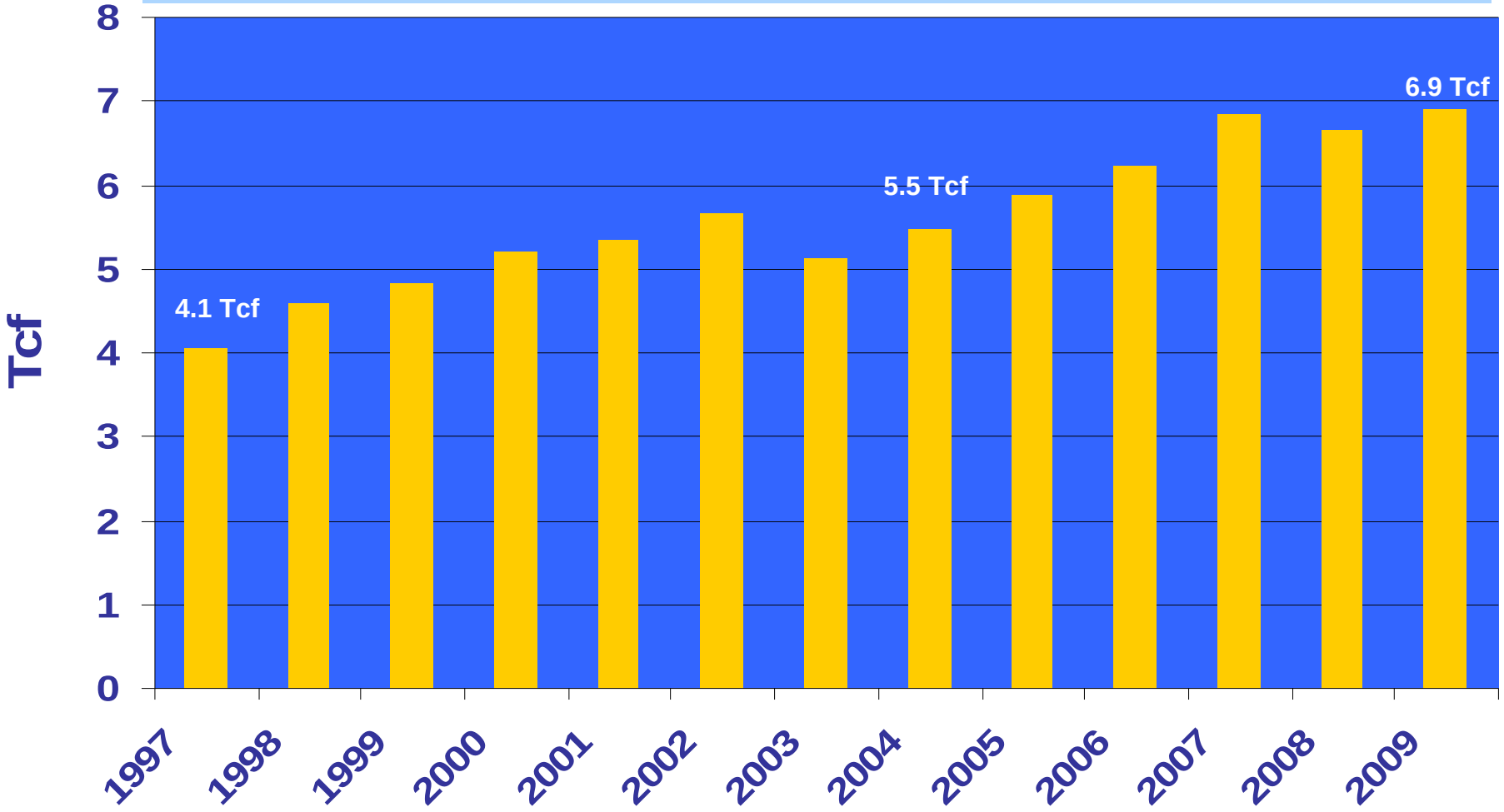
Over the last 20 years, consumption of natural gas has risen by 19 percent.



Source: Based on data from EIA Data 1 US Natural Gas Consumption Data

Natural Gas Electric Power Consumption from 1997 to 2009

The consumption of natural gas has grown in the electricity generation sector by 68 percent over the last 12 years.



Source: Based on data from EIA Data 1 US Natural Gas Consumption Data

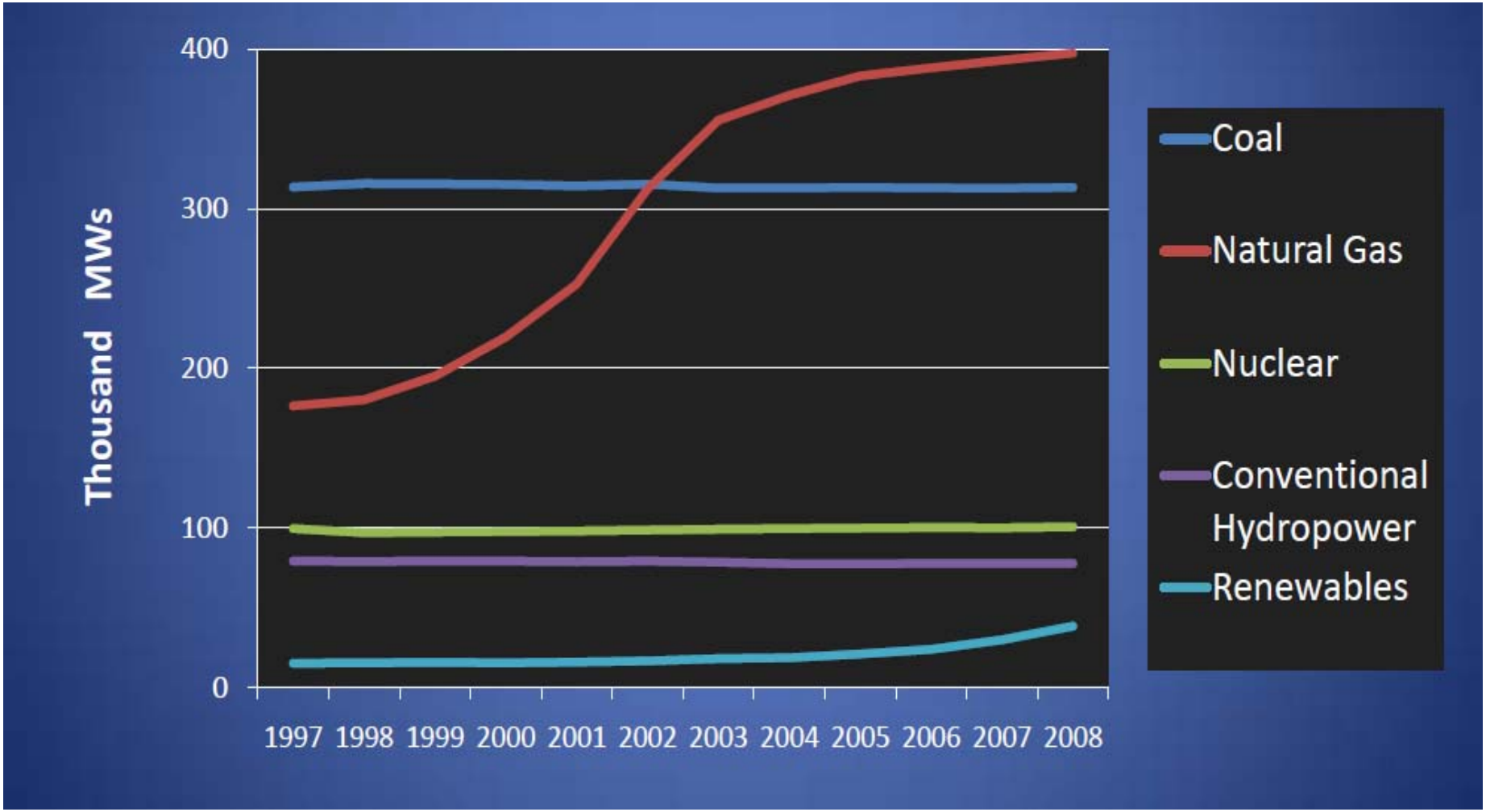
Natural Gas Development

- Natural gas accounts for 29 percent of the United States' total energy supply (2009) and plays a key role in meeting our energy demand.
- Although the U.S. currently produces approximately 21 trillion cubic feet (Tcf) per year additional sources of supply must be developed for three main reasons:
  - Traditional sources of supply have been depleted and new sources must be developed to account for this loss.
  - Consumption of natural gas is expected to rise because natural gas is seen by many as an essential part of any strategy to implement alternative forms of energy to combat global warming.
  - To meet the national goal of increased energy independence, additional production is needed because U.S. production is not sufficient to meet demand.

Natural Gas Development and Global Warming

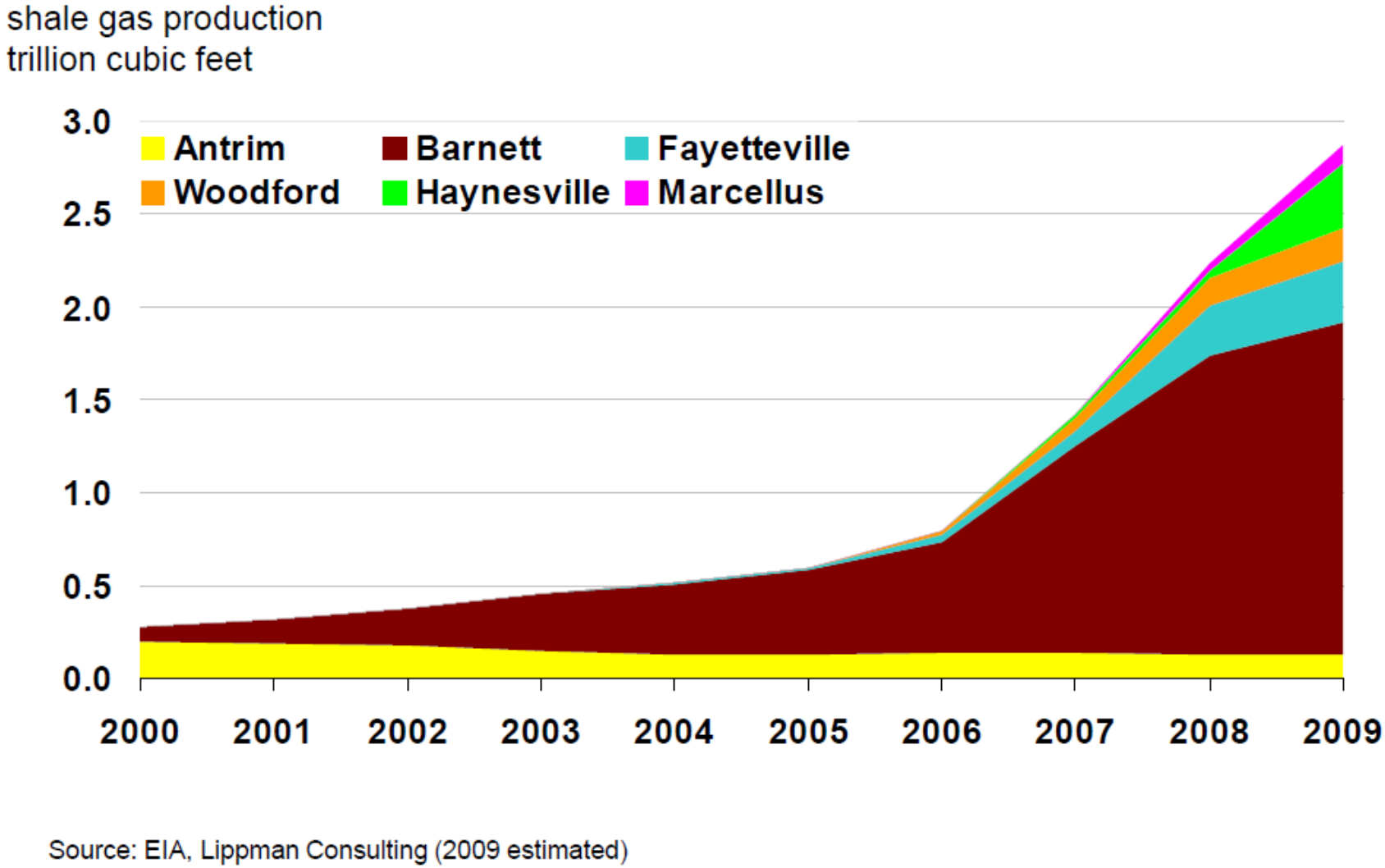
- Increased production from new sources is necessary because natural gas is an essential element of strategies designed to combat the challenges associated with global warming.
- The use of natural gas in electric generation is growing at a rapid pace.
  - Since 2004, the amount of natural gas used to generate electricity rose by 26 percent.
  - Compared to coal, natural gas emits 44 percent less carbon dioxide, 80 percent less nitrogen oxides, and 99 percent less sulfur dioxide.
- Of all fossil fuels, natural gas is be far the cleanest burning.
- Renewable sources, such as wind and solar, require a supplemental energy source when weather conditions or energy storage capacity is not available.
- Because of its wide availability on near instantaneous demand and its environmental benefits compared to other sources, natural gas is uniquely suited to serve as a supplemental supply for renewable energy sources.

