Unconventional Gas Resources

Methane to Markets Partnership Expo
Beijing, China

Well Completion and Production Challenges

October 31, 2007

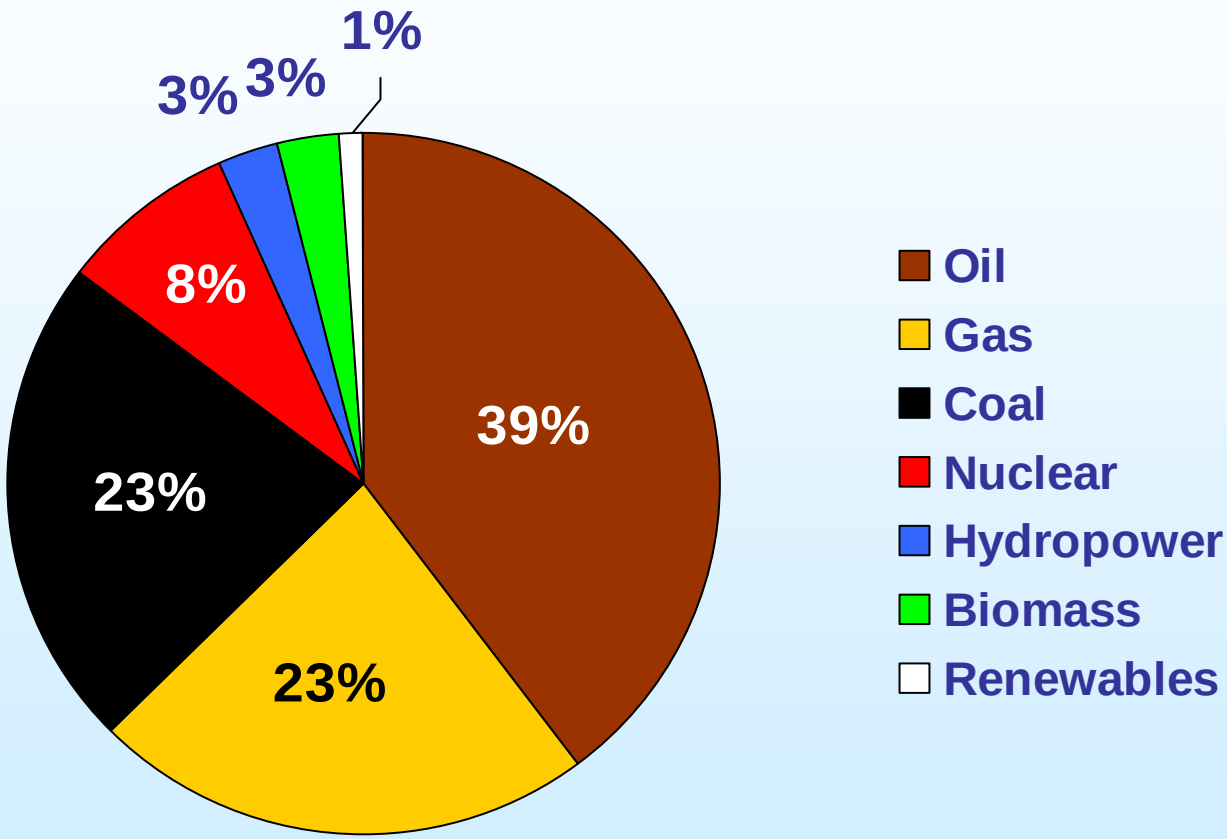
James A. Slutz
Deputy Assistant Secretary
Office of Oil and Natural Gas
Office of Fossil Energy
U.S. Department of Energy

Agenda

- U.S. Natural Gas Supply Challenges
- Unconventional Gas: Part of the Solution
  - Tight Gas
  - Gas Shales
  - Coalbed Methane
- Completion and Production Challenges
- Summary
- Questions

