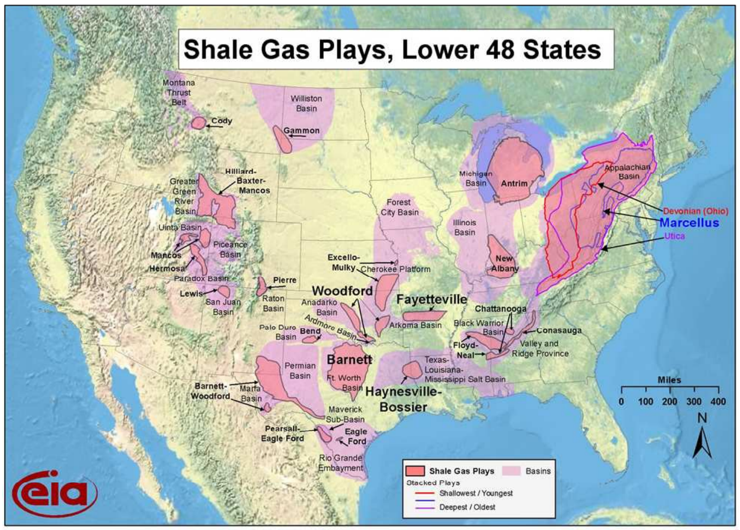
Enegis LLC



Source: Energy Information Administration based on data from various published studies.

Defining Unconventional Hydrocarbon Resources and Pursuing Geological Analysis and Assessments

REGIONAL WORKSHOP on the CHANGING GLOBAL GAS MARKET and UNCONVENTIONAL GAS

Jakarta, Indonesia

7 May 2013

Jeffrey Eppink, Enegis, LLC

What We Will Cover

- **What are unconventional (natural gas) resources?**
  - How have they suddenly thrust upon the scene?
  - How are they defined?
  - What are their characteristics?
- **How can they be assessed?**
  - Below- and above-ground risk
  - Geological analysis and assessments
- **The changing global gas market and unconven-tional gas**
  - How assessments can be used

WHAT ARE UNCONVENTIONAL RESOURCES?

How have they suddenly thrust upon on the scene?

How are they defined?

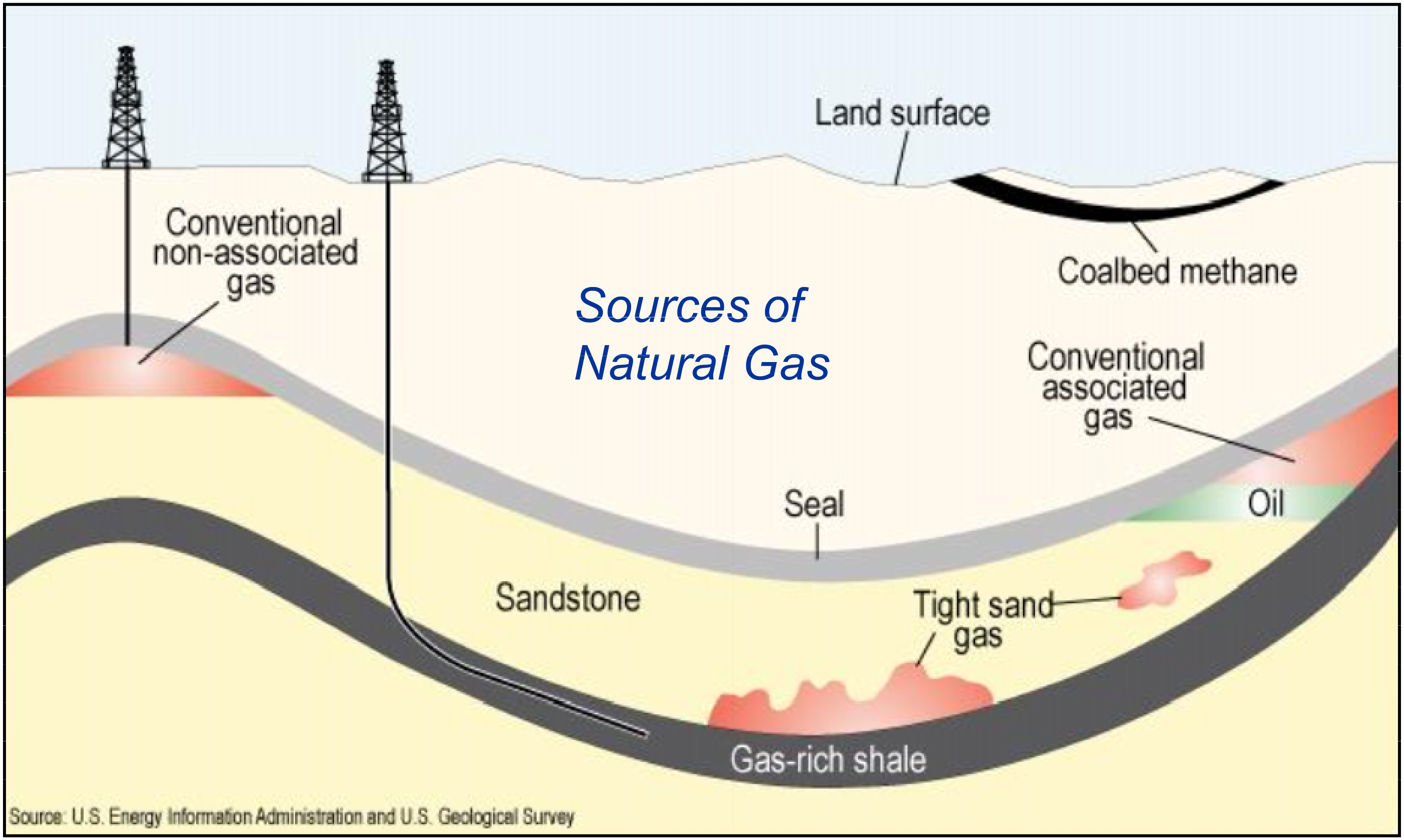
What are their characteristics?

What Is Unconventional Gas

- **Coalbed methane (CBM)**
- **Tight gas (low permeability sandstones)**
- **Gas shales**
- **Methane hydrates**

- **Volumetrically, gas shales are turning out to be the largest and most significant viable unconventional resource**
  - Gas shales will the resource assessment topic here
  - Resource assessment methodology is similar for all types

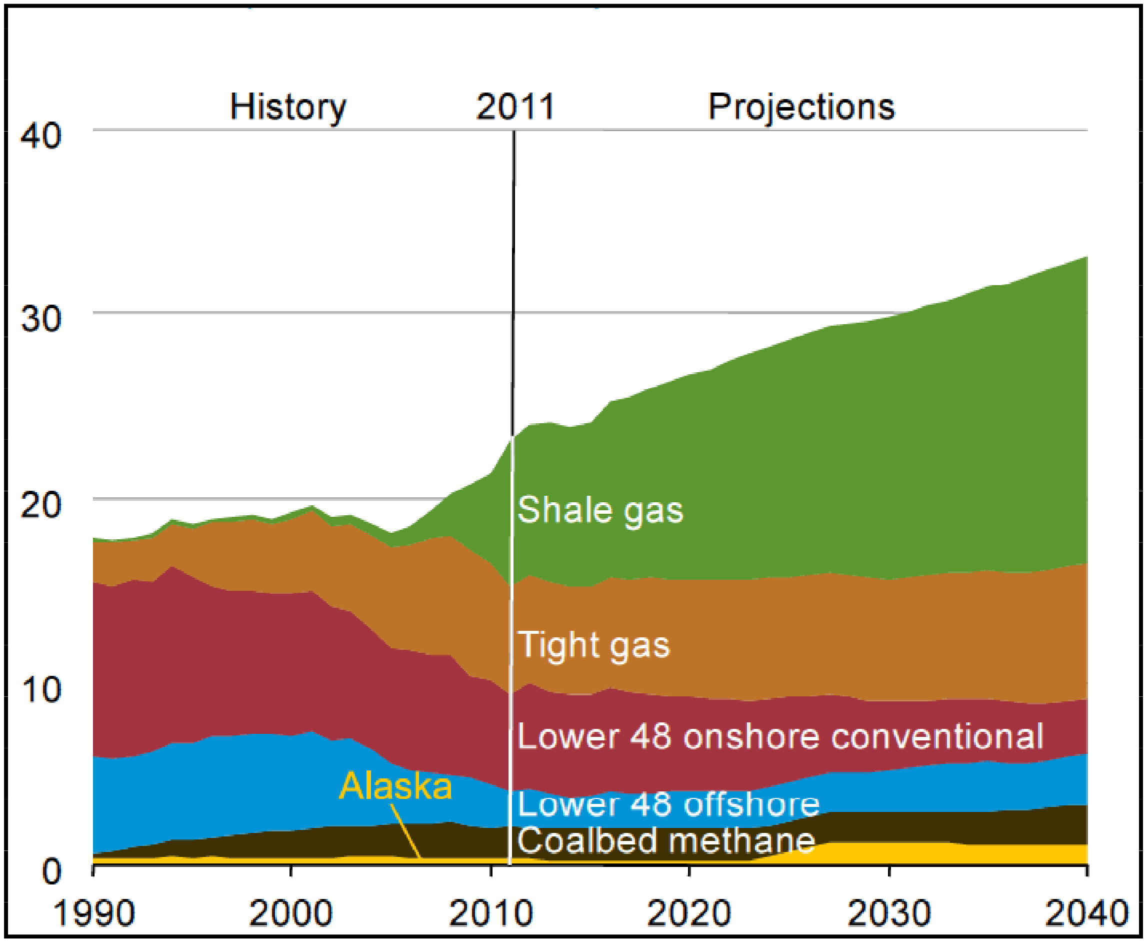
What Are Unconventional Resources?



"Unconventional" Gas Solidly Goes Mainstream

- **Growth in production is a result of the application of recent technological advances and continued drilling**
- **Unconventional gas is projected to dominate in 2040 with 85% of U.S. production share**
- **Shale gas is projected to grow to almost 50% of U.S. production from just a few percent**

U.S. natural gas production, 1990-20405, (trillion cubic feet)



Source: EIA AEO 2013

Shale Gas Plays, North America

Enegis, LLC

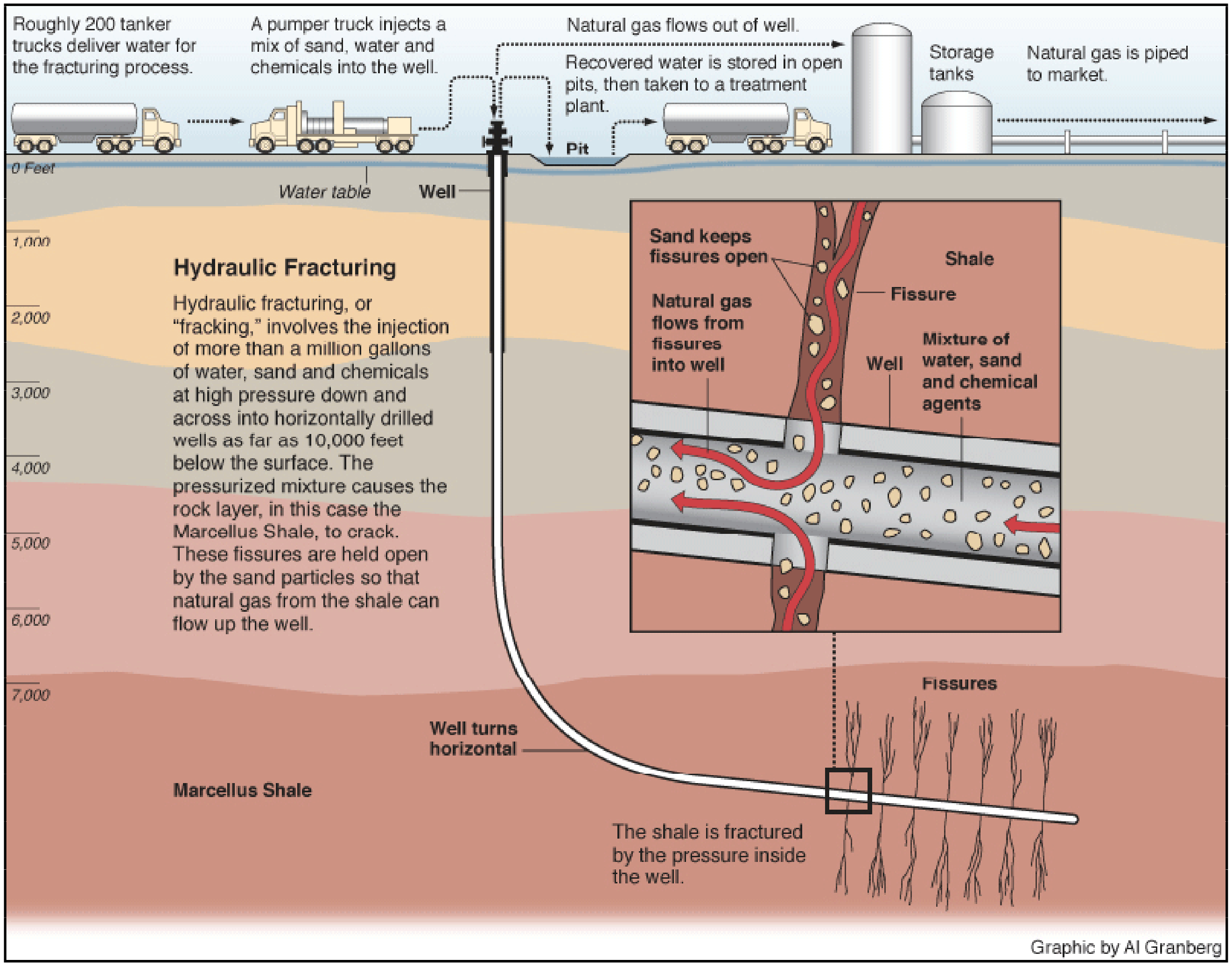
Source: EIA

Fundamentals of Shale Gas

- Self-sourced
- Rich in organic matter
- Organic matter ubiquitously distributed in the rock
- Maturity beyond oil window
- Subsidence and uplift history important
- Shallow enough for horizontal drilling
- Rock can be fracked for gas production