Existing Net Summer Capacity by Energy Source



Source: From Hydropower: A Comparative Energy Review by J. Mark Robinson; JMR Energy Infra, LLC

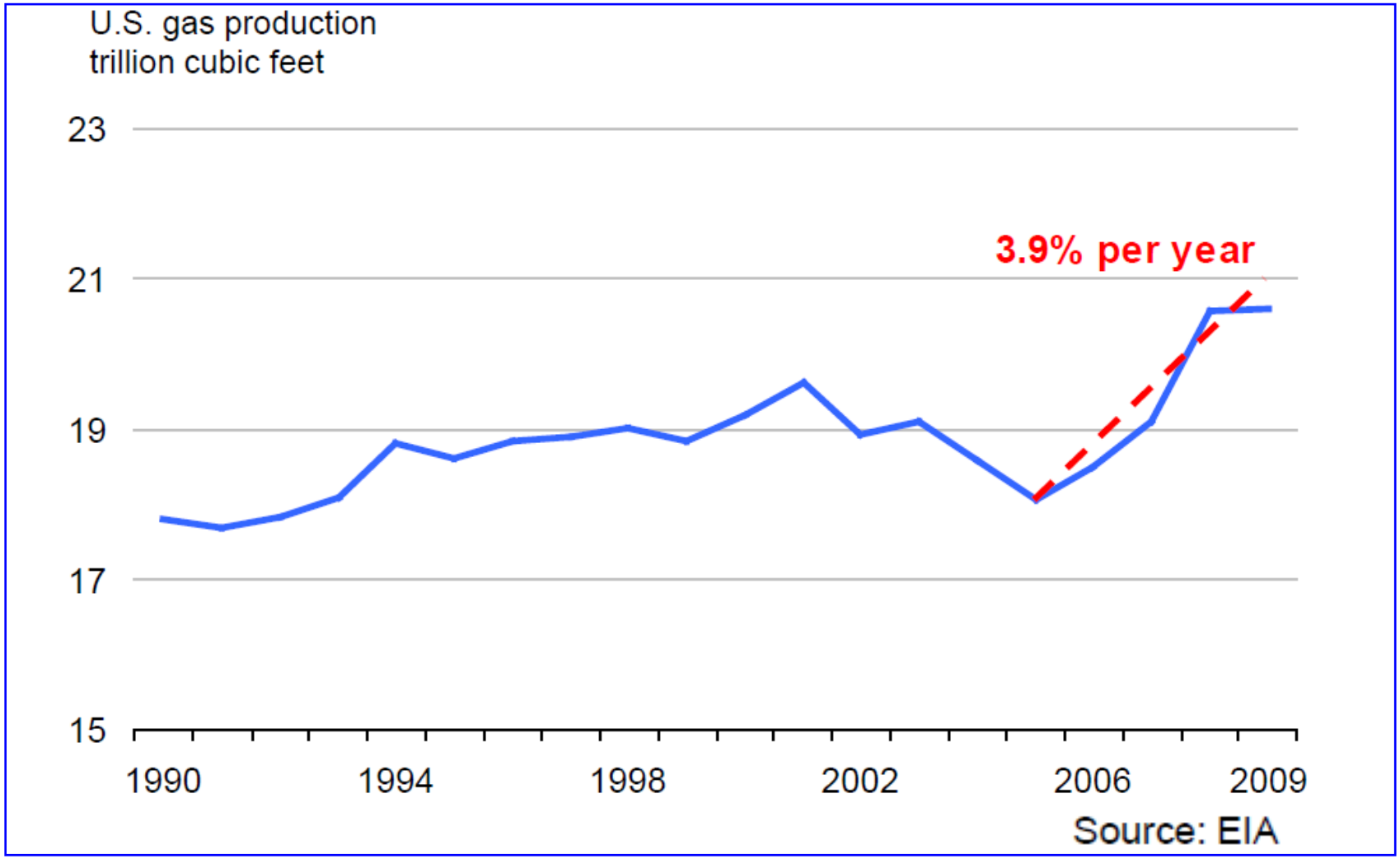
Shale Gas Production



Source: EIA, Lippman Consulting (2009 estimated)

Source: Glen Sweetnam, EIA, April 7, 2010 at 2010 Energy Conference.

In the last five years, accelerated shale production has caused total U.S. gas production to trend upward



Source: Glen Sweetnam, EIA, April 7, 2010 at 2010 Energy Conference.

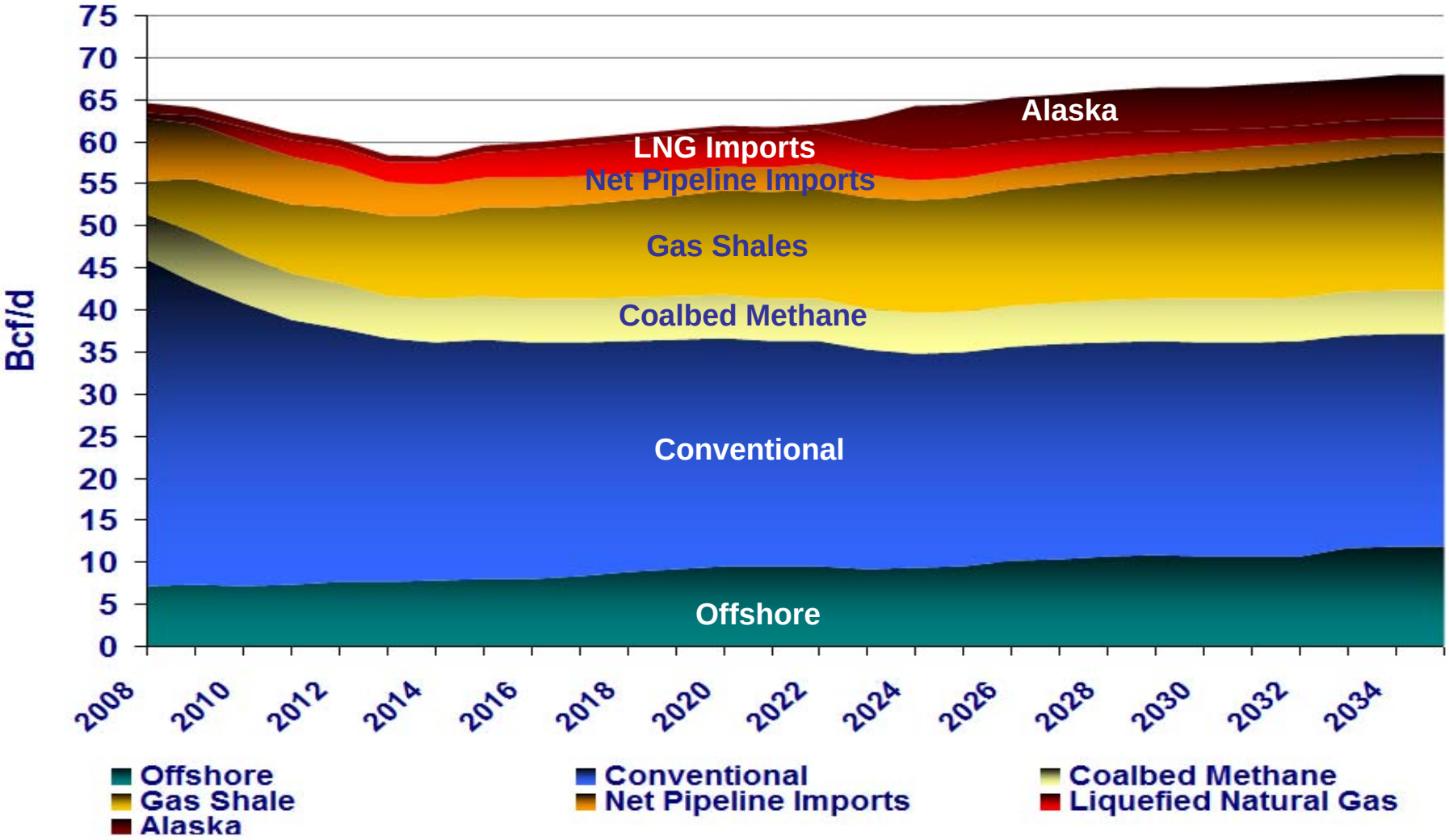
Need for New Production Sources

- Due to diminishing sources of traditional natural gas supplies, new production sources must be developed to meet the U.S. energy demand.
- Between 2008 and 2035, production from conventional onshore supply sources will decrease by 35 percent.
- From 2003 to 2008, the amount of natural gas produced from offshore wells has decreased by 42 percent.
- Half of the natural gas consumed is produced from wells drilled in the past 3.5 years.
- Shale gas is expected to provide the majority of the growth in gas supply over the next twenty years.

New Supplies of Natural Gas

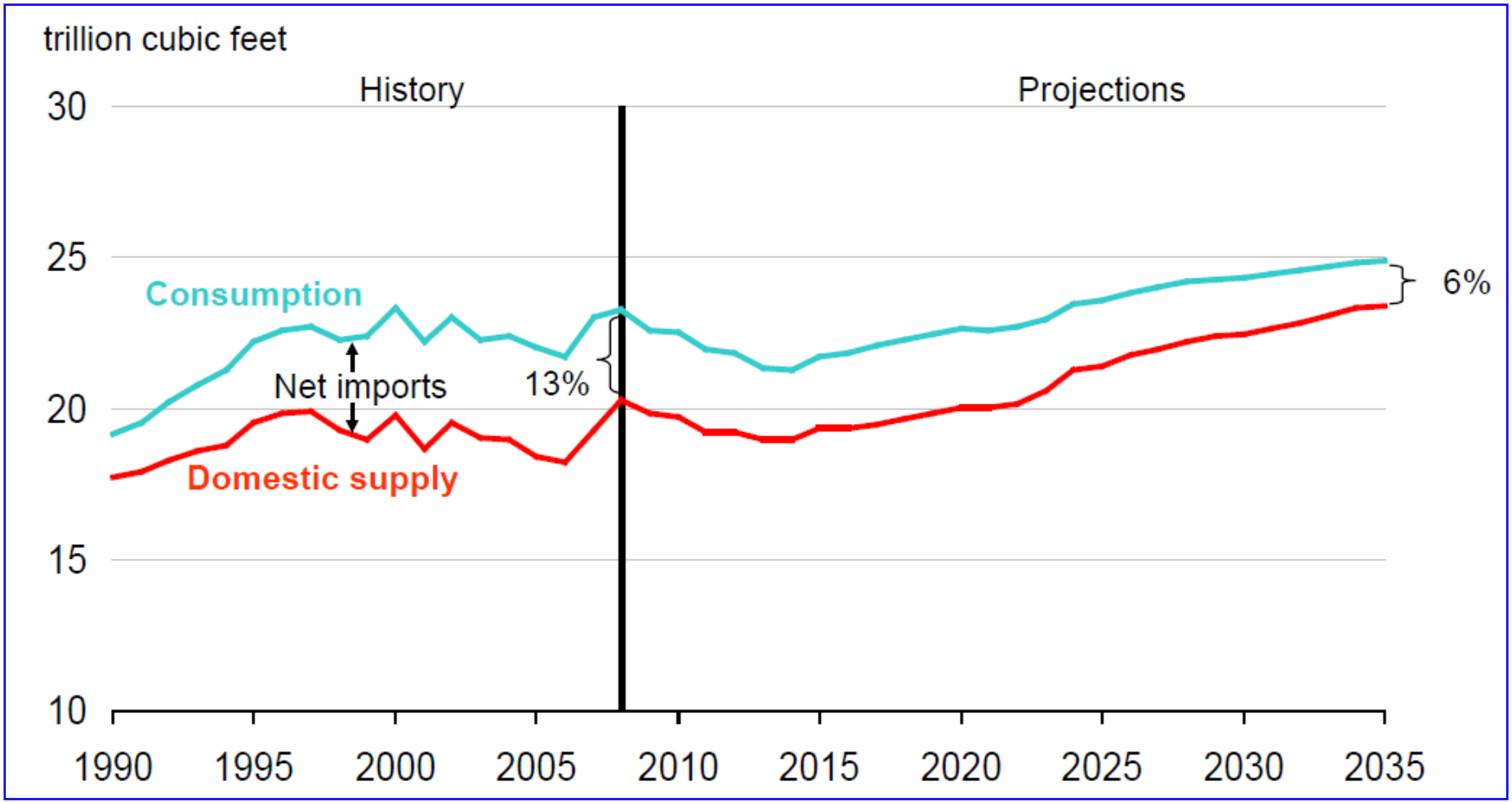
- New supplies of natural gas are important to striving for a goal of greater energy independence.
  - In 2009, consumption of natural gas outpaces domestic supply by approximately 2.75 Tcf per year.
  - The EIA estimates that this shortfall will be approximately 2.6 Tcf by 2020.
  - EIA's estimates that by 2035 the shortfall will be approximately 1.46 Tcf assuming increased domestic supply from shale sources and an Alaska Natural Gas Pipeline.
- The United States must import natural gas from foreign sources.
- Reliance on foreign sources of energy decreases our energy security and creates an outflow of money to foreign states and corporations.
- As a result, a broad consensus has developed that recognizes the need to develop domestic energy resources and no longer rely on unreliable and politically unstable foreign sources.