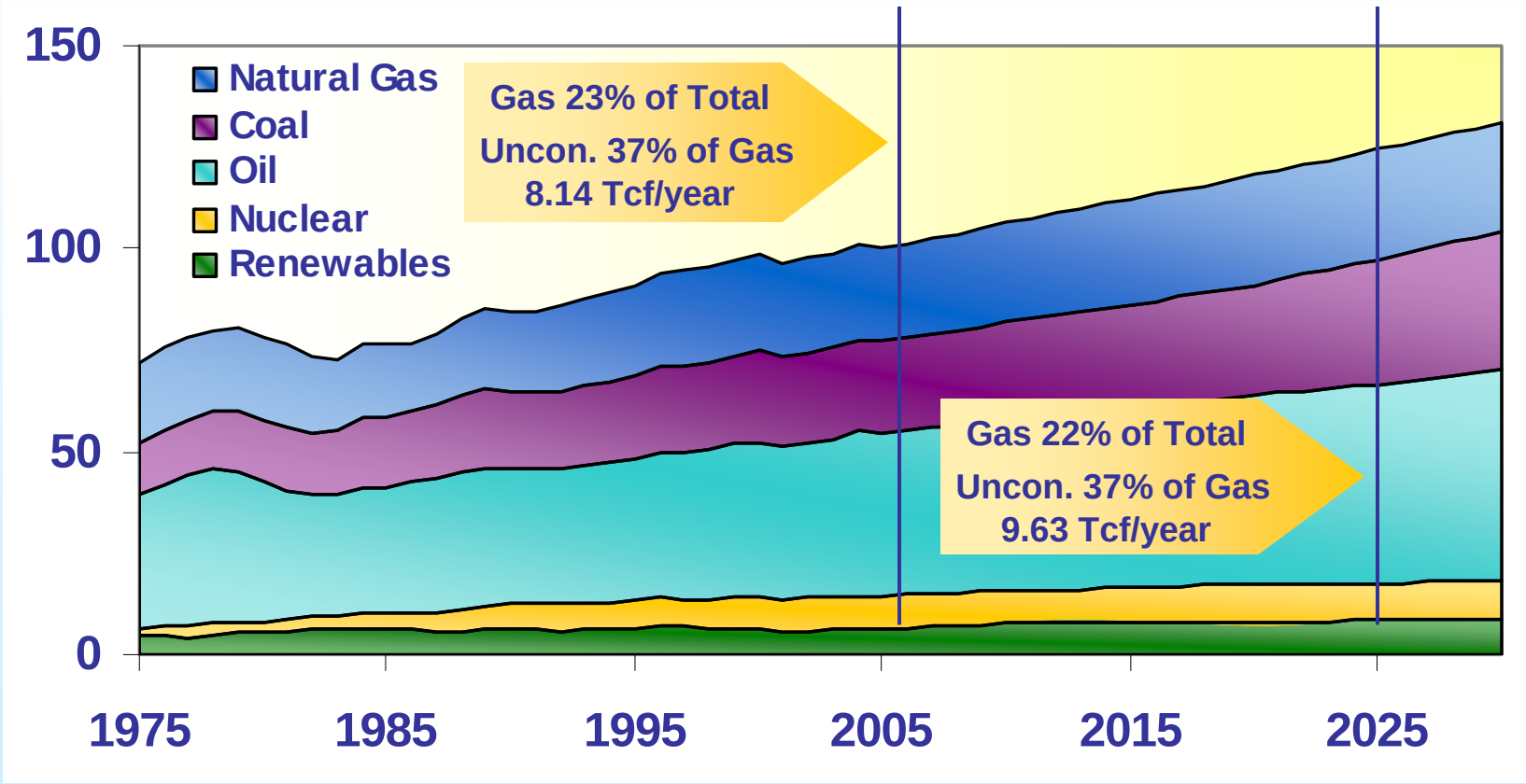
2007 U.S. Energy Use

Gas provides nearly one quarter of energy consumed



AEO 2007

U.S. Demand for Gas Will Continue to Rise



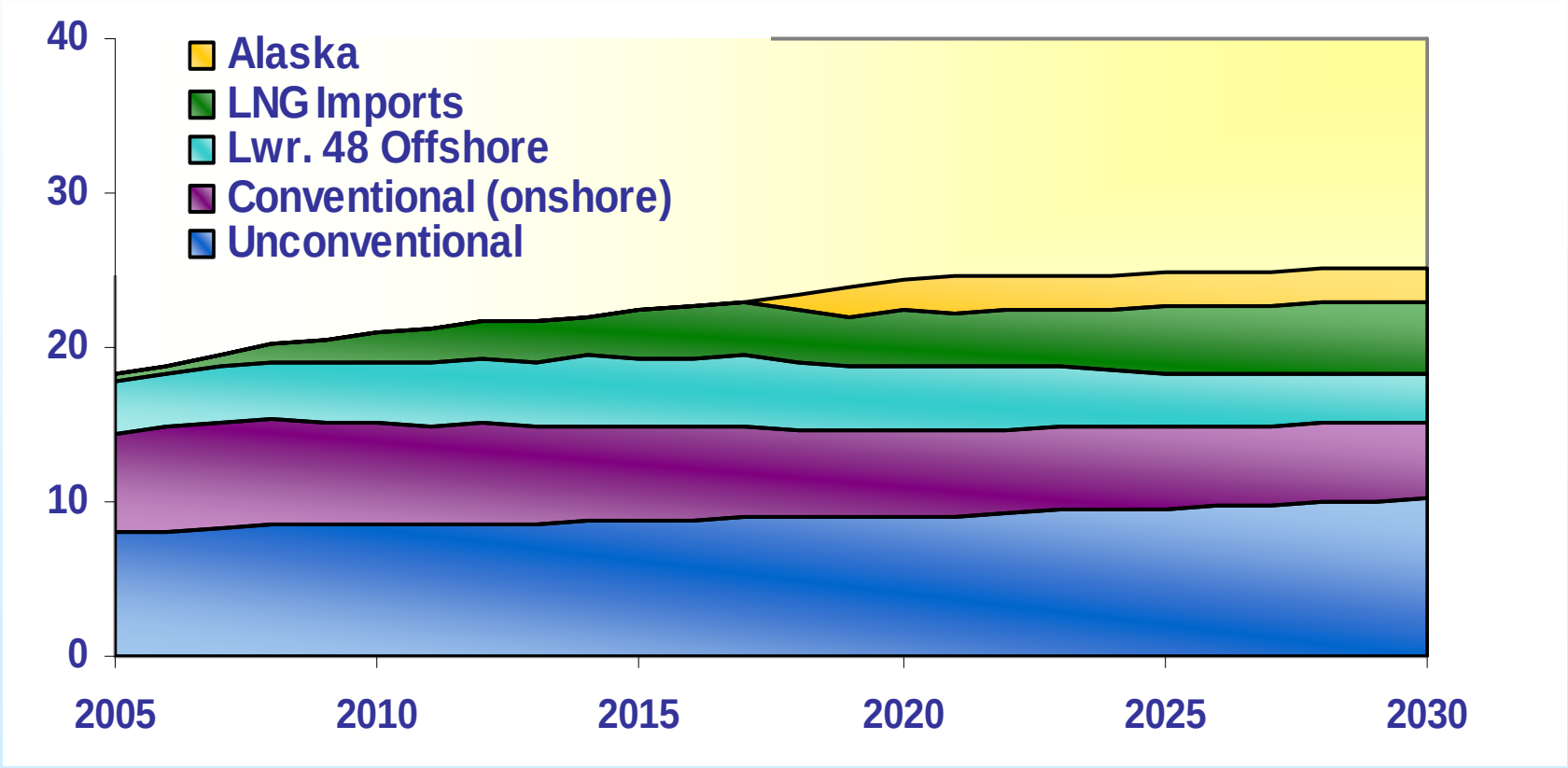
AEO 2007

U.S. Natural Gas Supply Challenges

- **Supply Issues**
  - Imports rising (19% of consumption in 2006)[1]
  - Growing dependence on imported LNG
  - Flat production despite record drilling
  - Remaining resource increasingly costly to produce
  - 88% of pipeline system installed prior to 1970's[2]
- **Environmental issues**
  - Competing land use/access restrictions
  - Finding sites for new pipelines/facilities difficult
  - More drilling required for unconventional sources (coalbed methane, shale gas, etc.) = more impact

1. DOE / EIA 2007; 2. NPC 2003

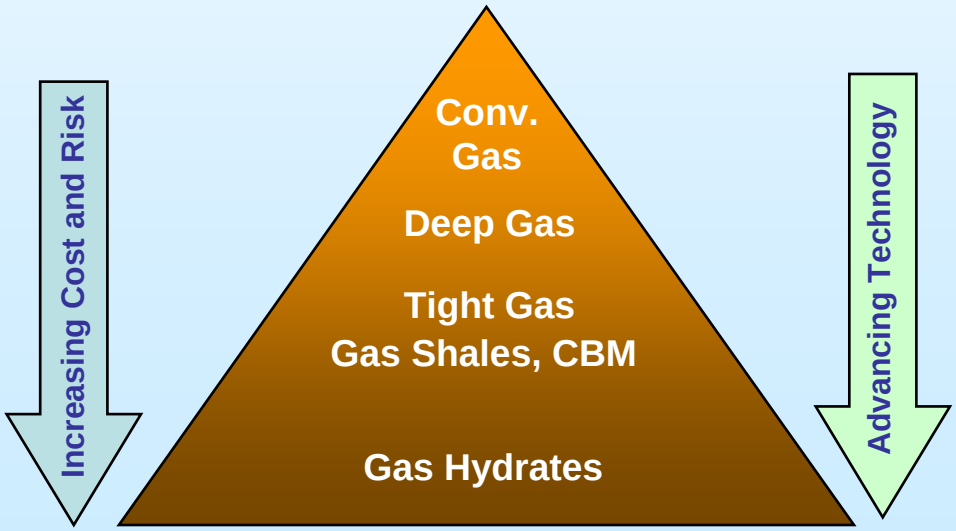
Unconventional Gas Volume Will Increase



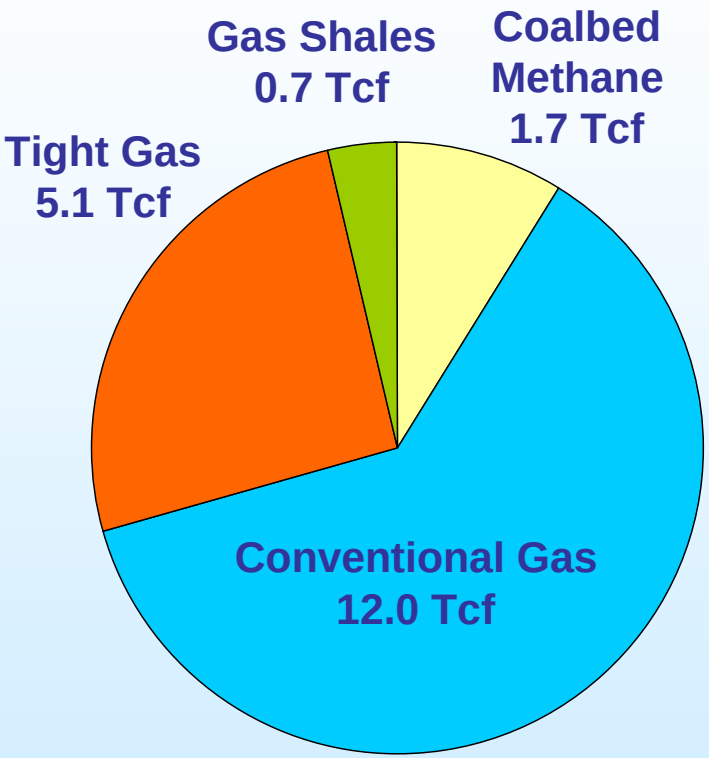
AEO 2007

Vast Domestic Resource Available
More Difficult and Costly to Produce

- **100s Tcf in-place: Ultra-Deep Gas**
  - Recoverable, but not economic
- **1000s Tcf in-place: Tight Gas Sands, Shales, CBM**
  - 2% recoverable now; how much higher?
- **100,000s Tcf in-place: Methane Hydrates**
  - Recoverability not established



Unconventional Gas Production and Recoverable Resource

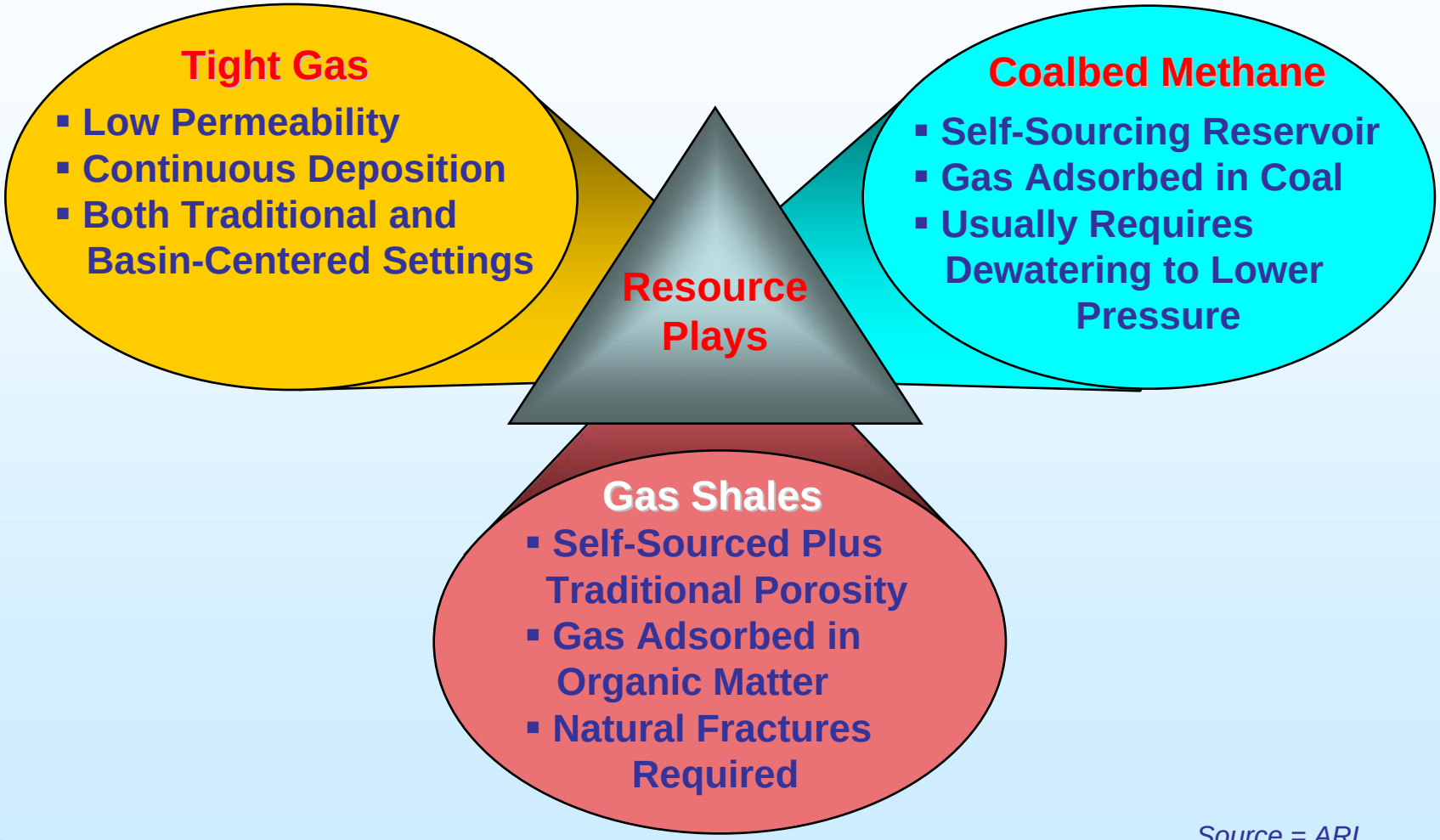


Total Production: 19.5 Tcf (2004)

