URTeC

Aug, 2014

Unconventional Reservoir Future

Science, Technology and Economics

Scott W. Tinker

Bureau of Economic Geology

The University of Texas at Austin, Austin

Acknowledgements

- BEG Shale Reserves & Production Team
  - Dr. Svetlana Ikonnikova, co-PI
- The Alfred P. Sloan Foundation
- IHS & DrillingInfo for database access
- For potential conflicts of interest see http://www.beg.utexas.edu/info/shale_rsrvs_prod.php

Outline

- Unconventional Reservoirs
- U. S. Shale Gas and Shale Oil
- Science, Technology & Economics

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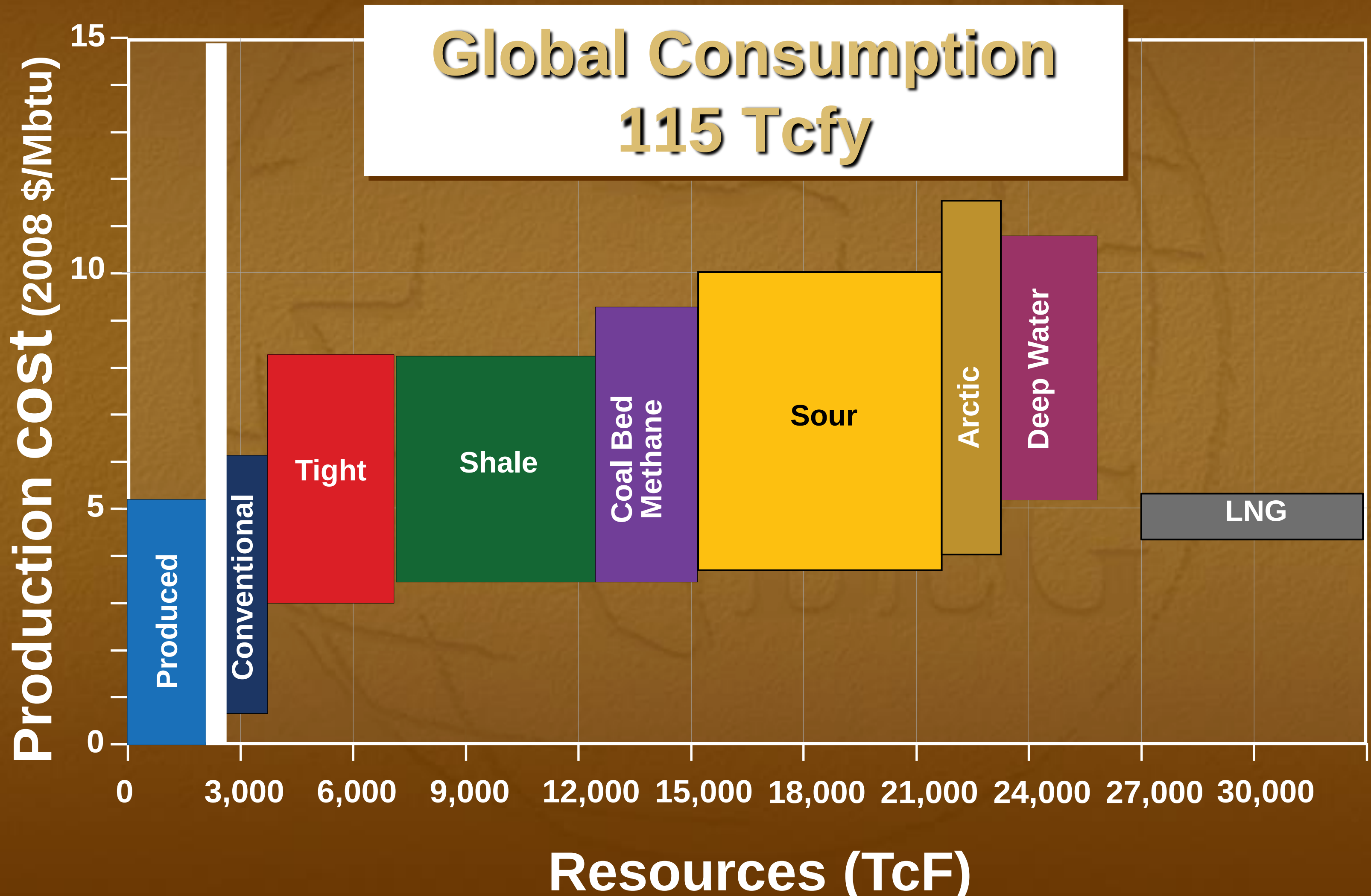
Global Natural Gas

Resources v. Cost



Source: IEA World Energy Outlook (2009)

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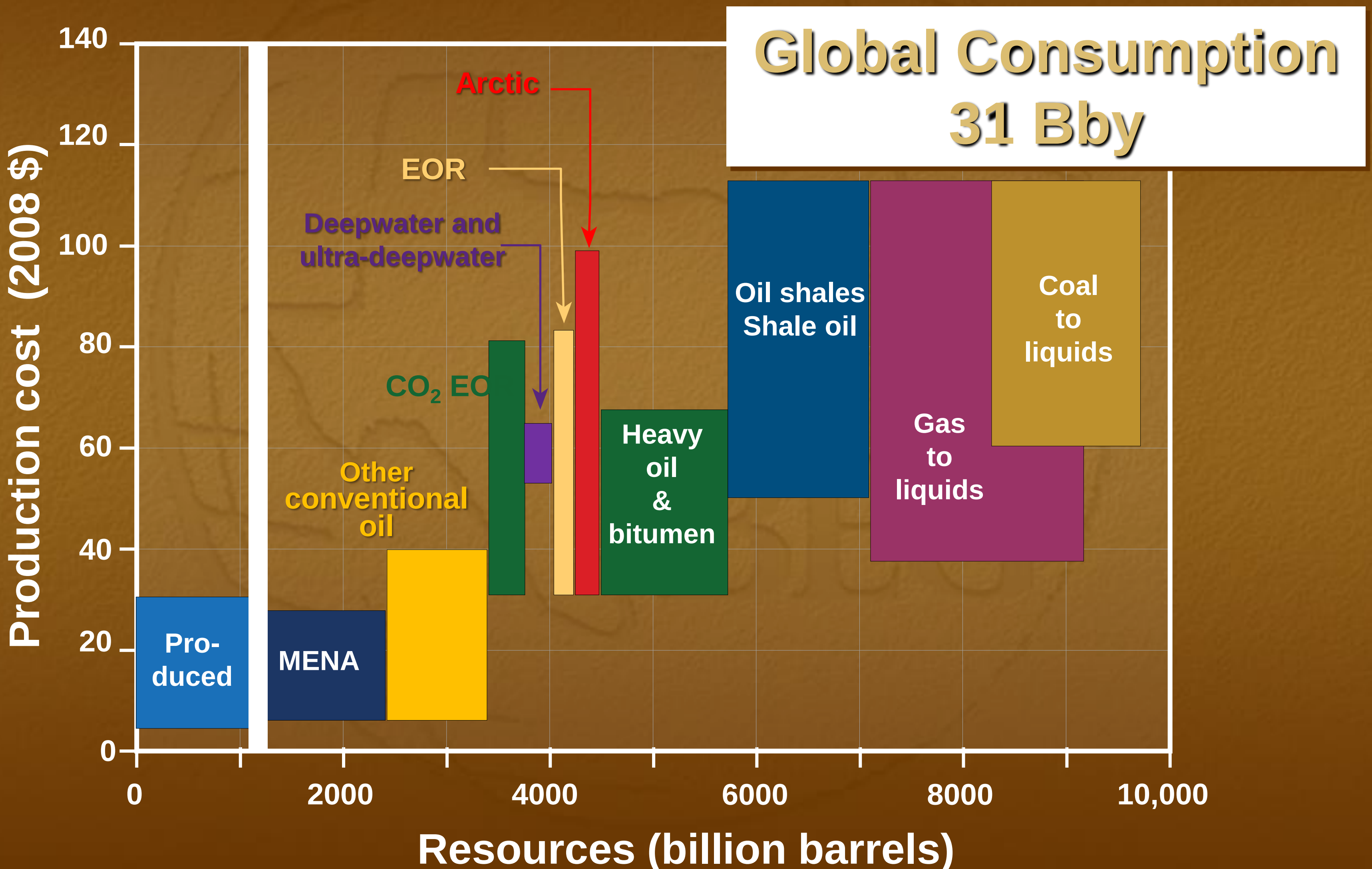
Global Oil

Resources v. Cost



Source: IEA World Energy Outlook (2009)

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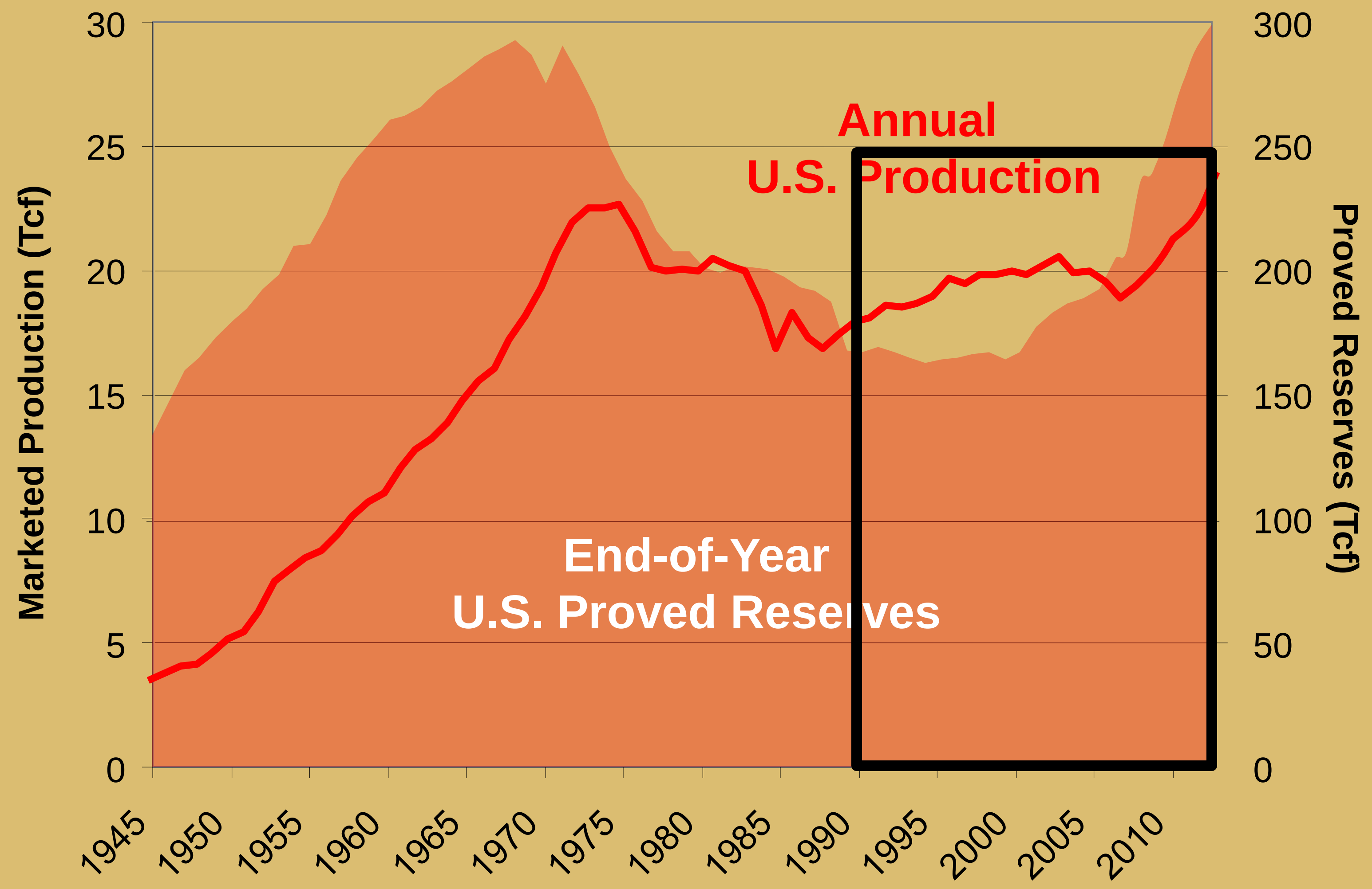
U.S. Natural Gas
Production and Reserves



Data: BP World Energy 2012

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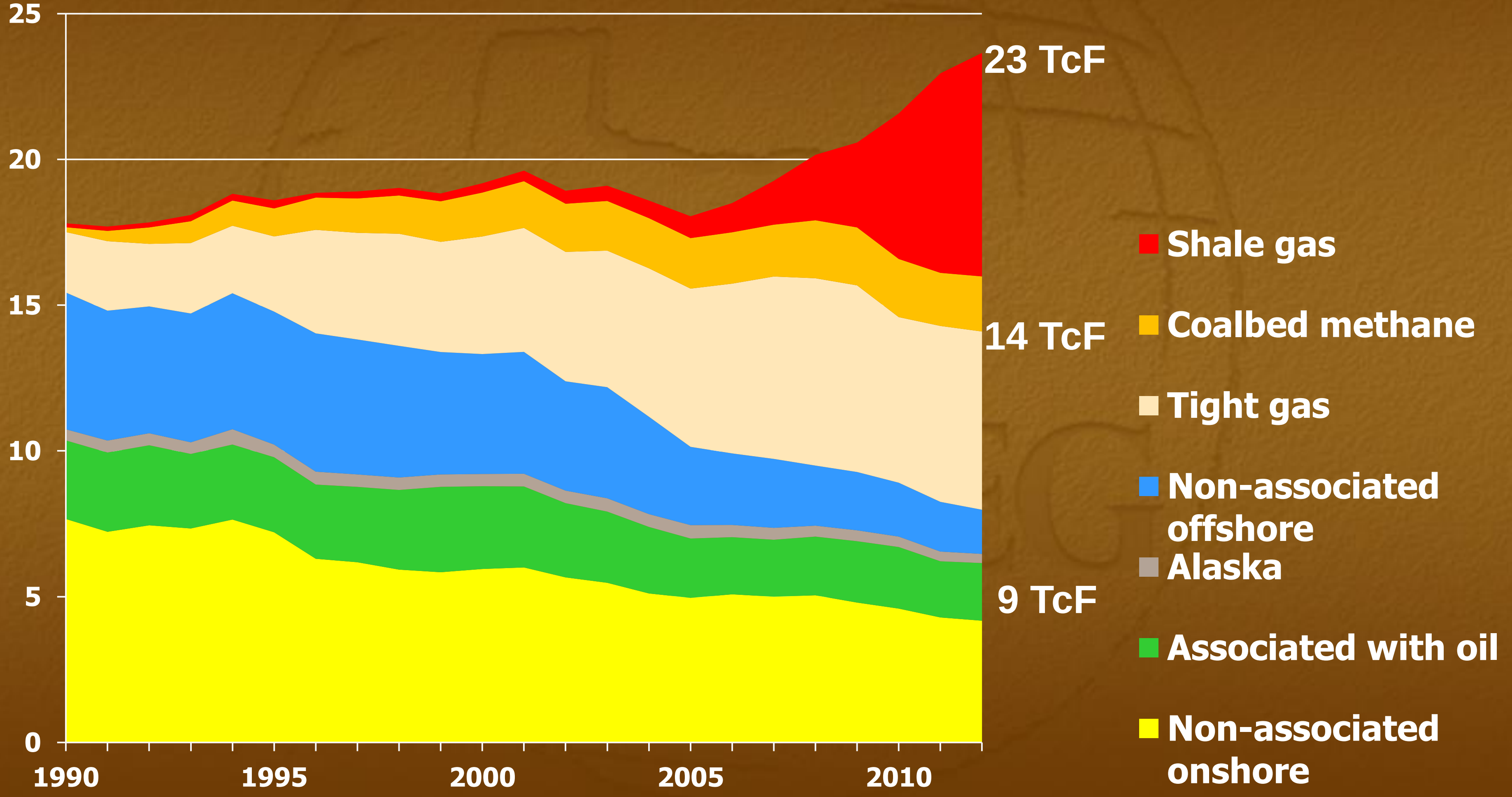
U.S. Natural Gas
Production (TcF)



http://www.eia.gov/energy_in_brief/about_shale_gas.cfm

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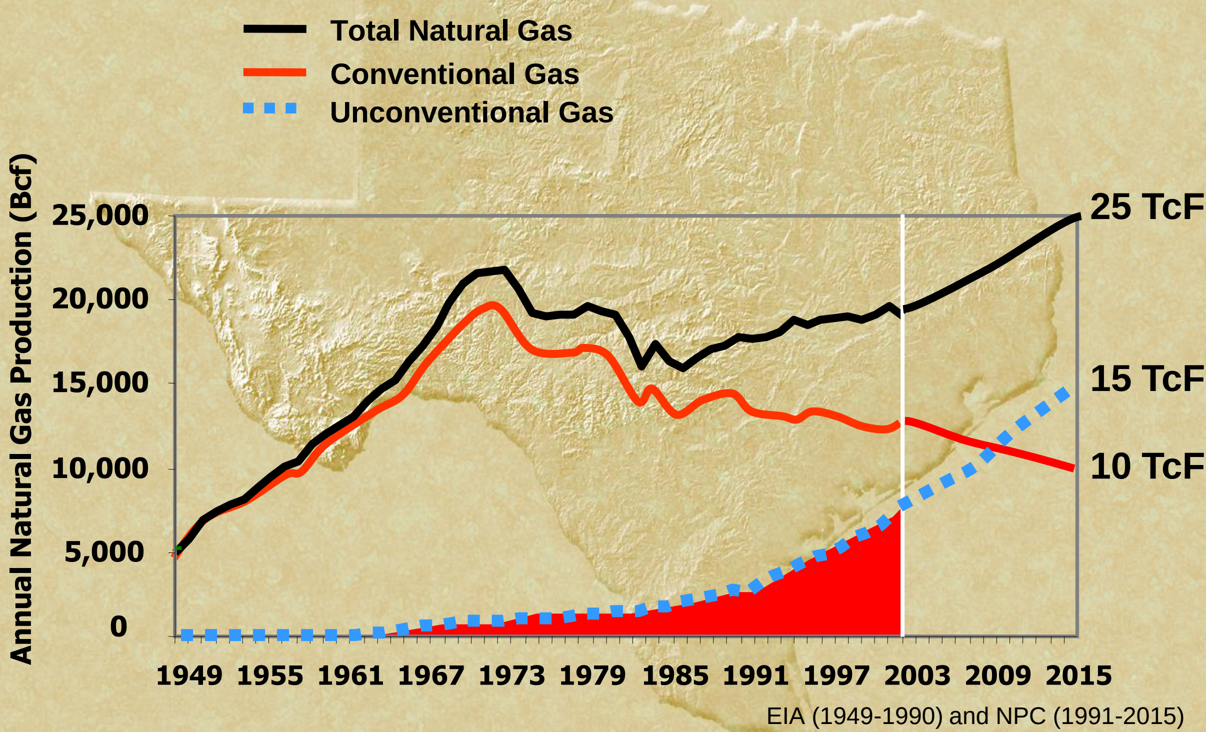
U.S. Natural Gas
Production (TcF)