Future U.S. Gas Supply



Source: EIA's Annual Energy Outlook 2010 and EIA spreadsheets.

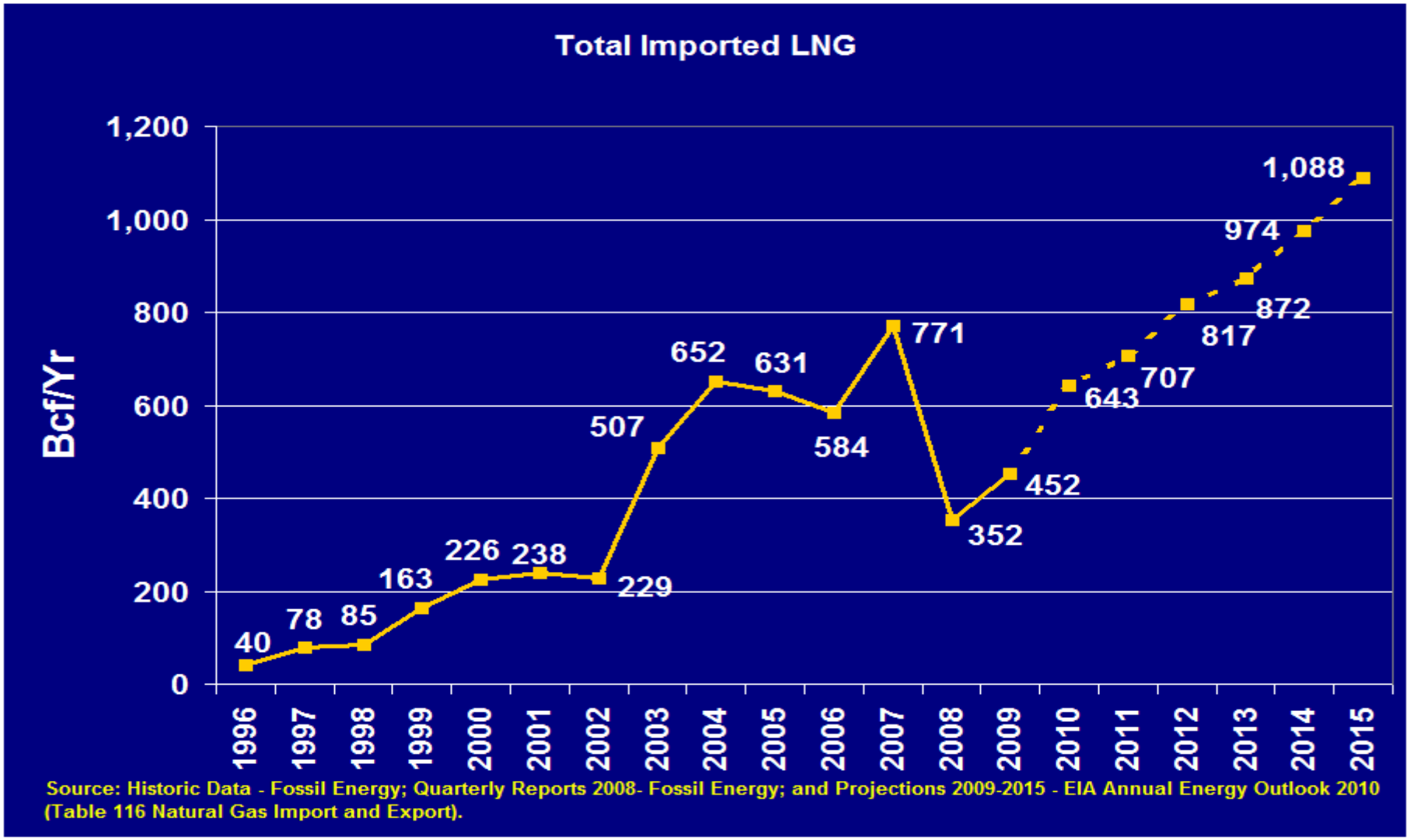
United States Natural Gas Imports



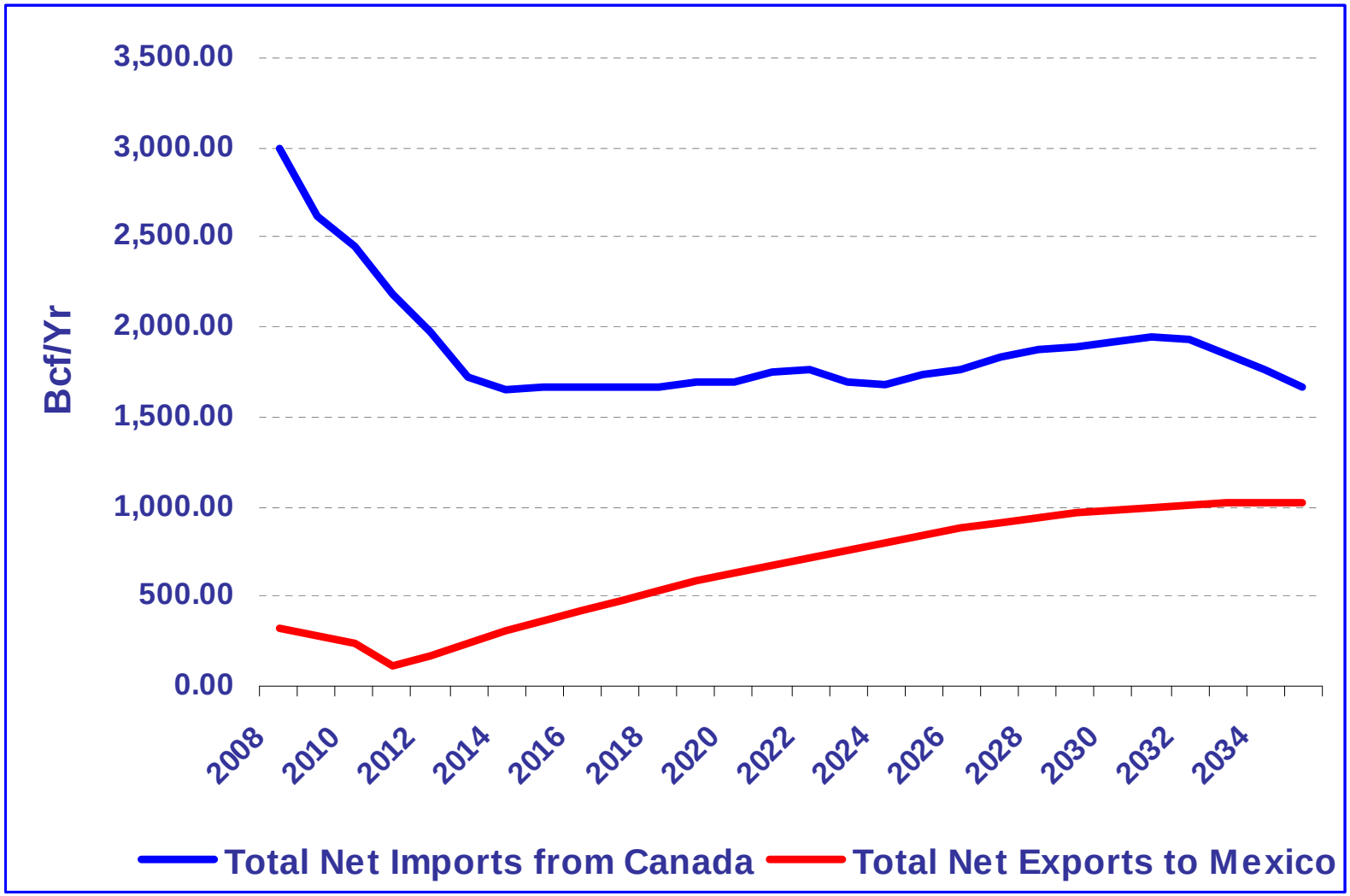
Source: EIA, *Annual Energy Outlook 2010*

Source: Glen Sweetnam, EIA, April 7, 2010 at 2010 Energy Conference.