Resource	Technically Recoverable (Tcf)
Tight Gas	379
Gas Shales	128
Coalbed Methane	73

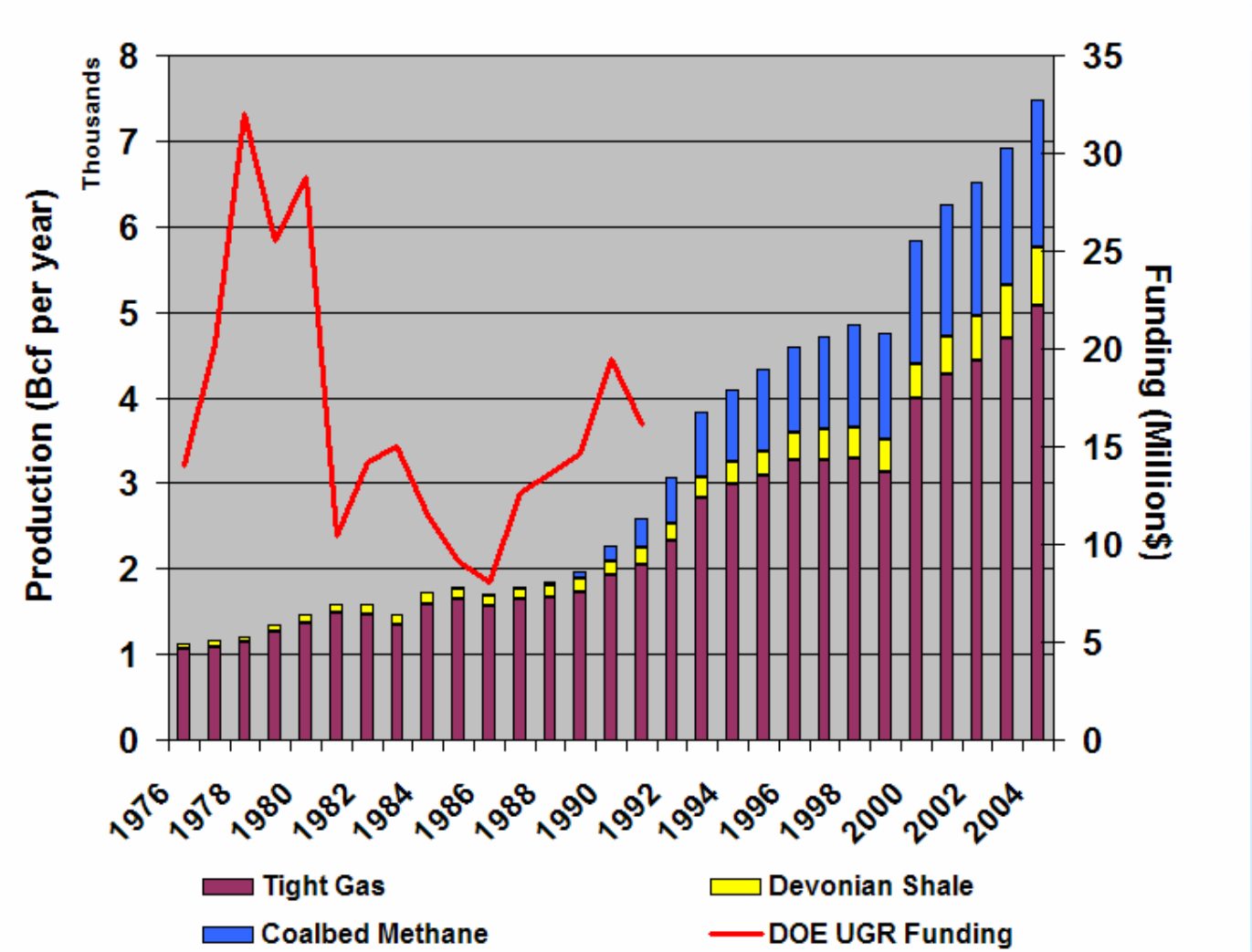
Source = EIA, ARI

Character of Unconventional Gas
"Resource Plays" Shape Challenges

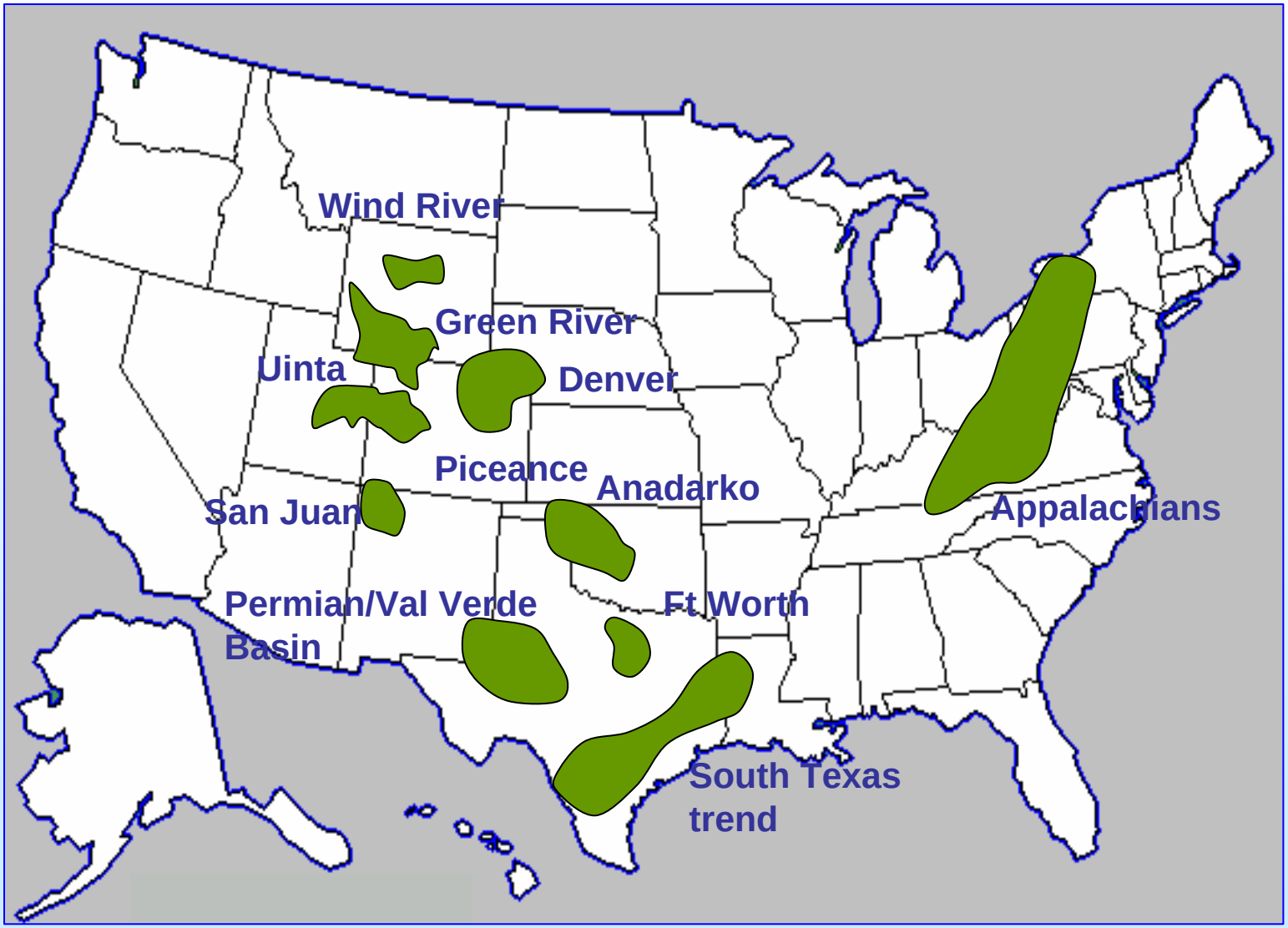


Source = ARI

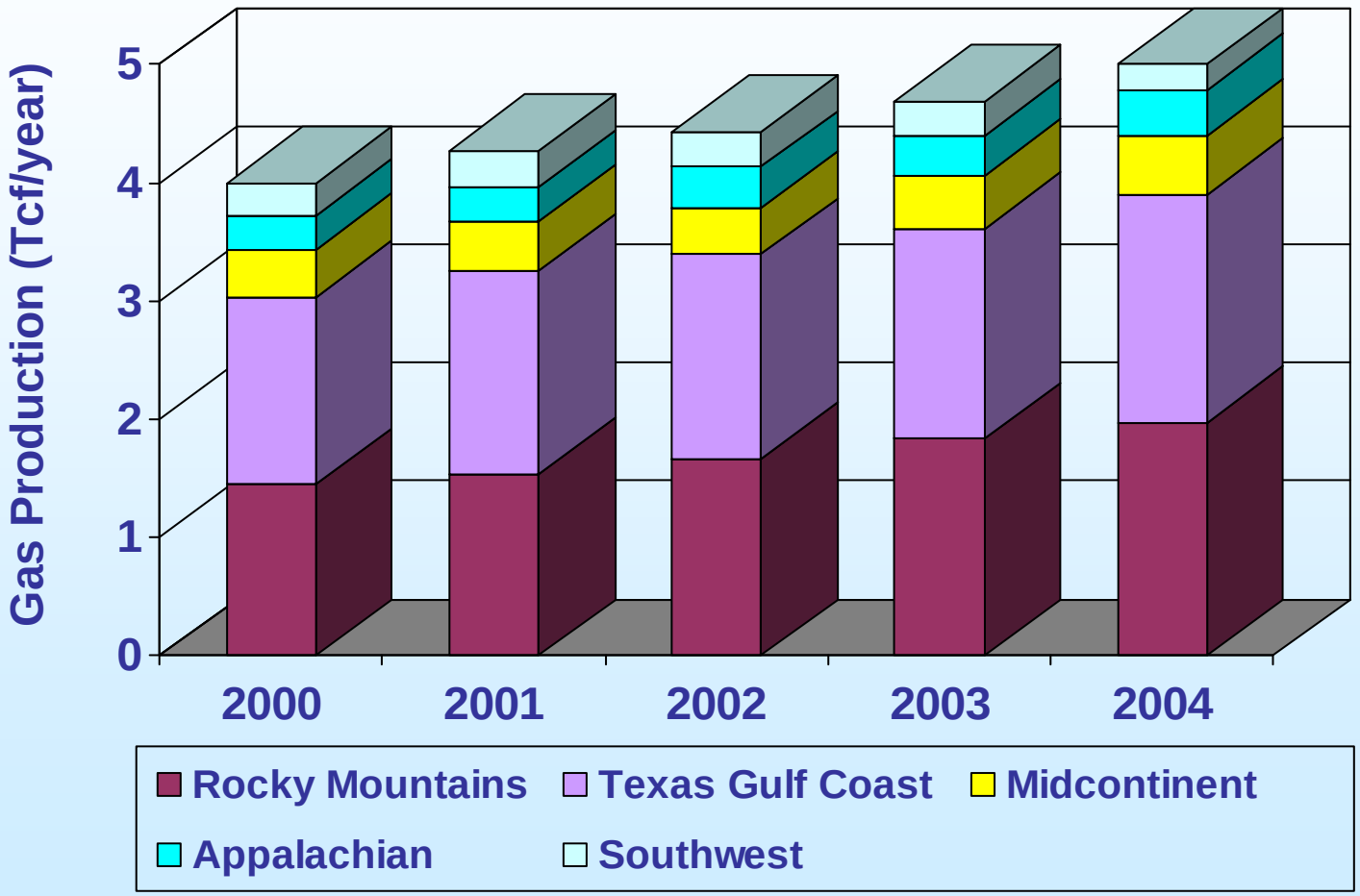
Federally Funded R&D Targeting Unconventional Gas Challenges Has Helped Production Growth



Primary U.S. Tight Gas Sand Basins



U.S. Tight Gas Sand Production by Region

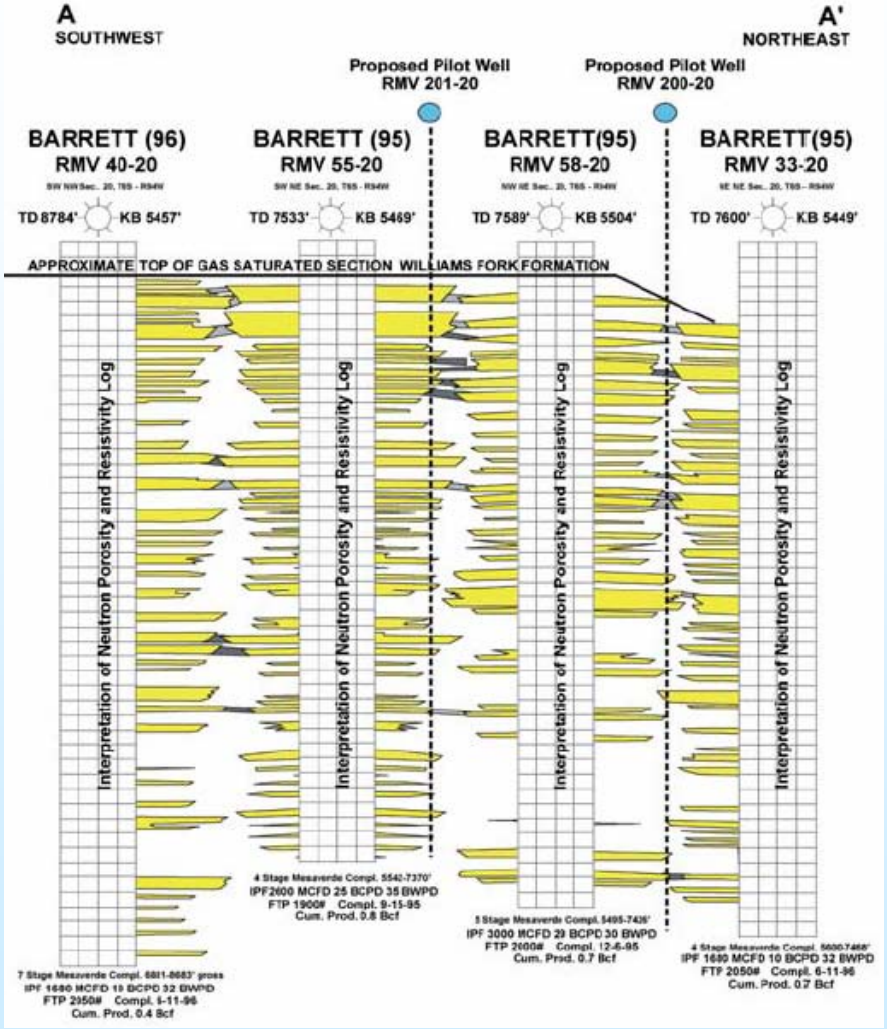


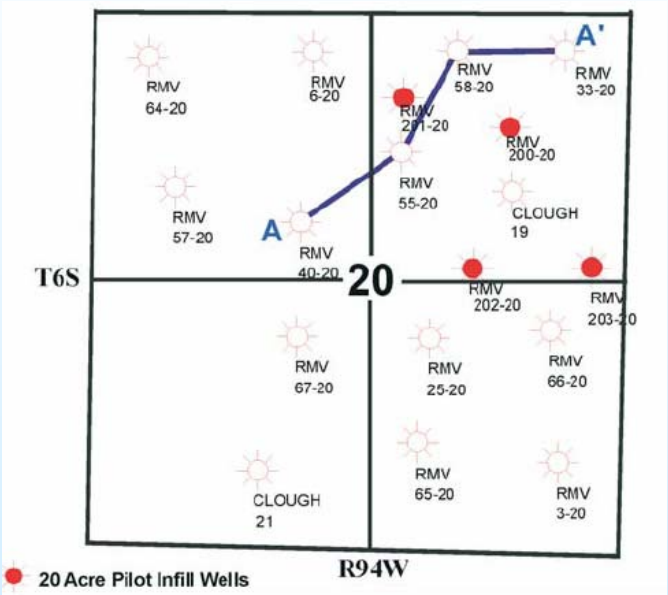
Source: DOE / EIA

Tight Gas Completion-Production Technology Advances

- **Advanced geologic modeling and fracture stimulation analysis led to smaller spacing**
  - **Lenticular sands with little continuity**
  - **Shift from 320 acres per well to < 20 acres**
  - **Increased recovery from <5% to >50%**
- **Advanced hydraulic fracture designs**
  - **Multizone completions (often 5-15 zones per well)**
  - **Ultimate recovery per well increased from 1.5 Bcf to 5-10 Bcf**