An Anticipated Evolution

From a 2004 Tinker Talk to the IPAA
US Natural Gas 2004 forecast



23 TcF

14 TcF

9 TcF

- Shale gas
- Coalbed methane
- Tight gas
- Non-associated offshore
- Alaska
- Associated with oil
- Non-associated onshore

http://www.eia.gov/energy_in_brief/about_shale_gas.cfm

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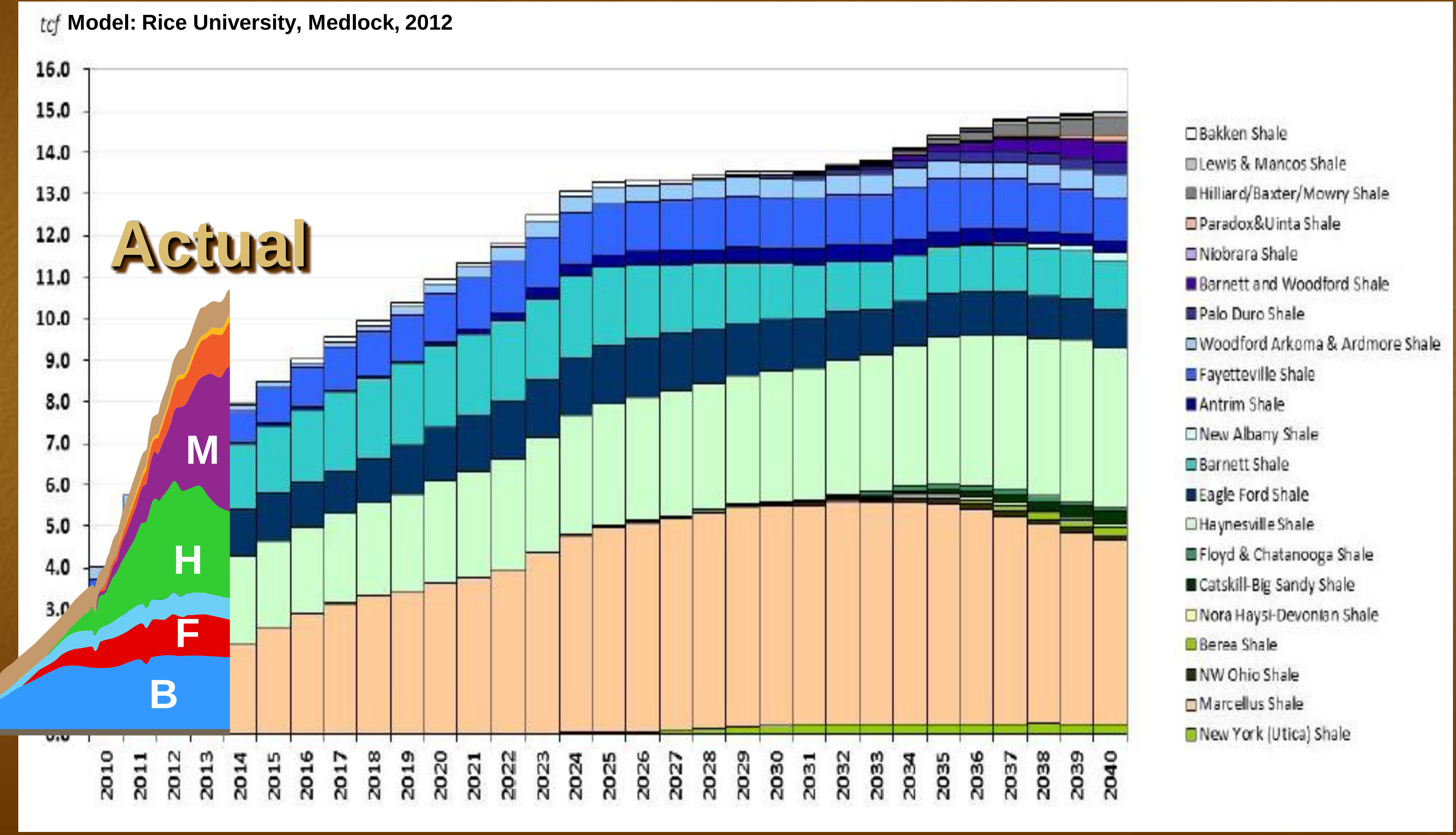
Shale Gas Forecast vs. Actual



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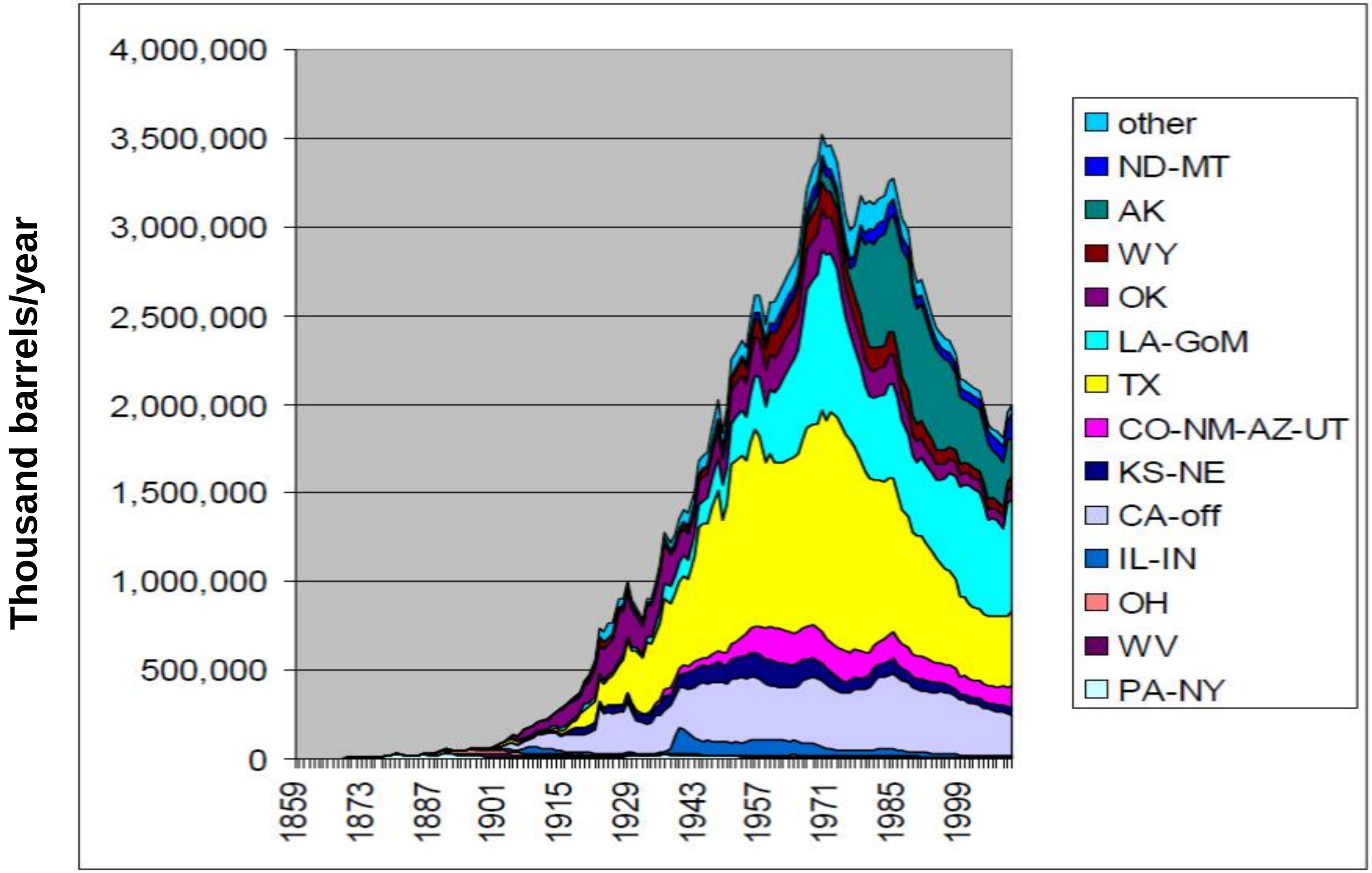
Annual US Oil Production



From: James D. Hamilton, Working Paper 17759, NATIONAL BUREAU OF ECONOMIC RESEARCH, 2012

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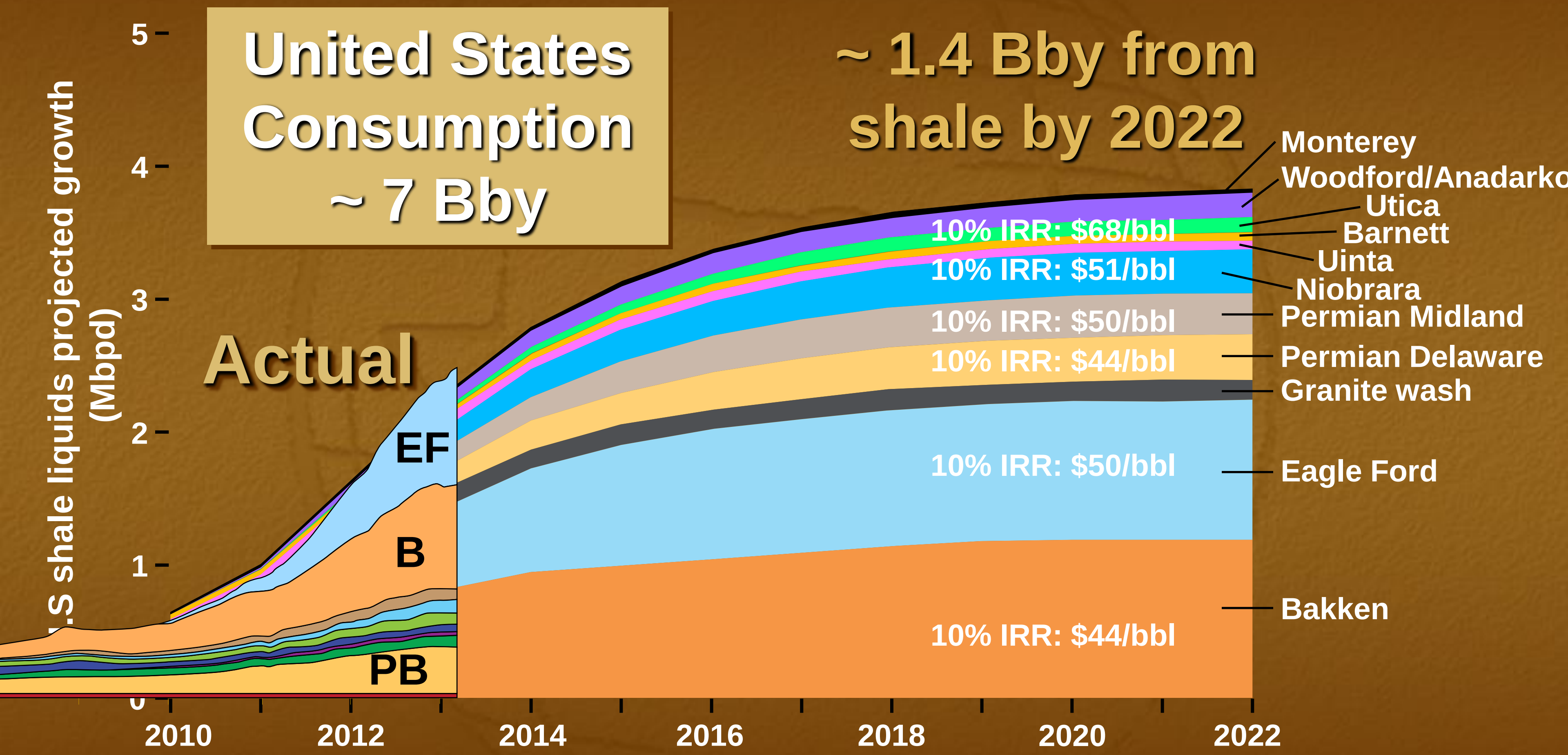
2010 U.S. SHALE LIQUIDS *PROJECTION*



After Morse et. al., 2012, Energy 2020: North America, the new Middle East: Citi GPS: Global Perspectives & Solutions, figure 14, p. 17.

IRR Source: Rystad Energy

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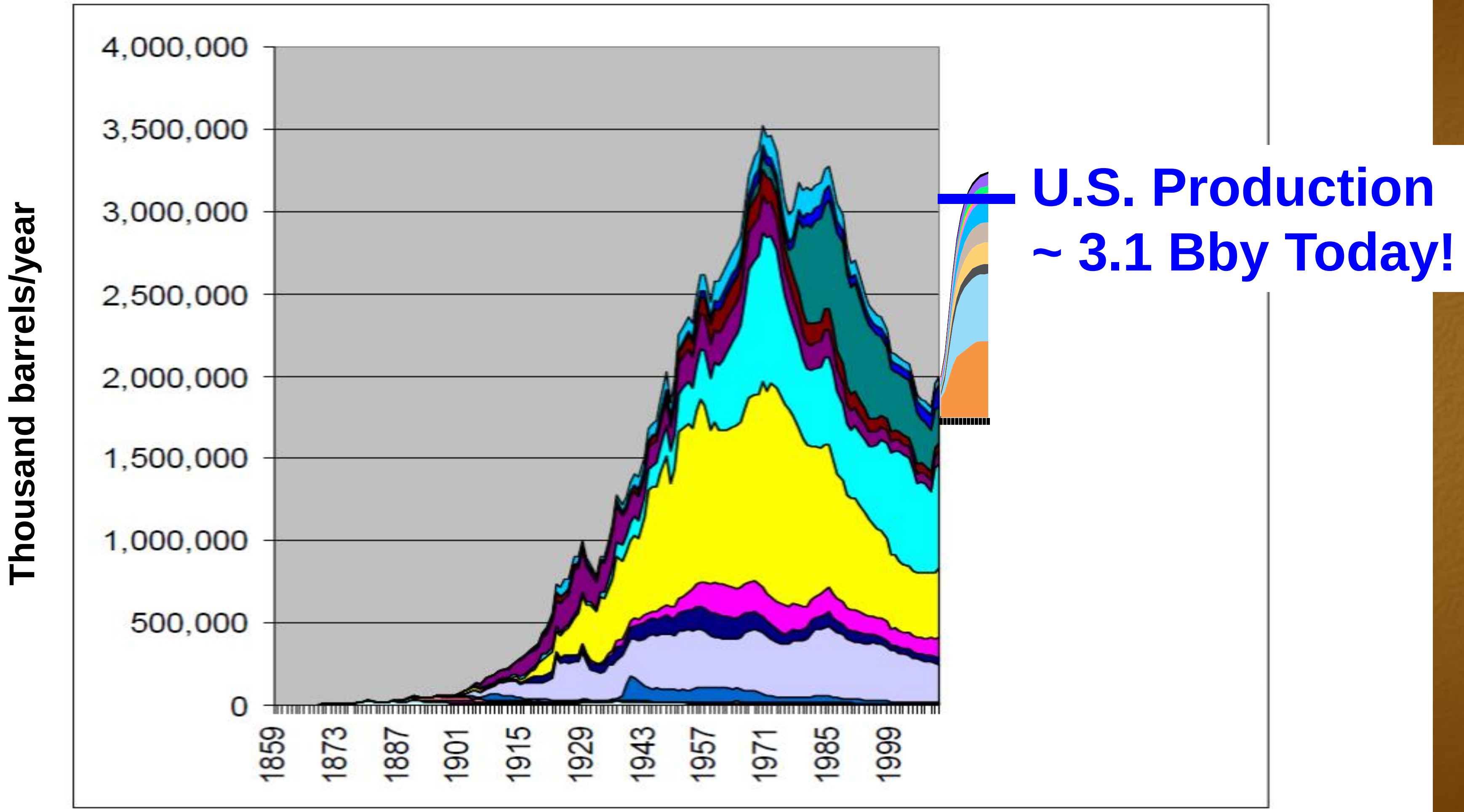
Annual US Oil Production



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Outline

- Unconventional Reservoirs
- **U. S. Shale Gas and Shale Oil**
- Science, Technology & Economics

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Unconventional Resource Plays

Modified from: EIA and National Geographic

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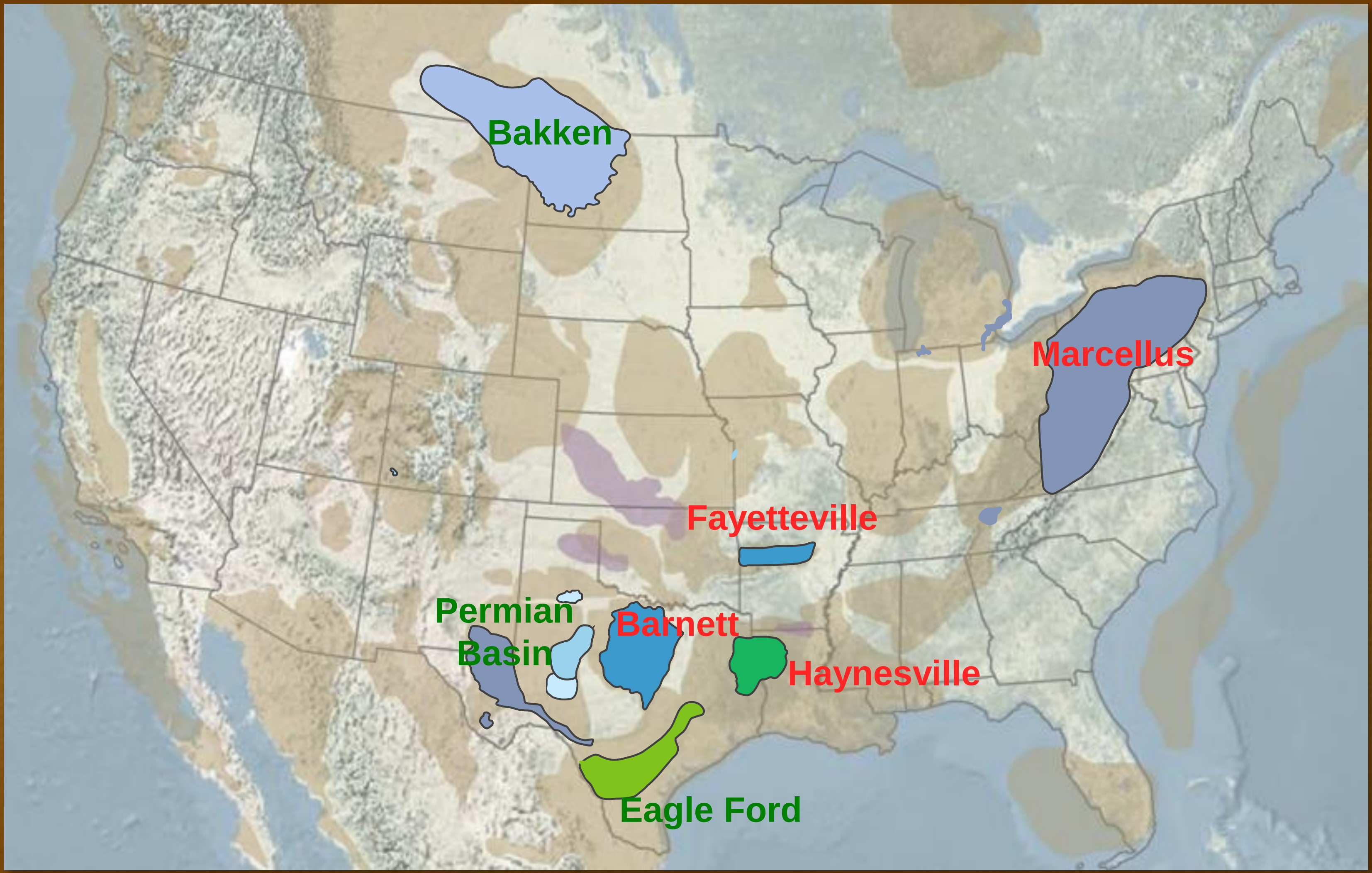
Unconventional Resource Plays