Existing and Projected LNG Imports



Future Net Canadian Imports and Net Mexican Exports

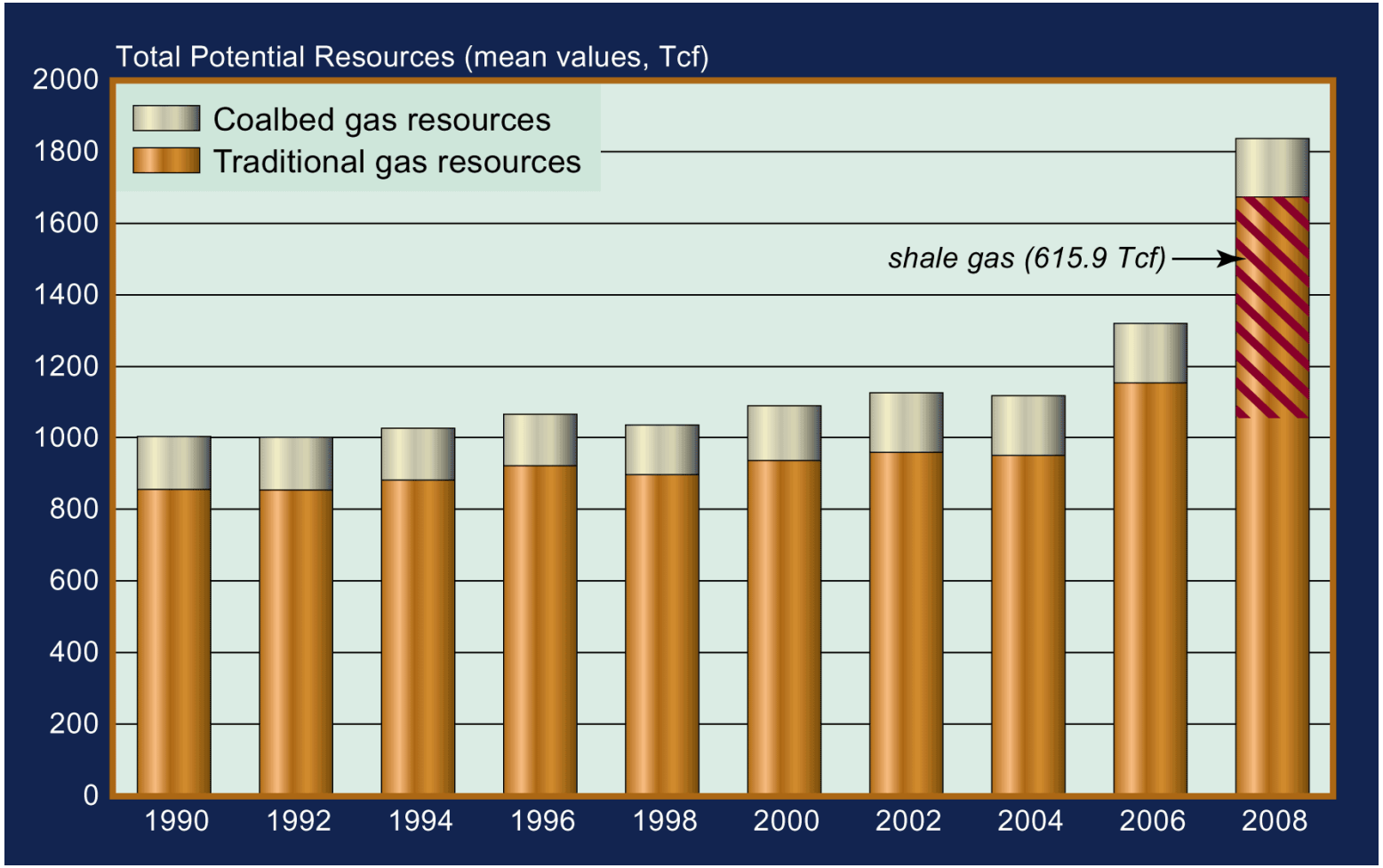


Source: Based on EIA Spreadsheets.

The growing importance of shale gas is substantiated by the fact that, of the 1,836 Tcf of total potential resources, shale gas accounts for 616 Tcf (33%).

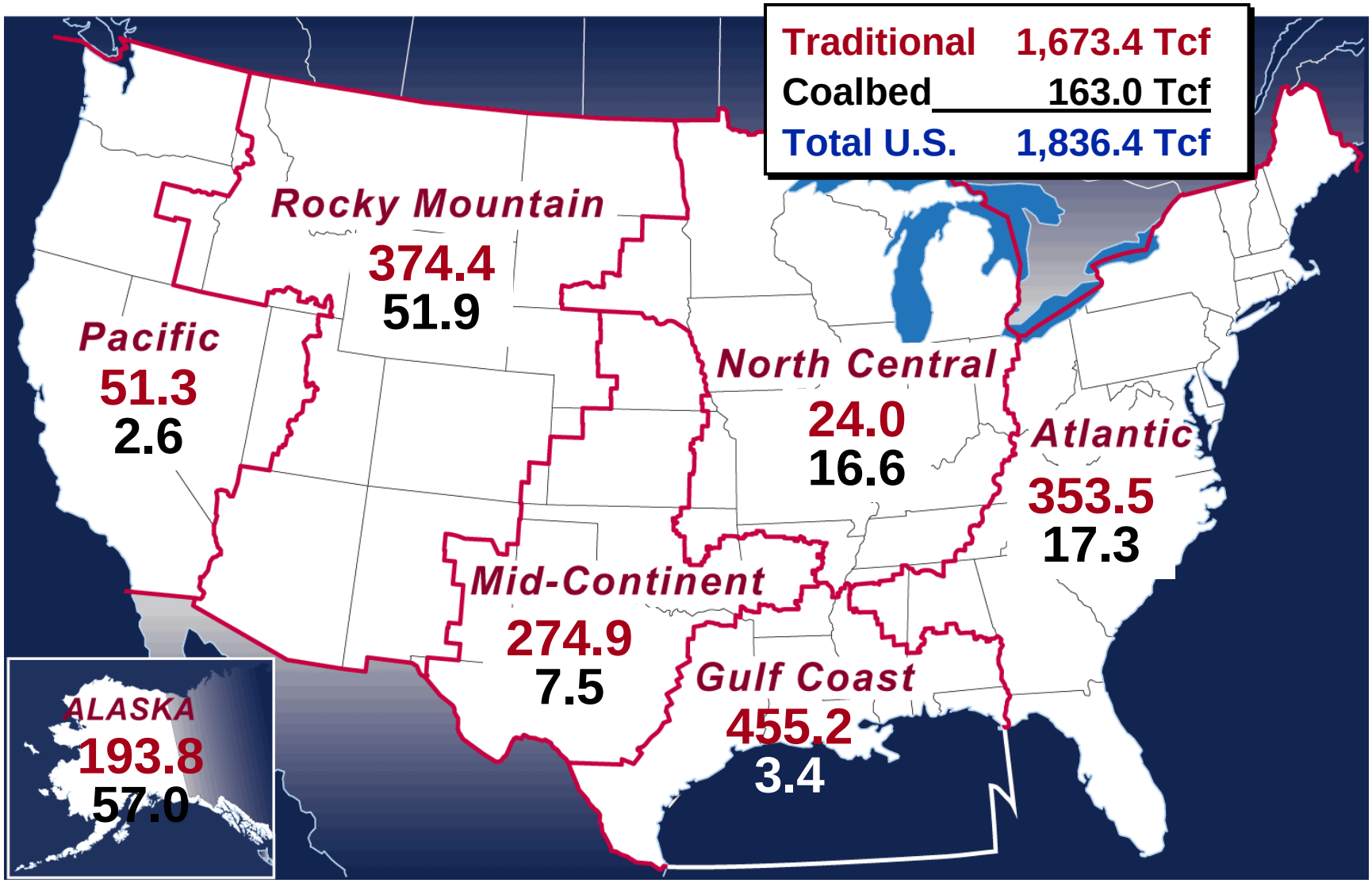
PGC Resource Assessments, 1990-2008

Total Potential Gas Resources (mean values)



Source: Report of the Potential Gas Committee (December 31, 2008) "Potential Supply of Natural Gas in the United States" June 18, 2009

Regional Resource Assessment



Source: Report of the Potential Gas Committee (December 31, 2008) "Potential Supply of Natural Gas in the United States" June 18, 2009

Technically Recoverable Gas in the U.S.

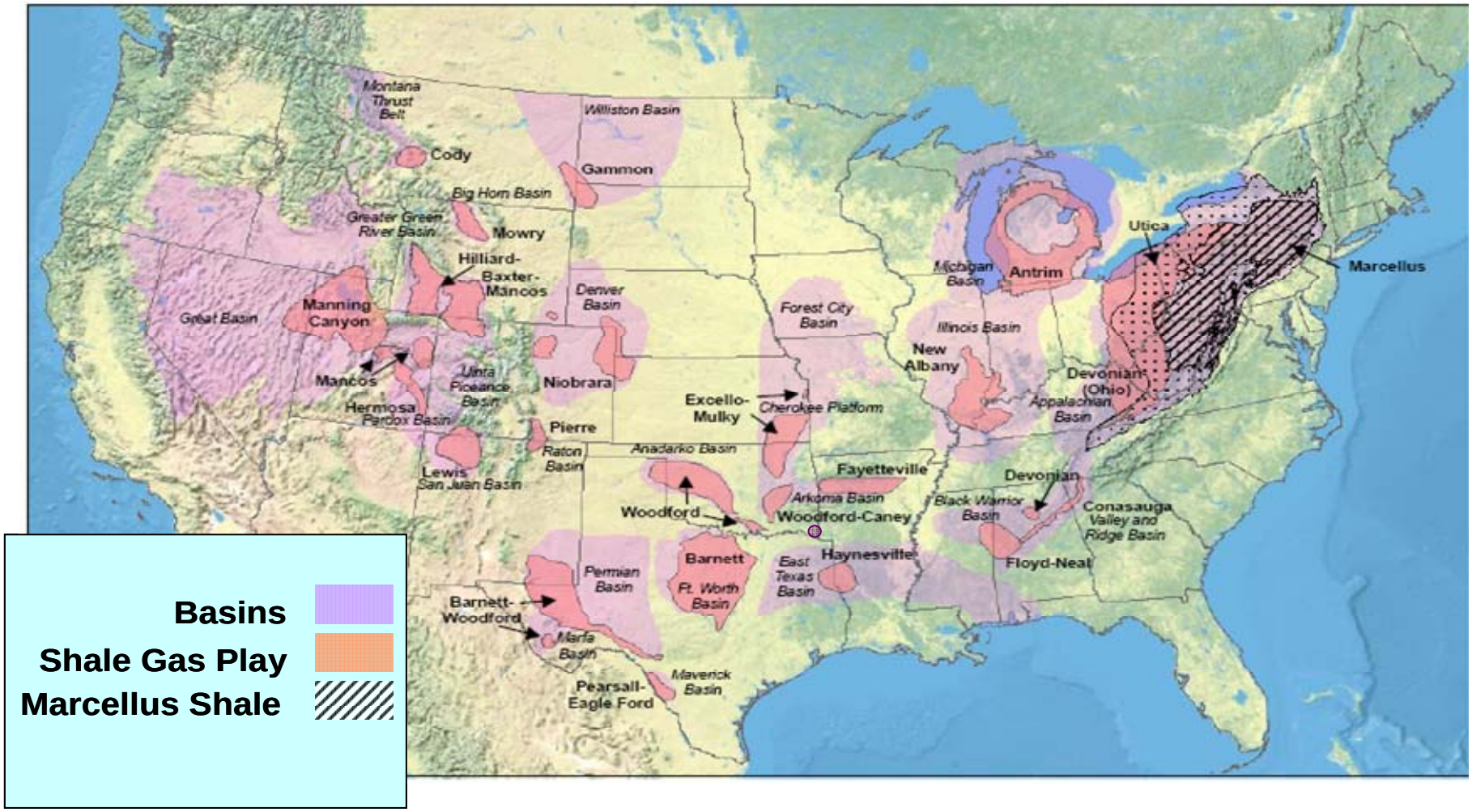
Natural Gas Resource Assessment of the Potential Gas Committee, 2008 (mean values)

Traditional Resources	1,673.4 Tcf
Coalbed Gas Resources	163.0 Tcf
Total U.S. Resources	1,836.4 Tcf
Proved Reserves (EIA)	237.7 Tcf*
Future Gas Supply	2,074.1 Tcf