- **Faster staged fracturing and emphasis on efficiency have lowered costs**

Lenticular Sands, Little Continuity





Impact of Reduced Well Spacing in Rulison Field, Piceance Basin, CO

Time Period	Wells & Spacing (acres/well)	Reserves/Well (Bcf)	Recovery (Bcf)
Initial	2 at 320	2.1	4
1994	2 at 160	2.2	4
1995	4 at 80	1.9	8
1996-97	8 at 40	1.8	14
1997	4 at 20 (pilot)	1.7	7
1998-2000	12 at 20	1.7	20
2004	32 at 10	1.7	55

Impact of Multizone Completions
Jonah Field, Green River Basin, WY

	1st Generation	2nd Generation	3rd Generation	4th Generation
Pay Selection	Bottom 40%	Bottom 20-50%	50%	50-100%
Frac Stages	1	1	3	Up to 10
Frac Fluid	Cross-linked gel	Nitrogen	Nitrogen/gel	Borate gel
IP (MMcfd)	1.4	1 to 4	3 to 5	5 to 15
EUR (Bcf)	1.5	2.0	3.0	5 to 10+

DOE Success: Hydraulic Fracture Mapping

Pinnacle Technologies

Objective

- Develop and test an advanced hydraulic fracture mapping system with improved instrumentation that combines seismic sensors and tiltmeters in one tool