Modified from: EIA and National Geographic

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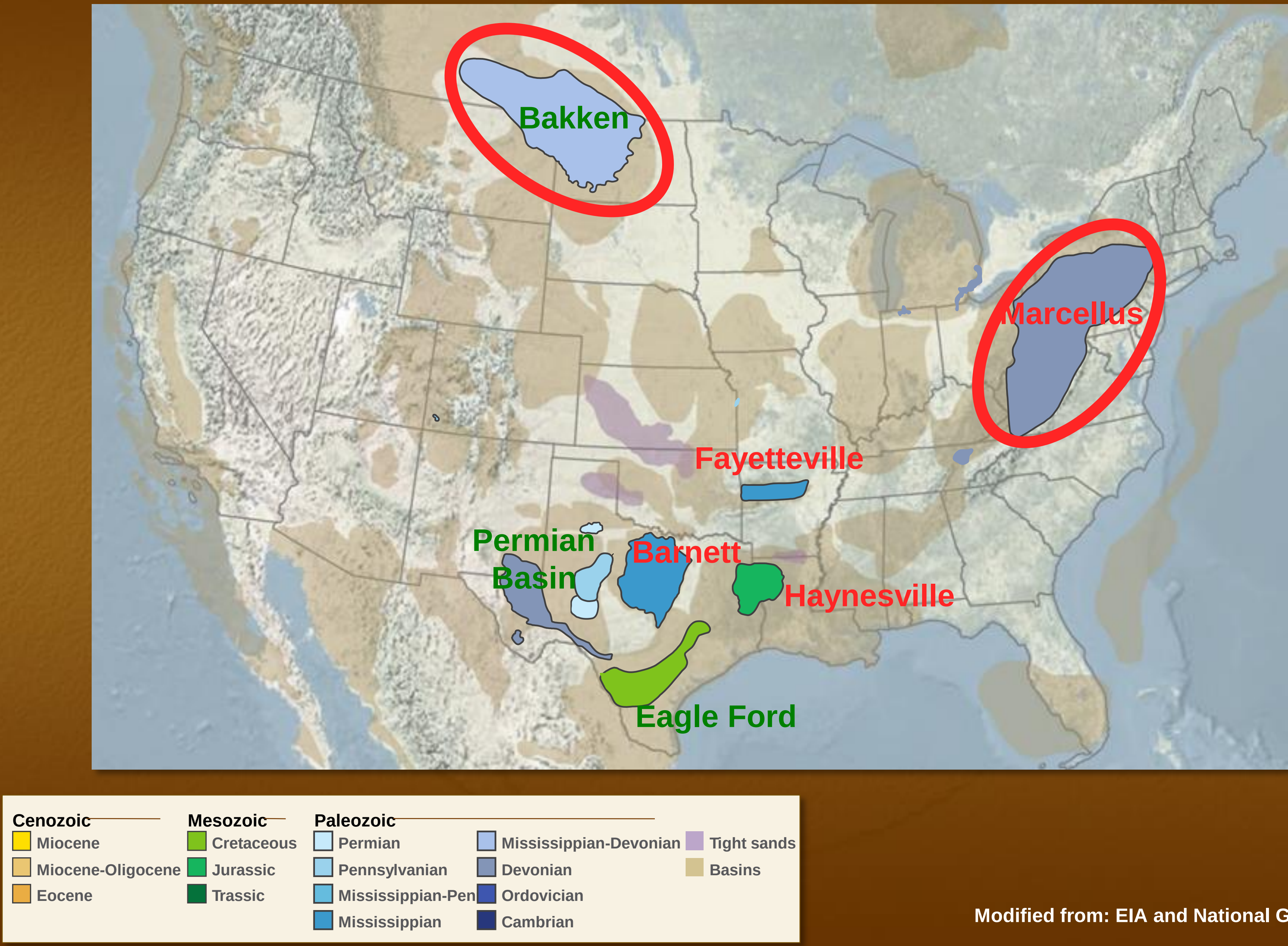
Unconventional Resource Plays



Modified from: EIA and National Geographic

Middle Devonian

nker, 2014

From Blakey; http://cpgeosystems.com/paleomaps.html

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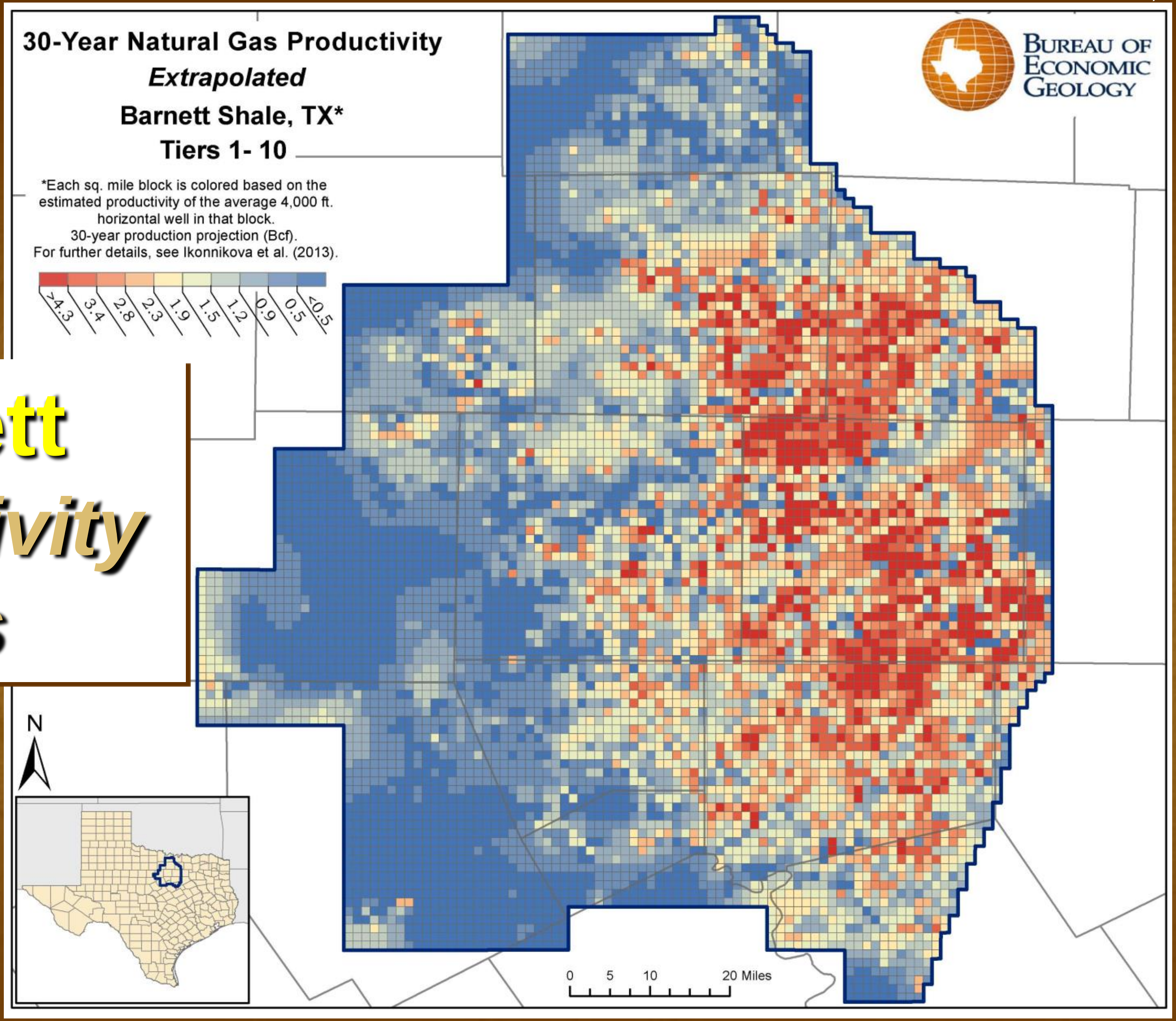
U.S. Shale Gas Integrated Study

- What is the *total* resource base in place?
- What portion is *technically* recoverable?
- What potion is *economically* recoverable?
- What is the long-term *production outlook*?

Barnett *Productivity Tiers*



Ikonnikova S., et al. 2013. SPE Res. Eval & Eng

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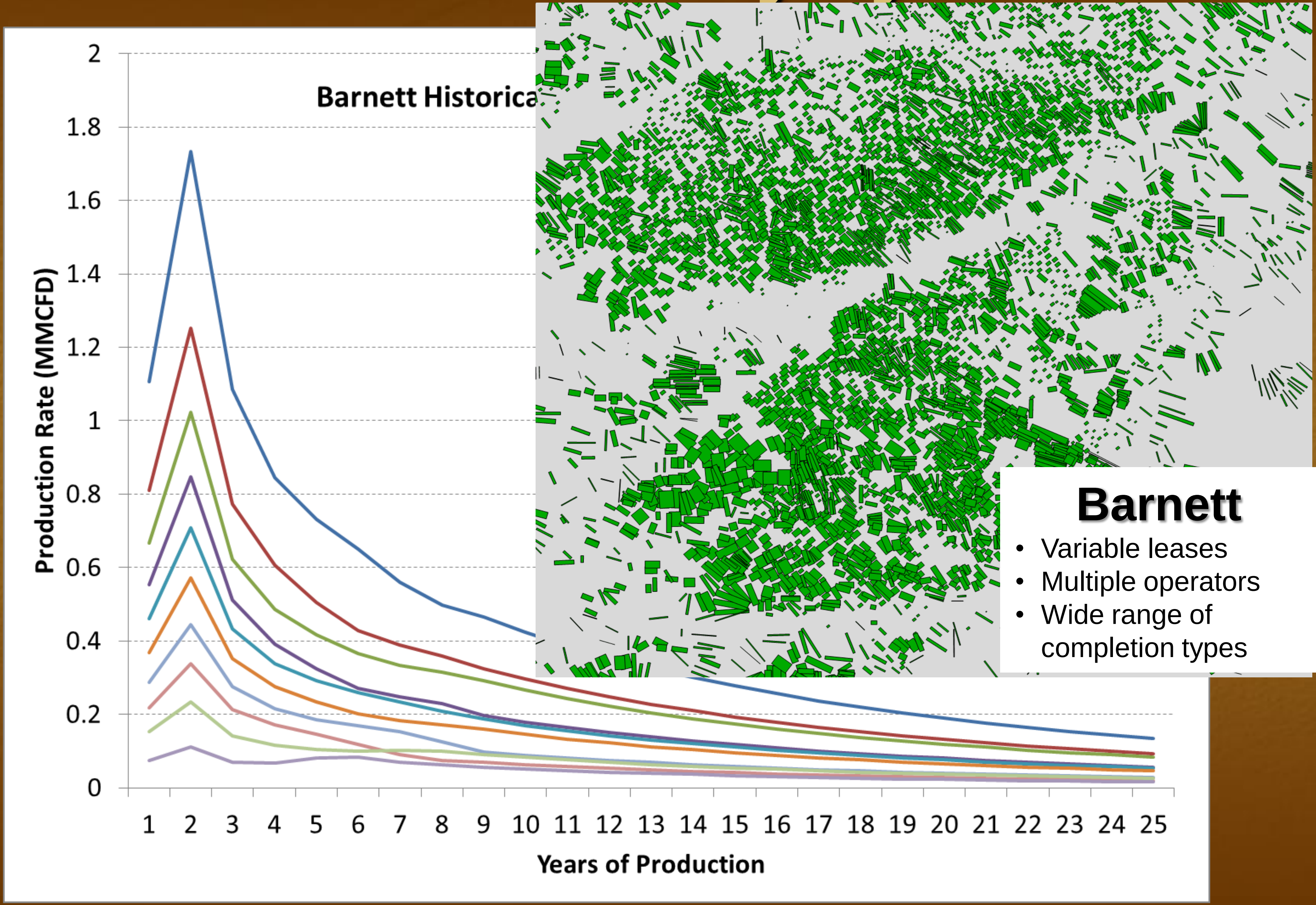
Well Profiles Vary by Tier



Barnett

- Variable leases
- Multiple operators
- Wide range of completion types

Barnett Drilling by Tier

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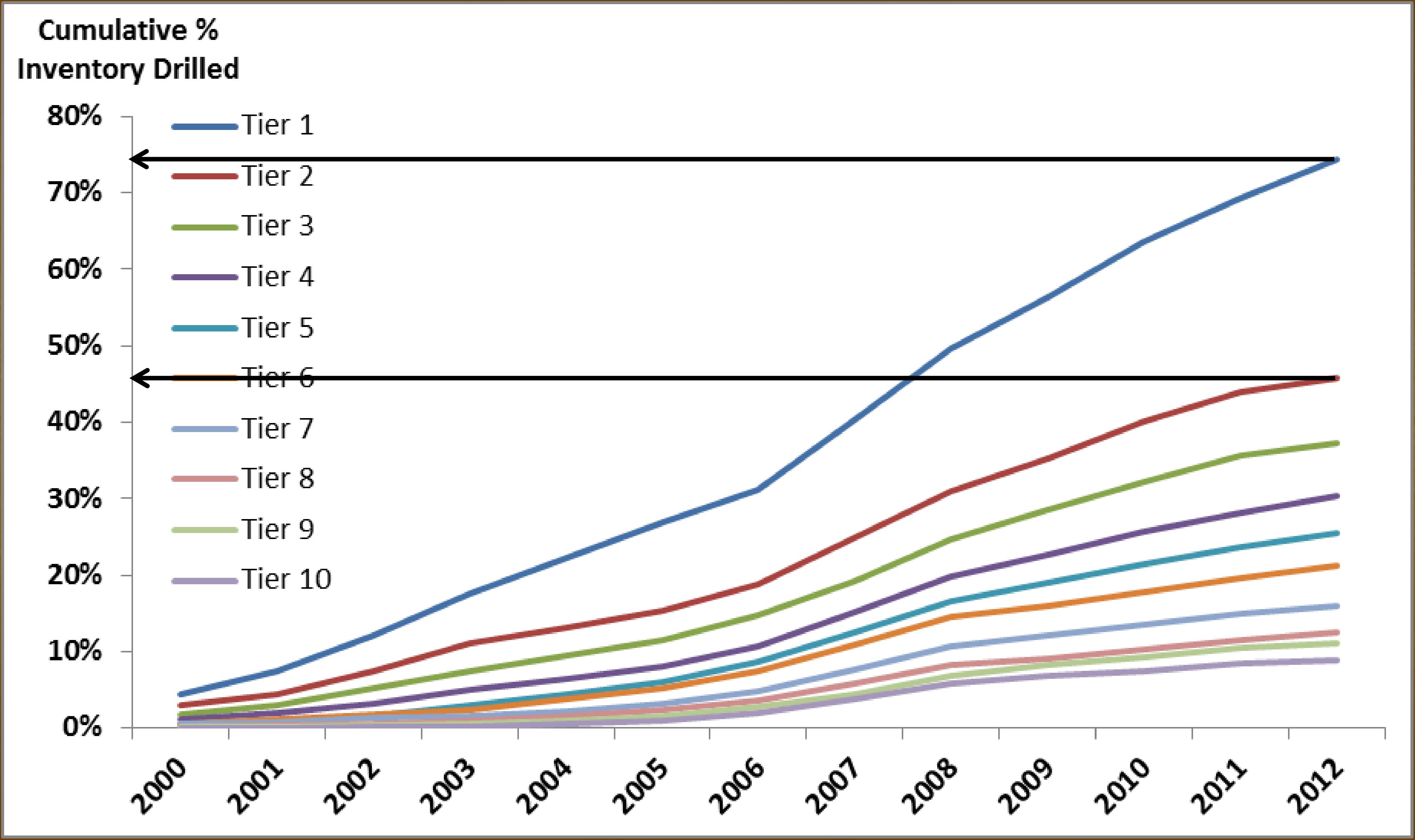
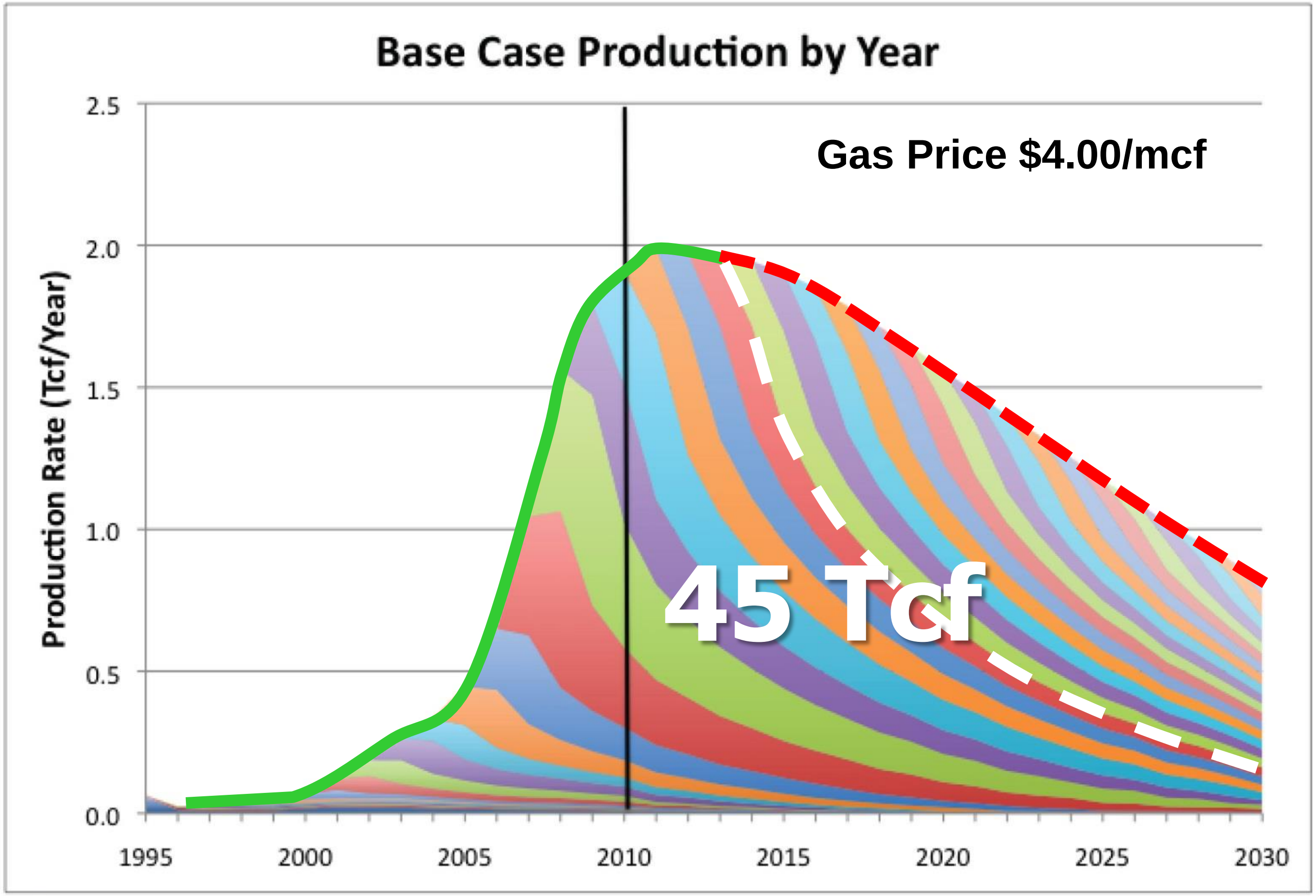