* Value as of year-end 2007

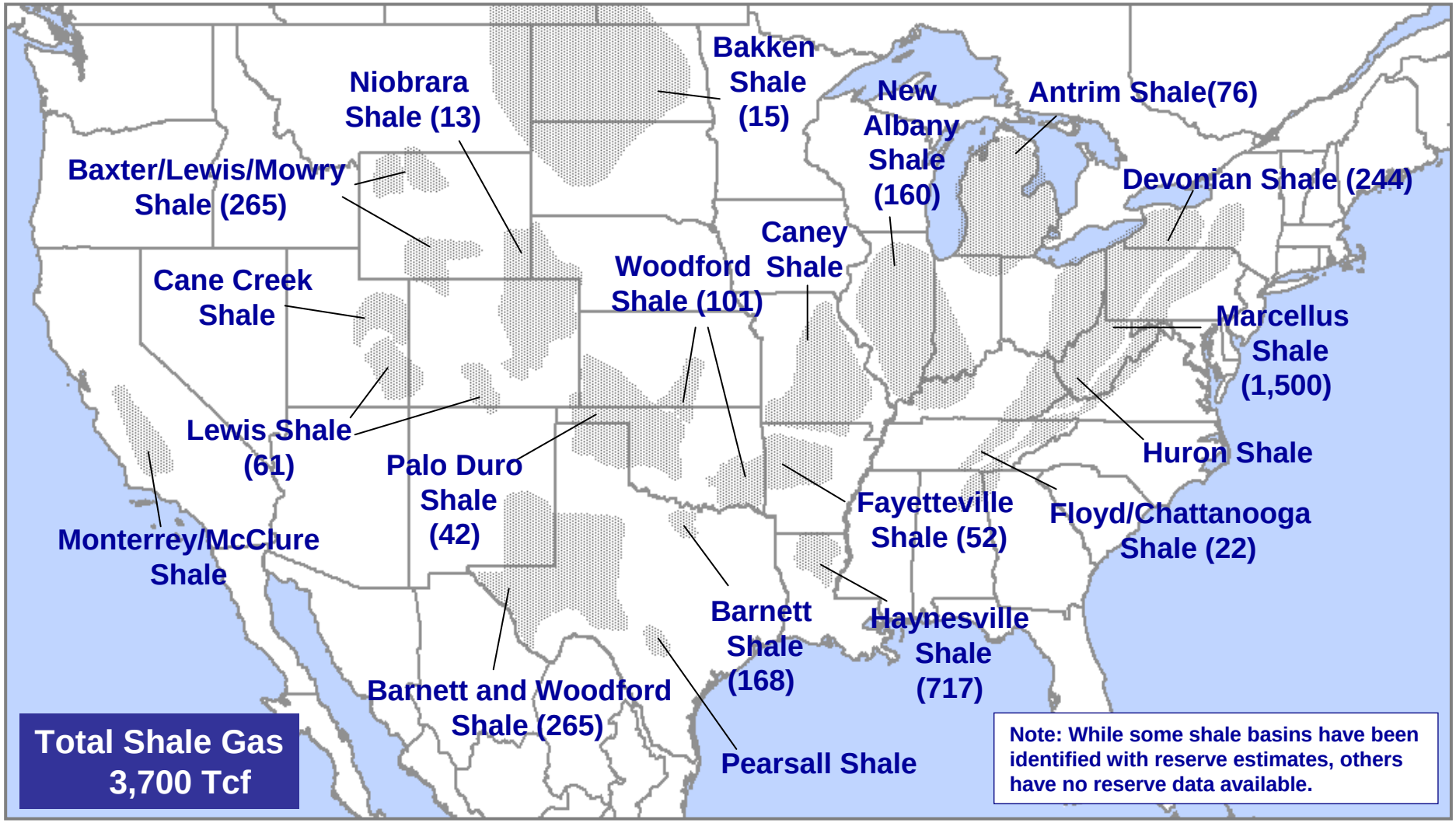
Source: Report of the Potential Gas Committee (December 31, 2008) "Potential Supply of Natural Gas in the United States" June 18, 2009

Gas Shales Plays in the United States



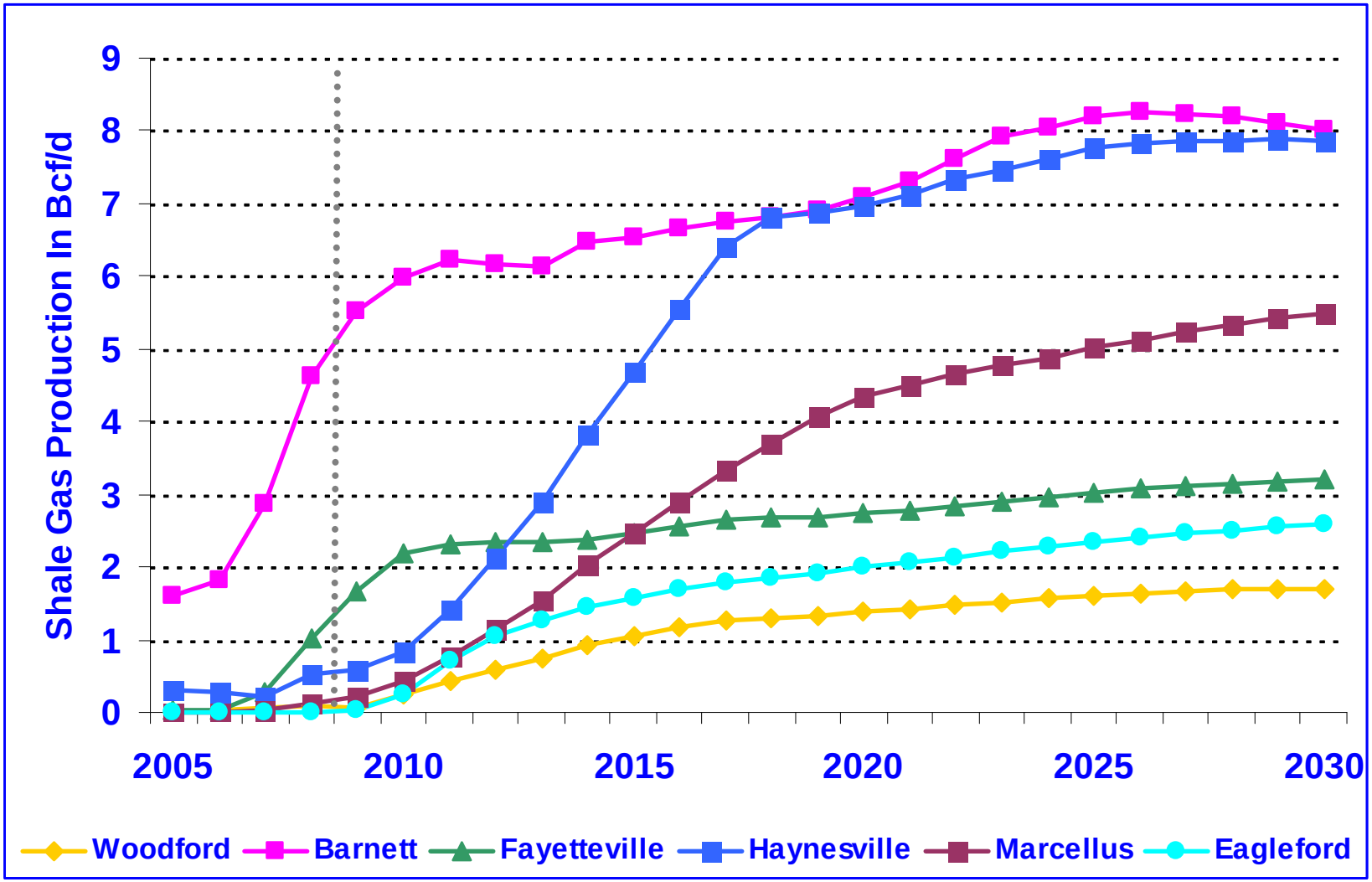
Source: EIA's Exploring Pipeline Dynamics to Connect New Markets – Slide Entitled: Gas Shales in the United States

United States Shale Basins
Maximum Reported Gas-in-Place (in Tcf)



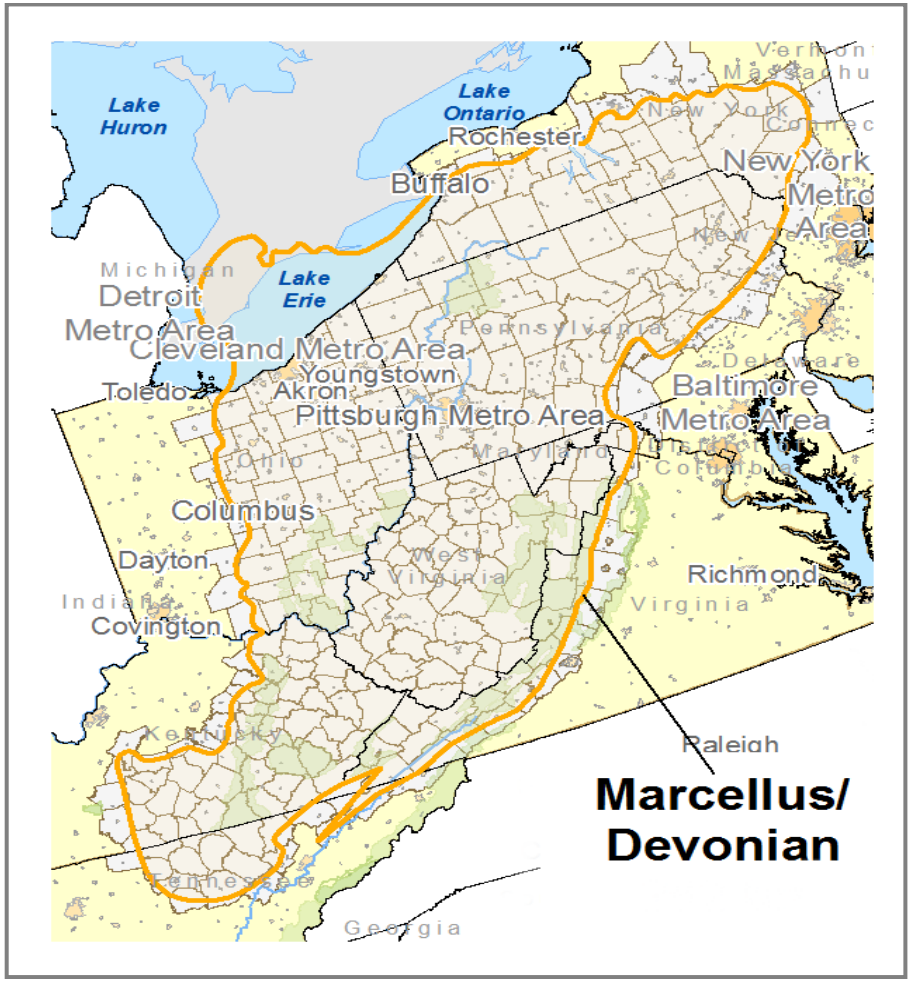
Source: Energy Velocity and Navigant Consulting's North American Natural Gas Supply Assessment – July 4, 2008

Shale Gas Estimates



Source: ICF International Data Base and Compass Report April 2010

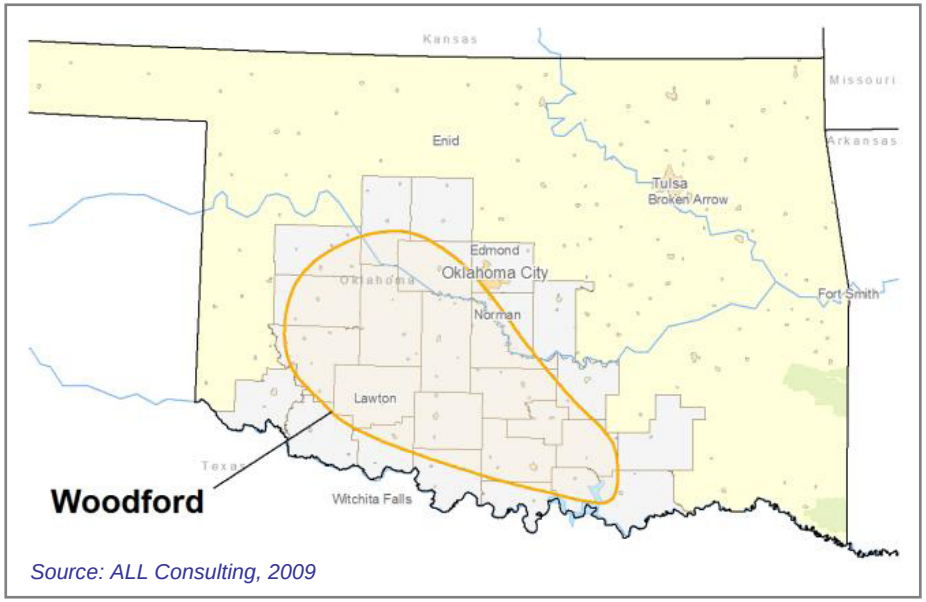
Marcellus Shale in the Appalachian Basin



- The Marcellus Shale spans six states in the northeastern U.S.
- Covers an area of 95,000 square miles at an average thickness of 50 ft to 200 ft
- Estimated depth of production is between 4,000 ft and 8,500 ft
- As of September 2008, there were a total of 518 wells permitted in Pennsylvania and 277 of the approved wells have been drilled
- The average well spacing is 40 to 160 acres per well
- The technically recoverable resources is estimated to be 262 Tcf
- The amount of gas in place is estimated to be up to 1,500 Tcf

Source: Exhibit 19 and text - Marcellus Shale in the Appalachian Basin, DOE's Modern Shale Gas Development in the United States; A Primer, dated April 2009