Enabling Technologies

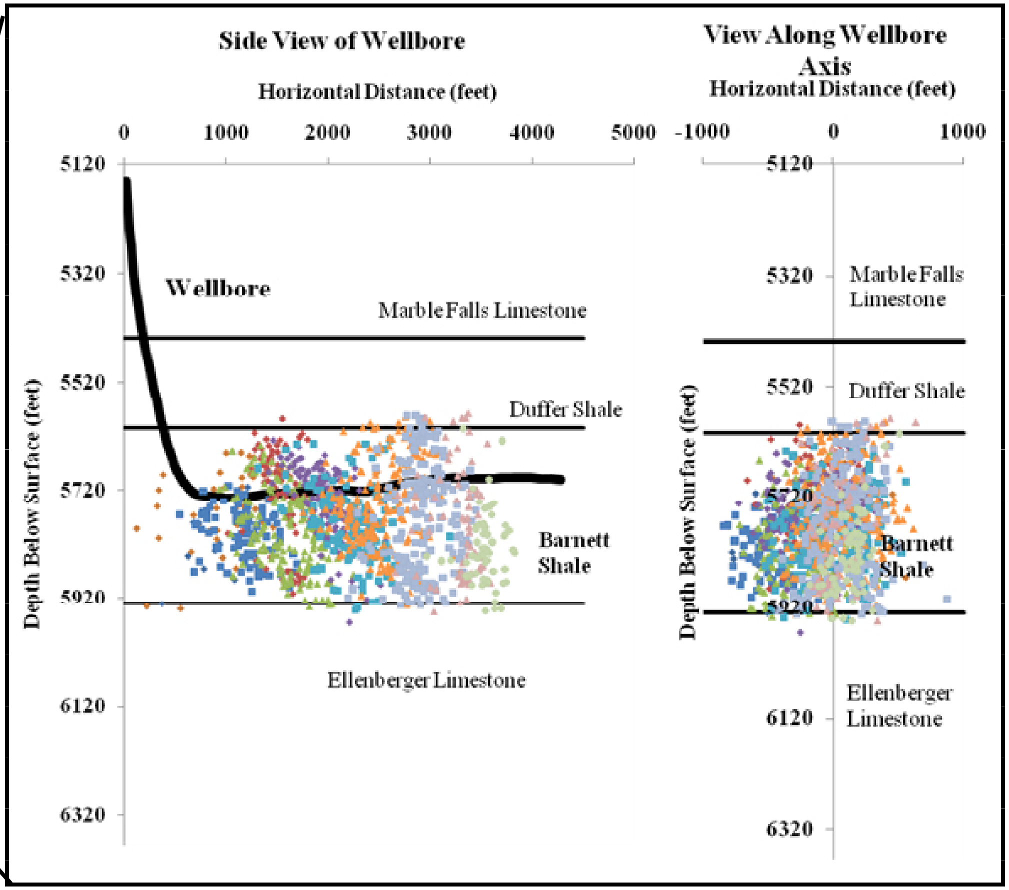
- **Horizontal drilling coupled with hydraulic fracturing ("fracking") have been the primary enabling technologies**



Source: ProPublica, http://www.propublica.org/special/hydraulic-fracturing-national

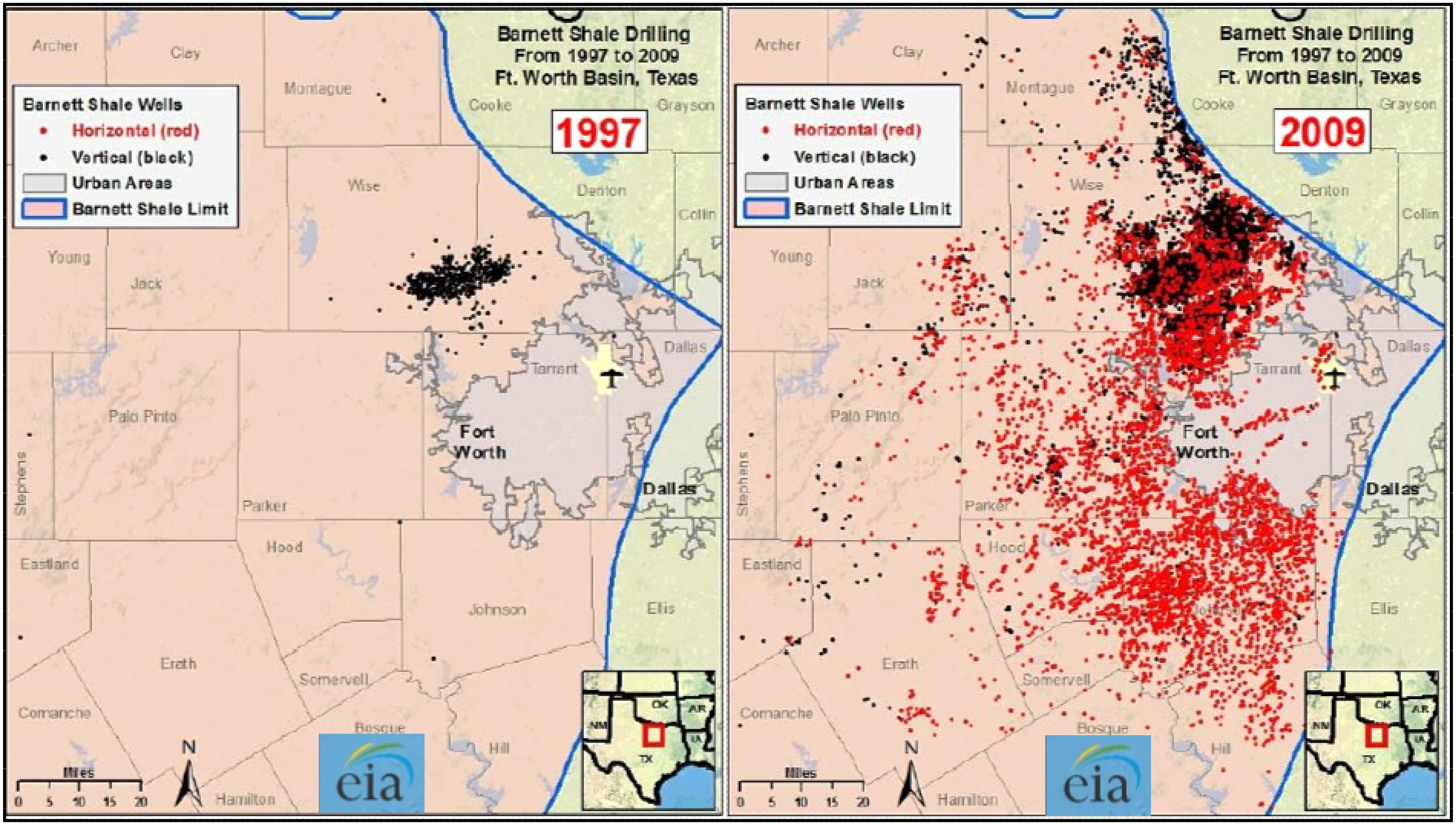
Ancillary Technologies

- **Geomechanics**
  - Natural fractures
- **Geochemistry**
  - Gas isotopes
- **Downhole drilling motors**
- **Downhole telemetry**
- **Microseismicity**



Source: Microseismic Diagram of Typical Hydraulic Fracturing Job in Barnett Shale
http://www.shalegaswiki.com/index.php/File:Microseismic_Diagram_of_Typical_Hydraulic_Fracturing_Job_in_Barnett_Shale.jpg

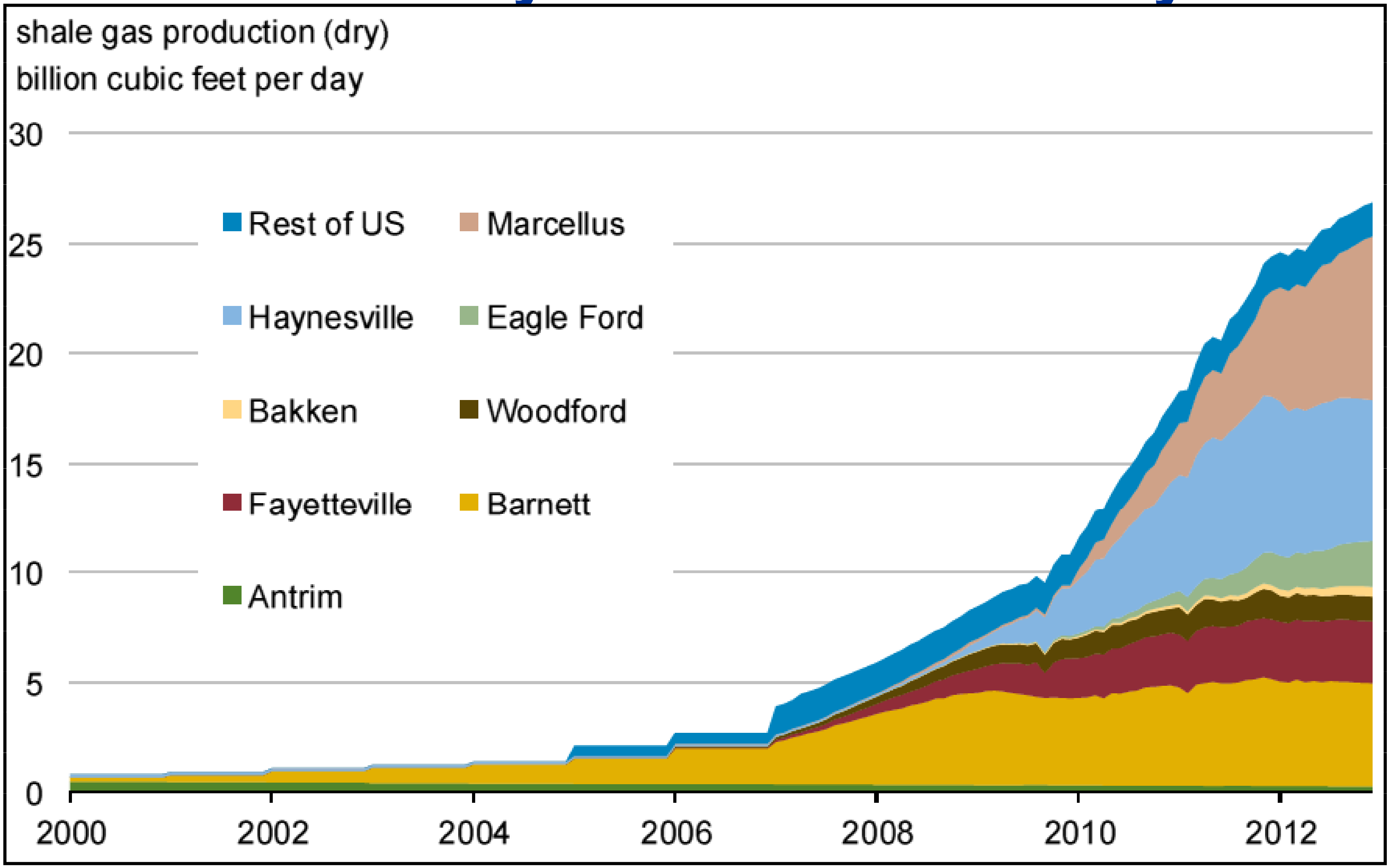
Shale Gas Takes Off…



Source: EIA

- More than 13,500 gas wells have been completed in the Barnett shale since '77

U.S. Production of Shale Gas Has Grown Dramatically in a Portfolio Of Plays



Source: LCI Energy Insight gross withdrawal estimates as of December 2012 and converted to dry production estimates with EIA-calculated average gross-to-dry shrinkage factors by state and/or shale play.

HOW CAN THEY BE ASSESSED?

Below- and above-ground risk

Geological analysis and assessments

Uncertainties That Impact the Growth of Shale Gas

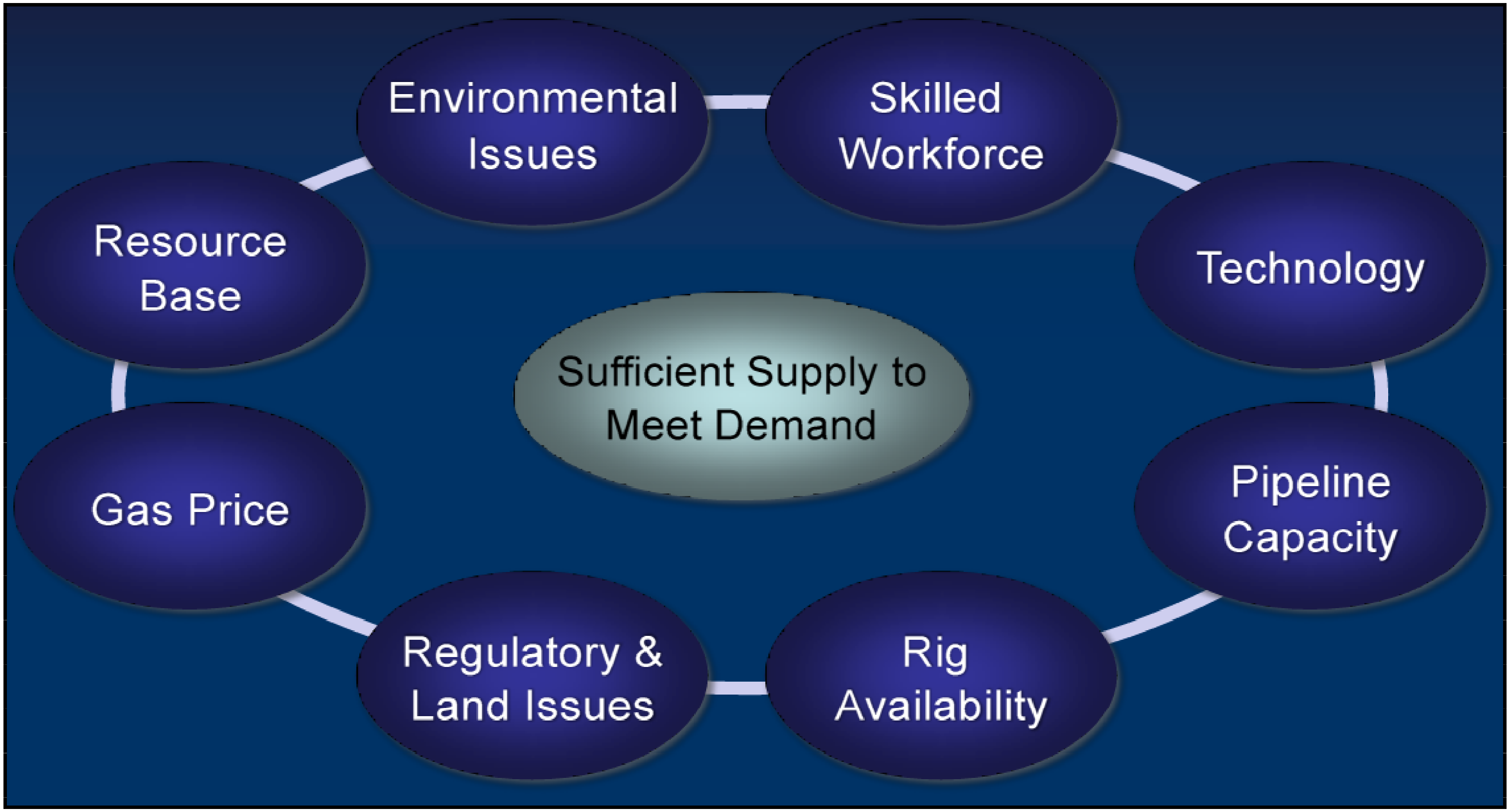
Issue	Risk	
	Above-ground	Below-ground
Resource quantities and distribution		X
Surface rights	X	
Mineral rights		X
Risk appetite of industry participants	X	X
Infrastructure/technology	X	X
Environmental constraints	X	X

Life Cycle Analysis

- **Exploration, development, production, and pipelining**
- **Environmental and regulatory considerations**
  - Surface disturbance
  - Water availability and management
  - Air quality