Accomplishments

- Completed field test of combined geophone/tiltmeter
- Tested placement of geophone/tiltmeter tool in treatment well. Good data sets gathered and tool survived hydraulic frac treatment
- Performed long term test of geophone/tiltmeter tool in San Andreas Fault Observatory at Depth (SAFOD) well
- Technology commercialized (2007)

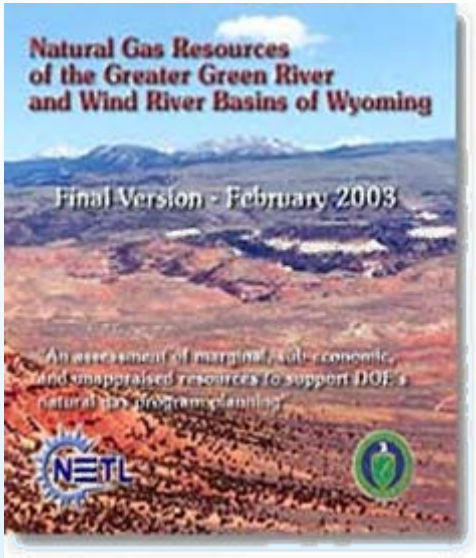
Benefits

- Single observation well required, reducing costs
- Extends the capability of the best technology for optimizing hydraulic fractures

DOE Success: Unconventional Gas Assessments

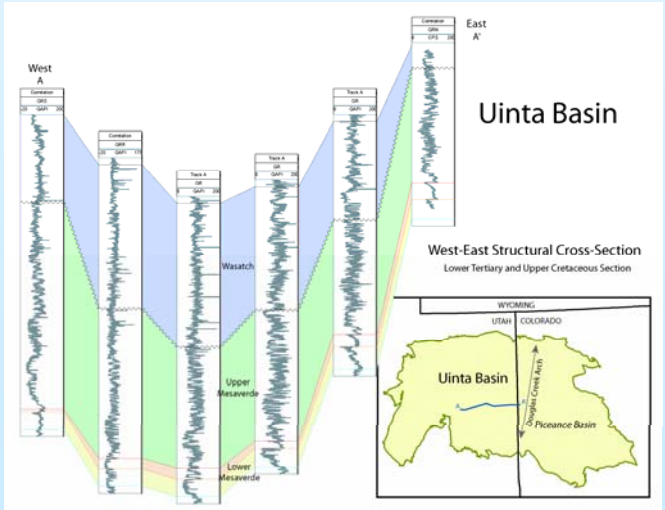
Accomplishments

- Completed detailed formation-based assessments of the Greater Green River, Wind River, Deep Anadarko, and Uinta Basins
- Confirmed the USGS view that a very large in-place, unconventional gas resource remains in the ground
- Distributed over 5000 CD's so far, which include archived maps, cross-sections, & well data

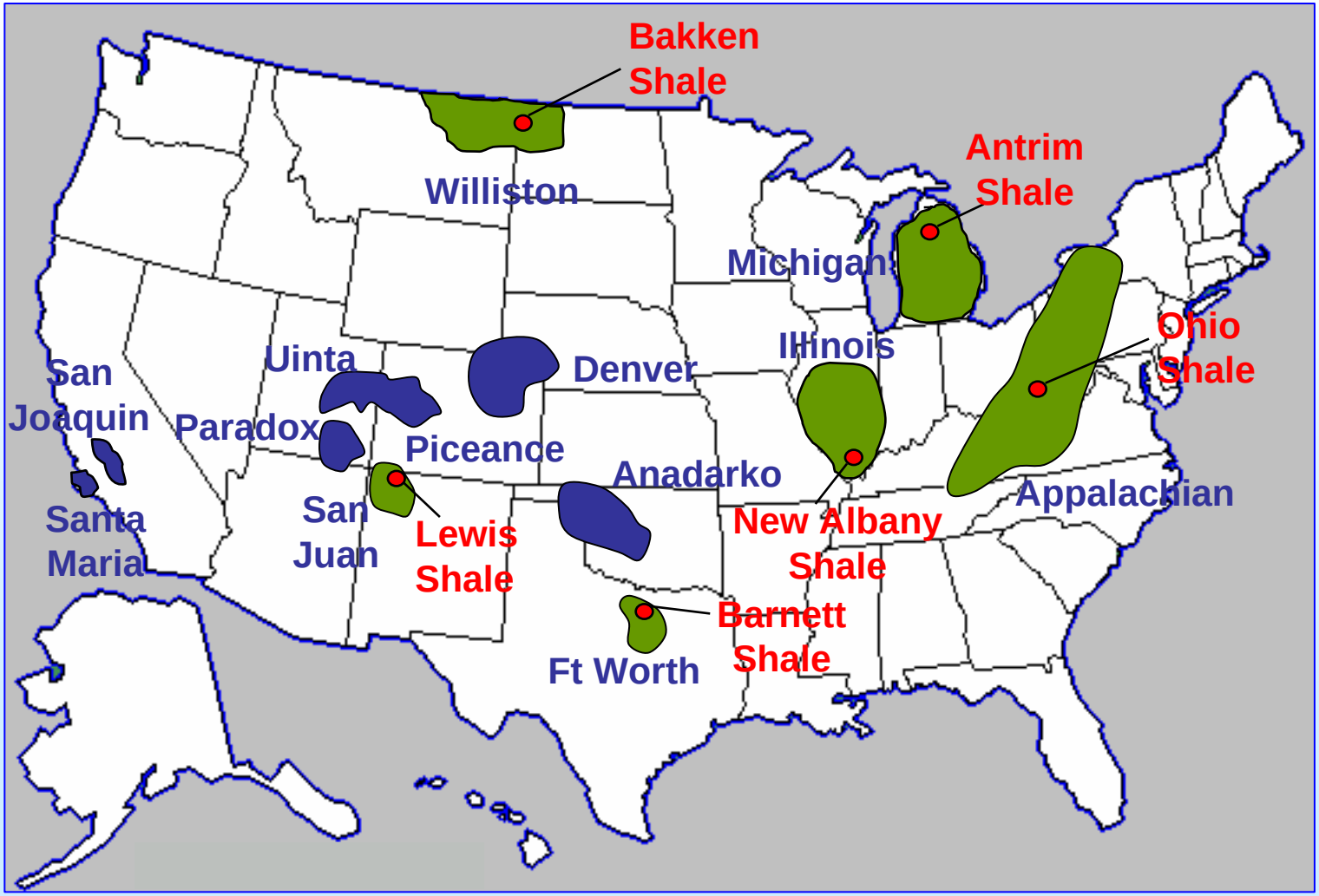


Benefits

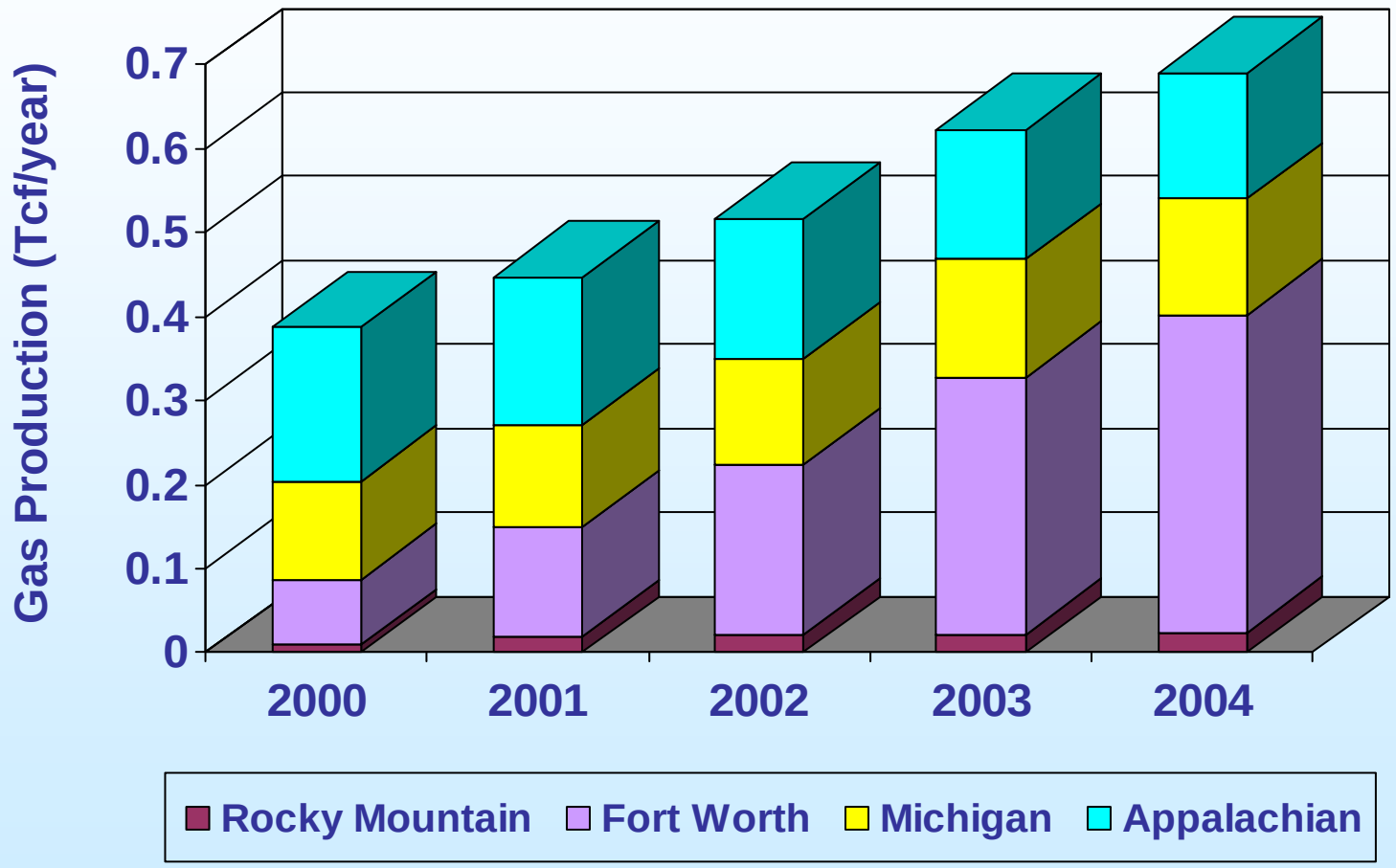
- Provide industry with detailed, basin-wide reservoir information, to guide their exploration and development efforts