Woodford Shale in South-Central Oklahoma



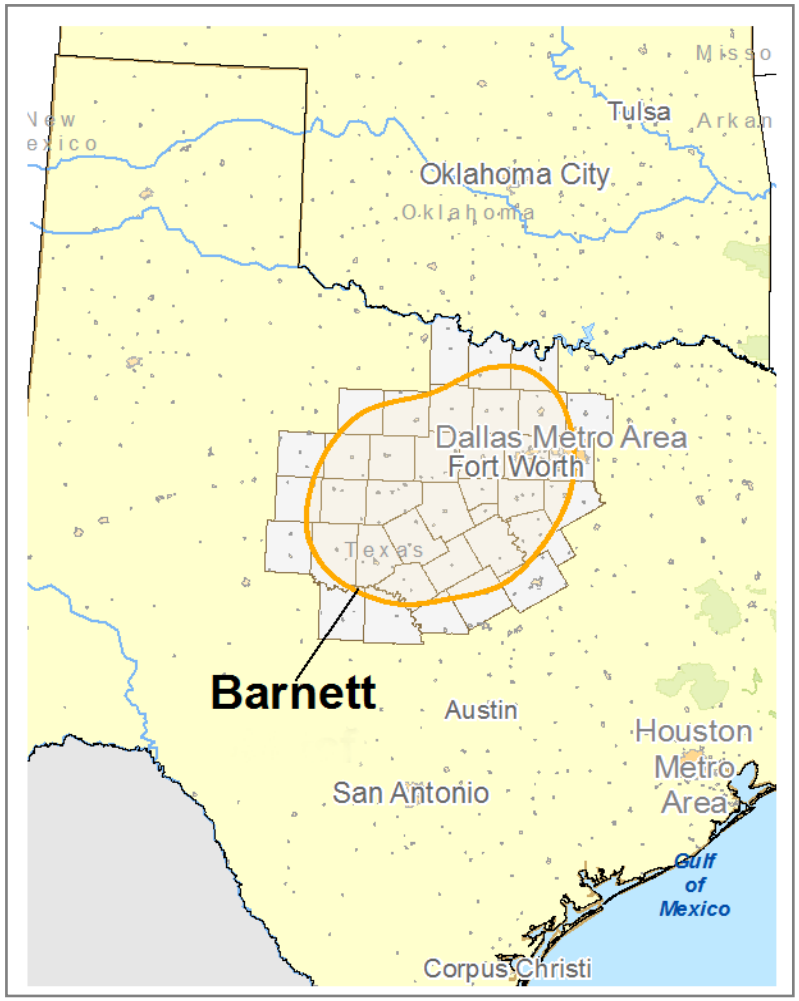
Source: ALL Consulting, 2009

- The Woodford Shale is located in south-central Oklahoma.
- This formation is a Devonian-age shale
- Covers an area of 11,000 square miles at an average thickness of 120 ft to 220 ft
- Estimated depth of production is between 6,000 ft and 11,000 ft
- The Woodford shale is in the early stages of development with recent production beginning in 2003 and 2004 with vertical well completions only.
- Due to the success in the Barnett Shale, horizontal drilling has been adopted.
- The average well spacing is 640 acres per well
- The technically recoverable resources is estimated to be 11.4 Tcf
- The amount of gas in place is estimated to be up to 101 Tcf *

*** Navigant Consulting's North American Natural Gas Supply Assessment – July 4, 2008**

Source: Exhibit 19 and text - Marcellus Shale in the Appalachian Basin, DOE's Modern Shale Gas Development in the United States; A Primer, dated April 2009

Barnett Shale in North-Central Texas



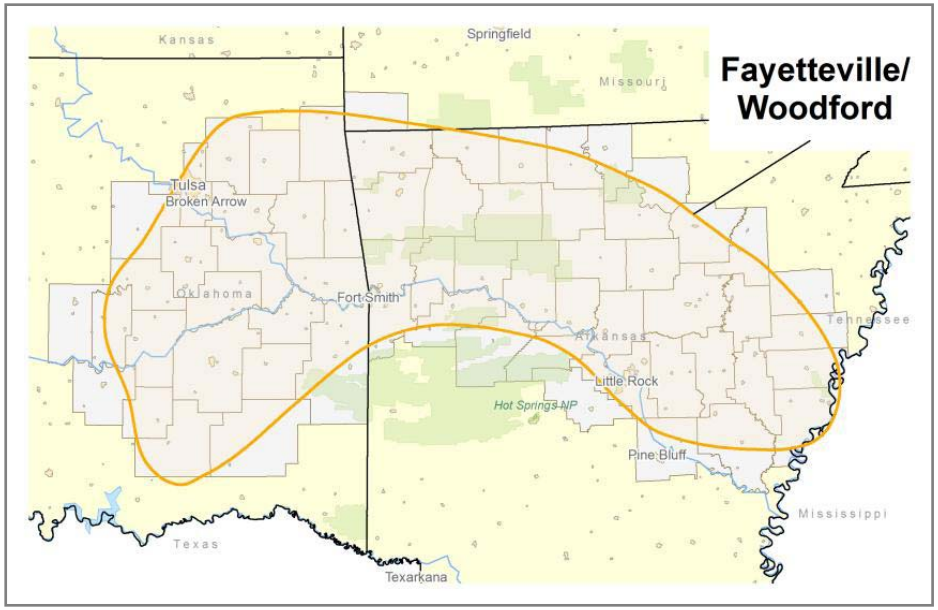
Source: ALL Consulting, 2009

- The Barnett Shale is located in the Fort Worth Basin of north-central Texas.
- This formation is a Mississippian-age shale
- Covers an area of about 5,000 square miles at an average thickness of 100 ft to 600 ft
- Estimated depth of production is between 6,500 ft and 8,500 ft
- With over 10,000 well drilled to date, it is the most prominent shale gas play in the US.
- Horizontal well completions are occuring at well spacing ranging from 60 to 160 acres per well.
- The technically recoverable resources is estimated to be 44 Tcf
- The amount of gas in place is estimated to be up to 168 Tcf *

*** Navigant Consulting's North American Natural Gas Supply Assessment – July 4, 2008**

Source: Exhibit 19 and text - Marcellus Shale in the Appalachian Basin, DOE's Modern Shale Gas Development in the United States; A Primer, dated April 2009

Fayetteville Shale in Northern Arkansas and Eastern Oklahoma

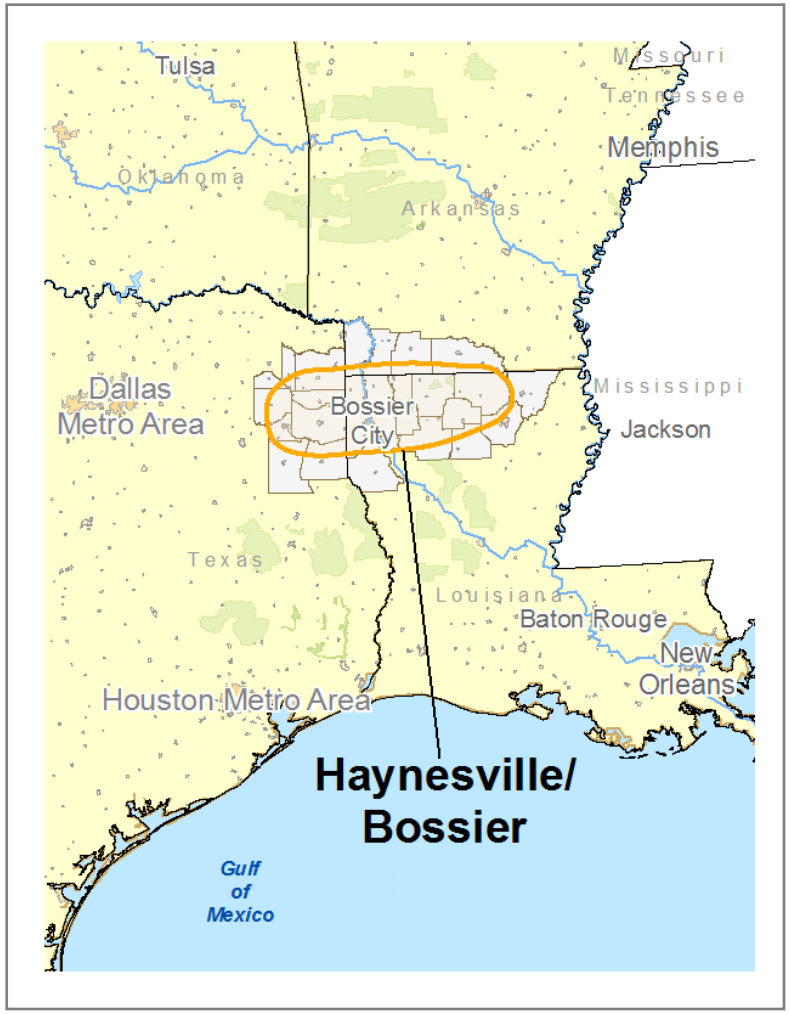


Source: ALL Consulting, 2009

- **The Fayetteville Shale is located in the Arkoma Basin of northern Arkansas and eastern Oklahoma.**
- **This formation is a Mississippian-age shale**
- **Covers an area of 9,000 square miles at an average thickness of 20 ft to 200 ft**
- **Estimated depth of production is between 1,000 ft and 7,000 ft**
- **Lessons learned from horizontal drilling and hydraulic fracturing in the Barnett when adopted to the Fayetteville Shale, made this play economical.**
- **Average well spacing range from 80 to 160 acres per well.**
- **The technically recoverable resources is estimated to be 41.6 Tcf**
- **The amount of gas in place is estimated to be up to 52 Tcf**

Source: Exhibit 19 and text - Marcellus Shale in the Appalachian Basin, DOE's Modern Shale Gas Development in the United States; A Primer, dated April 2009

Haynesville Shale in Northern Louisiana and Eastern Texas



Source: ALL Consulting, 2009

- The Haynesville Shale is located in Northern Louisiana Salt Basin in northern Louisiana and eastern Texas
- This formation is a Devonian-age shale
- Covers an area of 9,000 square miles at an average thickness of 200 ft to 300 ft
- Estimated depth of production is between 10,500 ft and 13,500 ft
- After several years of drilling and testing, the Haynesville Shale has the potential of significant gas reserves, although the full extent of the play will only be known after several more years of development.
- The average well spacing ranges from 40 to 560 acres per well
- The technically recoverable resources is estimated to be 251 Tcf
- The amount of gas in place is estimated to be up to 717 Tcf

Source: Exhibit 19 and text - Marcellus Shale in the Appalachian Basin, DOE's Modern Shale Gas Development in the United States; A Primer, dated April 2009

Antrim Shale in the Lower Peninsula of Michigan

Source: ALL Consulting, 2009

- The Antrim Shale is located within the Michigan Basin in the upper portions of the lower peninsula of Michigan.
- This formation is a Late Devonian-age shale
- Covers an area of 12,000 square miles at an average thickness of 70 ft to 120 ft
- Estimated depth of production is between 600 ft and 2,200 ft
- Aside from the Barnett, the Antrim Shale has been one of the most actively developed shale gas plays with its major expansion taking place in the late 1980s.
- The average well spacing ranges from 40 to 160 acres per well
- The technically recoverable resources is estimated to be 20 Tcf
- The amount of gas in place is estimated to be up to 76 Tcf

Source: Exhibit 19 and text - Marcellus Shale in the Appalachian Basin, DOE's Modern Shale Gas Development in the United States; A Primer, dated April 2009