BEG Shale Reserves and Production Project

Production Outlook for the Barnett Shale through 2030



Bureau of Economic Geology

Source: Bureau of Economic Geology/Univ. of Texas at Austin
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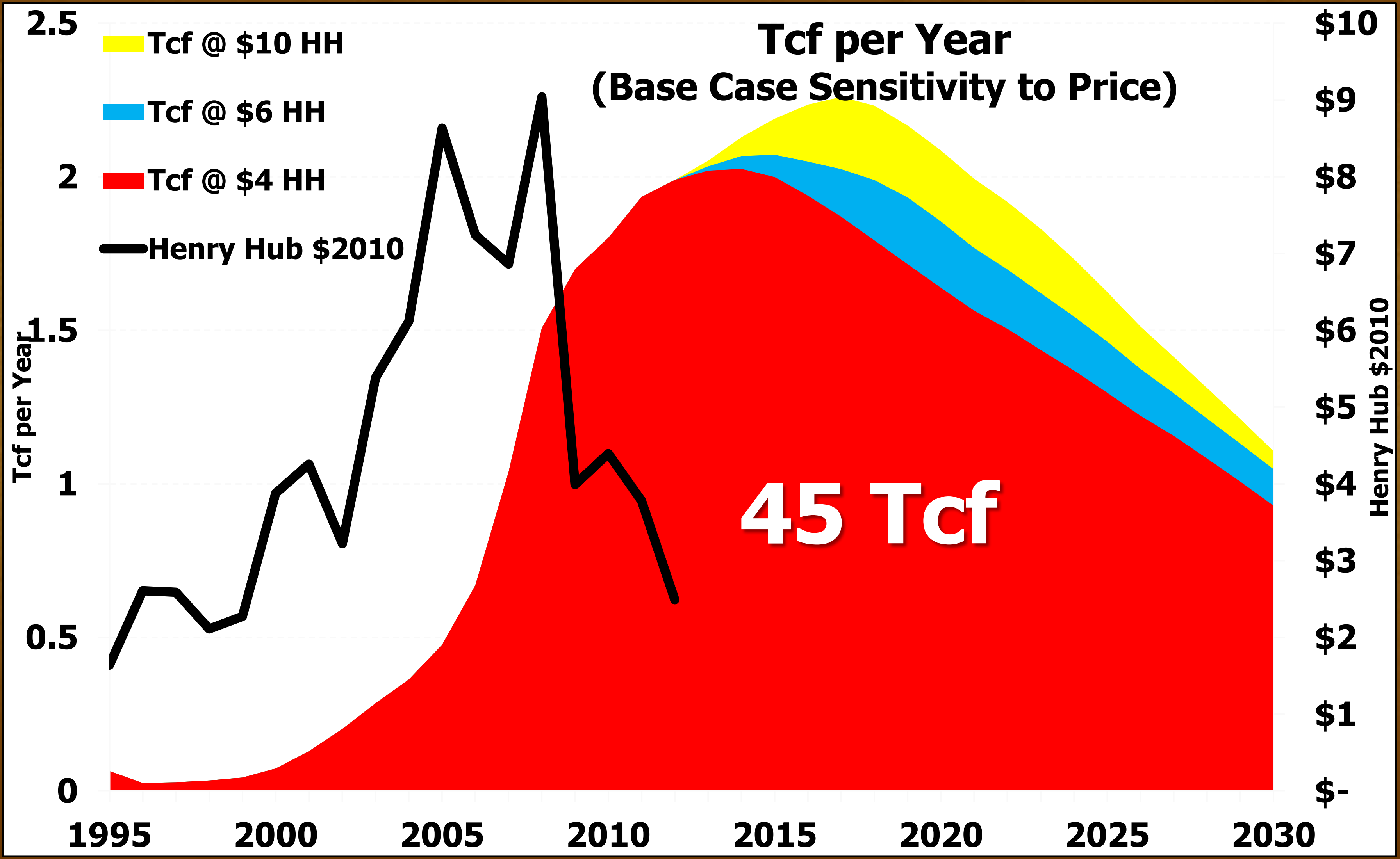
Barnett
Production Forecast



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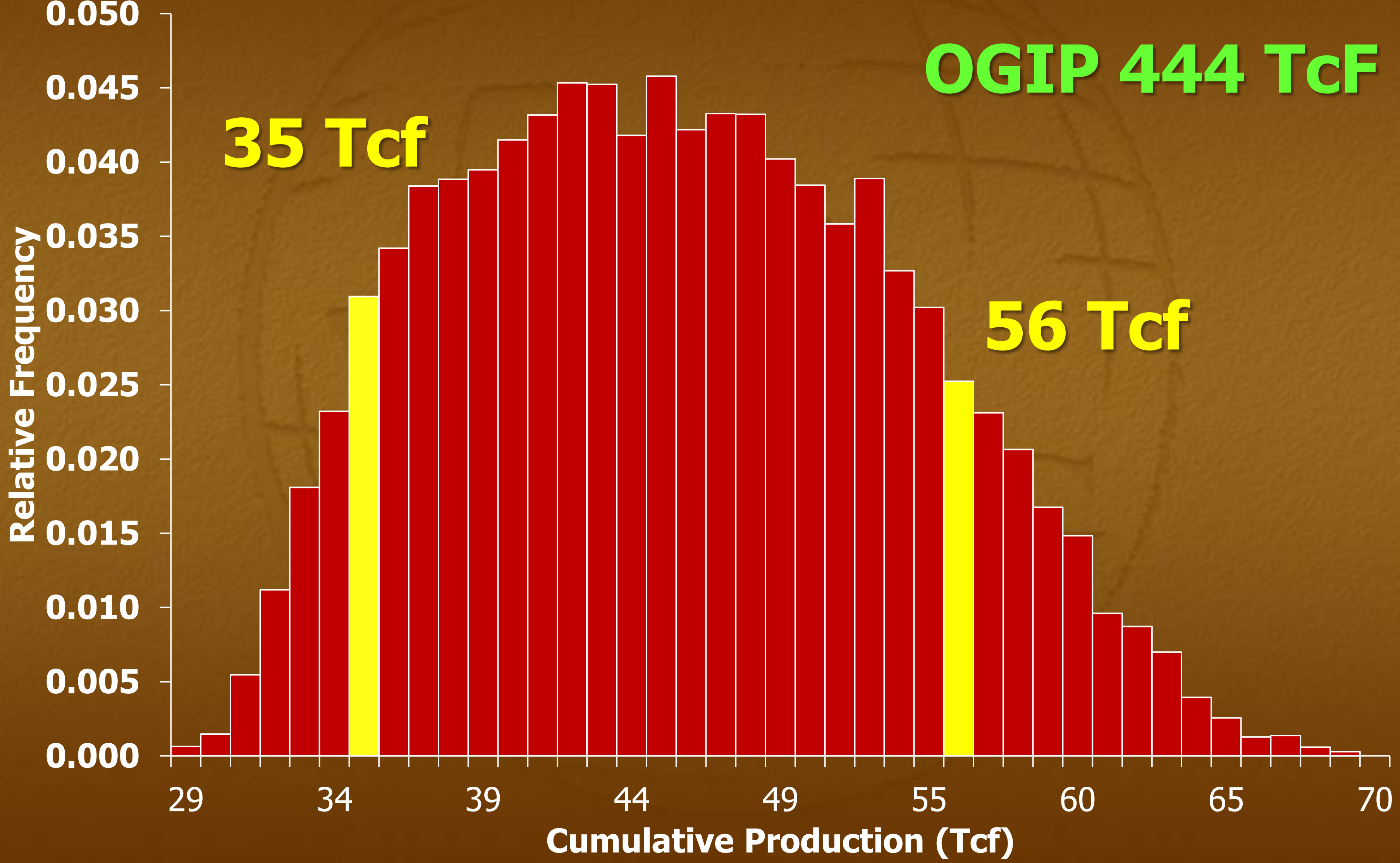
Barnett

Monte Carlo Production Distribution



Browning, J. et al. 2013. SPE Econ & Mgmt

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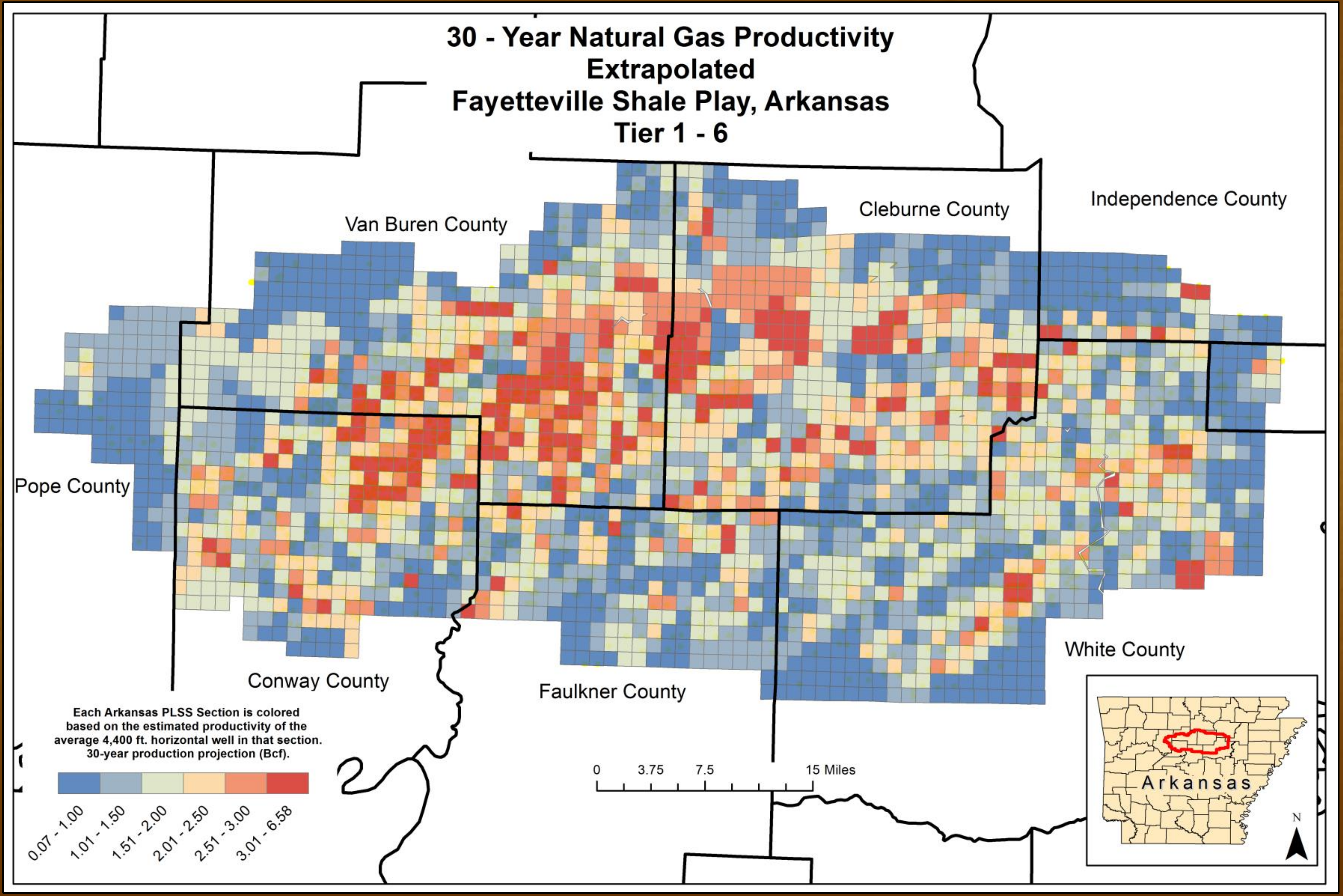
Fayetteville
Productivity Tiers



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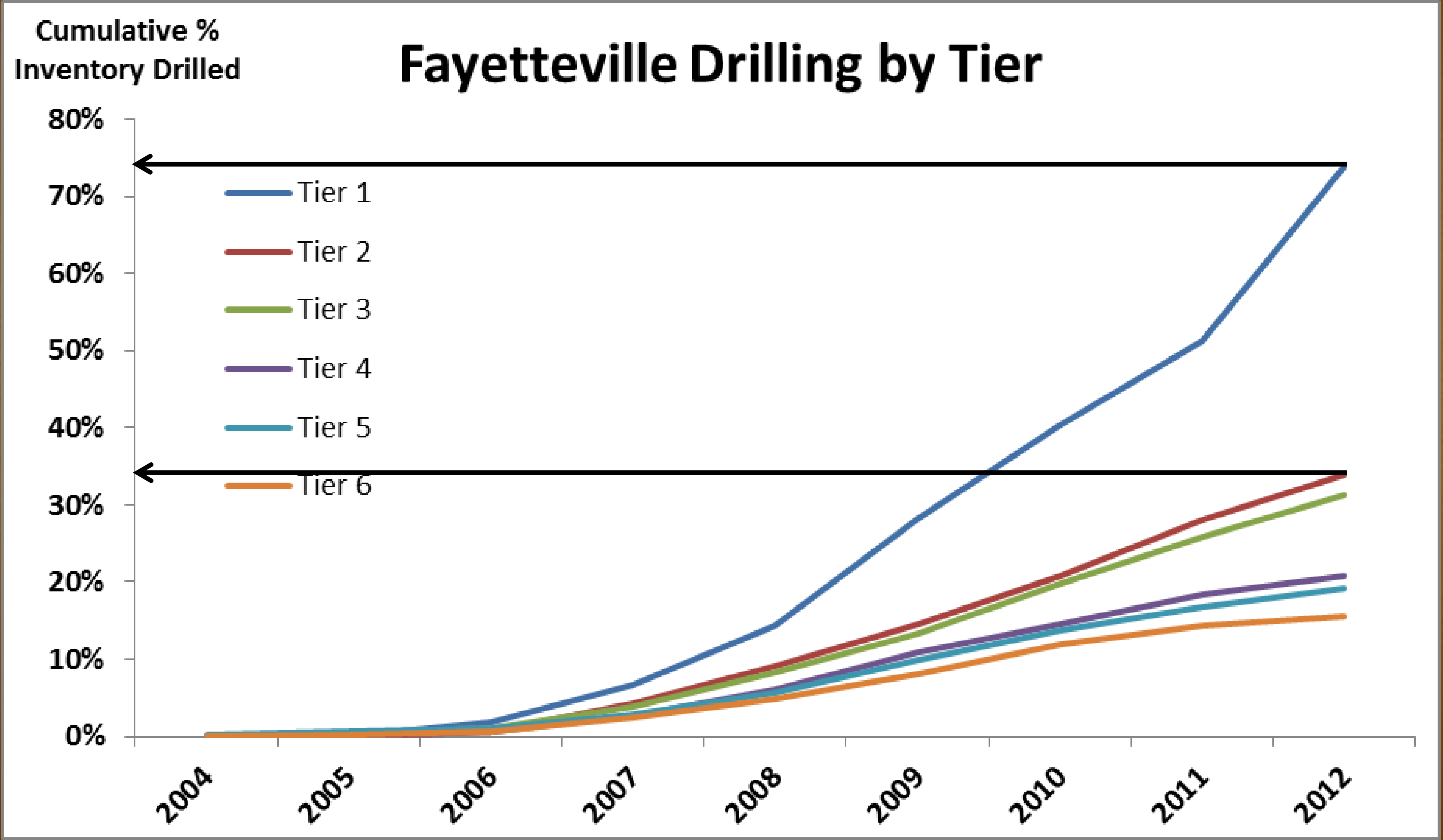
Fayetteville
Production Forecast