Primary U.S. Gas Shale Plays and Basins



U.S. Gas Shale Production by Region



Source: DOE / EIA

Individual Character of Gas Shales Shape Production Challenges

- **Devonian Shale (OH)**
  - Most historical production from Big Sandy field in KY and WV
  - Modest production began in 1920s and has continued to present
  - Wells produce 0.23 to 0.3 Bcf over 30 years
- **Antrim (MI)**
  - Must be dewatered like coal
  - Wells produce 0.4 to 0.8 Bcf at peak rates of 125-200 Mcfd and life of 20 years
  - >7800 wells drilled
- **New Albany (IL)**
  - Activity peaked in 1996 (~90 wells)
  - Must be dewatered
- **Lewis (NM & CO)**
  - Commonly commingled with deeper gas sands
  - Wells produce 2 Bcf at peak rates of 100-200 Mcfd and 6% decline rate
- **Fayetteville (AR)**
  - New play. Estimated EUR of 0.58 to 0.6 Bcf per well
  - Geologic equivalent of Barnett shale in Texas
- **Barnett**
  - Core Newark East Field produces >1 Bcfd. USGS estimates 26.7 Tcf gas-in-place.
  - Initial recovery rates of 8 to 15% are being boosted by new technology

DOE Gas Shales R&D Program Pioneered Technology Development in 70s and 80s

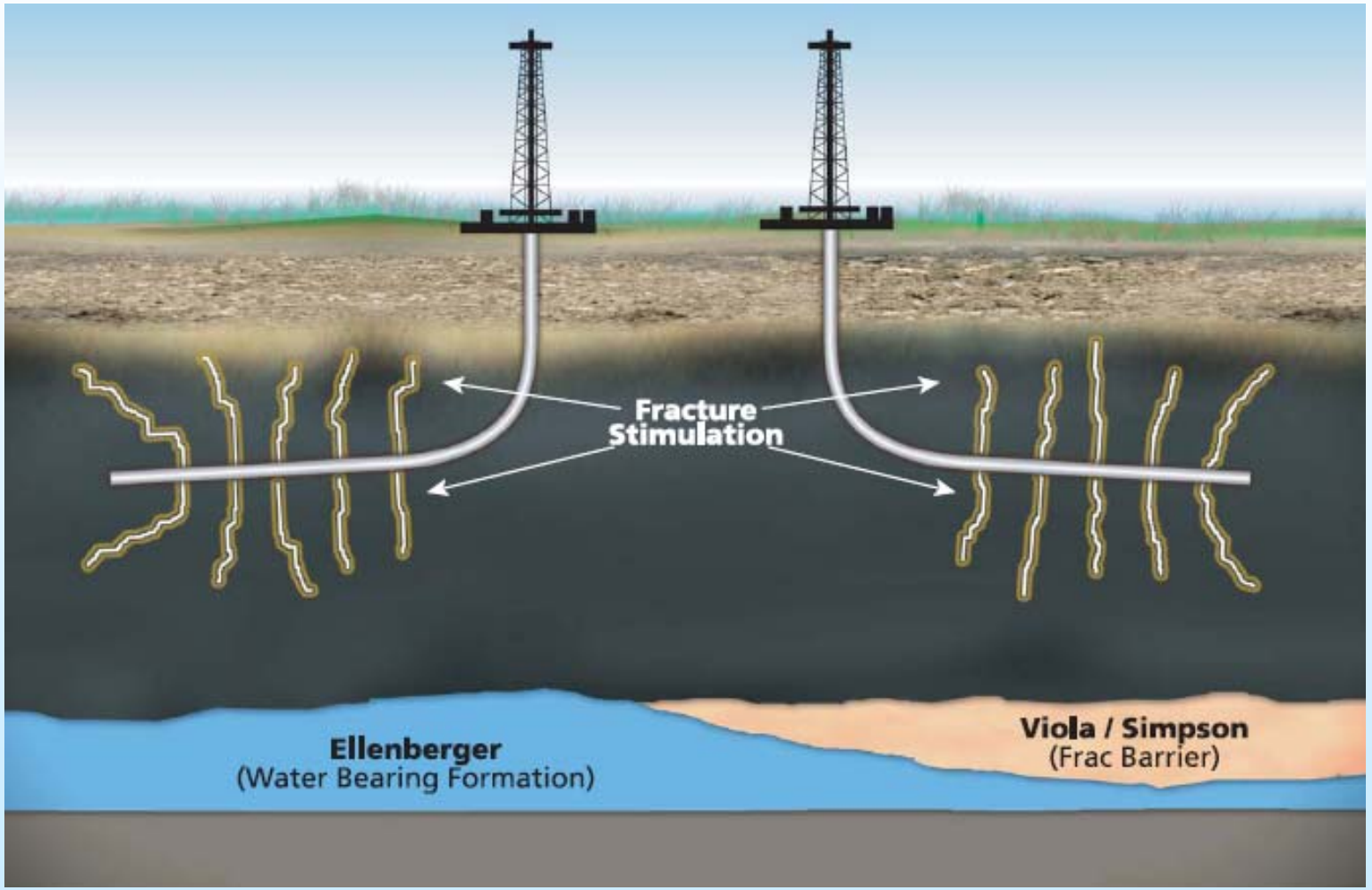
- **Horizontal Drilling for Gas Shales**
  - Drilled the first directional shale wells and the first air-drilled horizontal shale well
- **Foam Fracturing/CO_2 Fracturing**
  - Replaced open-hole explosive fracturing
  - Reduced volume of water used to transport proppant and lessened permeability damage
- **Formation Characterization and Evaluation**
  - Collected basic data on Eastern Gas Shales from more than 35 scientific test wells to define resource
  - Developed well logs and core analysis techniques designed specifically for shales

Barnett Shale Technology Advances

- **Advanced Horizontal Drilling**
  - Designed to intersect fractures
  - "3 times the well for 2 times the cost"
- **Advanced Fracturing Techniques**
  - Water fracs versus gel fracs
  - Must be contained to avoid water from underlying aquifer
- **Advanced 3-D Seismic**
  - Identifies where *not* to drill to avoid geologic features that might connect fractures to water

Photo: Devon Energy

Advanced Completion Technology



DOE Success: Coiled Tubing Drilling Demo

Gas Technology Institute

Objectives

- Demo first high efficiency hybrid CT rig built and operating in U.S.

Accomplishments

- Drilled 25 wells in the Niobrara
  - **300,000 feet of hole in 7 months**
  - **Drilled and completed 3,000' wells in 19 hours**

Benefits

- Made 1 Tcf of shallow bypassed tight gas in Niobrara economic
- Reduced the cost of drilling wells by 25-38%
- Reduced environmental impact

Photo courtesy Tom Gipson, ADT, LLC, Yuma, Colorado

DOE Success: Coiled Tubing Drilling Rig

Schlumberger

Objective

- Develop a modified coiled tubing rig capable of drilling side-track wells in less time and less cost than conventional drilling rigs