Influences on Gas Supply

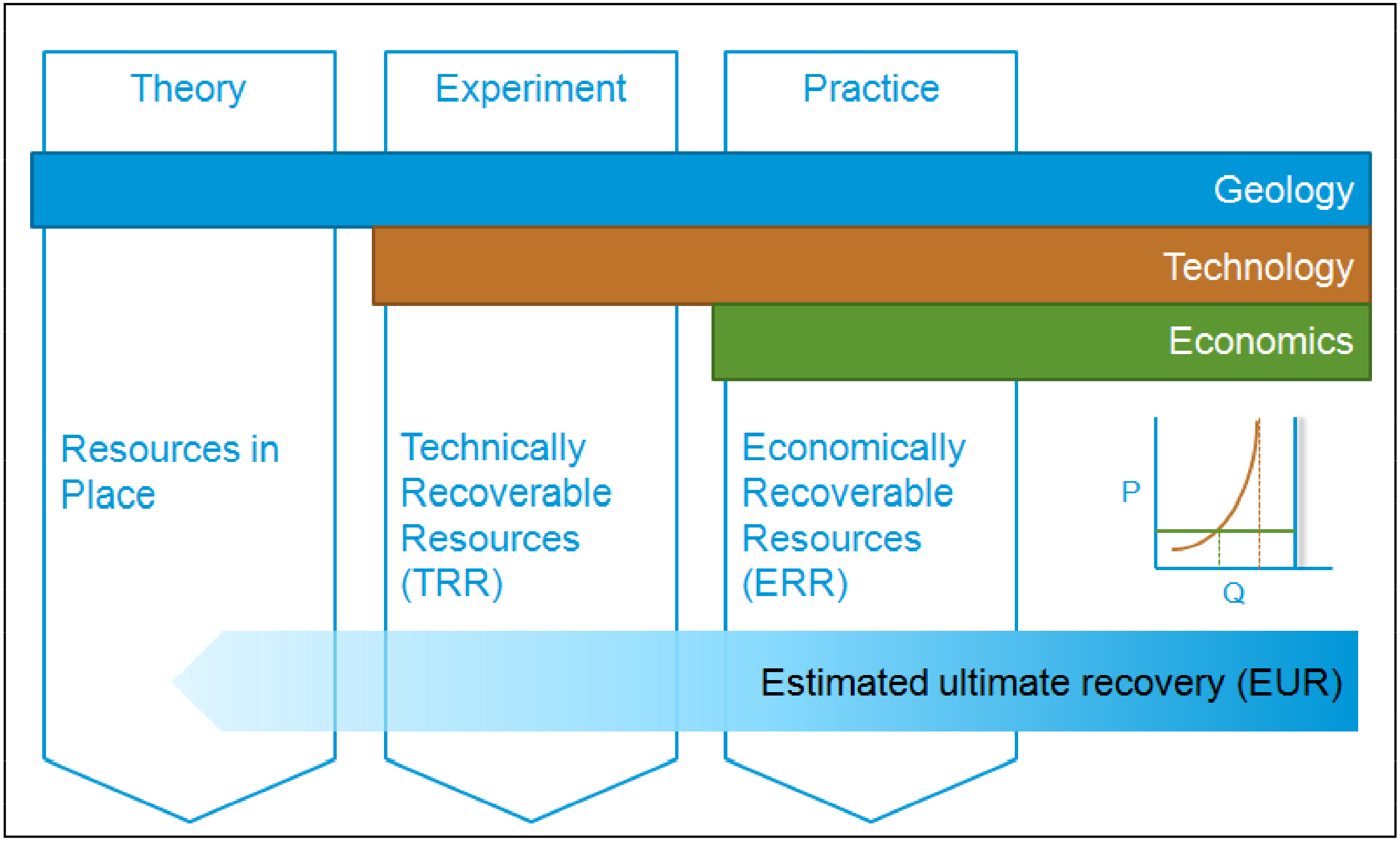
- **Bringing gas resources from theory to practice:**



Source: Potential Gas Committee (2013)

Geological Analysis and Assessments

- **Bringing gas resources from theory to practice:**

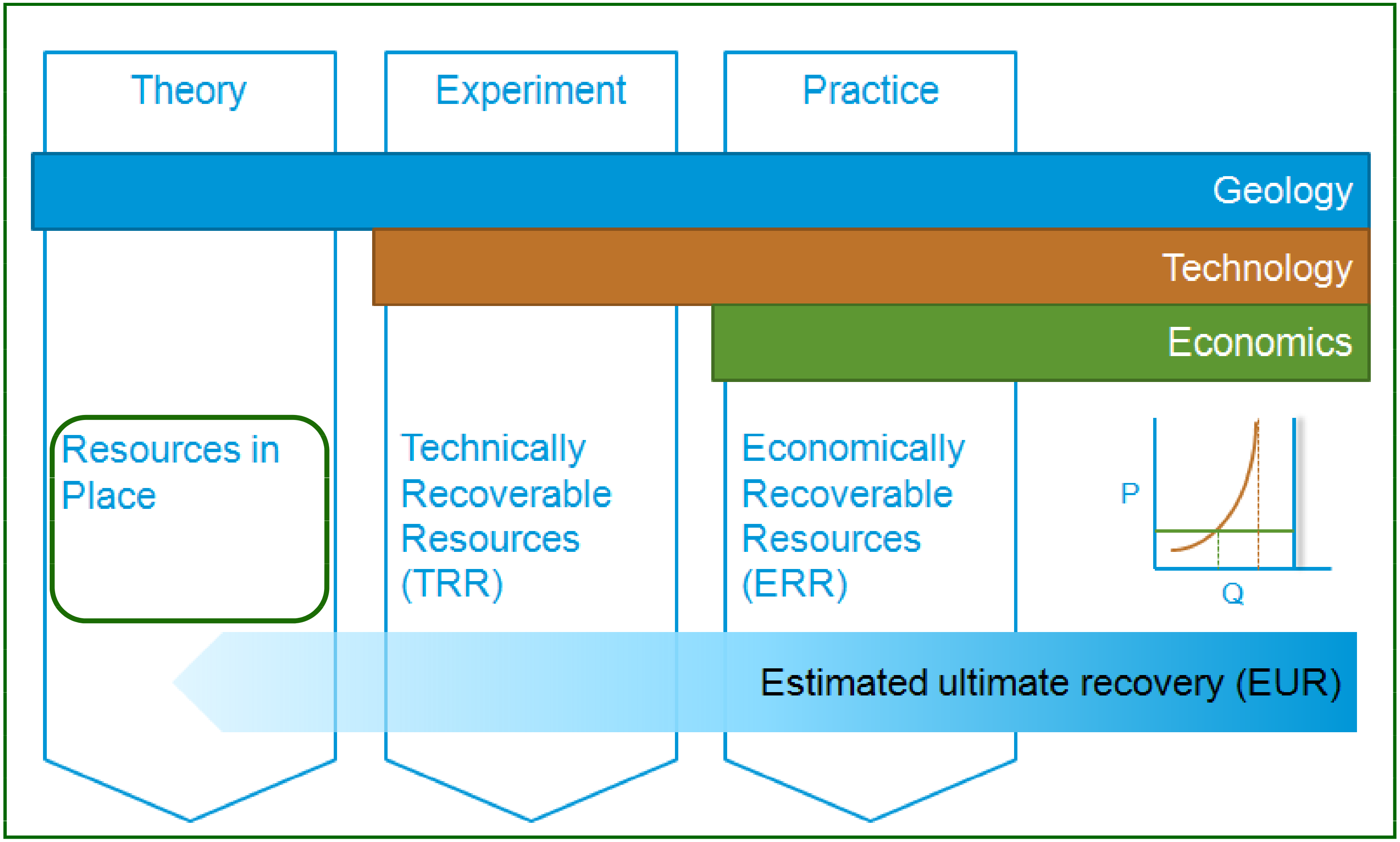


Source: Adam Sieminski, Administrator, U.S. Energy Information Administration, *Status and outlook for shale gas and tight oil development in the U.S.*, Platts – North American Crude Marketing Conference, March 01, 2013, Houston, TX

Resource Estimation Methodology

- **Comprises three steps that make up a resources continuum:**
  1. Gas-initially-in-place (GIIP)
  2. Technically recoverable resources (TRR)
     - A subset of GIIP comprising that portion that can be recovered by technical means without explicit consideration of economics
     - Considers “access” to the resource
  3. Economically recoverable resources (ERR)
     - A subset of TRR that meets economic criteria for potential production and is amenable for development into reserves

Bringing Gas Resources from Theory to Practice



Source: Adam Sieminski, Administrator, U.S. Energy Information Administration, *Status and outlook for shale gas and tight oil development in the U.S.*, Platts – North American Crude Marketing Conference, March 01, 2013, Houston, TX

Resource-in-Place

- **Start with a systematic estimate of gas-initially in-place (GIIP):**
  1. Conduct a preliminary review of a basin and select the shale gas formations to be assessed
  2. Determine the areal extent of the shale gas formations within the basin in addition to other parameters
     - thickness
     - porosity
     - organic matter type
     - thermal maturity
     - depth
     - aspect ratio
     - pore pressure
     - temperature
     - mineralology
     - Poisson ratio
     - water content

Resource-in-Place (cont'd)

3. Determine the 'prospective area' deemed likely to be suitable for development based on criteria and expert judgment
4. Estimate GIIP as a combination of
   - free gas (dominant in deeper shales)
   - adsorbed gas (adheres to organic matter of the shale; can be the dominant for the shallower and higher organically rich shales)
5. Establish and apply a composite 'success factor' that comprises play success and prospectivity; derive risked GIIP estimates by assigning probabilities to factors
   - dependent upon geological complexity

Gas Initially in Place Estimation

Free gas

$$GIIP = \frac{C_{Vol} \cdot A \cdot H \cdot \phi(1 - Swc)}{B_{gi}} \cdot \varsigma$$

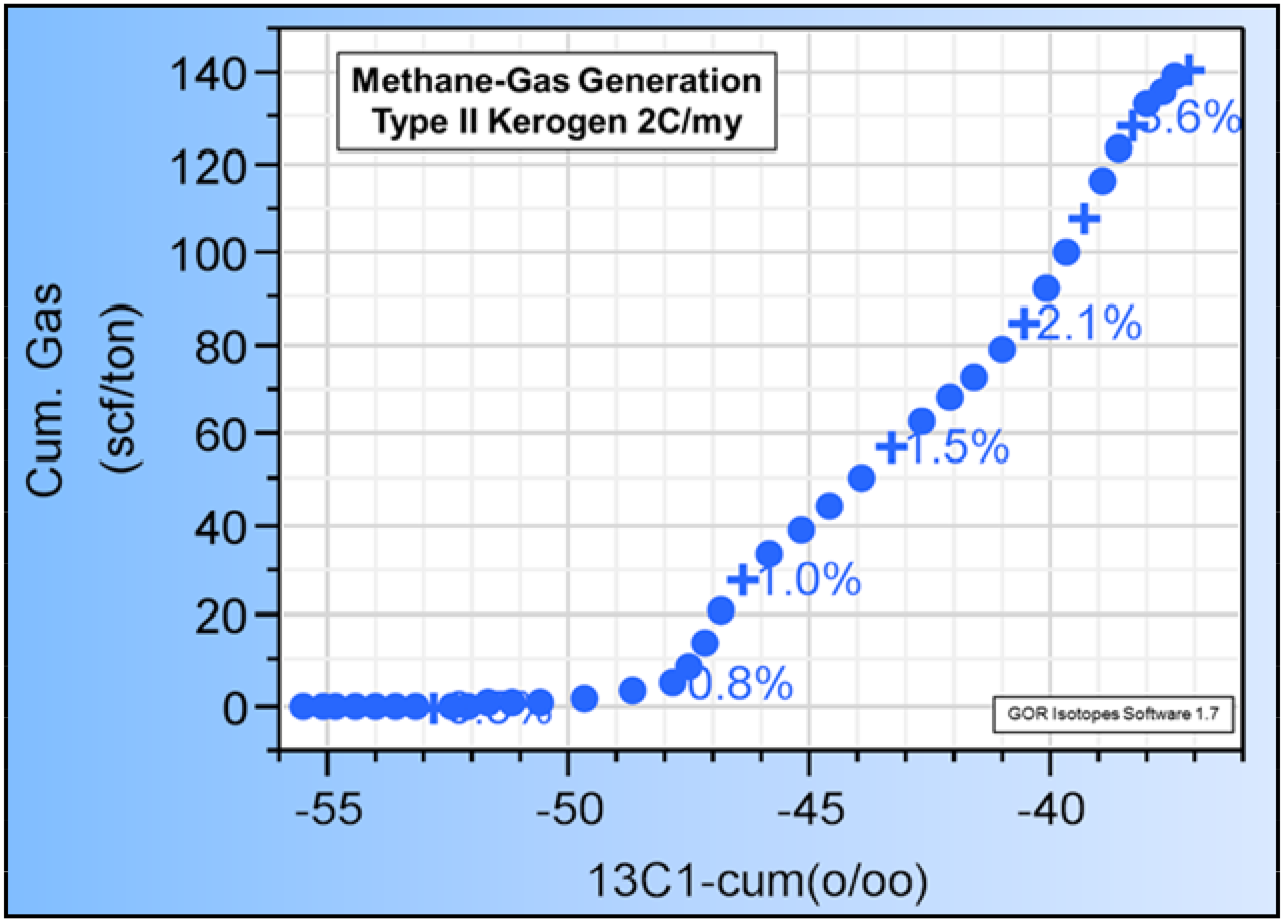
- **Where:**
  - *GIIP* = Gas initially in place, in standard cubic feet (scf) for CO_2
  - *A* = Area (acres)
  - *H* = Pay thickness (feet)
  - *Φ* = Porosity (fraction)
  - *Swc* = Connate water saturation (fraction)
  - *Bgi* = Initial gas formation volume factor in reservoir ft^3 per scf (reservoir cubic feet (rcf)/scf)
  - C_{Vol} = A volumetric constant, 43560 ft^3/ ac-feet (cubic foot/acre-foot)
  - ς = CH_4 concentration (volumetric percent)