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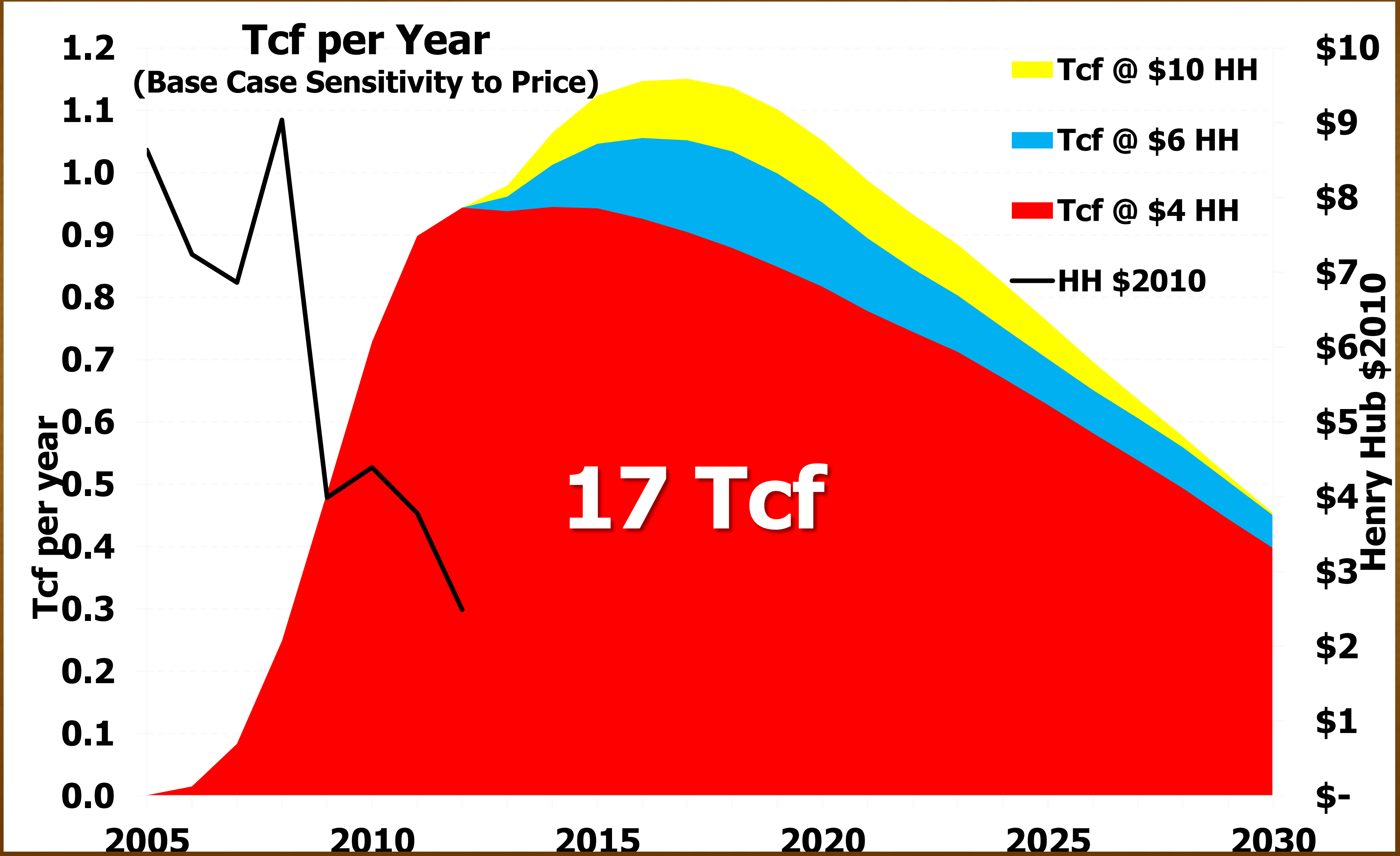
Fayetteville
Production Forecast



BEG Shale Reserves and Production Project

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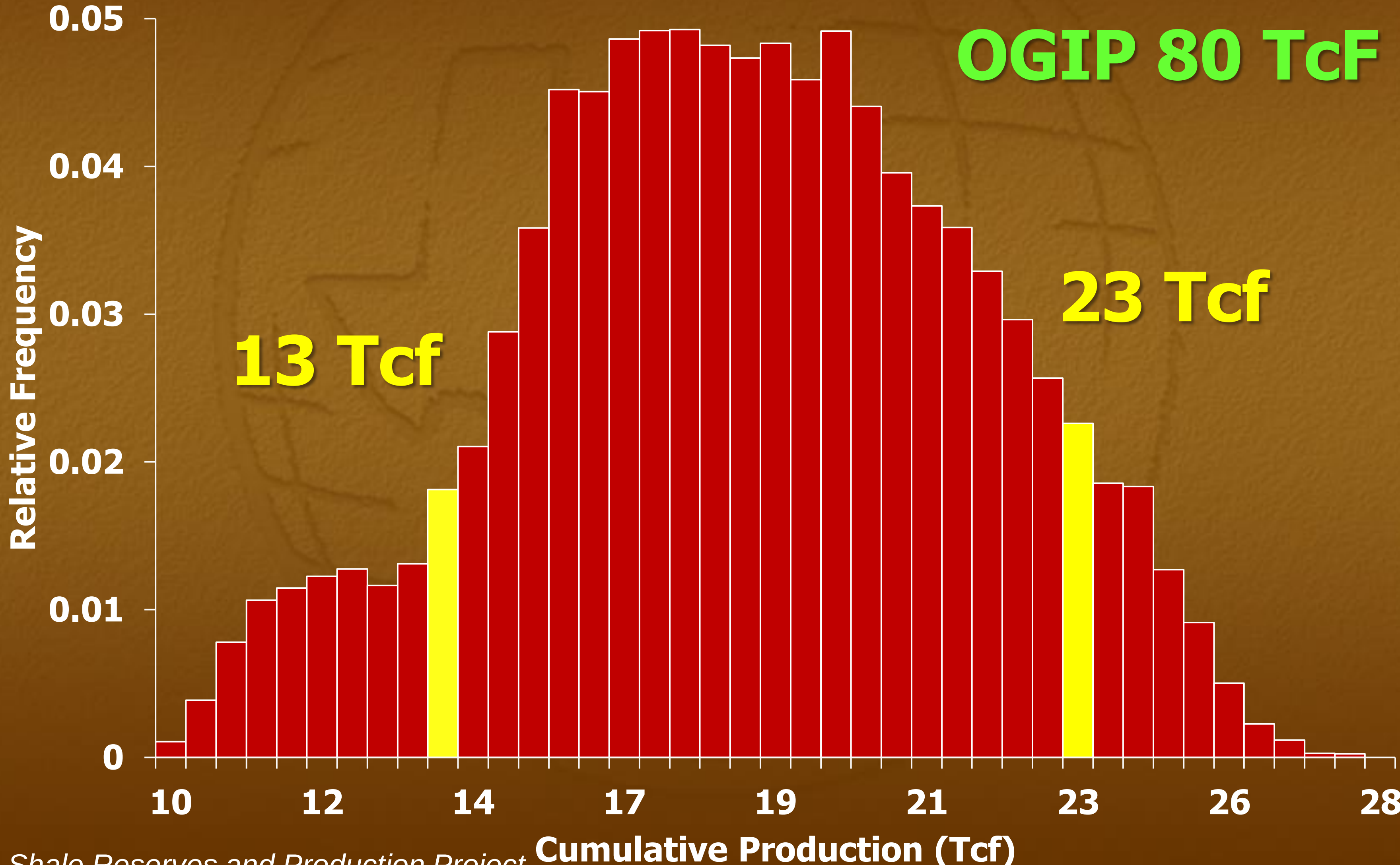
Fayetteville

Monte Carlo Production Distribution



BEG Shale Reserves and Production Project

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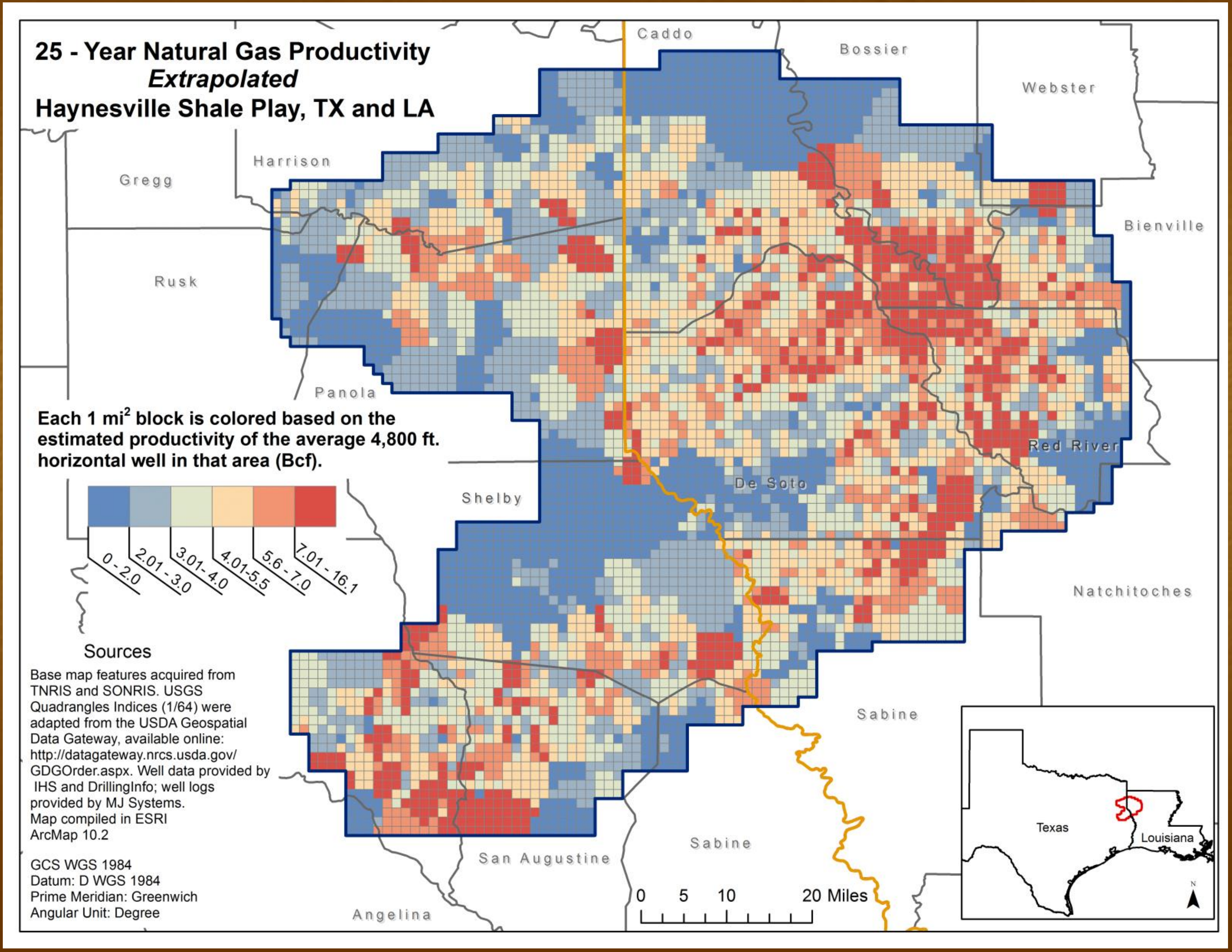
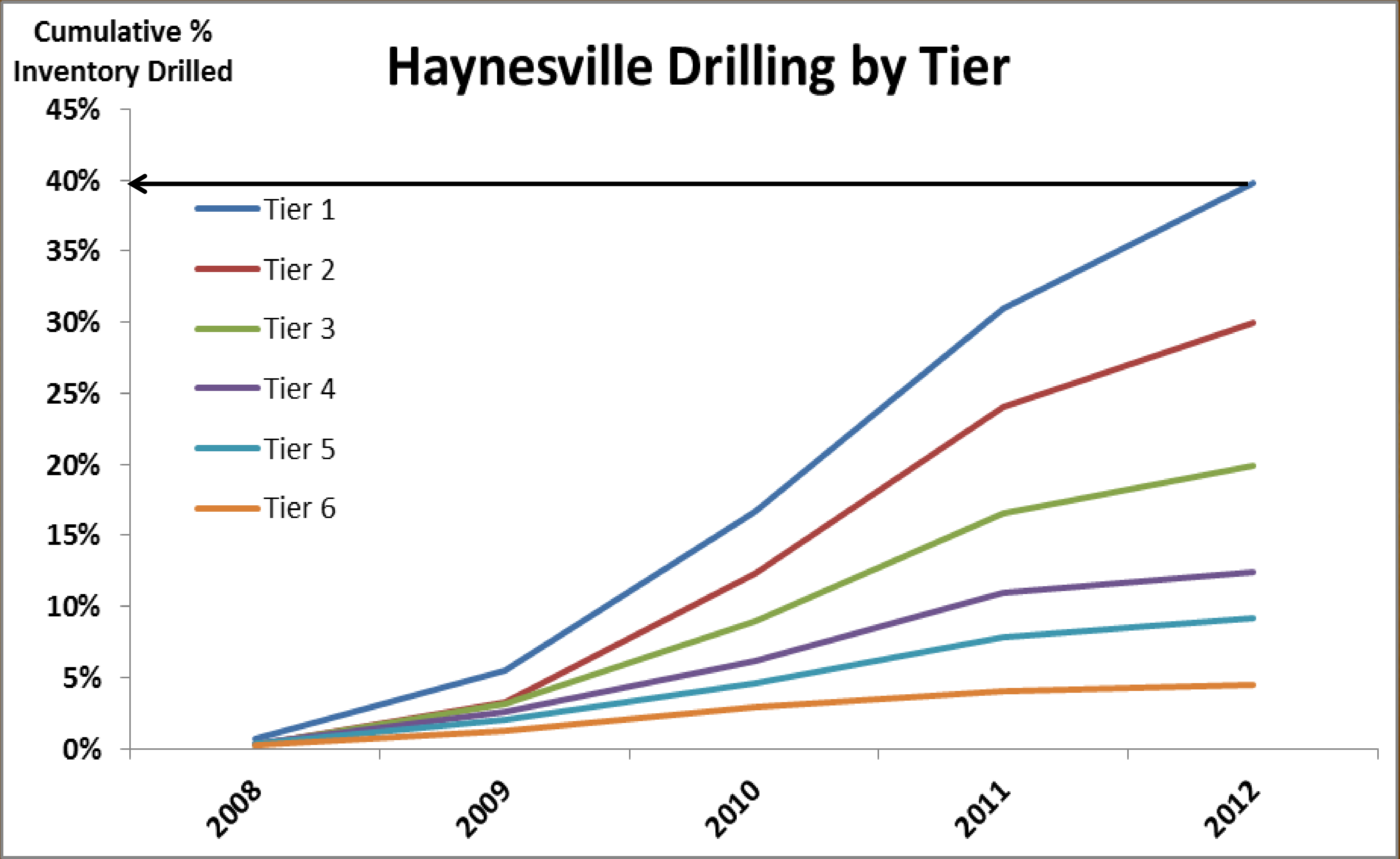
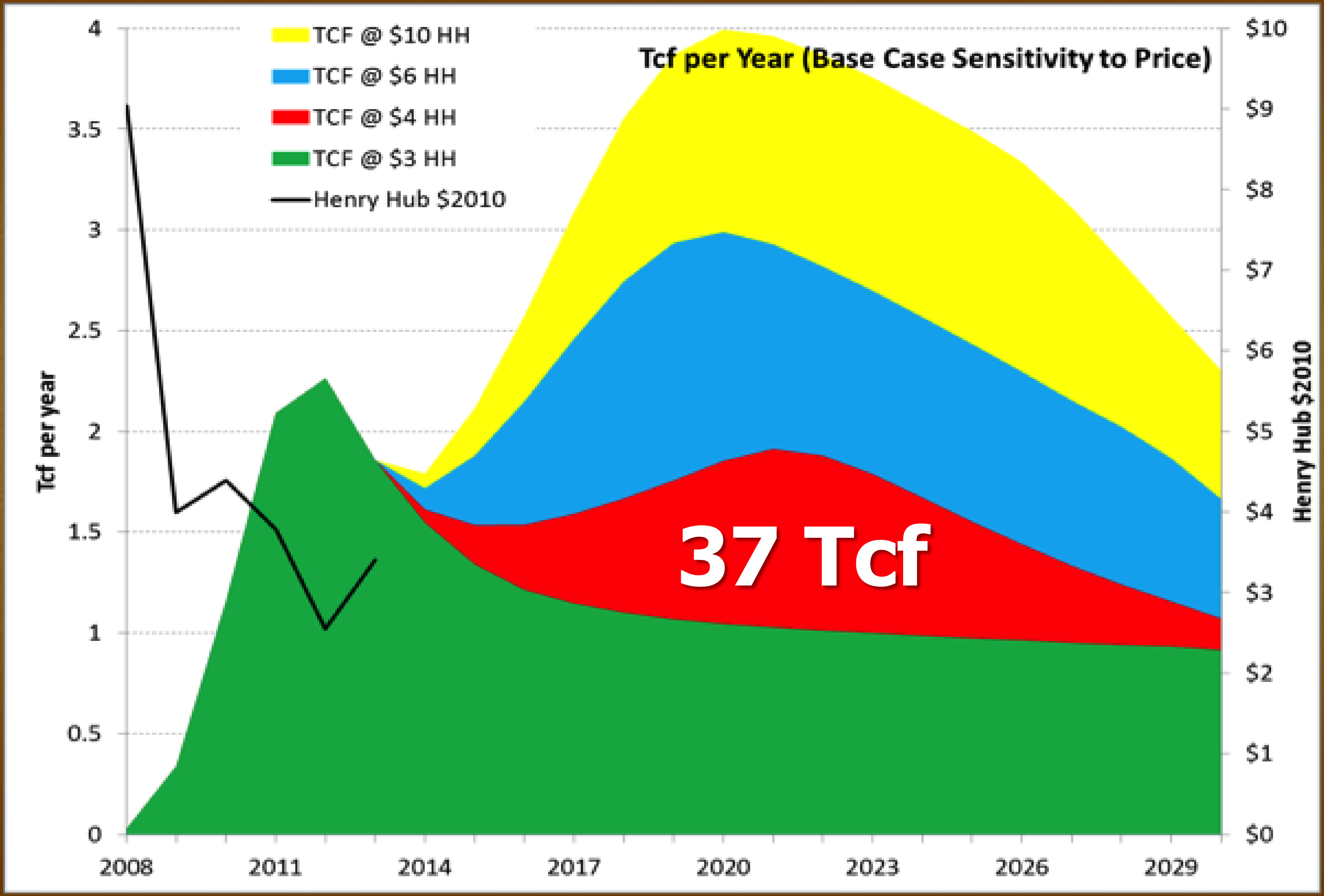
Haynesville
Productivity Tiers



Haynesville Production Forecast



Haynesville Production Forecast



BEG Shale Reserves and Production Project

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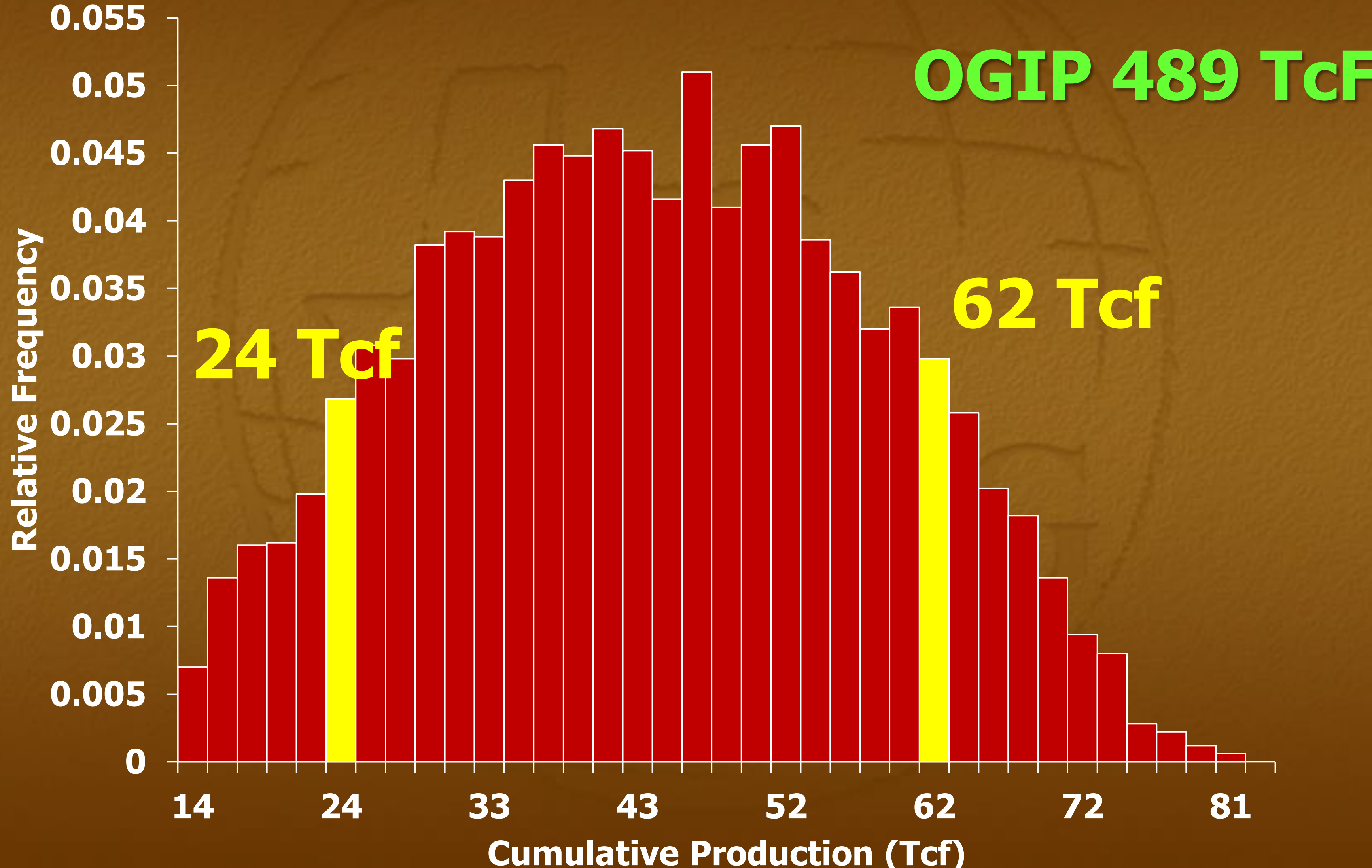
Haynesville