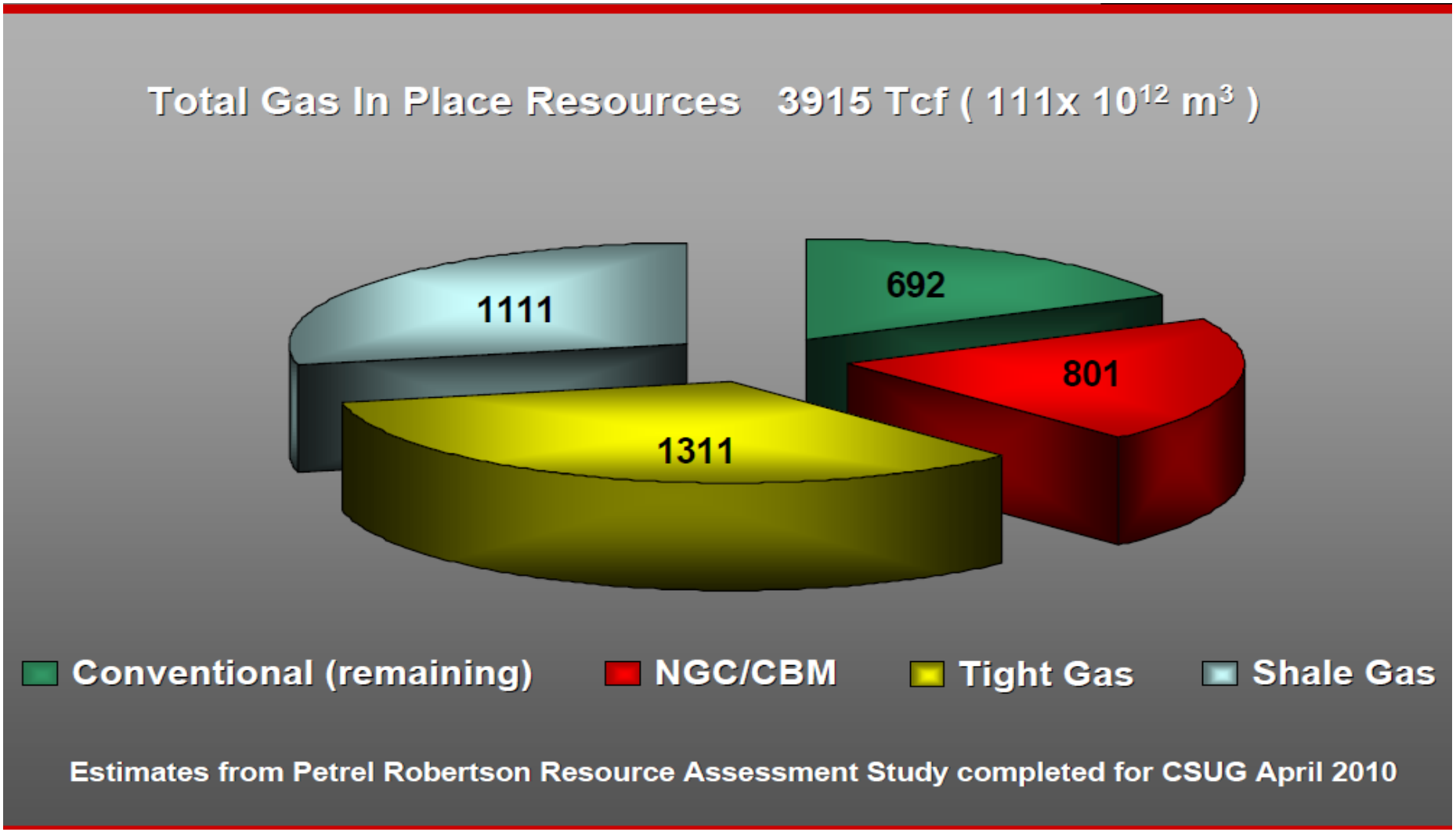
New Albany Shale in Southeastern Illinois, Southwestern Indiana, and Northwestern Kentucky

Source: ALL Consulting, 2009

- The New Albany Shale is located in the Illinois Basin in portions of southeastern Illinois, southwestern Indiana, and northwestern kentucky.
- This formation is a Devonian to Mississippian-age shale
- Covers an area of 43,500 square miles at an average thickness of 50 ft to 100 ft
- Estimated depth of production is between 500 ft and 2,000 ft
- The New Albany Shale is one of the largest shale gas plays
- The average well spacing is 80 acres per well
- The technically recoverable resources is estimated to be less than 20 Tcf
- The amount of gas in place is estimated to be up to 160 Tcf

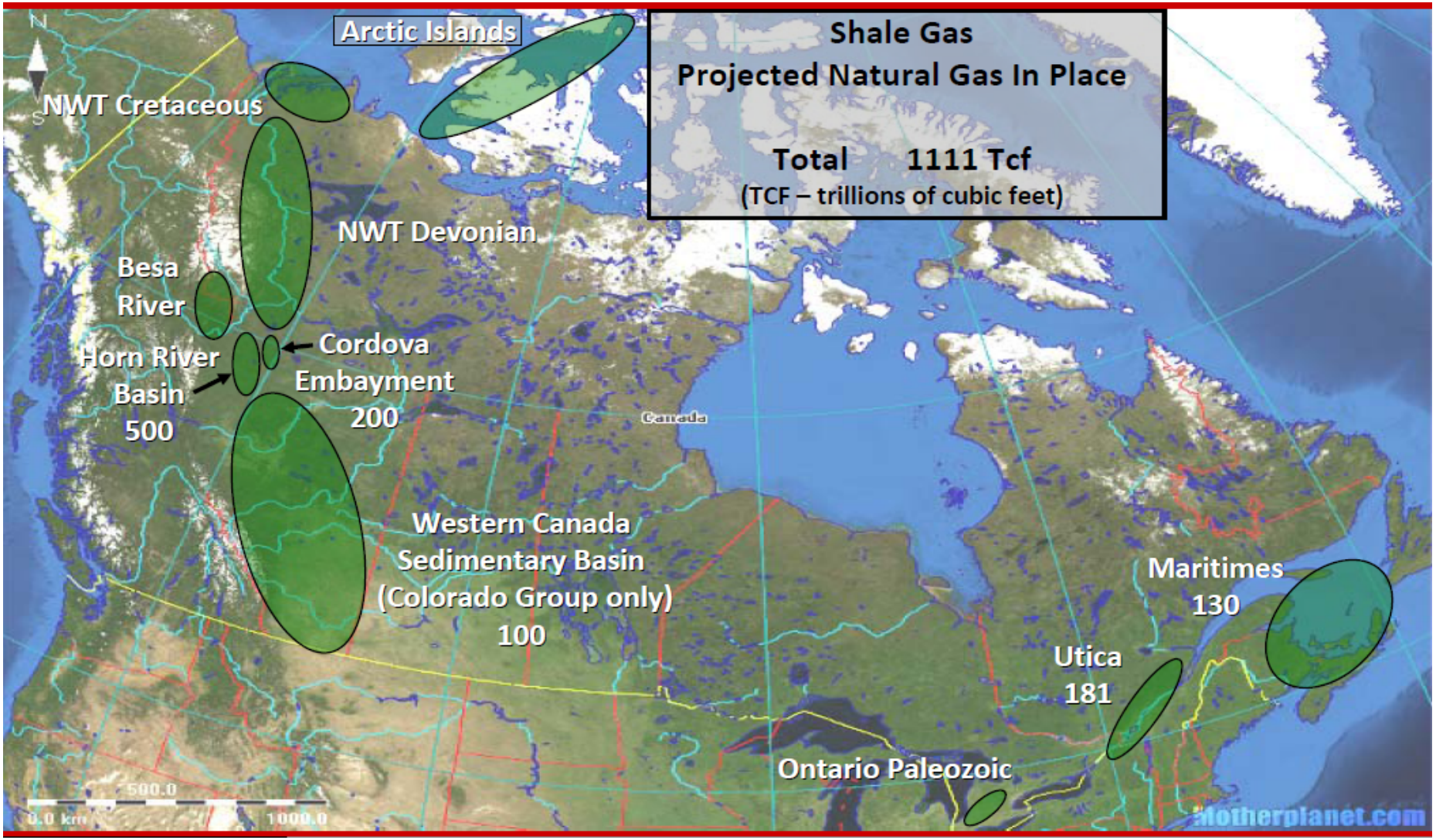
Source: Exhibit 19 and text - Marcellus Shale in the Appalachian Basin, DOE's Modern Shale Gas Development in the United States; A Primer, dated April 2009

Canada's Natural Gas Resource Base



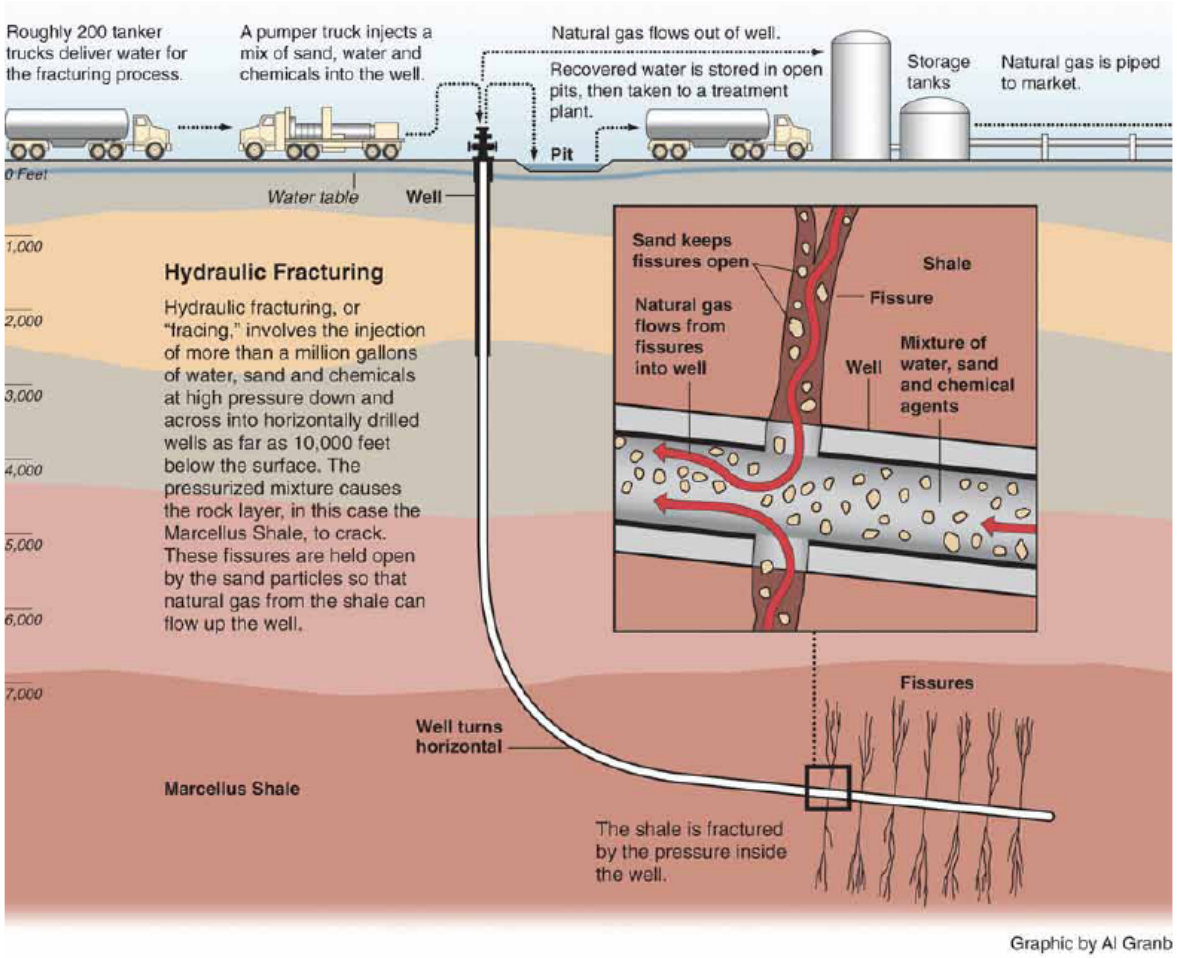
Source: Canadian Society for Unconventional Gas, CSUG Technical Luncheon, May12, 2010

Canada's Shale Gas



Source: Canadian Society for Unconventional Gas, CSUG Technical Luncheon, May12, 2010