Adsorbed gas

$GC = (V_L * P) / (P_L + P)$

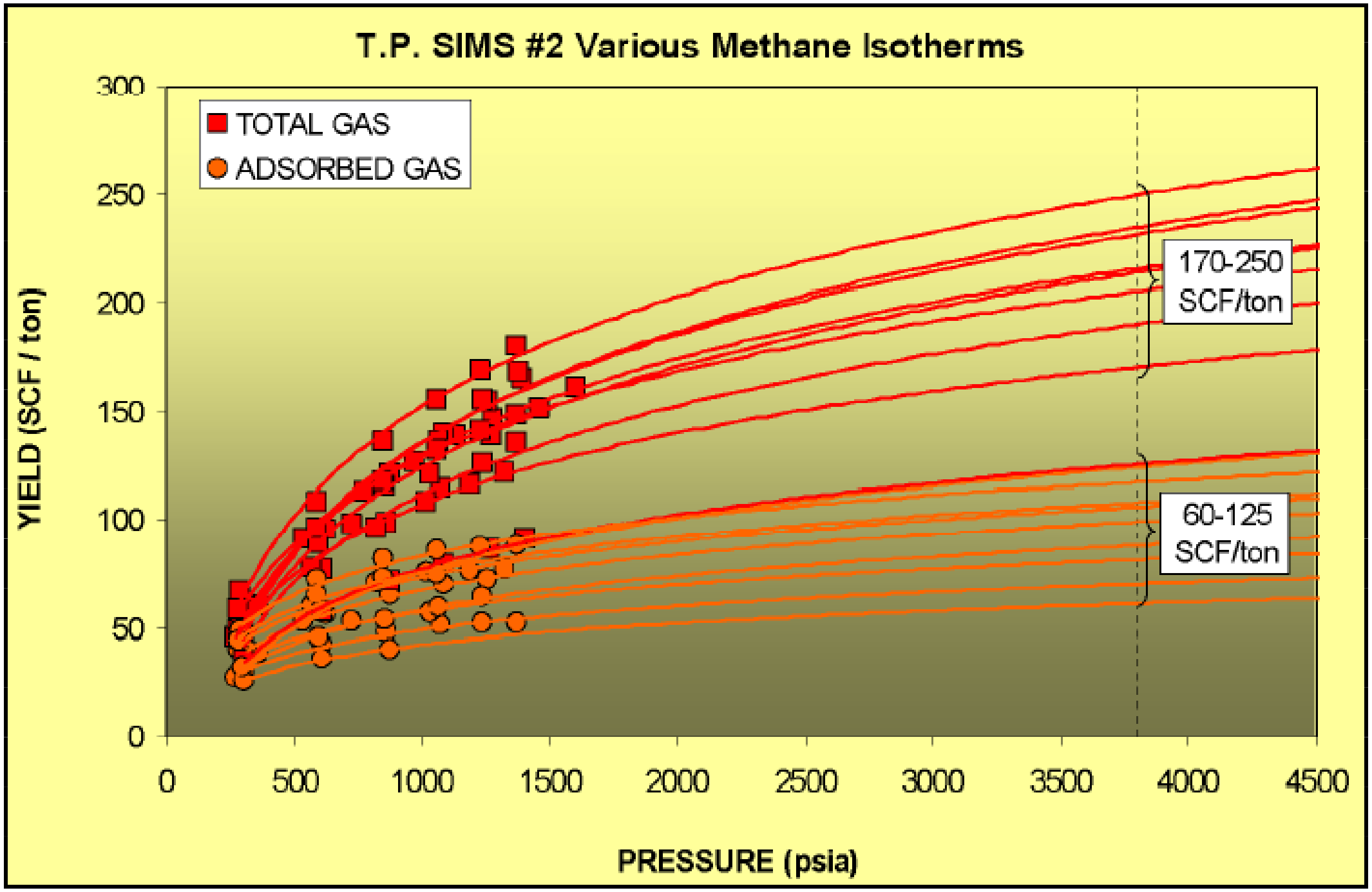
- **Where:**
  - *GC* = Gas content, scf per ton converted to gas concentration using typical shale density of 2.65 to 2.8 gm/cc
  - *P* = Original reservoir pressure
  - V_L = Langmuir value (F[organic richness and thermal maturity of the shale])
  - P_L = Langmuir pressure (F[gas release due to delta pressure])

Gas Isotope Analyses Provide Information on Gas Potential



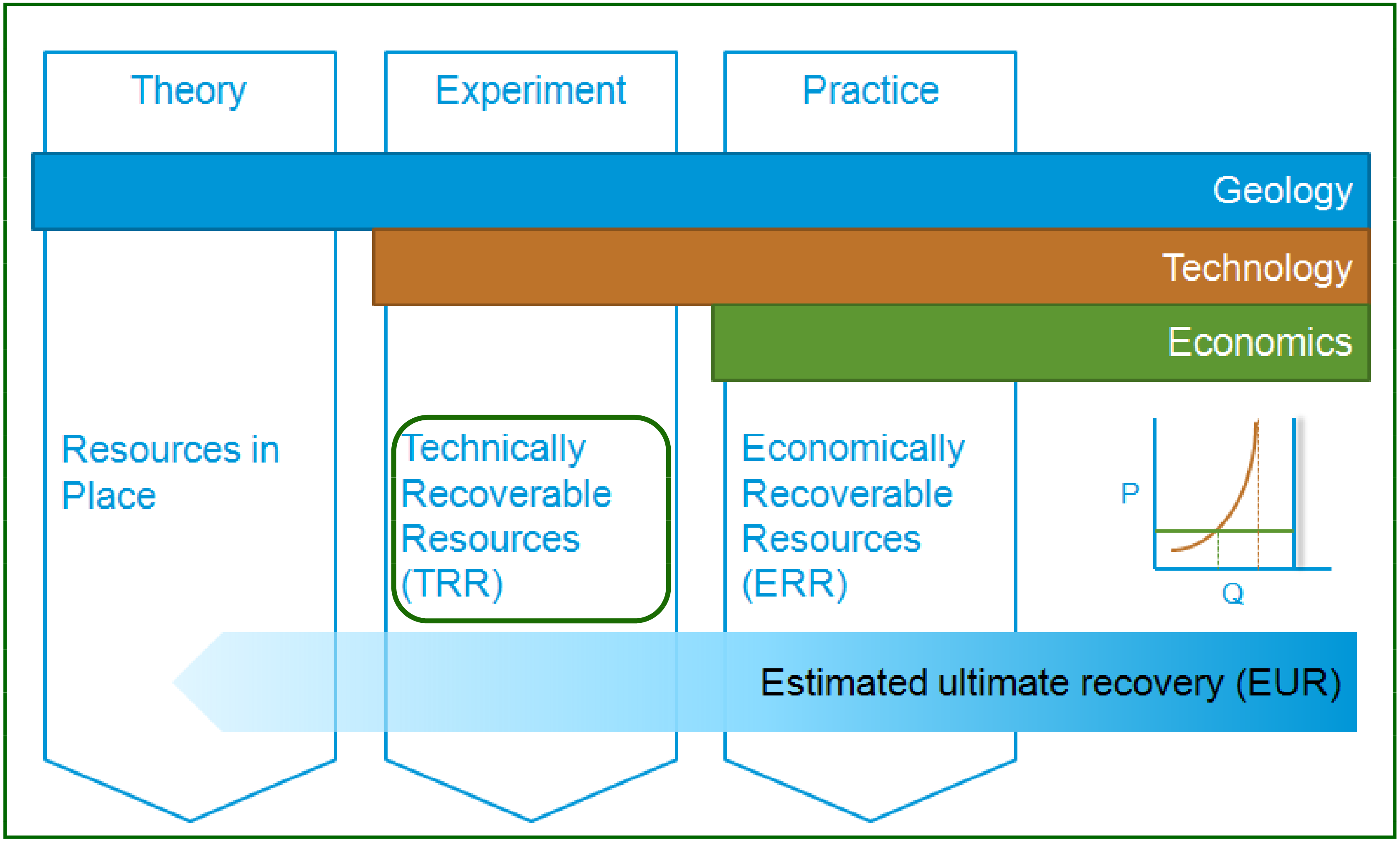
Source: GasConsult Intl

Example Gas Yield



Source: GRI Report 5086-213-1390, 1991

Bring Gas Resources from Theory to Practice

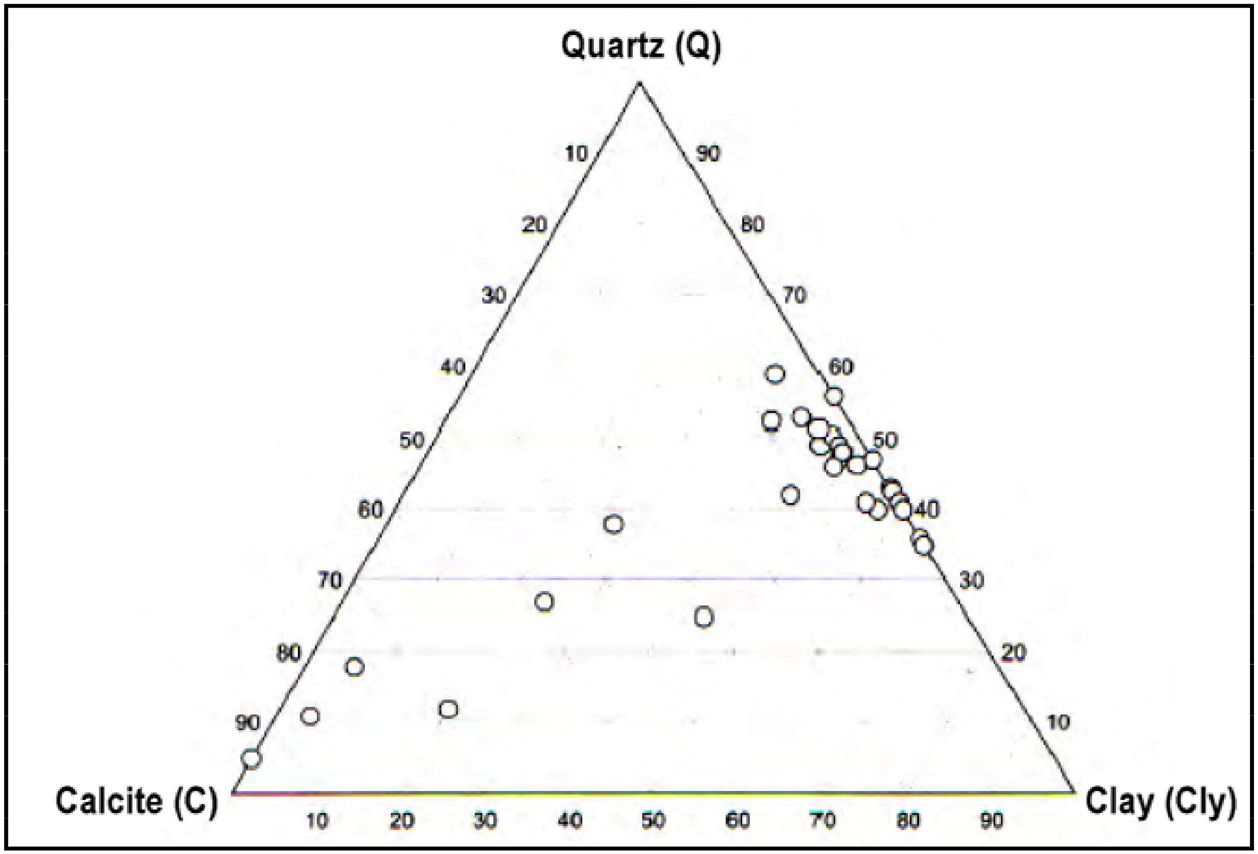


Source: Adam Sieminski, Administrator, U.S. Energy Information Administration, *Status and outlook for shale gas and tight oil development in the U.S.*, Platts – North American Crude Marketing Conference, March 01, 2013, Houston, TX

Technically Recoverable Resource (TRR)

- One of the basic metrics for quantifying the total resource base that analysts use to estimate future natural gas productionpotential
- Estimate for shale gas is established by multiplying the risked GIIP by a shale gas recovery factor that incorporates a number of shale gas basin- and formation-specific geological inputs and analogs
- Factors can include mineralogy, geologic complexity, depth and other inputs that assess the response of a geologic formation to the application of recovery technology

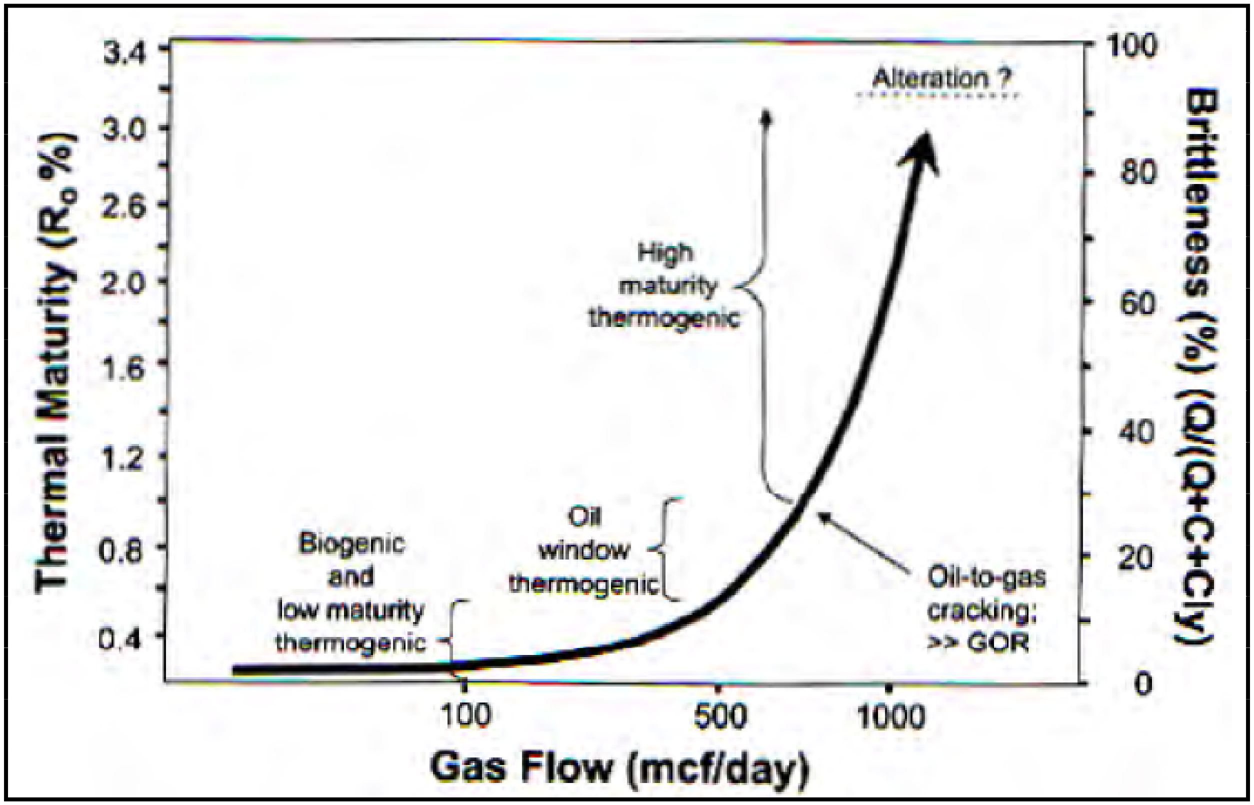
Factors Affecting Recovery from Gas Shales



Source: World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States and AAPG 4/2007, pp. 494, 49

- **Depositional Environment and Diagenetic Potential**
  - Ternary diagram of shale mineralogy (Marcellus Shale) useful for classifying the mineral content

Factors Affecting Recovery from Gas Shales



Source: World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States and AAPG 4/2007, pp. 494, 49

- **Relationship of shale mineralogy (quartz, calcite and clay) and thermal maturity to gas flow**
  - Characterizes implications of shale formation mineralogy to shale brittleness and shale response to hydraulic fracturing

Technically Recoverable Resources (TRR)

- **Result from the well analysis**

  Area (acres)