Monte Carlo Production Distribution



BEG Shale Reserves and Production Project

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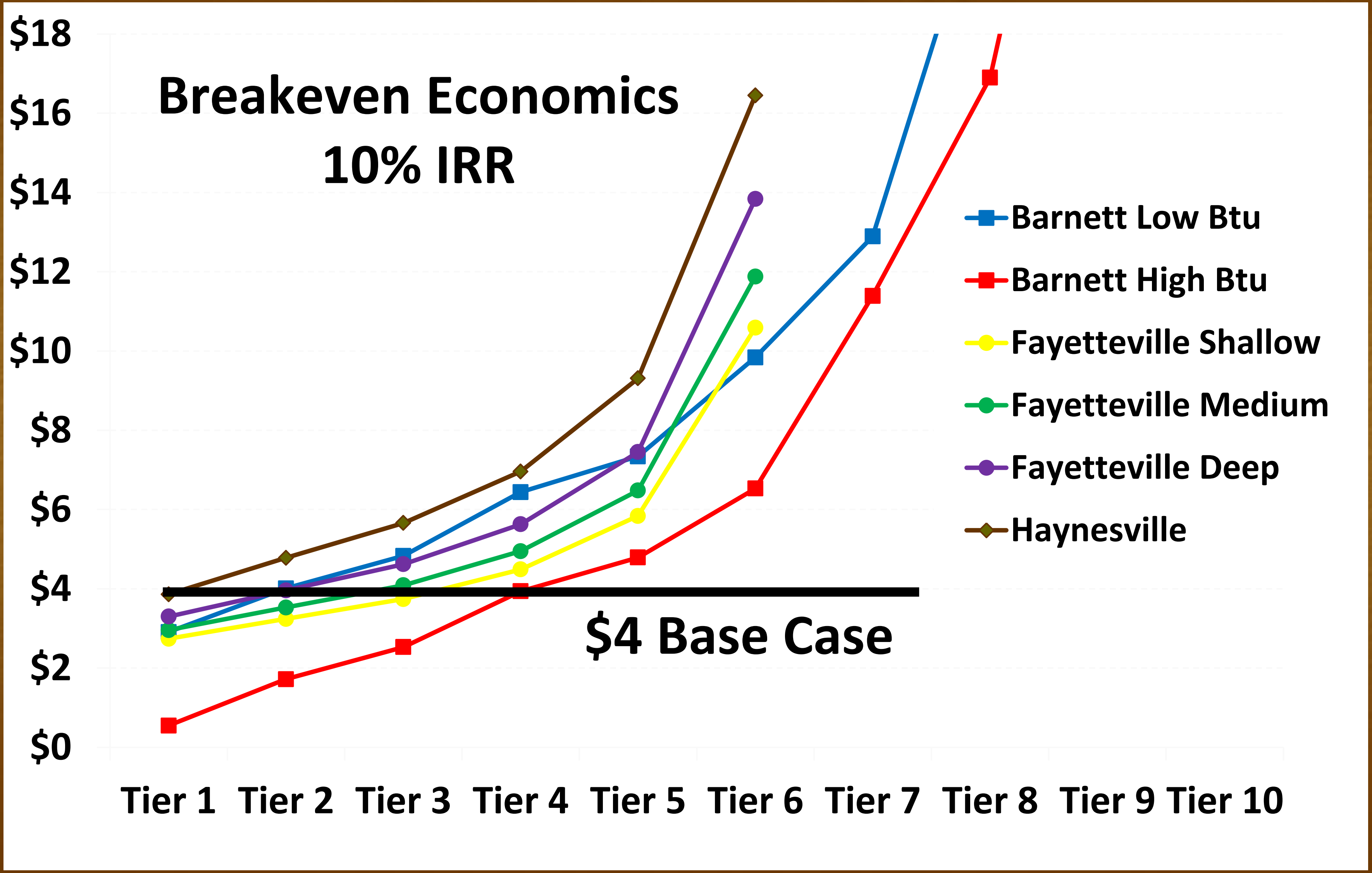
Economics by Tier (Bcf)



BEG Shale Reserves and Production Project

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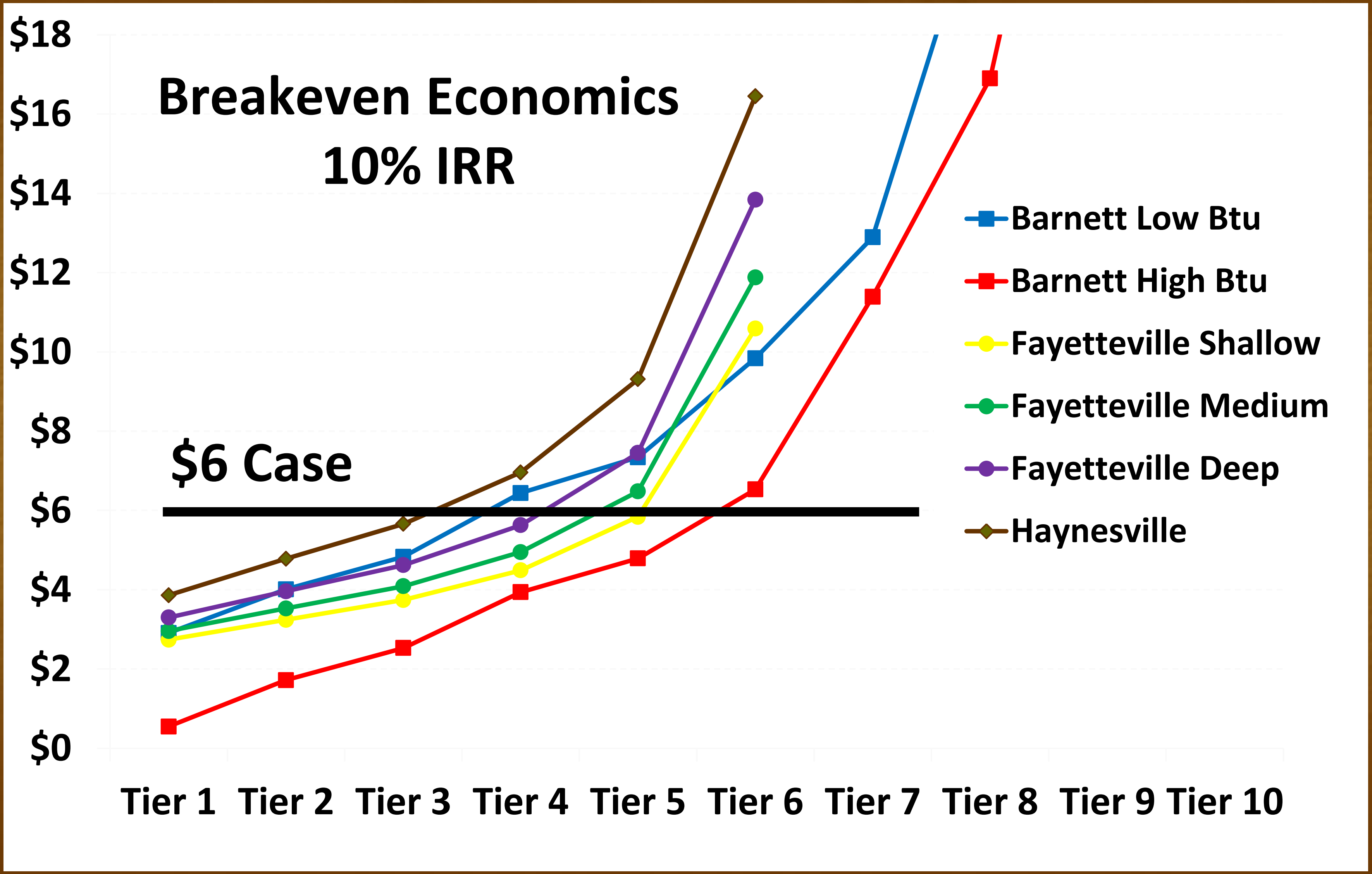
Economics by Tier (Bcf)



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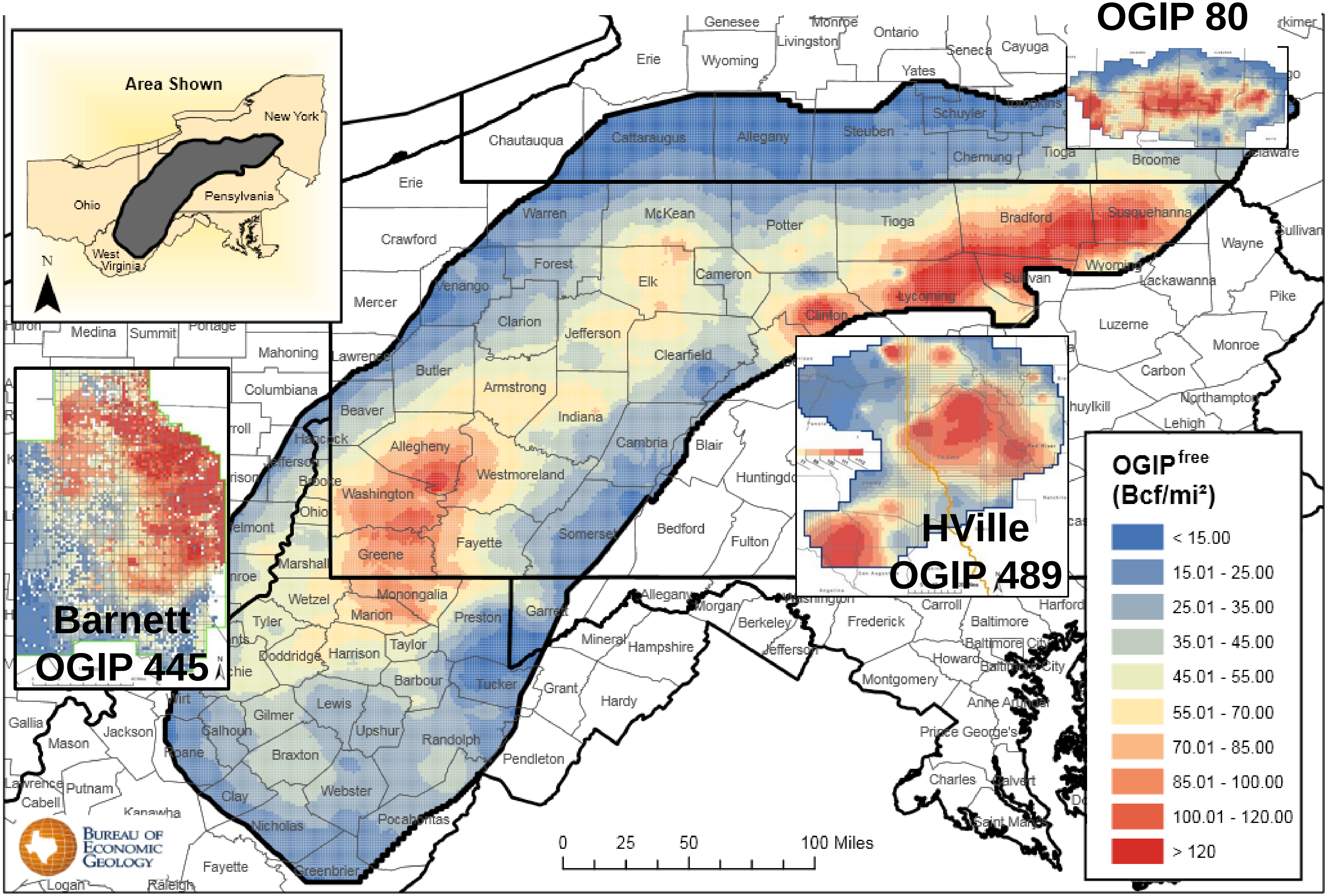
Marcellus OGIP

1712 Tcf OGIP free

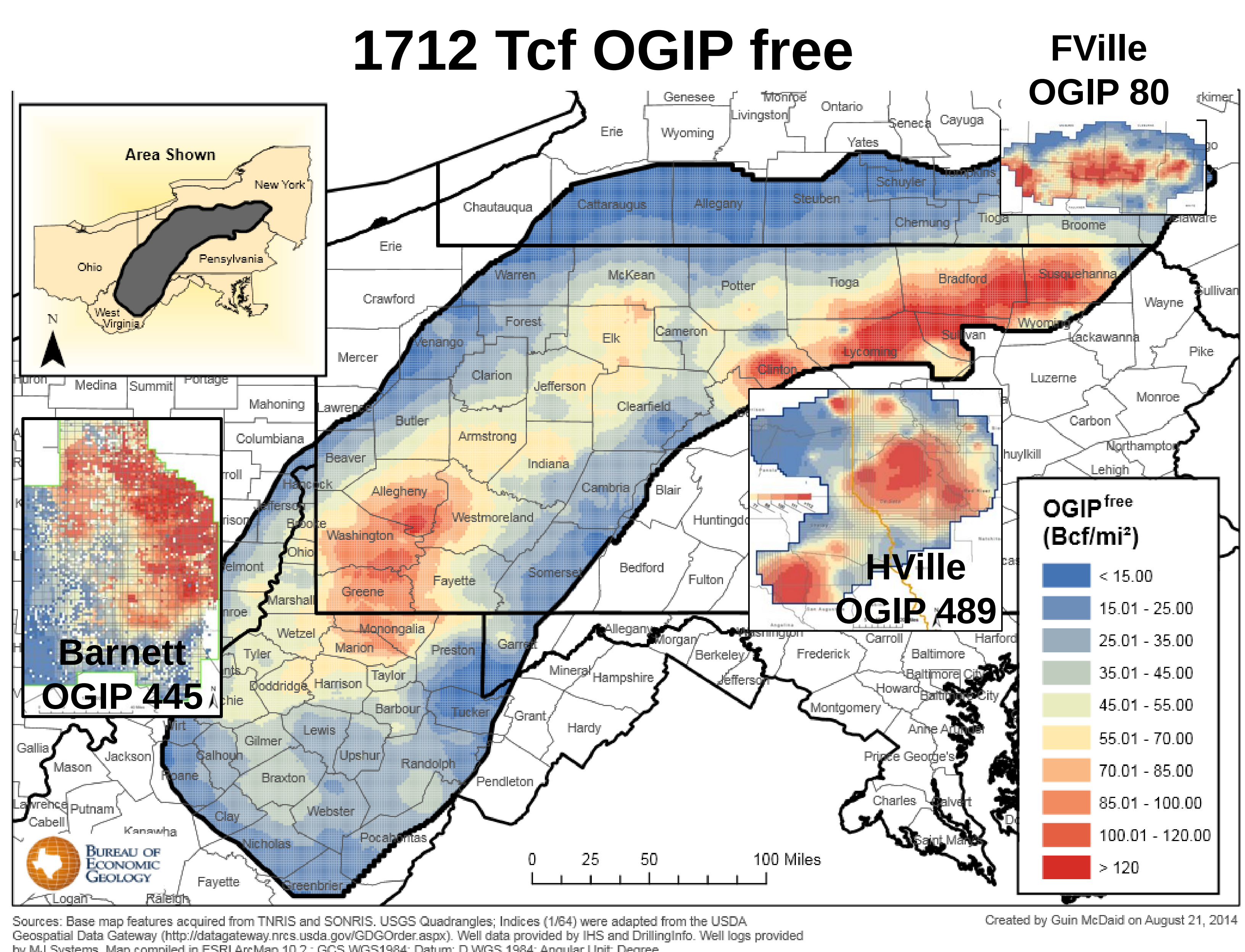


Sources: Base map features acquired from TNRIS and SONRIS. USGS Quadrangles; Indices (1/64) were adapted from the USDA Geospatial Data Gateway (http://datagateway.nrcs.usda.gov/GDGOrder.aspx). Well data provided by IHS and DrillingInfo. Well logs provided by MJ Systems. Map compiled in ESRI ArcMap 10.2.; GCS WGS1984; Datum: D WGS 1984; Angular Unit: Degree