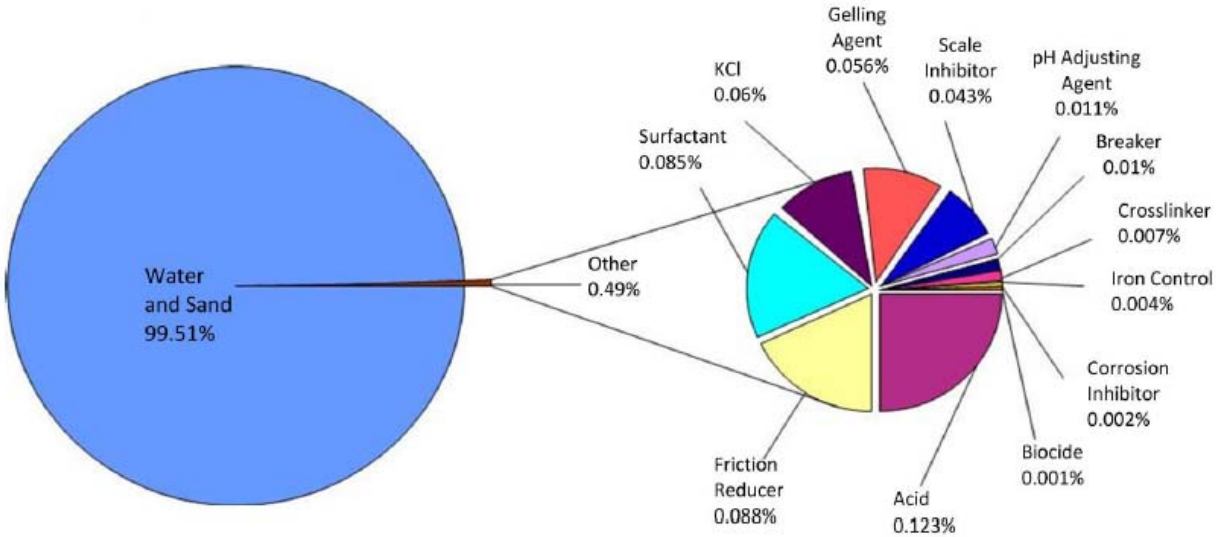
Hydraulic Fracturing in Shale



- In order to produce shale gas, new drilling technologies have been developed.
- Hydraulic fracturing and horizontal drilling have allowed previously unrecoverable sources of gas to be developed economically and environmentally safe manner.
- CERA – 2 to 4 million gallons of water is required to drill and complete a well.
- CERA – Fracturing generally takes place below drinking water aquifers with impermeable formations in between.

Source: Environmental America Research and Policy Center – Toxic Chemicals on Tap – November 2009, and CERA's Friction Over Fraccing

Volumetric Composition of a Fracture Fluid

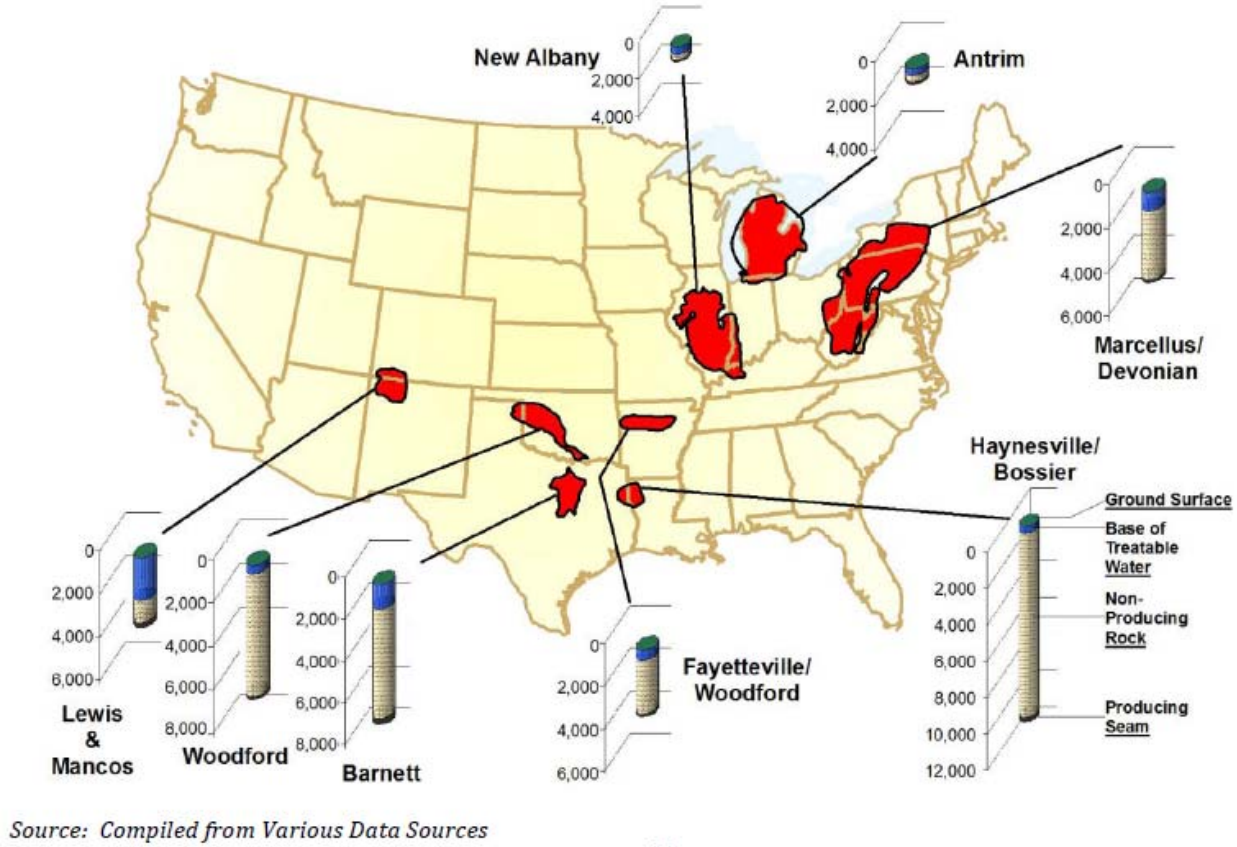


Source: ALL Consulting based on data from a fracture operation in the Fayetteville Shale, 2008

- **Hydraulic fracturing used for a nine-stage hydraulic fracturing treatment of a Fayetteville Shale horizontal well**
- **Make-up of fracturing fluid varies from one geologic basin or formation to another**
- **Additives represent less than 0.5% of the total fluid volume**
- **Overall the concentration of additives in most slickwater fracturing fluids is a relatively consistent 0.5% to 2% with water making up 98% to 99.5%**

Source: DOE's Modern Shale Gas Development in the United States: A Primer April 2009

Comparison of Target Shale Depth and Base of Treatable Groundwater



- Natural barriers in the rock strata that act as seals holding gas in the target formation
- Without such seals, gas and oil would migrate to the surface
- Most shale gas wells (outside of those completed in the New Albany and the Antrim) are expected to be drilled at depths greater than 3,000 feet
- For any fluid present in the producing zone to reach treatable groundwater the fluid must migrate through these overlying zones

Source: DOE's Modern Shale Gas Development in the United States: A Primer April 2009

Estimated Water Needs for Drilling and Fracturing in Selected Shale Gas Plays

The drilling and hydraulic fracturing of a horizontal shale gas well may typically require 2 to 4 million gallons of water, with about 3 million gallons being the most common.

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: ALL Consulting from discussions with various operators, 2008

Source: DOE's Modern Shale Gas Development in the United States: A Primer April 2009

Water for Drilling and Hydraulic Fracturing

- Frequently comes from surface water bodies such as rivers and lakes, but can also come from groundwater, private water sources, municipal water, and re-used produced water.
- While the water volumes needed to drill and stimulate shale gas wells are large, they generally represent a small percentage of the total water resource used in the shale gas basins.
- Calculations indicate that water use will range from less than 0.1% to 0.8% by basin.
- Example: the Susquehanna River Basin alone is nearly 150 million gallons per day, while the projected total demand for peak Marcellus Shale activity in the same area is 8.4 million gallons per day.
- Operators need water when drilling activity is occurring, requiring that water be procured over a relatively short period of time.
- Water withdrawals during periods of low stream flow could affect fish and other aquatic life, fishing and other recreational activities, municipal water supplies, and other industries such as power plants.
- One alternative is to make use of seasonal changes in river flow to capture water when surface water flows are greatest.

Source: DOE's Modern Shale Gas Development in the United States: A Primer April 2009

Currently Produced Water Management by Shale Gas Basin

Shale Gas Basin	Water Management Technology	Availability	Comments
Barnett Shale	Class II injection wells[303]	Commercial and non-commercial	Disposal into the Barnett and underlying Ellenberger Group[304]
	Recycling[305]	On-site treatment and recycling	For reuse in subsequent fracturing jobs [306]
Fayetteville Shale	Class II injection wells[307]	Non-commercial	Water is transported to two injection wells owned and operated by a single producing company [308]
	Recycling	On-site recycling	For reuse in subsequent fracturing jobs[309]
Haynesville Shale	Class II injection wells	Commercial and non-commercial	
Marcellus Shale	Class II injection wells	Commercial and non-commercial	Limited use of Class II injection wells[310,311]
	Treatment and discharge	Municipal waste water treatment facilities, commercial facilities reportedly contemplated[312]	Primarily in Pennsylvania
	Recycling	On-site recycling	For reuse in subsequent fracturing jobs[313]
Woodford Shale	Class II injection wells	Commercial	Disposal into multiple confining formations[314]
	Land Application		Permit required through the Oklahoma Corporation Commission[315]
	Recycling	Non-commercial	Water recycling and storage facilities at a central location[316]
Antrim Shale	Class II injection wells	Commercial and non-commercial	
New Albany Shale	Class II injection wells	Commercial and non-commercial	

Source: DOE's Modern Shale Gas Development in the United States: A Primer April 2009

- State, local governments, and shale gas operators seek to manage produced water in a way that protects surface and ground water resources
- Underground injection has traditional been the primary disposal option for oil and gas produced water
- Treatment of produced water may be feasible through either self-contained systems at well sites or fields or municipal waste water treatment plants or commercial treatment facilities
- Re-use of fracturing fluids; however, treatment may be necessary

Shale Development Concerns

- Water Usage for Hydraulic Fracturing
  - >1.2 million gallons for a vertical well
  - >3.5 million gallons for a horizontal well
- Disposal of effluent
  - Chemicals and sand are combined with the water for hydraulic fracturing
  - Effluent must be pumped into deep formations
  - Recycling may allow reuse of up to 5% of the returned water

Economic Development

- Production of shale gas has significant economic benefits to both the local community and the state.
  - Increased production creates jobs both directly and indirectly.
  - Landowners benefit from natural gas production through royalty payments.
  - The state and local community gains much needed revenue.
  - All natural gas customers benefit from diversification of supplies.

Production, Jobs, and Landowner Benefits

- Production of natural gas will create jobs both directly and indirectly
  - In 2008, development of the Marcellus Shale created over 29,000 jobs and added $2.3 billion to the Pennsylvania economy
  - By 2020, Marcellus production could be responsible for up to 175,000 jobs and $13.5 billion.
- The local economy also benefits because individual mineral rights owners receive royalty payments for gas that is produced and surface land owners receive lease payments.
- The combination of more people with jobs and increased income due to royalty and lease payments further helps the local and state economy as more money trickles down through the economic, generating second, positive impacts on business ranging from local cafes to major equipment suppliers .
- This furthers overall job growth in the state.

Production and State and Local Government Benefits

- The state and local governments benefit from increased natural gas production from both severance taxes and higher revenues from income and sales taxes.
  - In Pennsylvania, 2008 state and local tax revenue increased by $240 million because of Marcellus Production.
  - It is estimated that between 2009 and 2020, Pennsylvania will receive approximately $13 billion dollars in state and local taxes
- States can raise revenue through the use of severances taxes.
  - In Oklahoma, depending on the price of gas, there is a severance tax of 1 to 7% on each Mcf produced.
- Because of the economic downturn, many states are experiencing budget shortfalls and have been forced to cut jobs or government programs.
- Increasing production of shale gas will mitigate these budget impacts through increased tax revenue.

Production and Supply Diversity

- All natural gas customers will benefit from shale production because of supply diversity.
- Supply diversity increases the reliability of natural gas for end users.
  - If supplies are concentrated in a particular region, customers may experience shortages and/or higher prices as a result of natural disaster.
  - Developing more resources throughout the country will mitigate this risk and benefit all customers.