  ÷ drainage area of a well

  × % of area not yet drilled

  × % area with potential

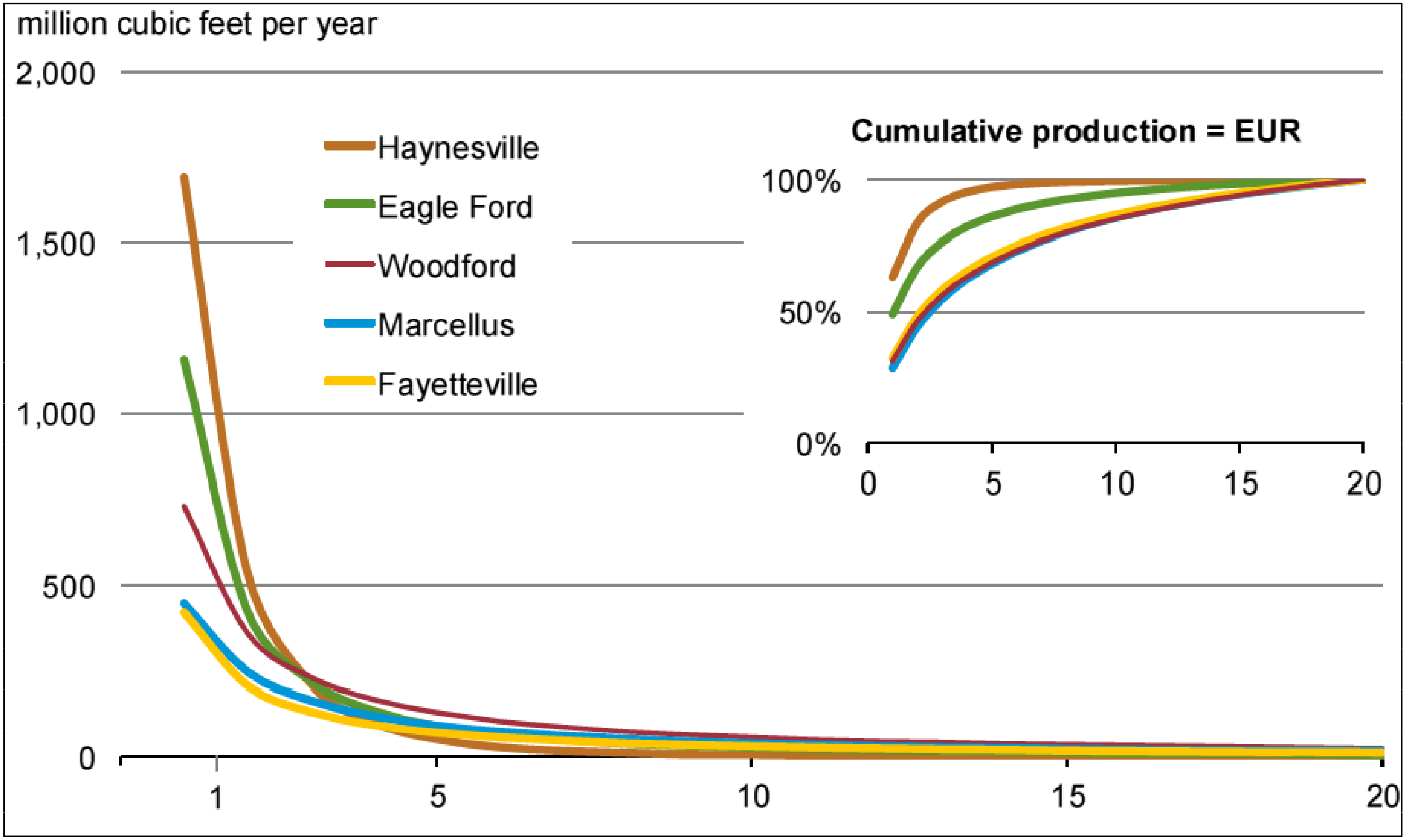
  × distribution of Estimated Ultimate Recovery (EUR) /well

  = undiscovered TRR

The Focus Is on the Timing of Production

- **Initial production (IP) and decline curve define the Estimated Ultimate Recovery (EUR) per well, which is dependent upon:**
  - average IP rate per well
  - average decline curve (can vary by region and vintage)
- **Well spacing**
  - defines per unit recovery

EUR per Well



Source: EIA, Annual Energy Outlook 2012

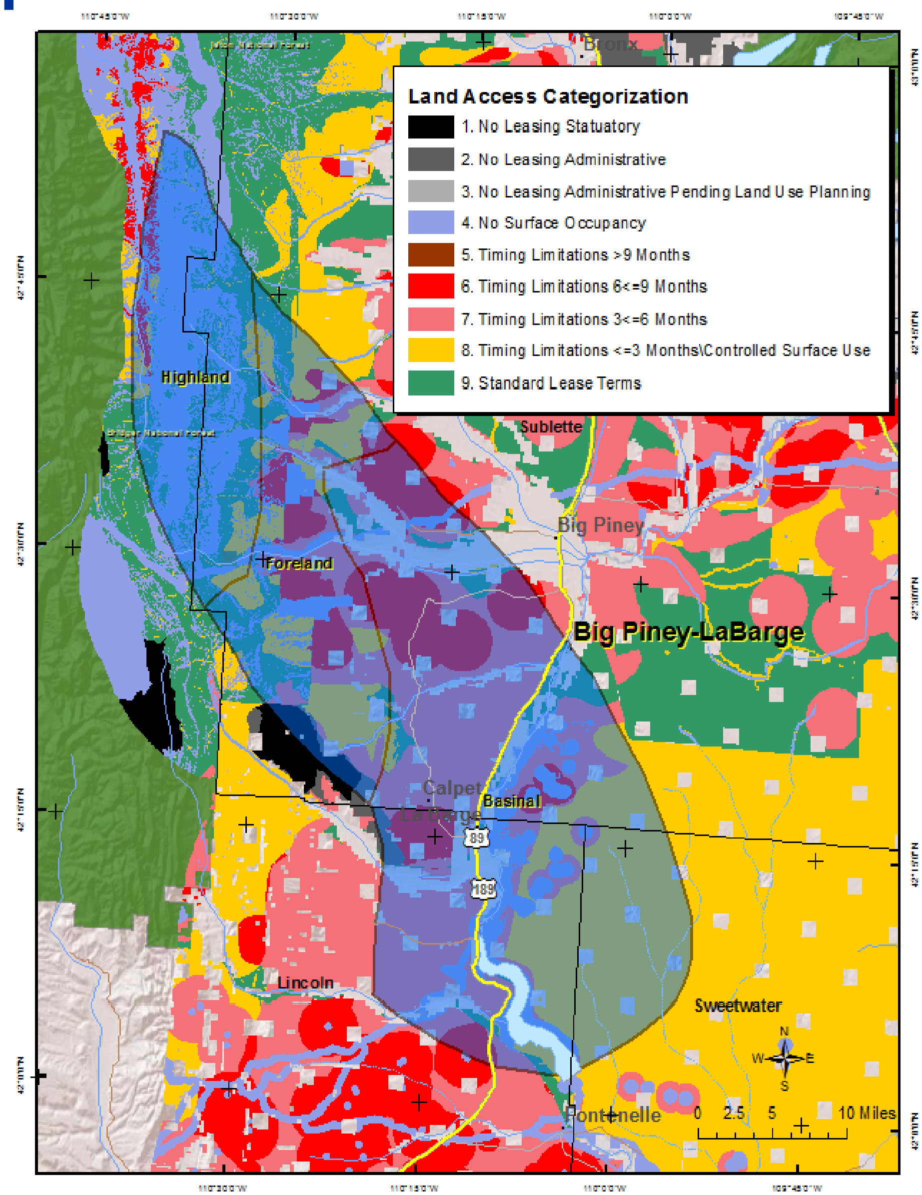
- **Typical wells in shale gas resource plays can have steep decline curves**

Access Applied to TRR

TRR x Access factor

= Accessible undiscovered TRR

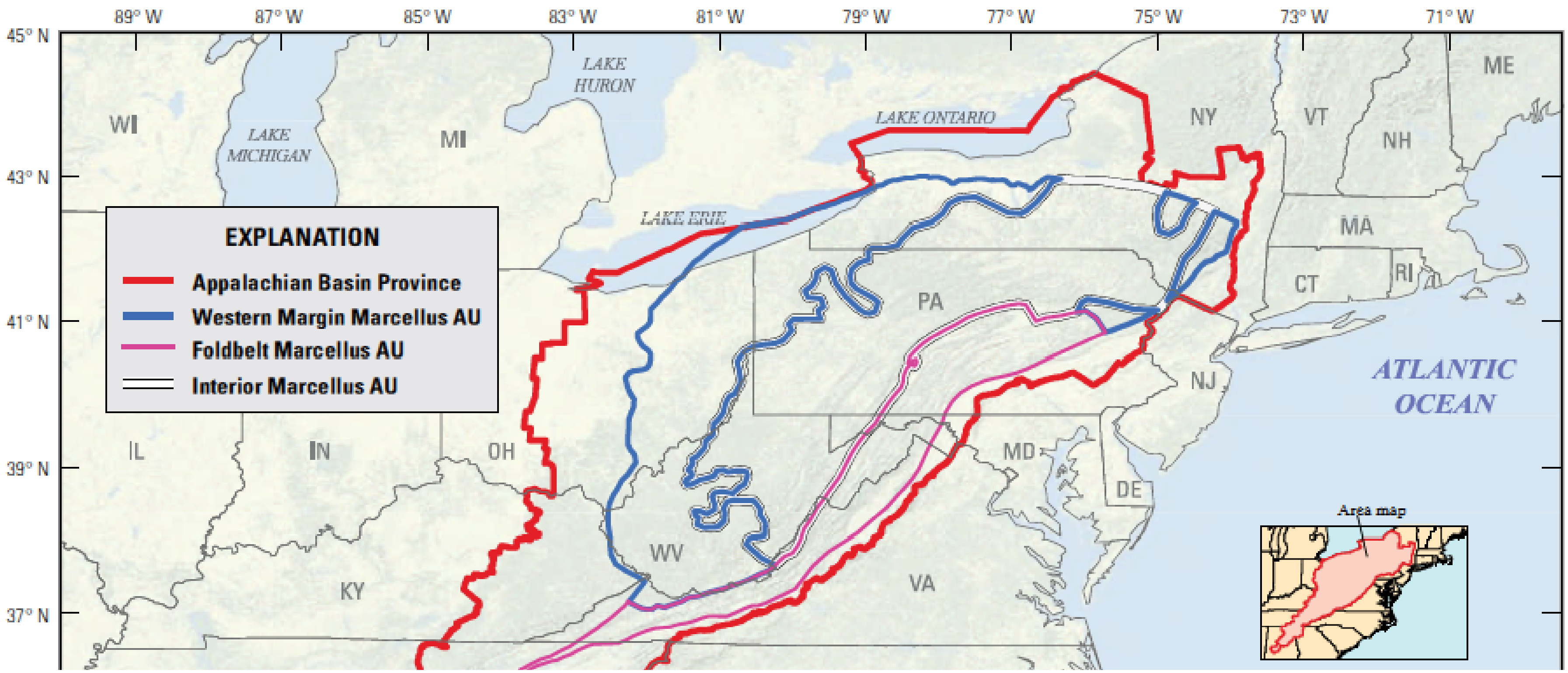
- Access to the resource determined by, for example, consideration of the Bureau of Land Management's Energy Policy and Conservation Act Inventory



Shale Gas Plays, Lower 48 States

Source: Energy Information Administration based on data from various published studies.

Devonian Marcellus Shale

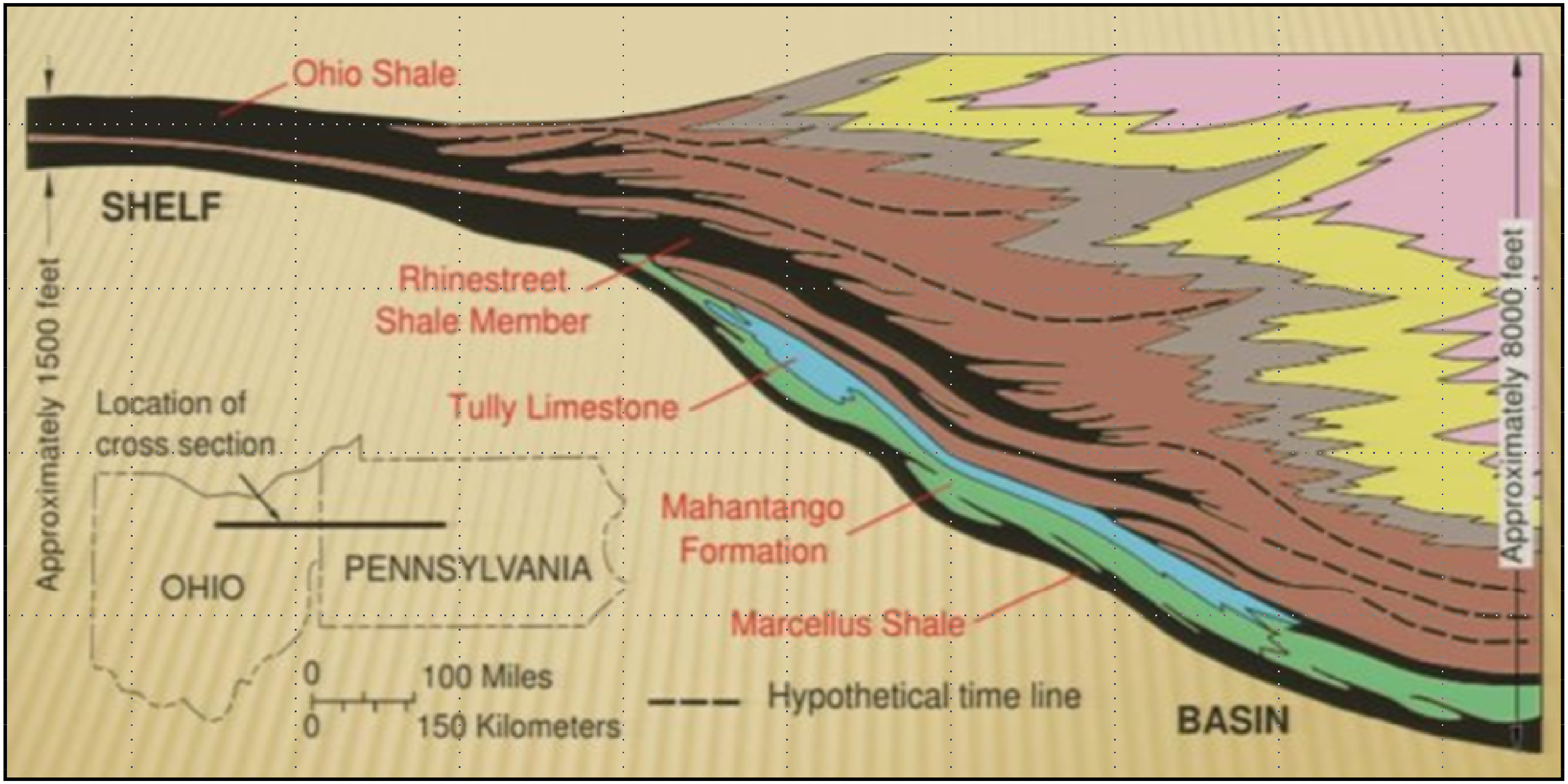


Total Petroleum System (TPS) and Assessment Units (AU)	Field type	AU probability	*Total undiscovered resources*							
			Gas (BCFG)				*NGL (MMBNGL)*			
			F95	F50	F5	Mean	F95	F50	F5	Mean
Devonian Shale-Middle and Upper Paleozoic TPS										
Foldbelt Marcellus AU	*Gas*	1.0	345	698	1,410	765	0	0	0	0
Interior Marcellus AU	*Gas*	1.0	41,607	76,078	139,106	81,374	1,497	2,982	5,938	3,255
Western Margin Marcellus AU	*Gas*	1.0	1,002	1,907	3,629	2,059	57	113	224	124
Total undiscovered resources			**42,954**	**78,683**	**144,145**	**84,198**	**1,554**	**3,095**	**6,162**	**3,379**