Created by Guin McDaid on August 21, 2014

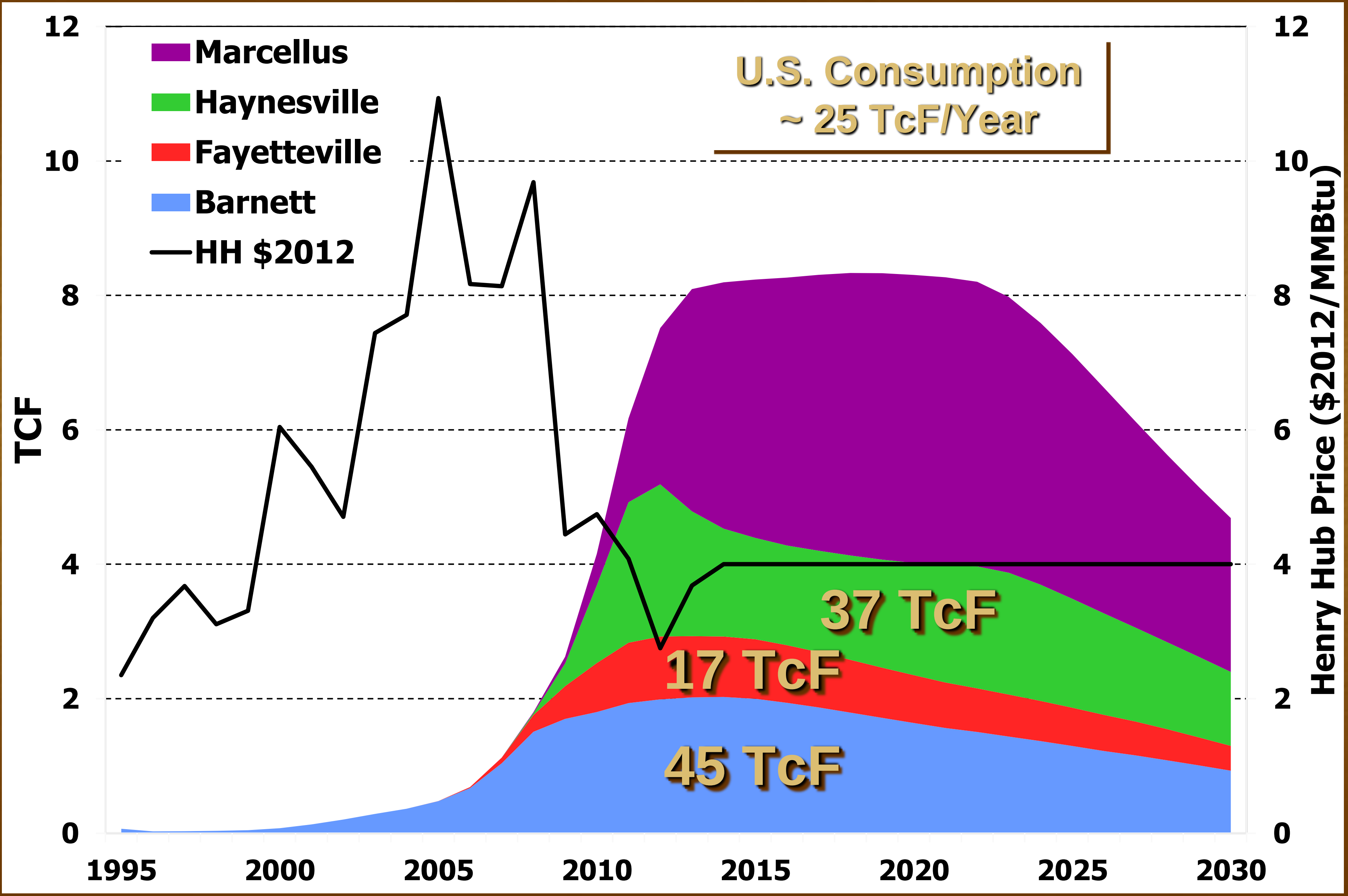
All Maps Shown with Common Distance Scale

Marcellus OGIP



All Maps Shown with Common Distance Scale

Base Case ($4) Stacked Production



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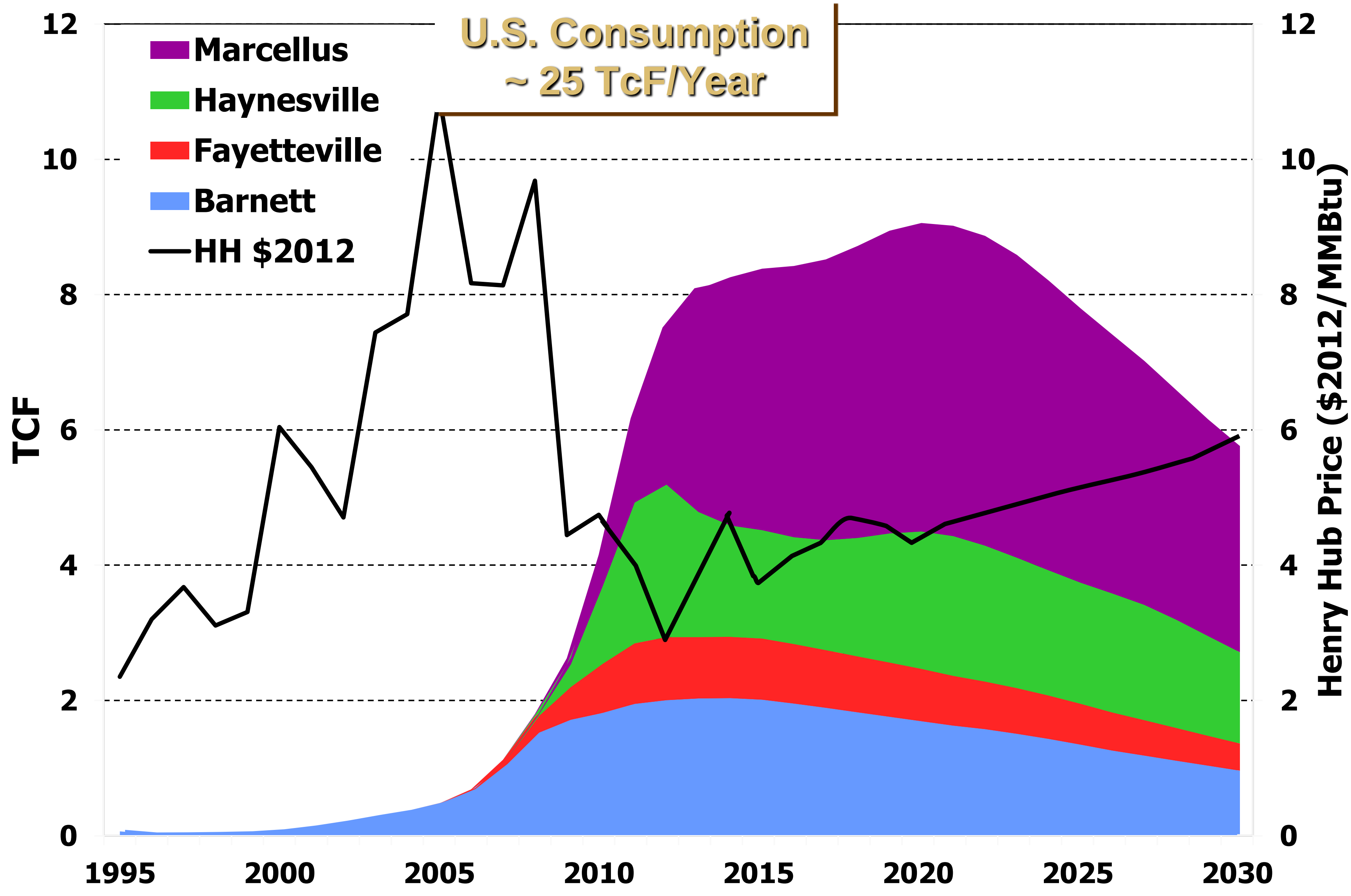
EIA Price Case Stacked Production



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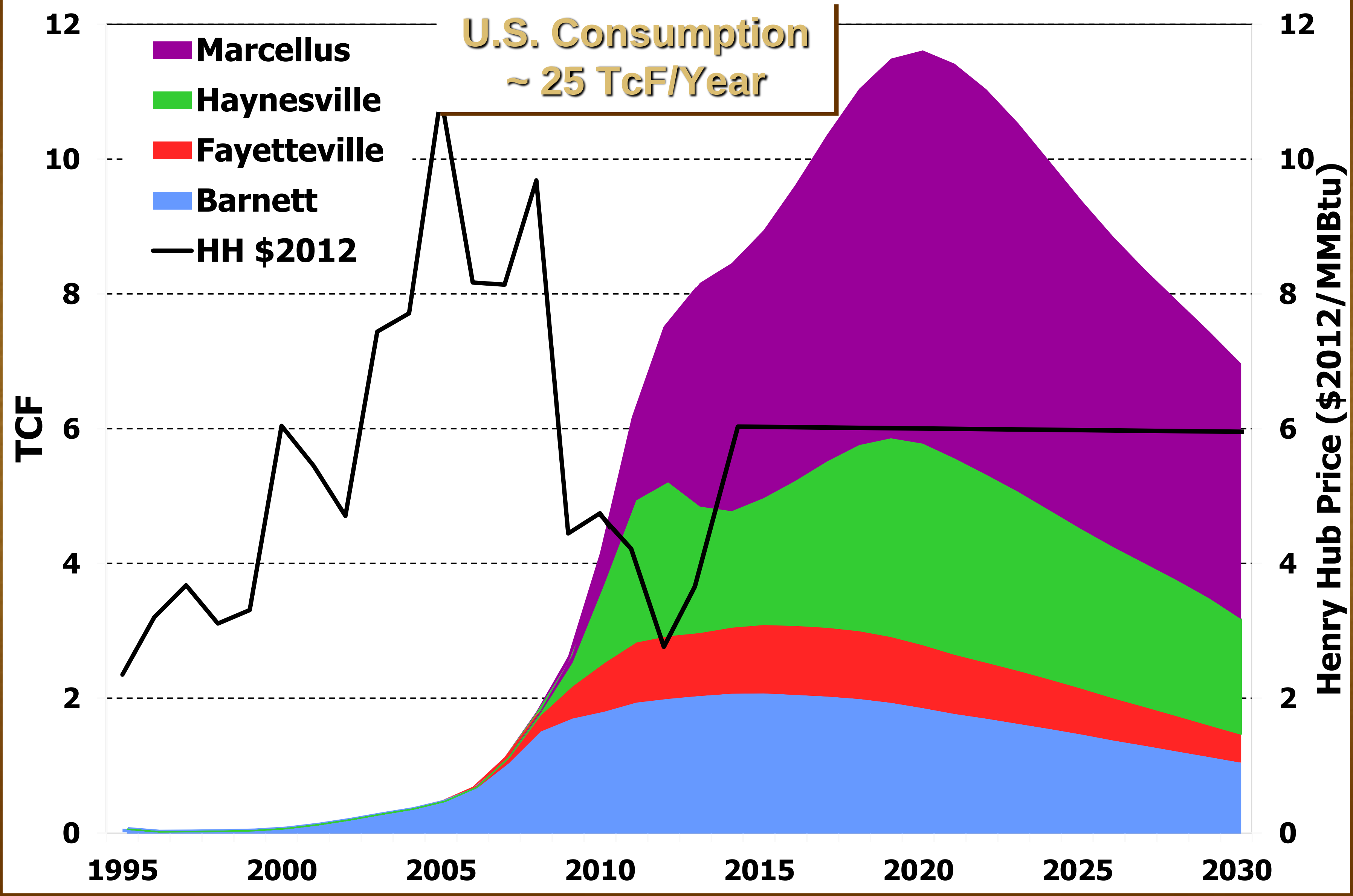
$6 Case Stacked Production



BEG Shale Reserves and Production Project

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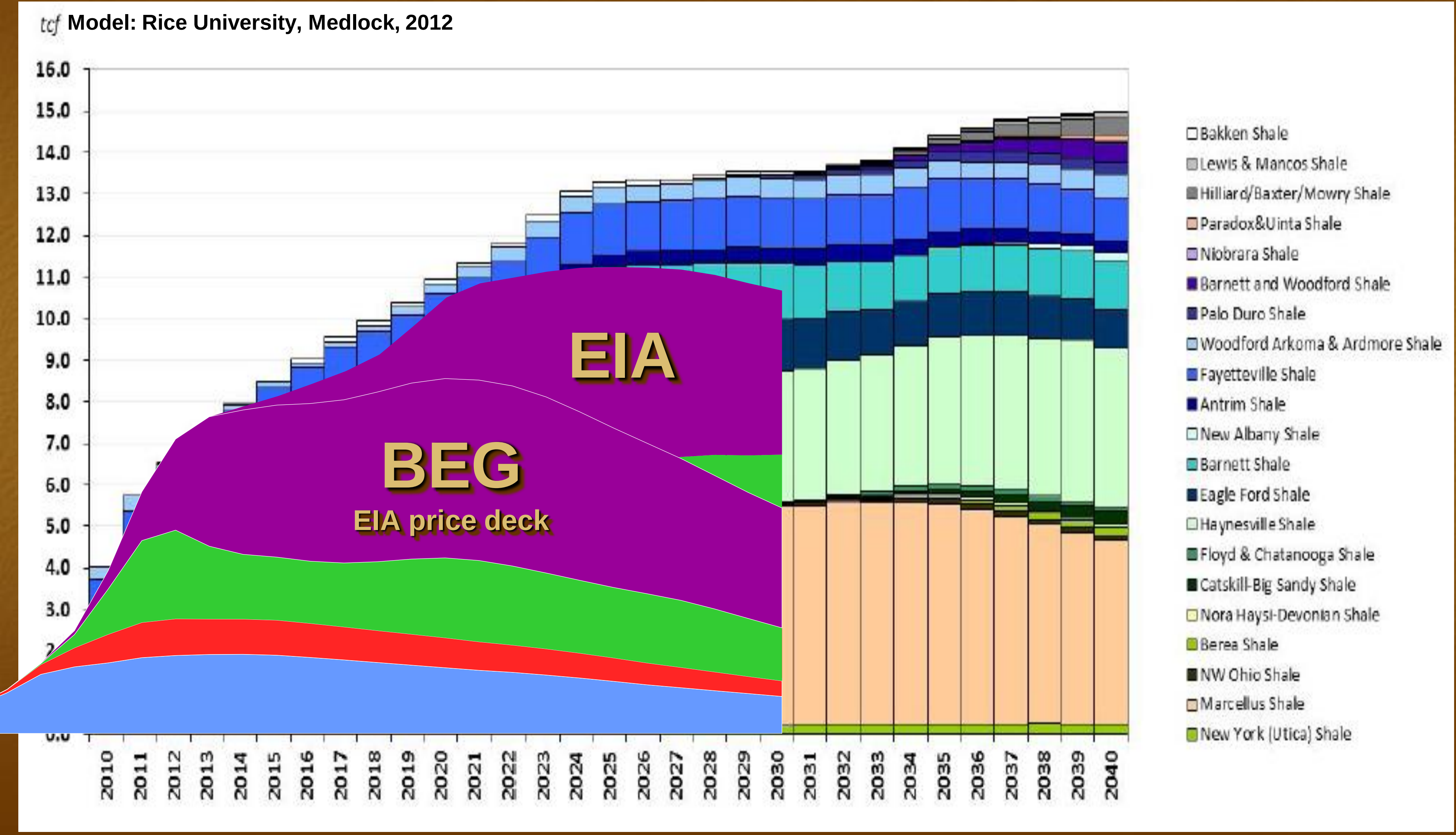
Forecast vs. Actual



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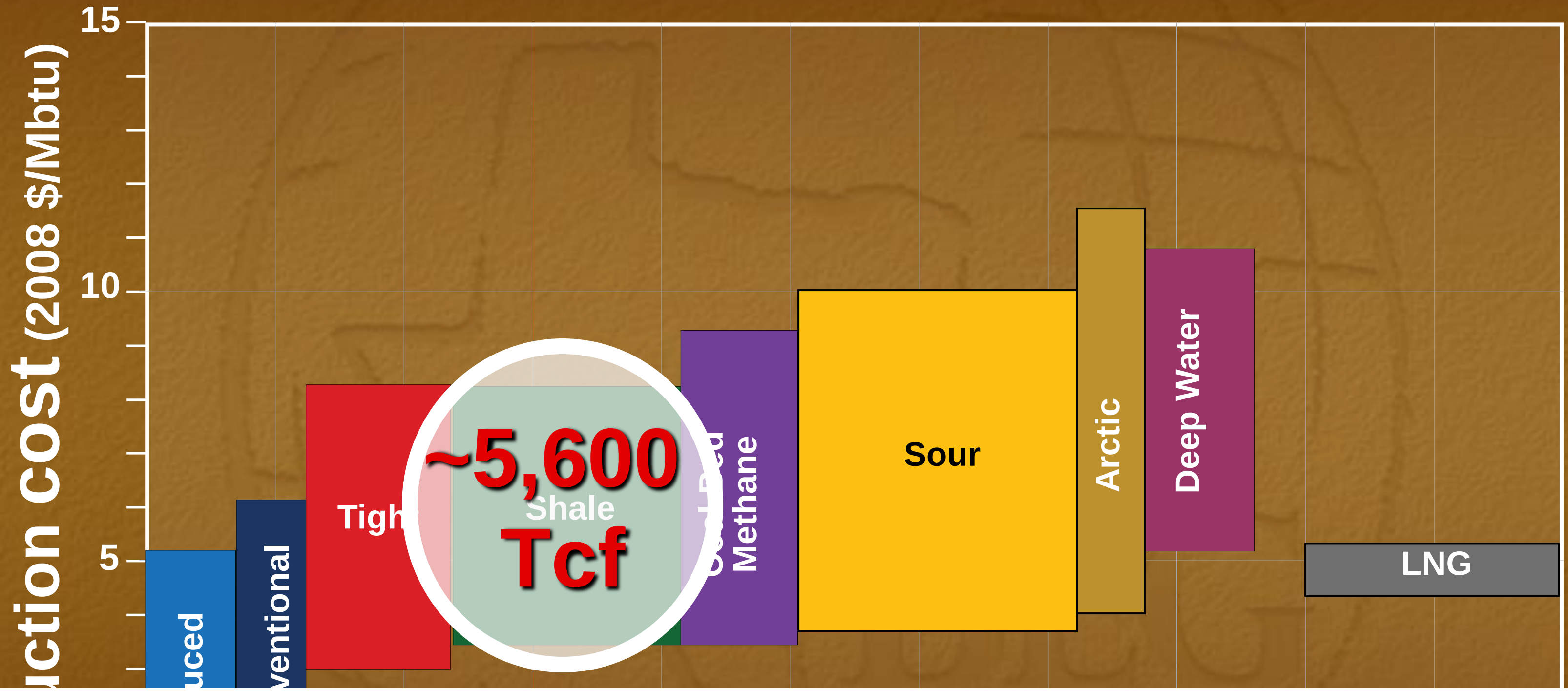
Global Natural Gas

Resources v. Cost



	Barnett	Fayetteville	Haynesville	Marcellus	Total
BEG Original Gas in Place (Tcf)	444	80	489	1712	2725
BEG ($4) Production – 2050 *Marcellus through 2070	45	17	37		
Field Wide Recovery %	10%	21%	8%		