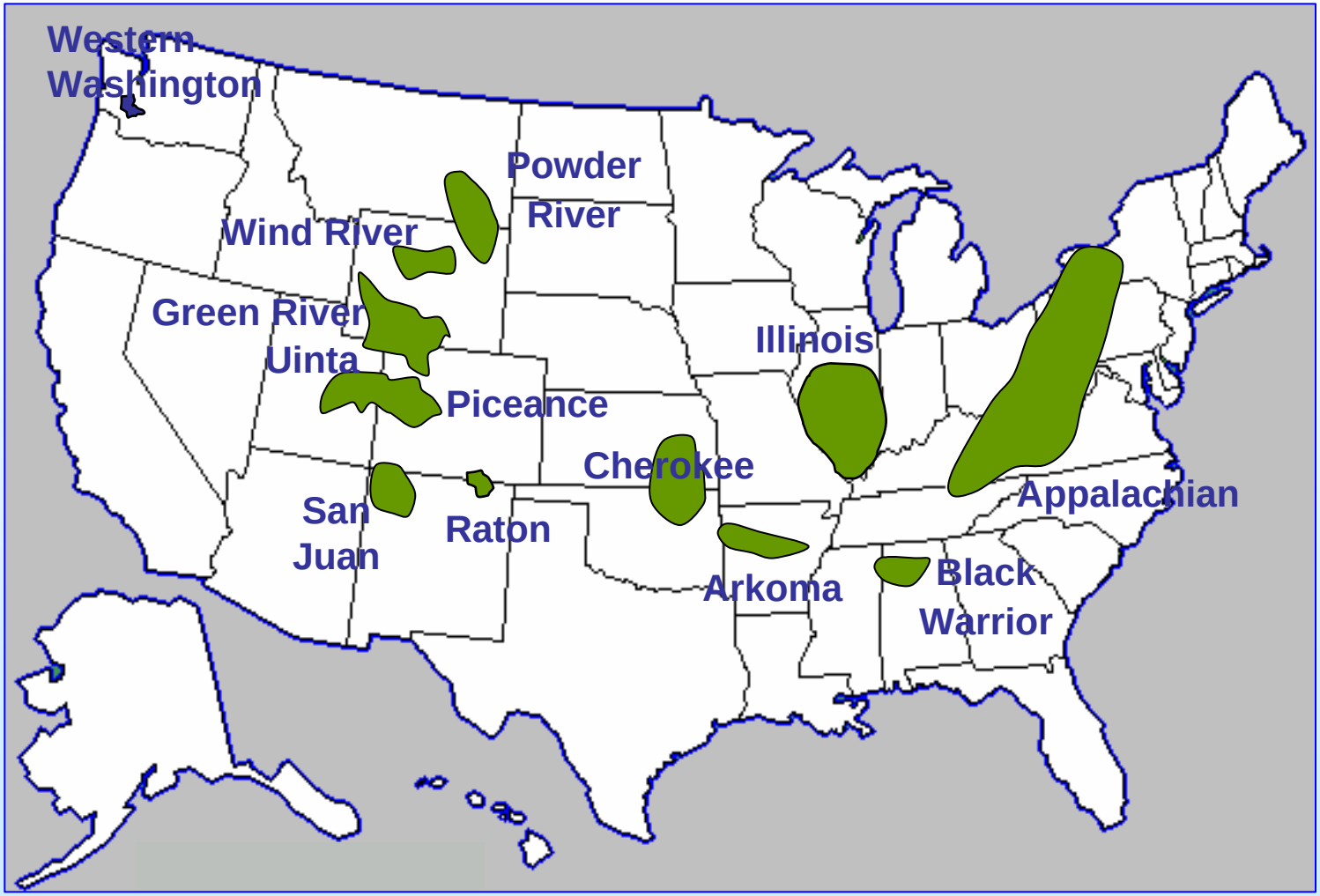
Accomplishments

- Completed all testing and modifications to improve safety, efficiency, underbalanced tool deployment, and data acquisition capabilities
- Now commercial in Barnett Shale

Benefits

- Advancements include: fatigue sensor; better hydraulic / control system, safer, smaller
- Will accelerate and enhance development of the Barnett Shale gas resource, commercializing as much as 45 TCF of unconventional gas in this region

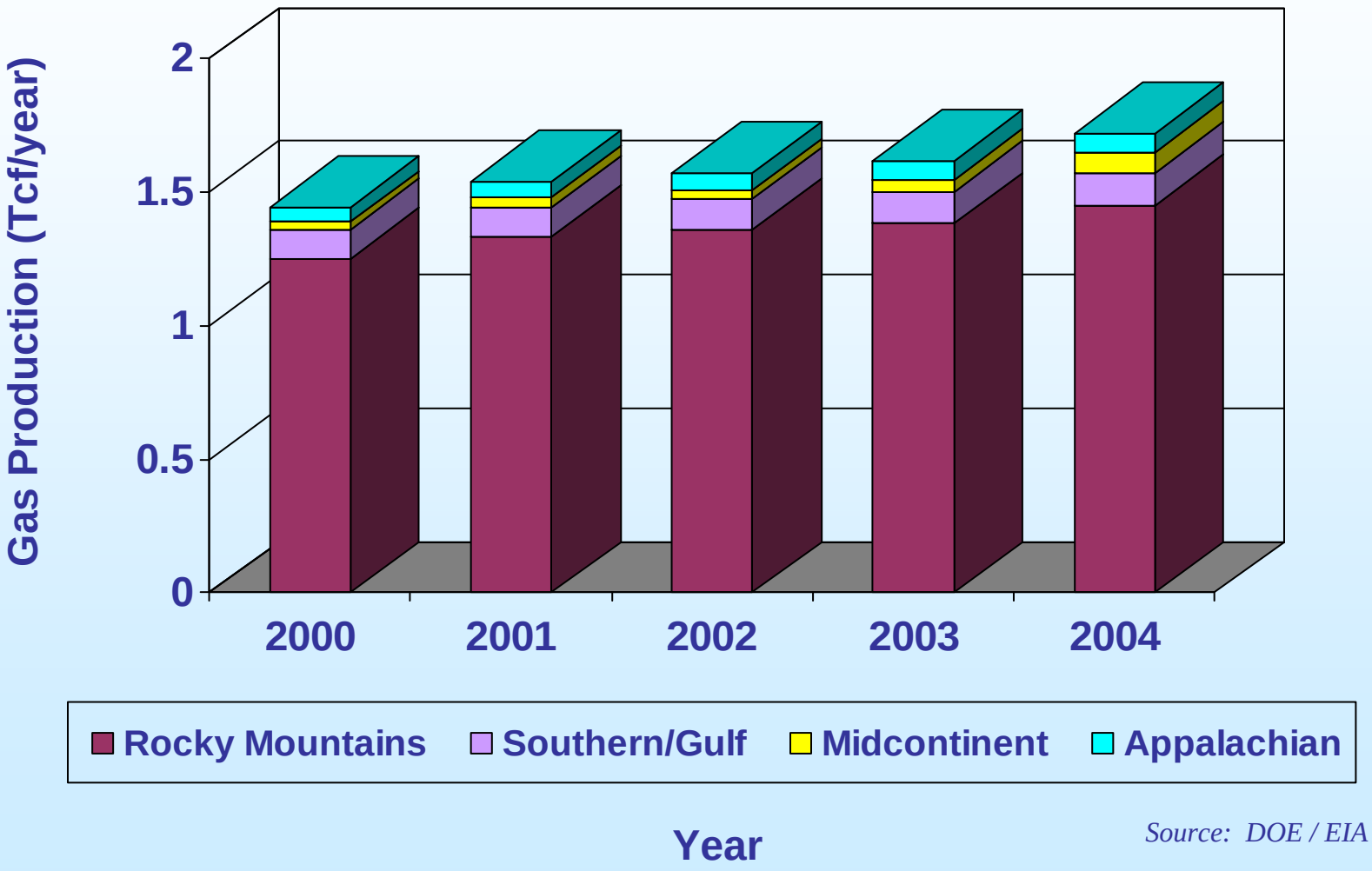
U.S. Coalbed Methane Basins



Coalbed Methane Resource and Production

Region	Resource (Tcf)	2004 Production (Bcf/year)
San Juan Basin	84	958
Powder River Basin	39	320
Other Rocky Mt. Basins	439	174
Cherokee and Arkoma Basins	10	75
Black Warrior Basin	20	121
Illinois/Appalachian Basins	87	72

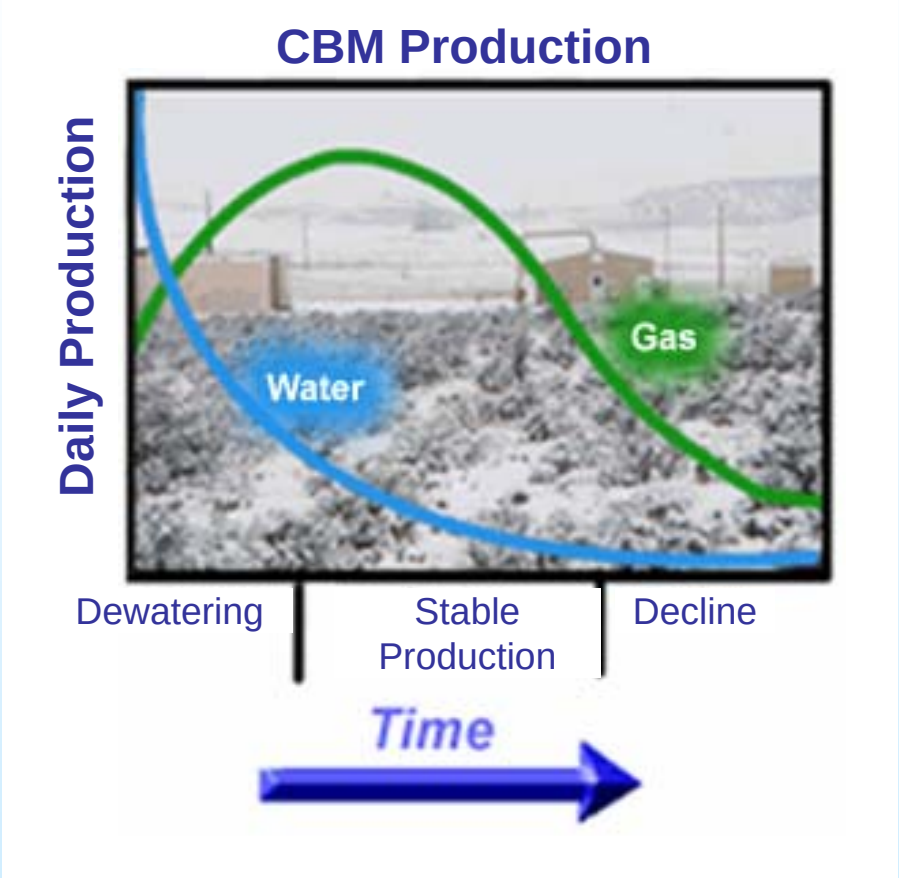
U.S. Coalbed Methane Production by Region