Source: USGS Fact Sheet 2011-3092

- **USGS Undiscovered TRR**

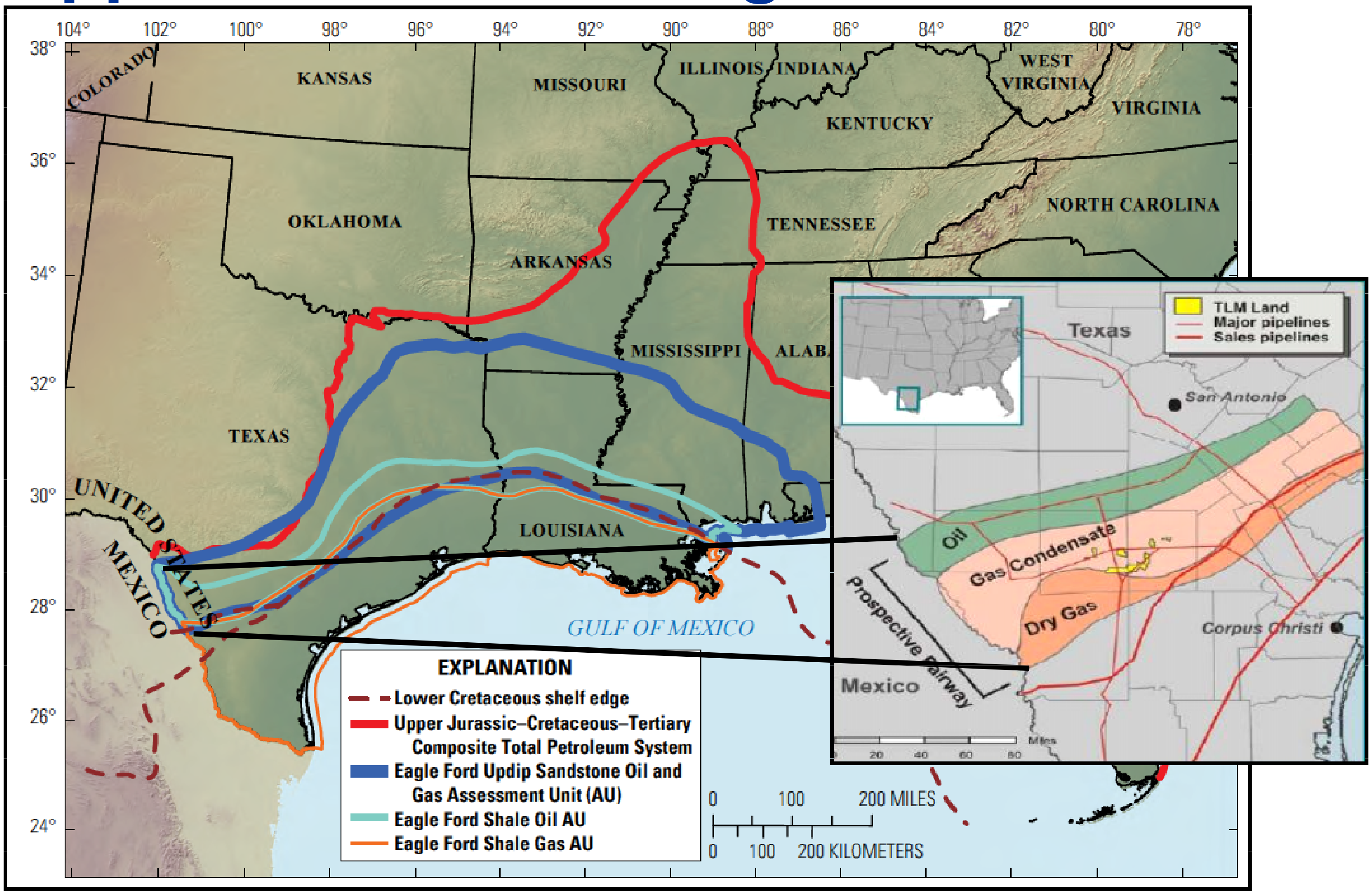
Devonian Marcellus Shale



Source: John A. Harper, Pennsylvania Geological Survey

- **The Marcellus Shale extends from a zero isopach in the west to an erosional truncation within the Appalachian fold and thrust belt in the east**

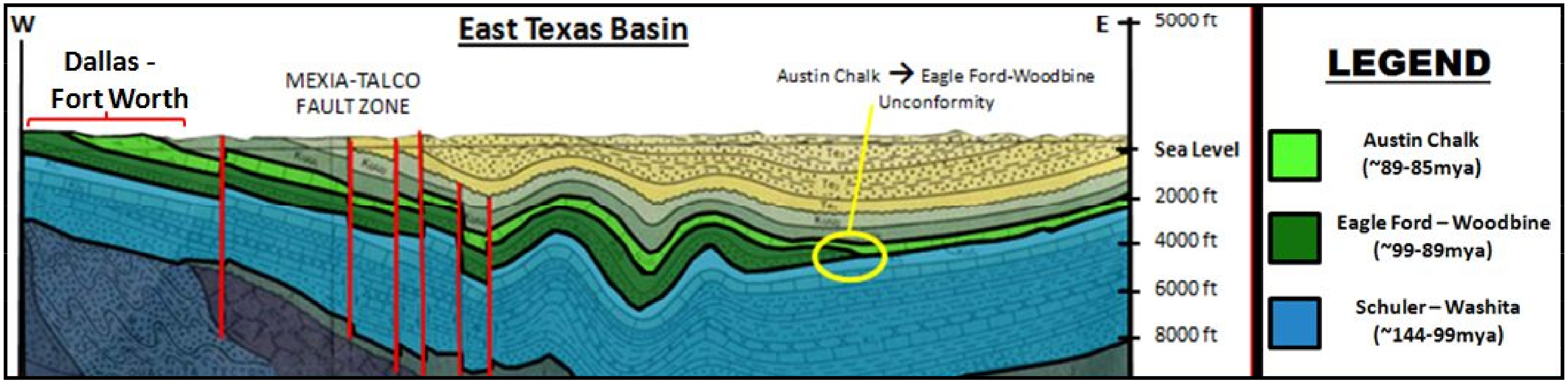
Upper Cretaceous Eagle Ford Shale



Source: USGS Fact Sheet 2012-3093 and EIA,

- **The Upper Cretaceous Eagle Ford Shale comprises a petroleum system ranging from oil to natural gas**

Upper Cretaceous Eagle Ford Shale



Source: Joshua Doubek, http://commons.wikimedia.org/wiki/File:Eagle_Ford_Unconformity.JPG

Total Petroleum Systems (TPS) and Assessment Units (AU)	Field type	*Total undiscovered resources*											
		Oil (MMBO)				*Gas (BCFG)*				*NGL (MMBNGL)*			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Upper Jurassic–Cretaceous–Tertiary Composite TPS (504901)													
Eagle Ford Updip Sandstone Oil and Gas AU (50490128)	*Oil*	41	136	253	141	53	184	381	197	1	4	8	4
	Gas					86	289	571	305	3	11	24	12
Total conventional resources		**41**	**136**	**253**	**141**	**139**	**473**	**952**	**502**	**4**	**15**	**32**	**16**
Eagle Ford Shale Oil AU (50490170)	*Oil*	341	758	1,687	853	625	1,486	3,533	1,707	12	29	74	34
Eagle Ford Shale Gas AU (50490167)	*Gas*					23,470	46,150	90,747	50,219	851	1,809	3,842	2,009
Total continuous resources		**341**	**758**	**1,687**	**853**	**24,095**	**47,636**	**94,280**	**51,926**	**863**	**1,838**	**3,916**	**2,043**
Total undiscovered oil and gas resources		**382**	**894**	**1,940**	**994**	**24,234**	**48,109**	**95,232**	**52,428**	**867**	**1,853**	**3,948**	**2,059**

Source: USGS Fact Sheet 2012-3093

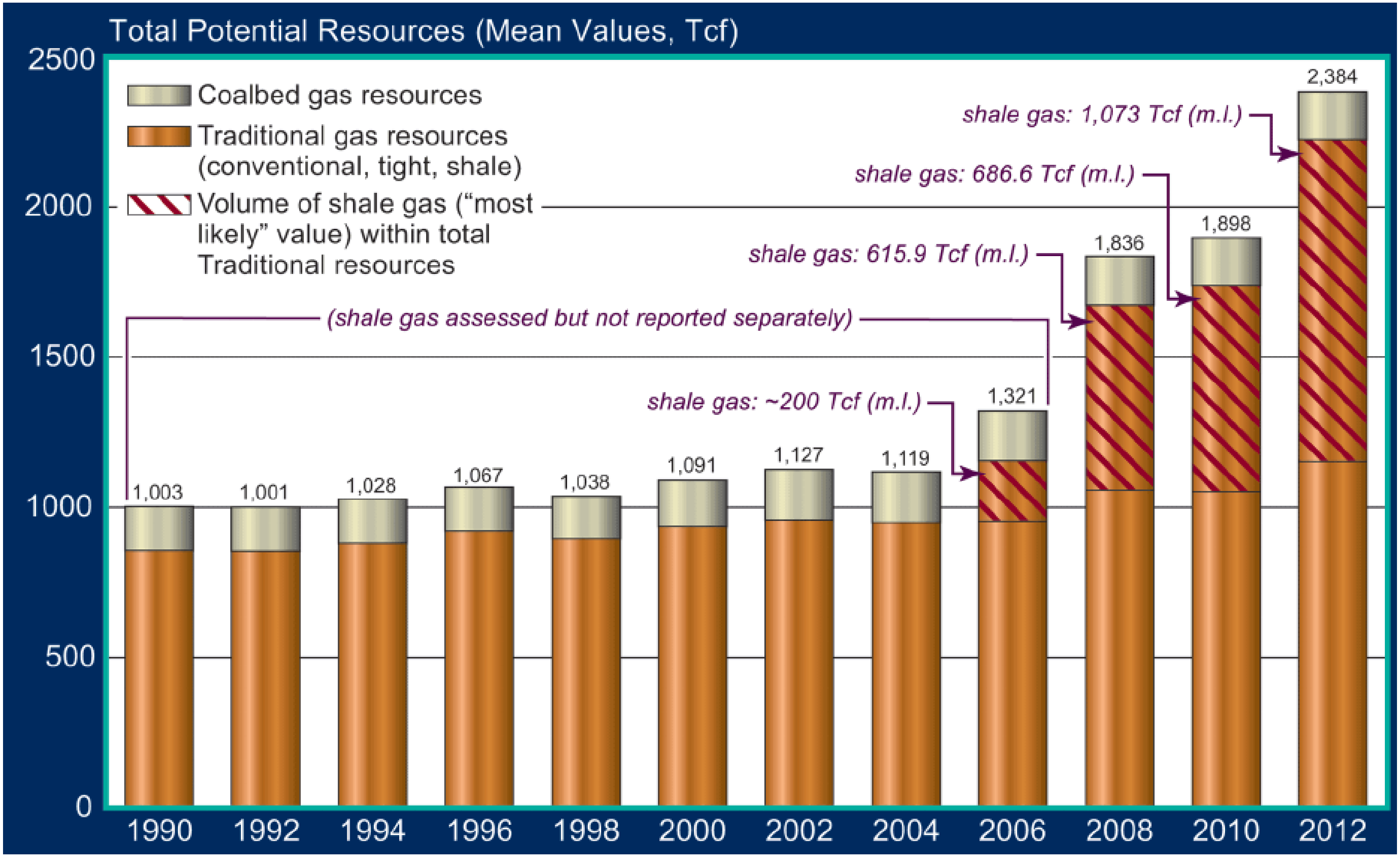
- **USGS Undiscovered TRR**

Estimates of Undeveloped Technically Recoverable Shale Gas and Shale Oil Resources Remaining in U.S. Discovered Shale Plays (EIA)

Play	Technically Recoverable Resource	
	Gas (Tcf)	Oil (BBO)
Marcellus	410.34	…
Big Sandy	7.40	…
Low Thermal Maturity	13.53	…
Greater Siltstone	8.46	…
New Albany	10.95	…
Antrim	19.93	…
Cincinnati Arch*	1.44	…
Total Northeast	**472.05**	**…**
Haynesville	74.71	…
Eagle Ford	20.81	…
Floyd-Neal & Conasauga	4.37	…
Total Gulf Coast	**99.99**	**…**
Fayetteville	31.96	…
Woodford	22.21	…
Cana Woodford	5.72	…
Total Mid-Continent	**59.88**	**…**
Barnett	43.38	…
Barnett Woodford	32.15	…
Total Southwest	**75.52**	**…**
Hilliard-Baxter-Mancos	3.77	…
Lewis	11.63	…
Williston-Shallow Niobraran*	6.61	…
Mancos	21.02	…
Total Rocky Mountain	**43.03**	…
Total Lower 48 U.S.	**750.38**	**…**

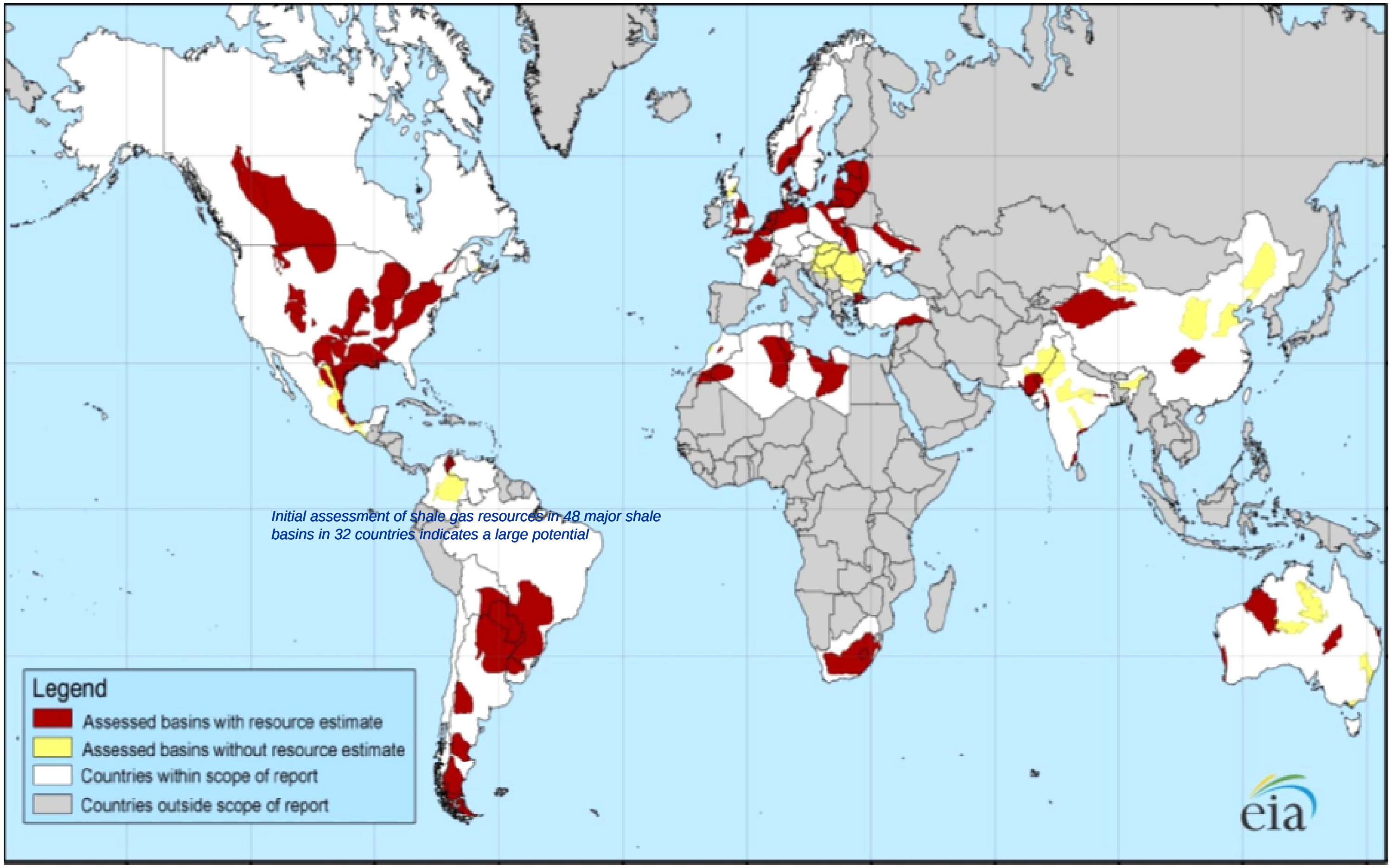
Source: EIA

Potential Gas Committee



Source: Potential Gas Committee (2013)

Shale Gas Internationally



Source: EIA

- **Initial assessment by EIA of shale gas in 48 major shale basins in 32 countries indicates a large potential**

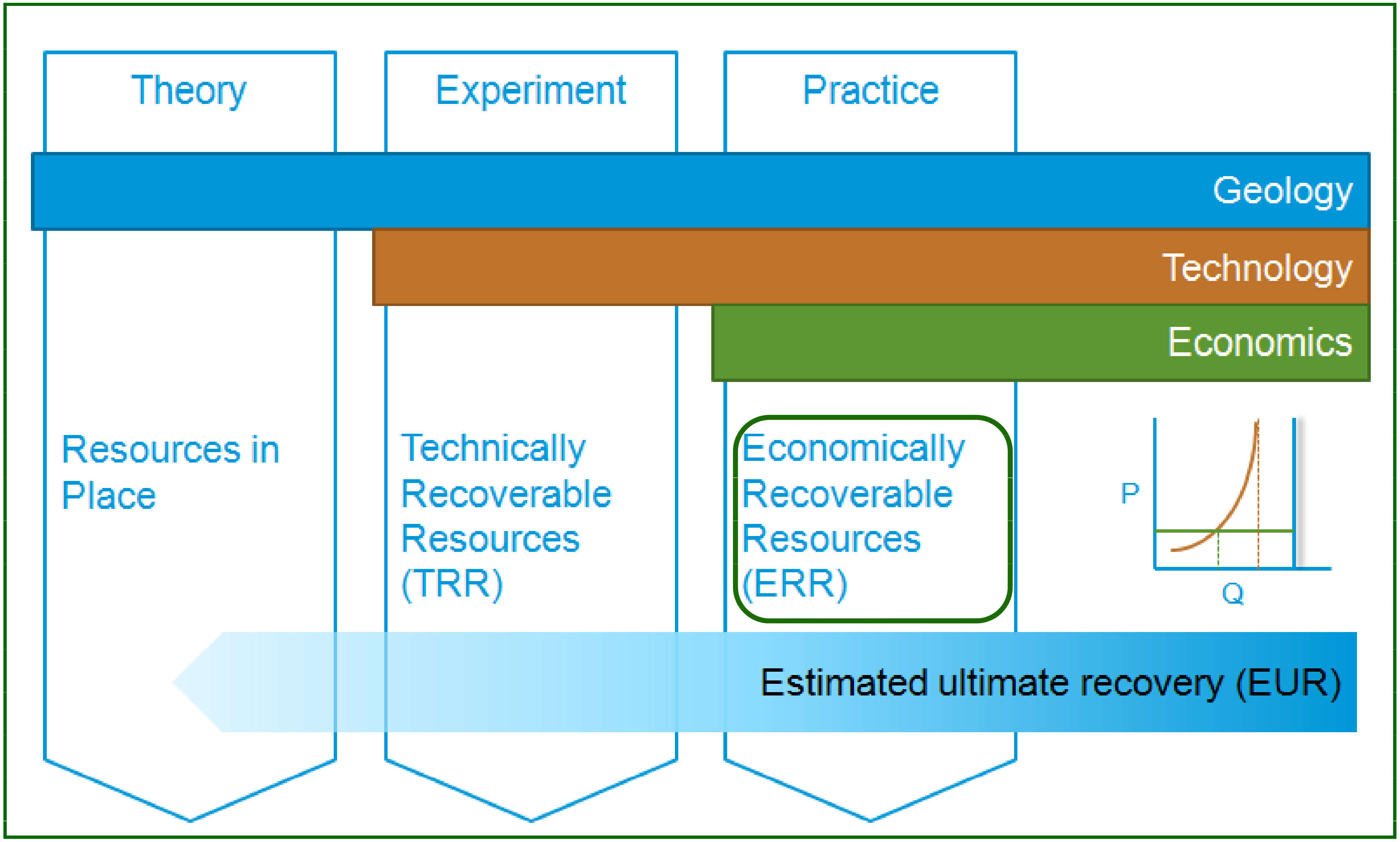
Shale Gas Internationally

Continent		Technically Recoverable (Tcf)
North America (non U.S.)	Canada, Mexico	1,069
	U.S.	862
Total North America		1931
Africa	Morocco, Algeria, Tunisia, Libya, Mauritania, Western Sahara, South Africa	1,042
Asia	China, India, Pakistan	1,404
Australia		396
Europe	France, Germany, Netherlands, Sweden, Norway, Denmark, U.K., Poland, Lithuania, Ukraine, Turkey	624
South America	Colombia, Venezuela, Argentina, Bolivia, Brazil, Chile, Uruguay, Paraguay	1,225
Total		6,622
Total without U.S.		5,760

Source: EIA

- **Estimates of technically recoverable shale gas resources in the 48 assessed shale gas basins**

Bringing Gas Resources from Theory to Practice

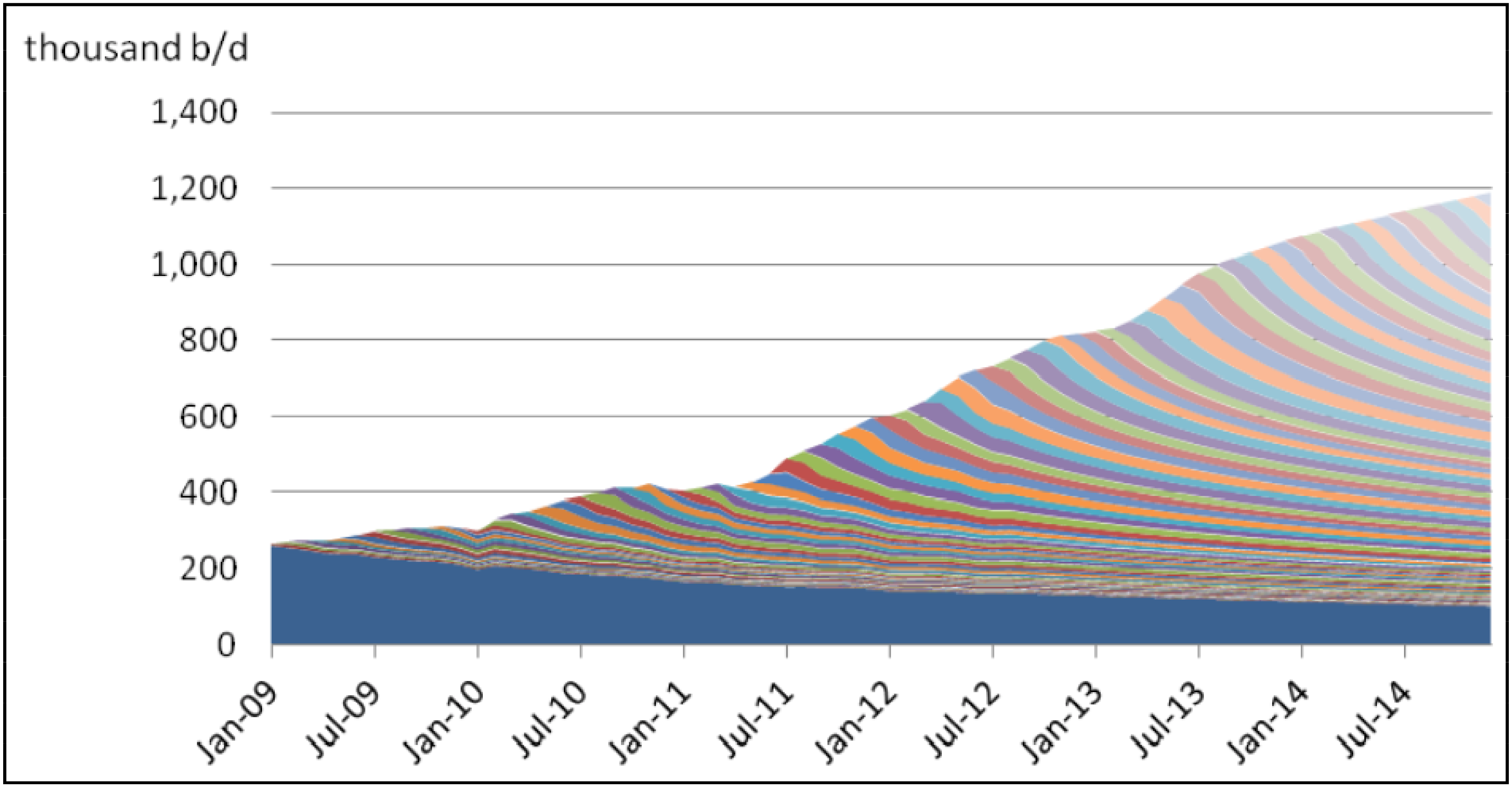


Source: Adam Sieminski, Administrator, U.S. Energy Information Administration, *Status and outlook for shale gas and tight oil development in the U.S.*, Platts – North American Crude Marketing Conference, March 01, 2013, Houston, TX

Economically Recoverable Resources (ERR)

- A subset of TRR that meets economic criteria for potential production and are amenable for development into reserves
- Fundamentally considers
  - CAPEX
    - Drilling and completion (e.g., fracking)
  - OPEX
    - Lifting on other operating costs
- Can consider
  - number of active rigs
  - how many wells a rig can drill (rig efficiency)

Unconventional Developments Can Be a Treadmill



Source: Source: DrillingInfo history through August 2012, EIA Short-Term Energy Outlook, February 2013 forecast

- **Example: Oil production by monthly vintaging of wells in the Williston Basin**

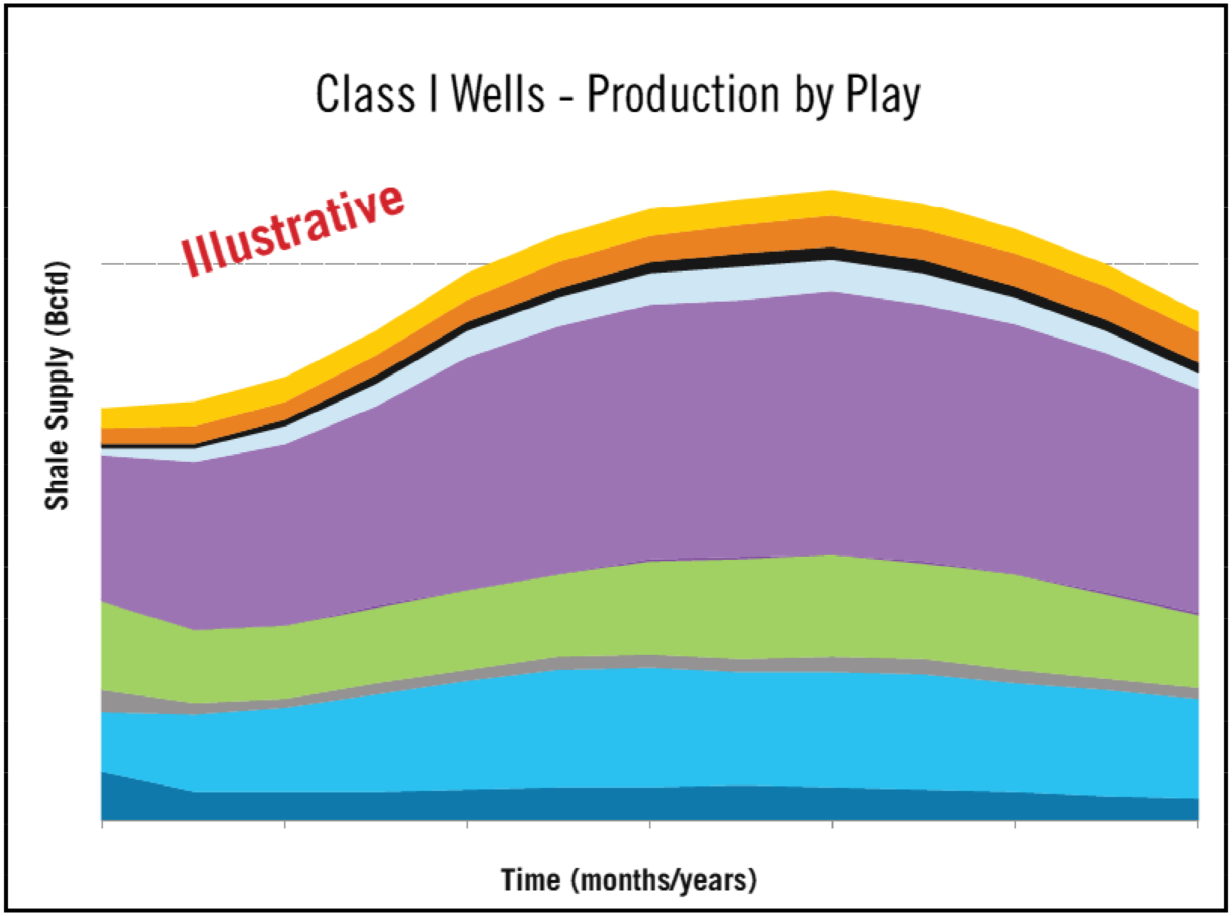
THE CHANGING GLOBAL GAS MARKET AND UNCONVENTIONAL GAS?