Source: DOE / EIA

Factors Controlling CBM Production

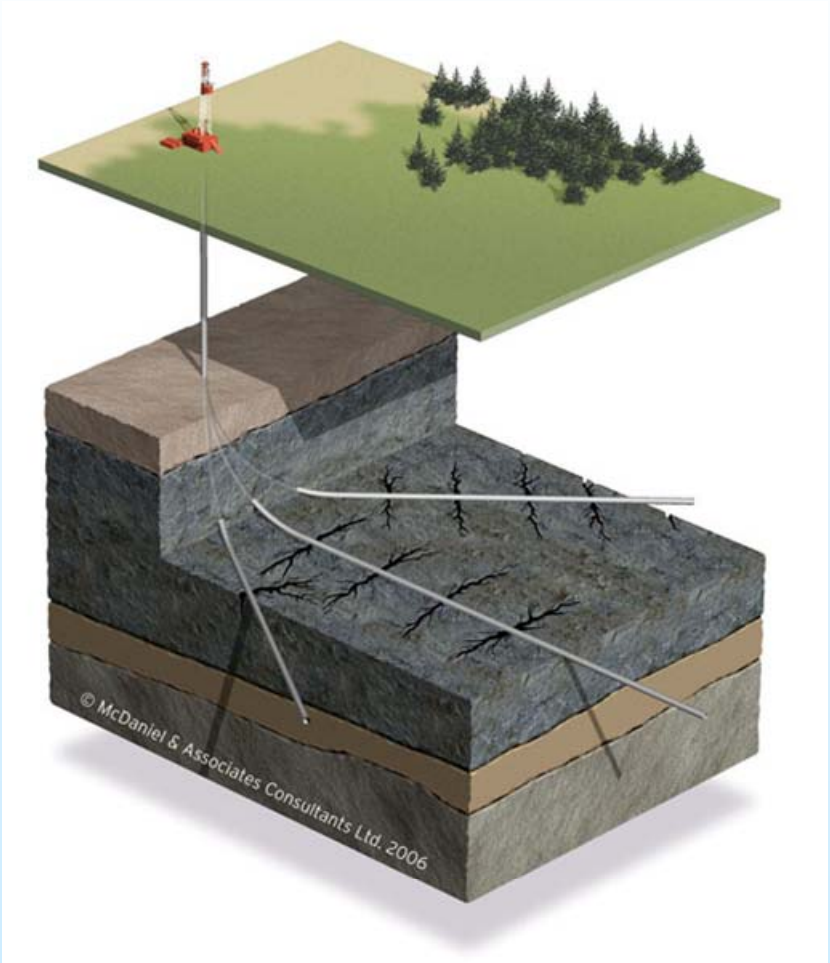
- Fracture permeability
- Development cost
- Gas migration
- Coal maturation
- Coal distribution
- Geologic structure
- CBM completion options
- Hydrostatic pressure
- Produced water management
- Impacts vary from basin to basin



Coalbed Methane Completion-Production Technology Advances

- **Multi-Seam Completion (MSC) Technology**
  - Allows gas from thin coal seams to be produced along with that from thicker ones
  - successful MSC in the Powder River Basin (PRB) CBM play will increase economically recoverable resource by 20+ Tcf
- **Advanced Horizontal Drilling**
  - Improved directional control of horizontal drilling
  - Multilateral drilling to access multiple cleat systems
- **Enhanced CBM (ECBM) Recovery**
  - Injection of CO_2 or N_2
  - U.S. CO_2-ECBM/sequestration potential assessed at 90 Gt CO_2 and 150 Tcf incremental recovery
- **Advanced Water Management**
  - Downhole separation and disposal, low cost reverse osmosis, phytoremediation, advanced membrane treatment

Coalbed Methane Completion-Production Technology Advances



DOE Success: Membrane Filtration Technology for Treatment of Produced Water

Texas Engineering Experiment Station

Goal

- Develop portable reverse osmosis membrane filtration technology for produced water

Accomplishments

- The desalination technology has been commercialized through GeoPure Water Technologies.
- System will process 20 gallons per minute of feed water

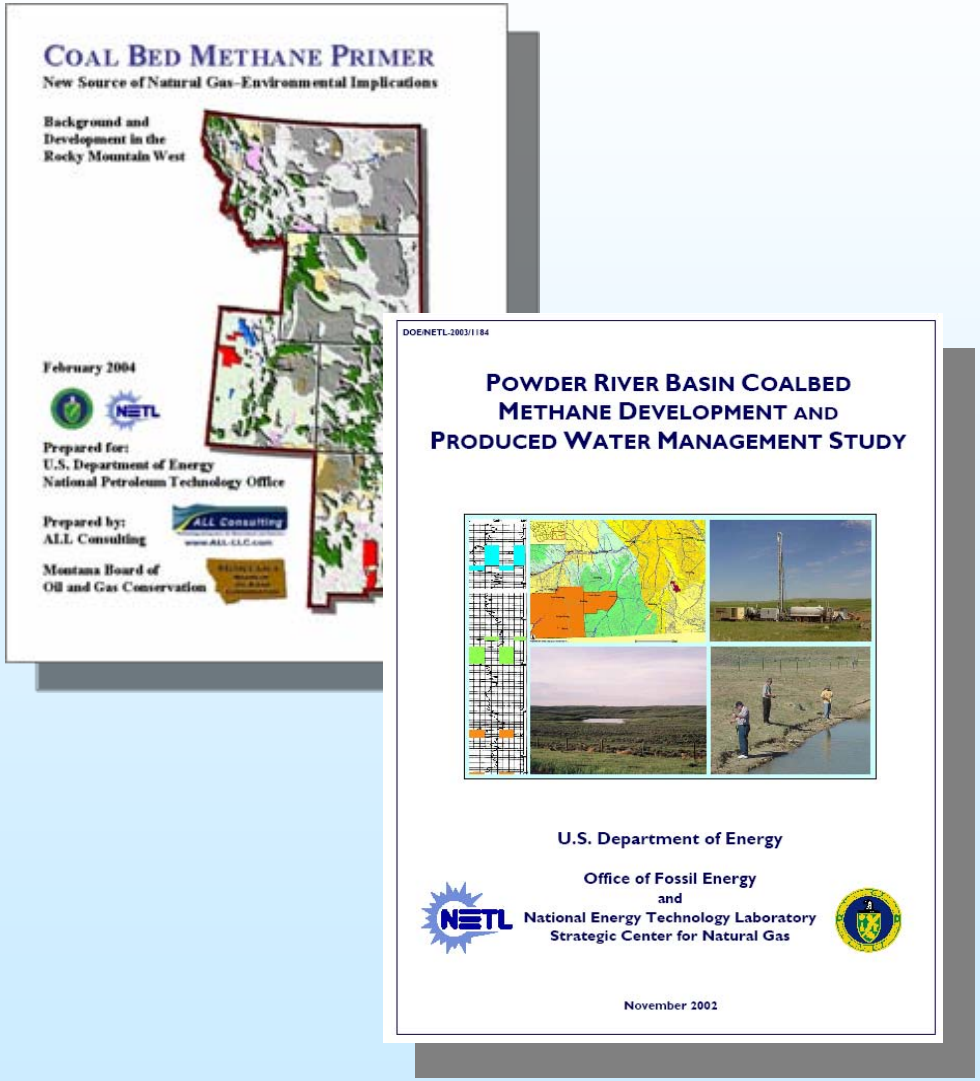
Benefits

- Reduces disposal costs by 75%
- Provides fresh water for beneficial use

Recent DOE Coalbed Methane Publications

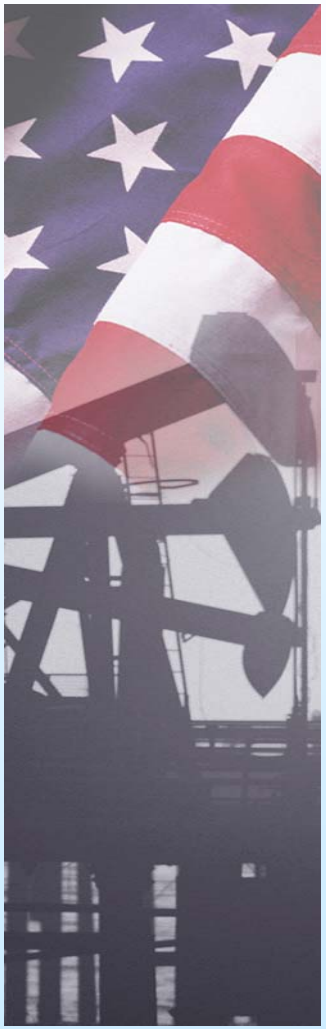
- Analysis of Produced Water Management Alternatives
- Basic Primer on Coalbed Methane
- Available from DOE via websites

www.fossil.energy.gov
www.netl.doe.gov



Closing Thoughts

- **Unconventional Gas Growing in Importance to U.S.**
  - Large resource in multiple basins
  - Technical challenges vary from basin to basin and resource to resource
- **New Approaches Call for Innovative Thinking**
  - Some solutions can be transferred from basin to basin, some need modification
- **Integration of Technologies Will be Key**
  - Engineers, geologists, land use specialists
- **Environmental Issues Demand Technology Solutions**
  - Opportunities for R&D collaboration with industry
  - Prerequisite for resource access



Visit Our Websites

Fossil Energy website:

www.fe.doe.gov

NETL website:

www.netl.doe.gov