How assessments can be used

Putting Assessments to Use—An Example

- **Enegis, LLC, together with the Berkeley Research Group have created the Shale Resource Potential ("ShaRP") model of the U.S.**
  - ShaRP combines expert economic modeling and shale gas expertise to meet the business and policy challenges presented by shale production and LNG exports
- **Features**
  - Provides detailed analysis of major plays at the sub-play level
  - Divides shale resources into well "classes", each with unique production potential, EUR rates, production parameters & economics
  - Integrates detailed Natural Gas Liquid (NGL) revenue analysis as related to net dry gas production costs
  - Includes capital and drilling costs, environmental compliance costs (e.g. wastewater treatment, fugitive methane, etc.), non-drill costs, direct operating costs, and royalties and production taxes

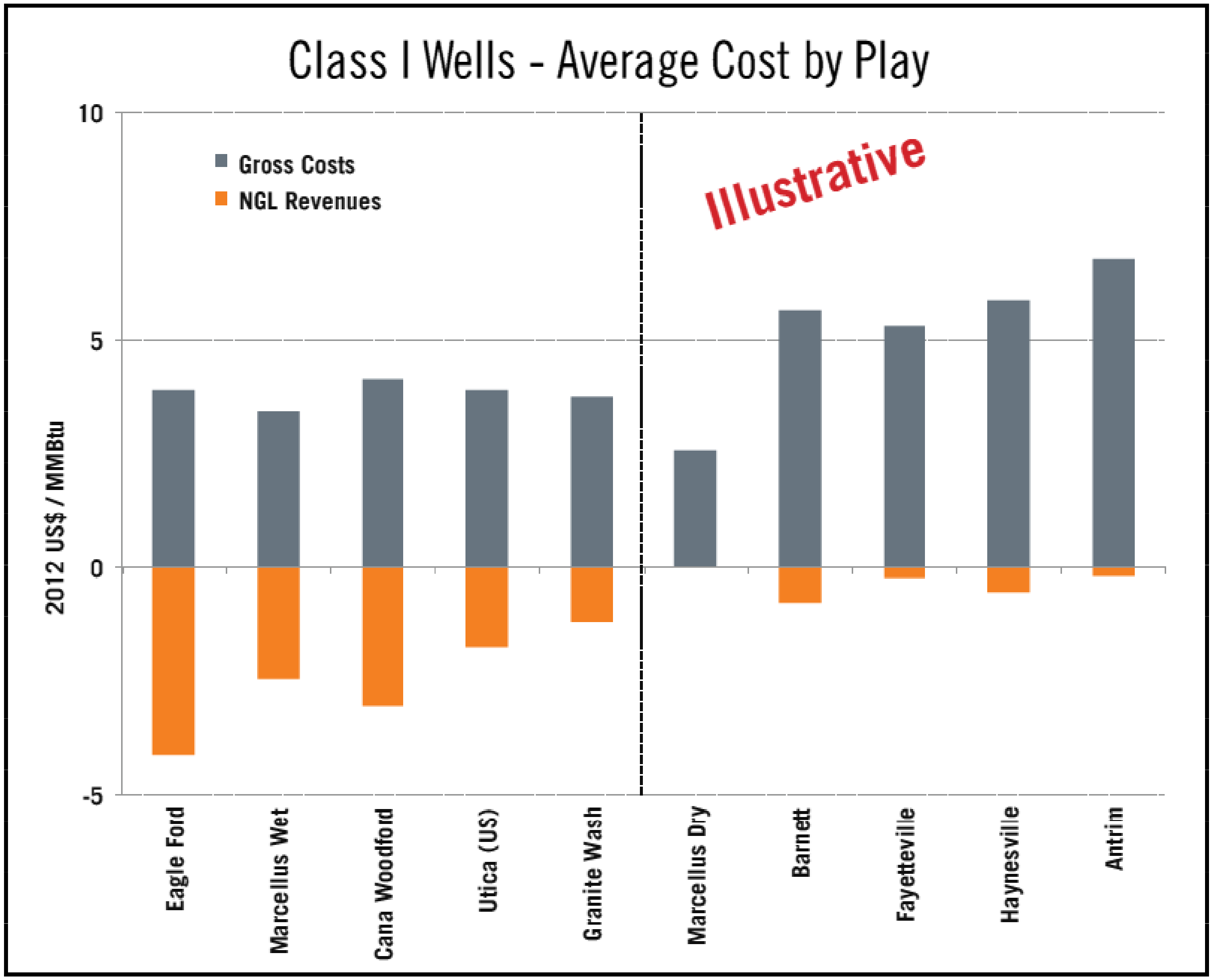
ShaRP Analysis



Source: Enegis, LLC, and Berkeley Research Group

- **ShaRP evaluates shale production “sweet spots” as well as other economic and non-economic classes of wells**

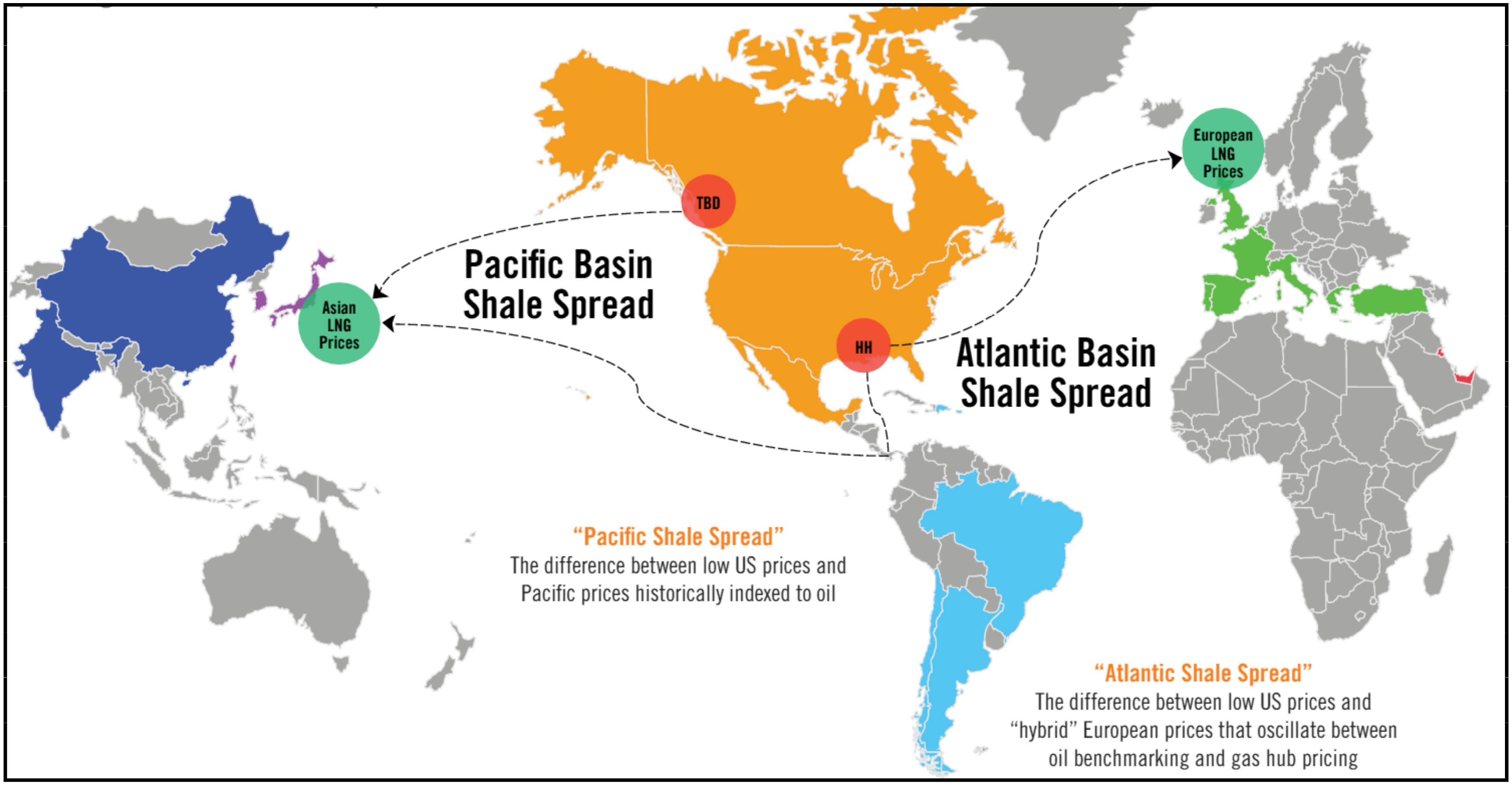
ShaRP Analysis



Source: Berkeley Research Group

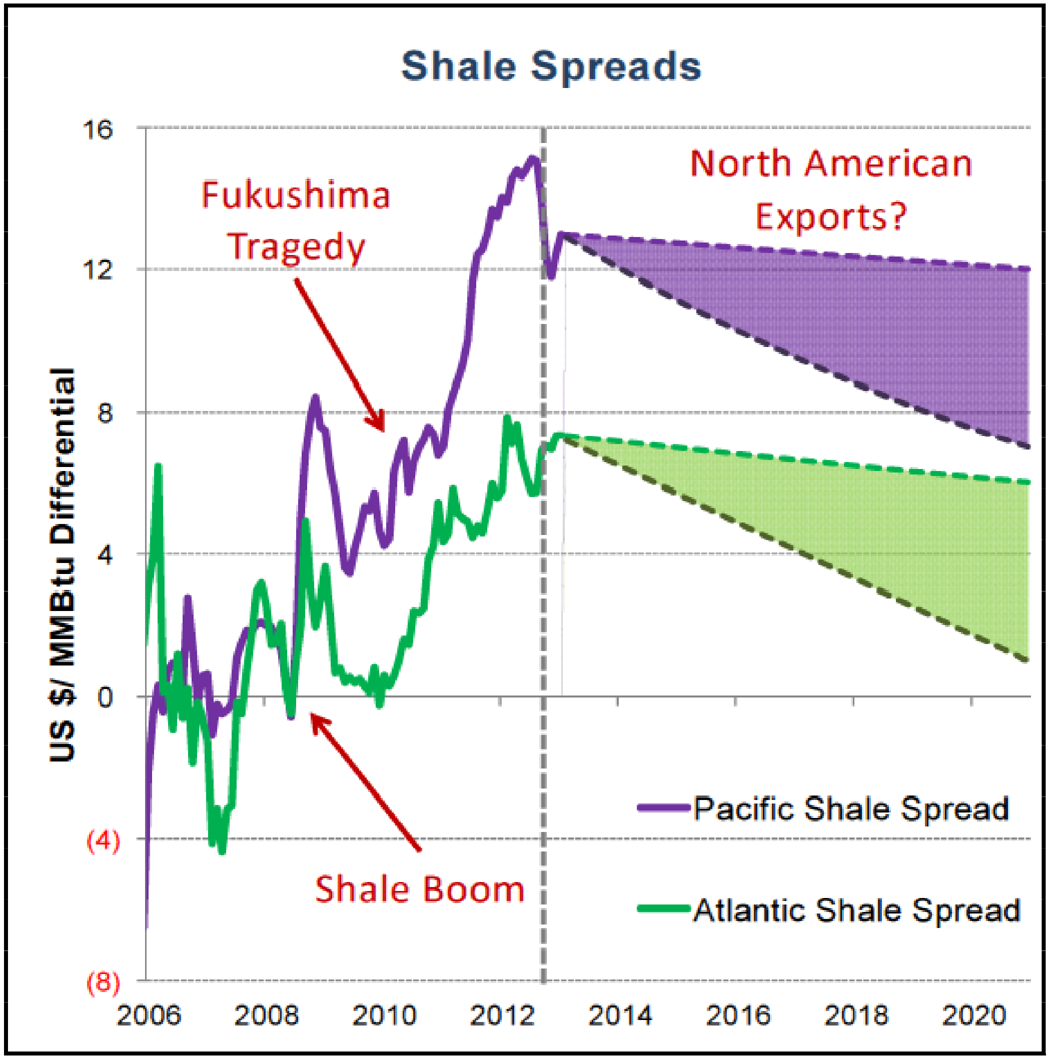
- **Liquid (NGL) revenue analysis as related to net dry gas production costs**

The Sustainability of Shale Production and the Scalability of Global LNG Demand Will Drive Shale Spreads and Thus LNG Export Economics



Source: Berkeley Research Group

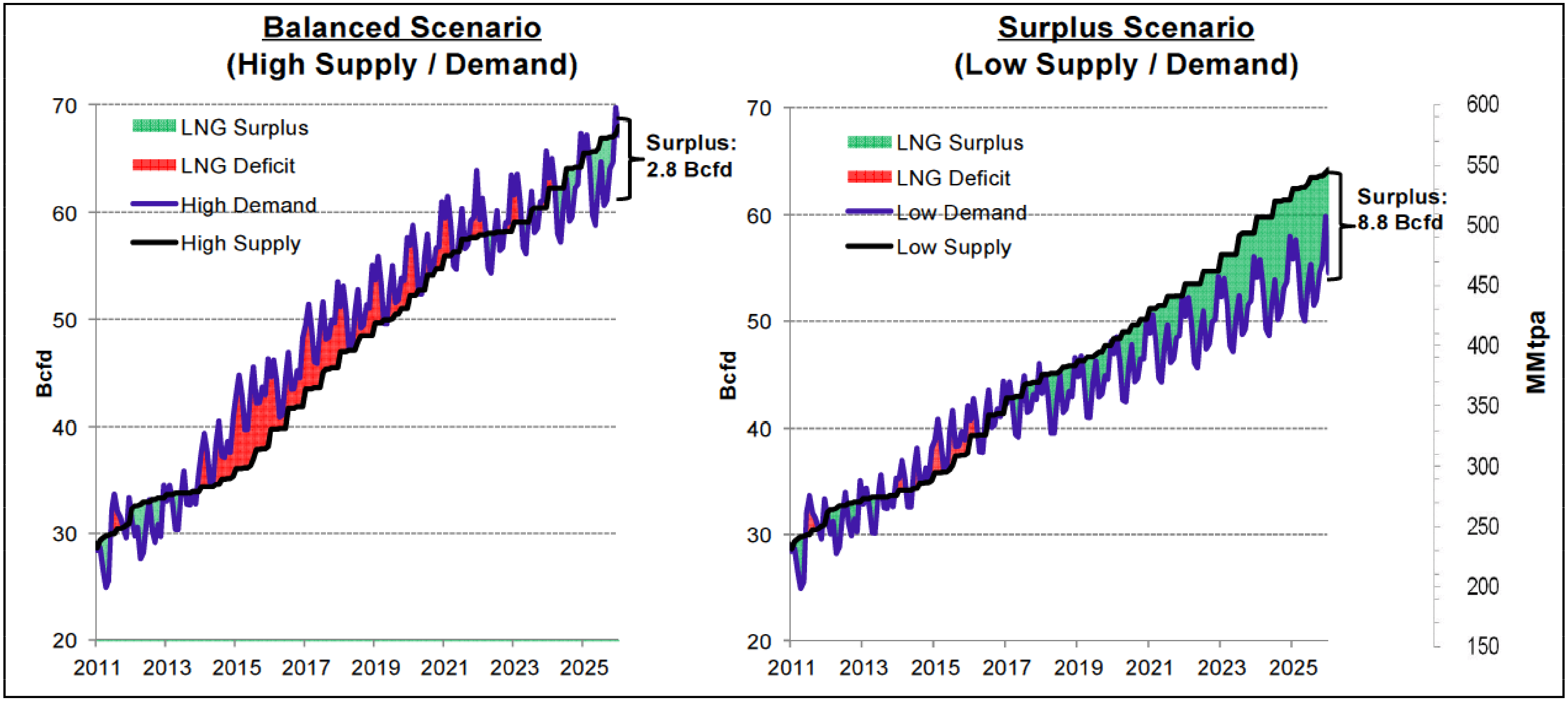
The Importance of Shale Spreads



Source: Berkeley Research Group

- Business implications:
  - Drive LNG exporters
  - Expose LNG investors and lenders to risks and benefits
  - Provide competitive trade advantage to gas consumers
  - Afford procurement leverage to Asian and European LNG importers
- Policy implications:
  - Impact GDP, employment, and other factors of concern to National governments
  - Affect LNG export options, feasibility, and timing of interest to state, provincial, and local governments

Global LNG Supply / Demand Balance



Source: Berkeley Research Group

Can Demand Absorb the New Supply?

- **Substantial surpluses could develop if demand is low, but if demand is robust then markets could remain tight through 2015 and then rebalance in 2020-2025**

Conclusions

- **What are unconventional (natural gas) resources?**
  - Coalbed methane (CBM)
  - Tight gas (low permeability sandstones)
  - Gas shales—volumetrically large
- **How can they be assessed?**
  - Consider below- and above-ground risk
  - Geological analysis and assessments can be complex but are tractable
- **The changing global gas market and unconventional gas**
  - Resource assessments provide a foundation for analyzing markets

THANK YOU

Please let us know how we can help

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