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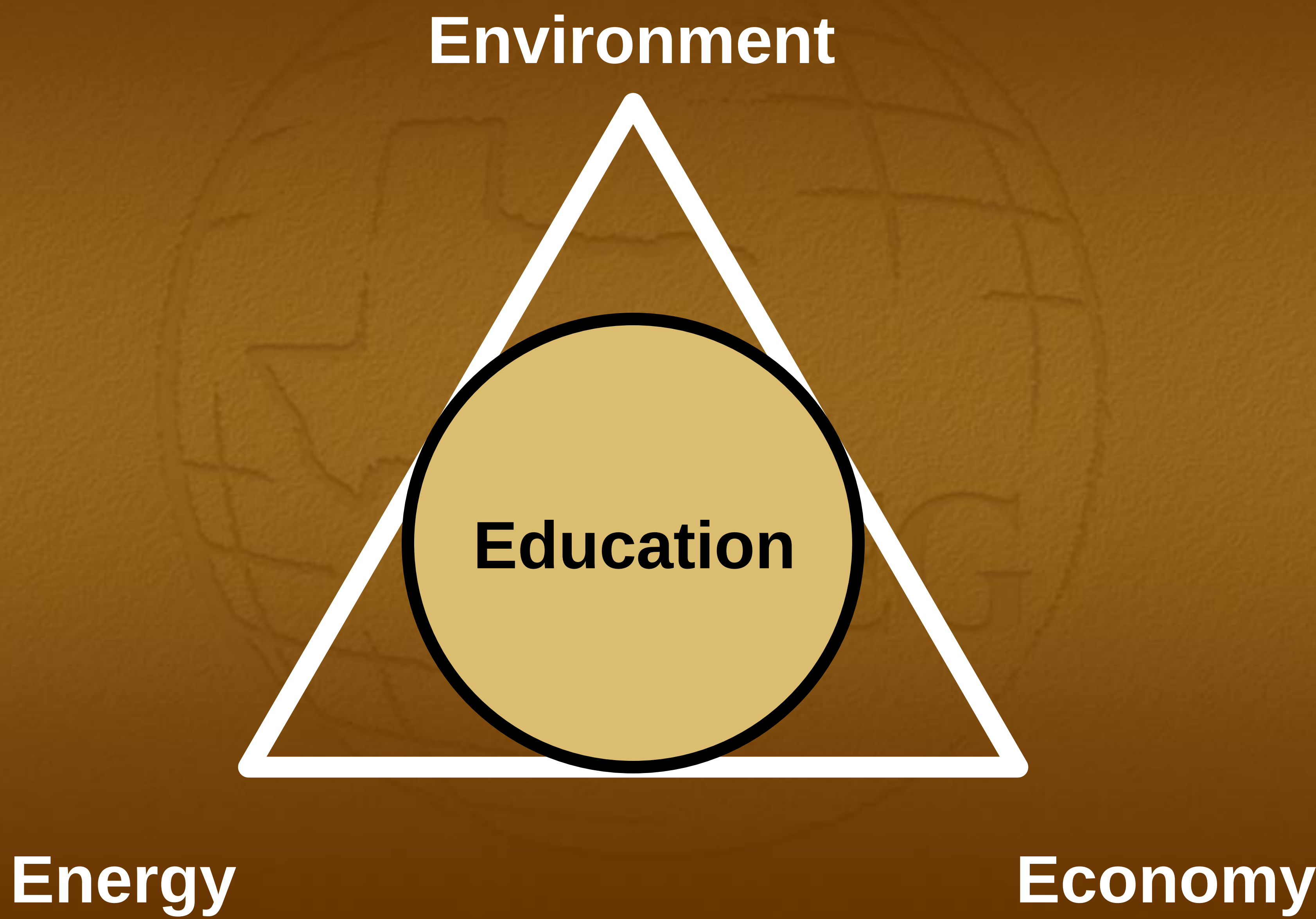
The 5E Waltz



The Radical Middle

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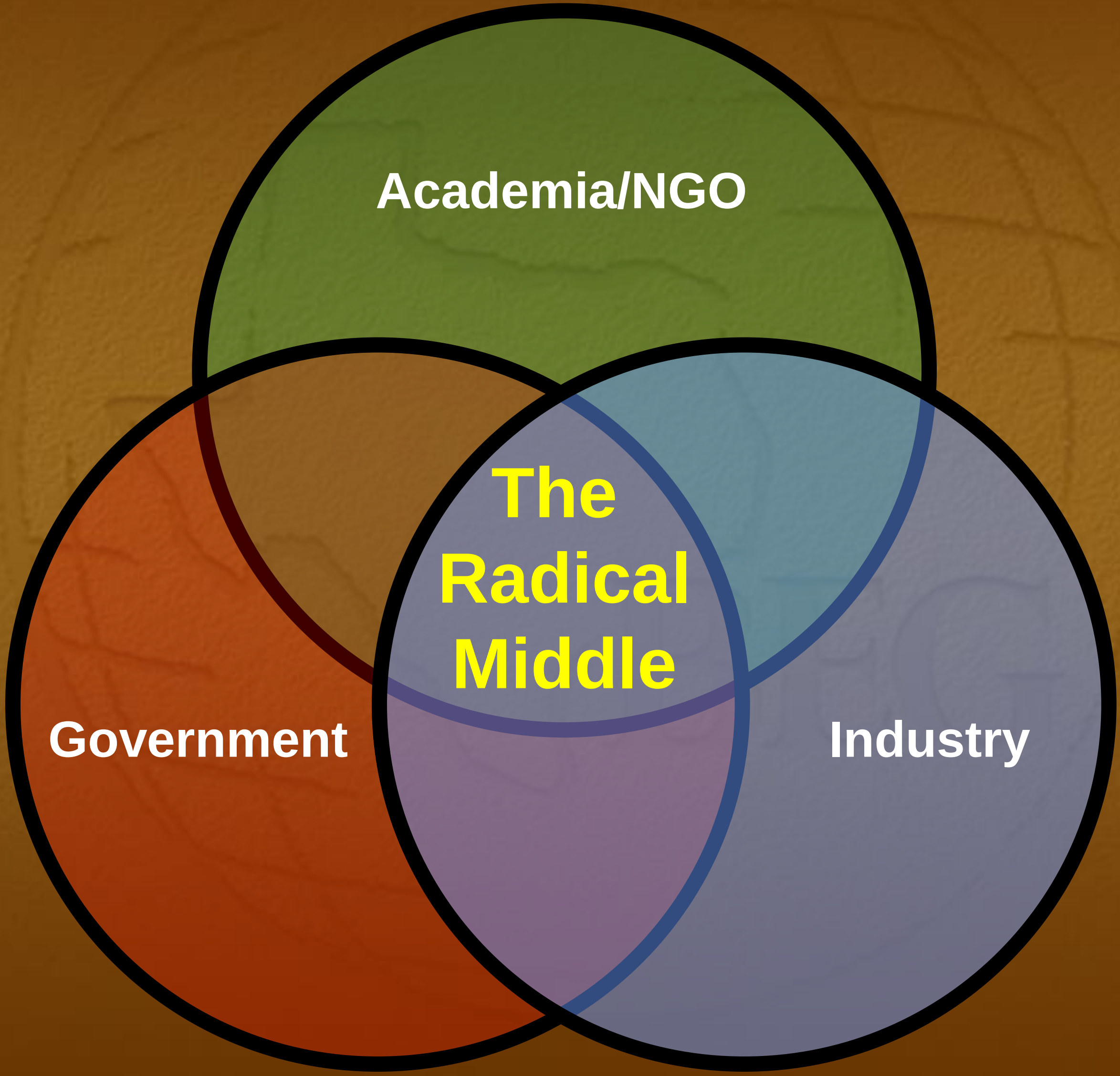

Some Key Questions

- Can we re-complete existing wells economically?
- Will technology and economics allow for development of the large OGIP and OOIP in middle tiers?
- Can we improve facilities and manage flaring, choking of wells and other operational limitations?

- Can we improve fracture characterization and increase the number of contributing stages?
- Do we understand rock mechanics and what creates surface area?
- Can we forecast and manage decline of production and improve our estimates of EUR?
- Can we drill fewer wells from fewer pads?
- Can we use less water?

- What controls induced fracture morphology and can we improve our imaging of fracture networks?
- Can we improve characterization of hydraulic fractures by deploying smart nanosensors?
- Can we improve our understanding of adsorbed gas? Porosity? Permeability?

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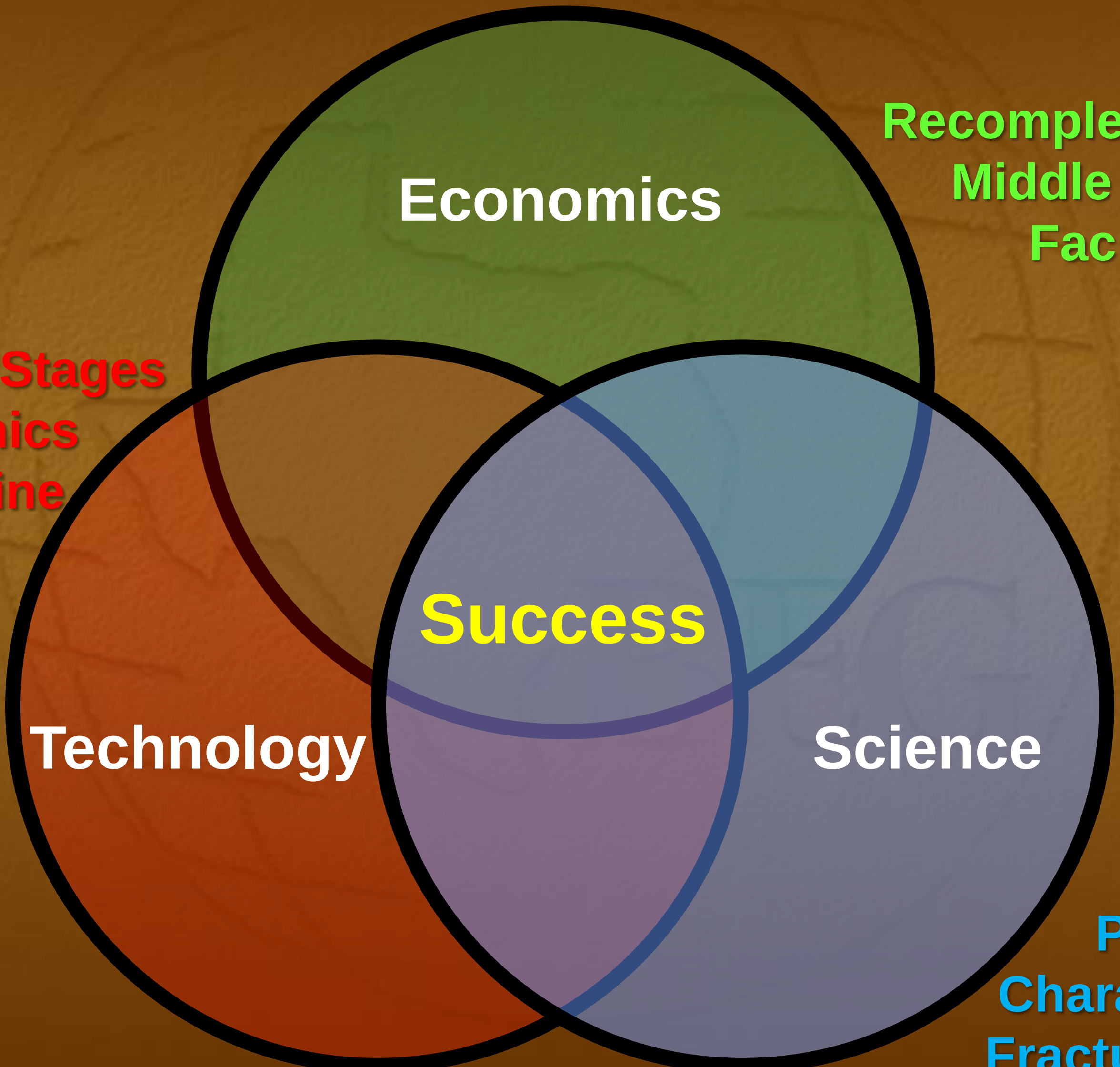
The Radical Middle

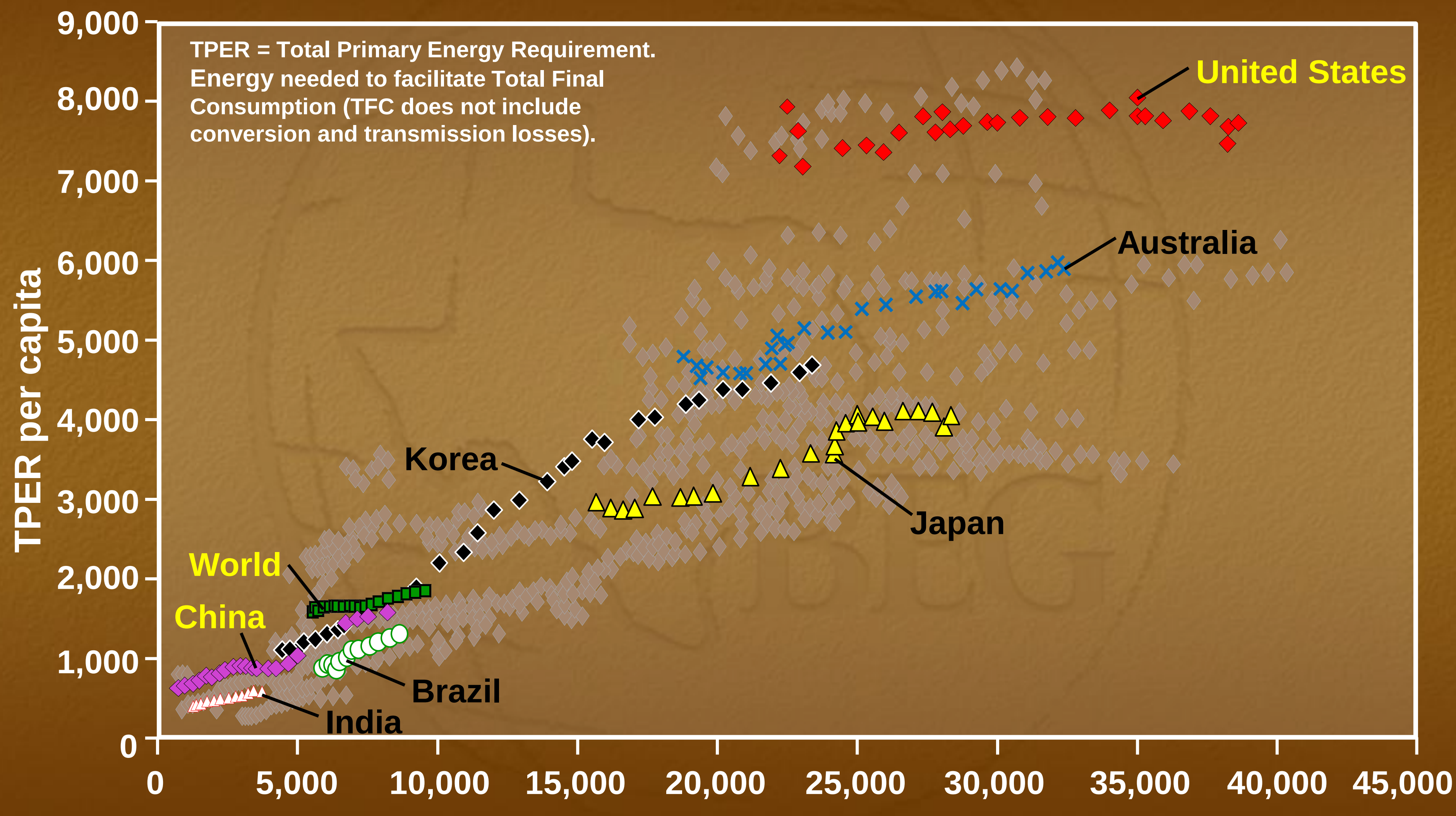
Recompletions
Middle Tiers
Facilities

Contributing Stages
Rock Mechanics
Manage Decline
Fewer Wells
Less Water



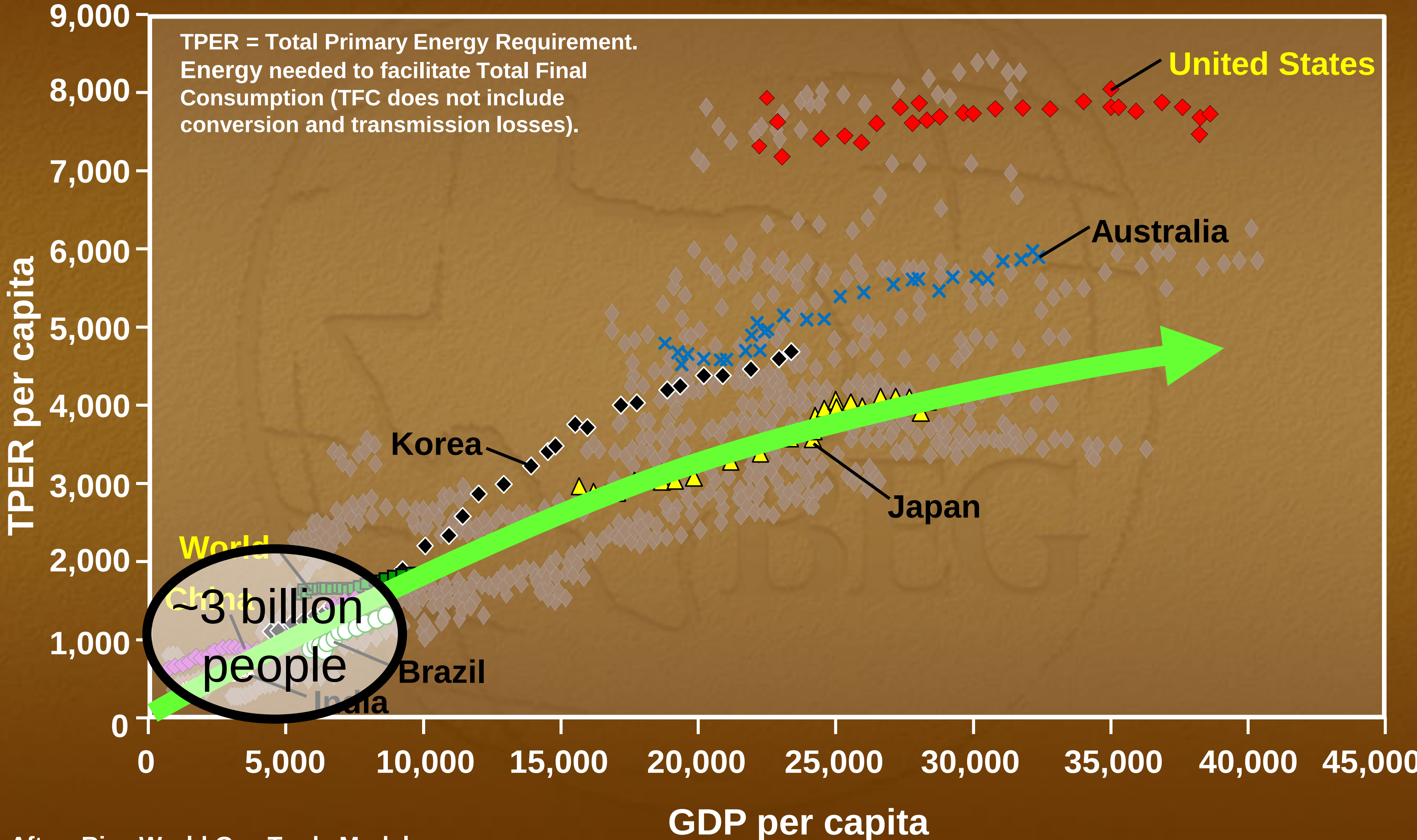
Porosity
Adsorption
Permeability
Characterization
Fracture Imaging

Energy and the Economy



After: Rice World Gas Trade Model
Medlock, 2012

Energy and the Economy



After: Rice World Gas Trade Model
Medlock, 2012

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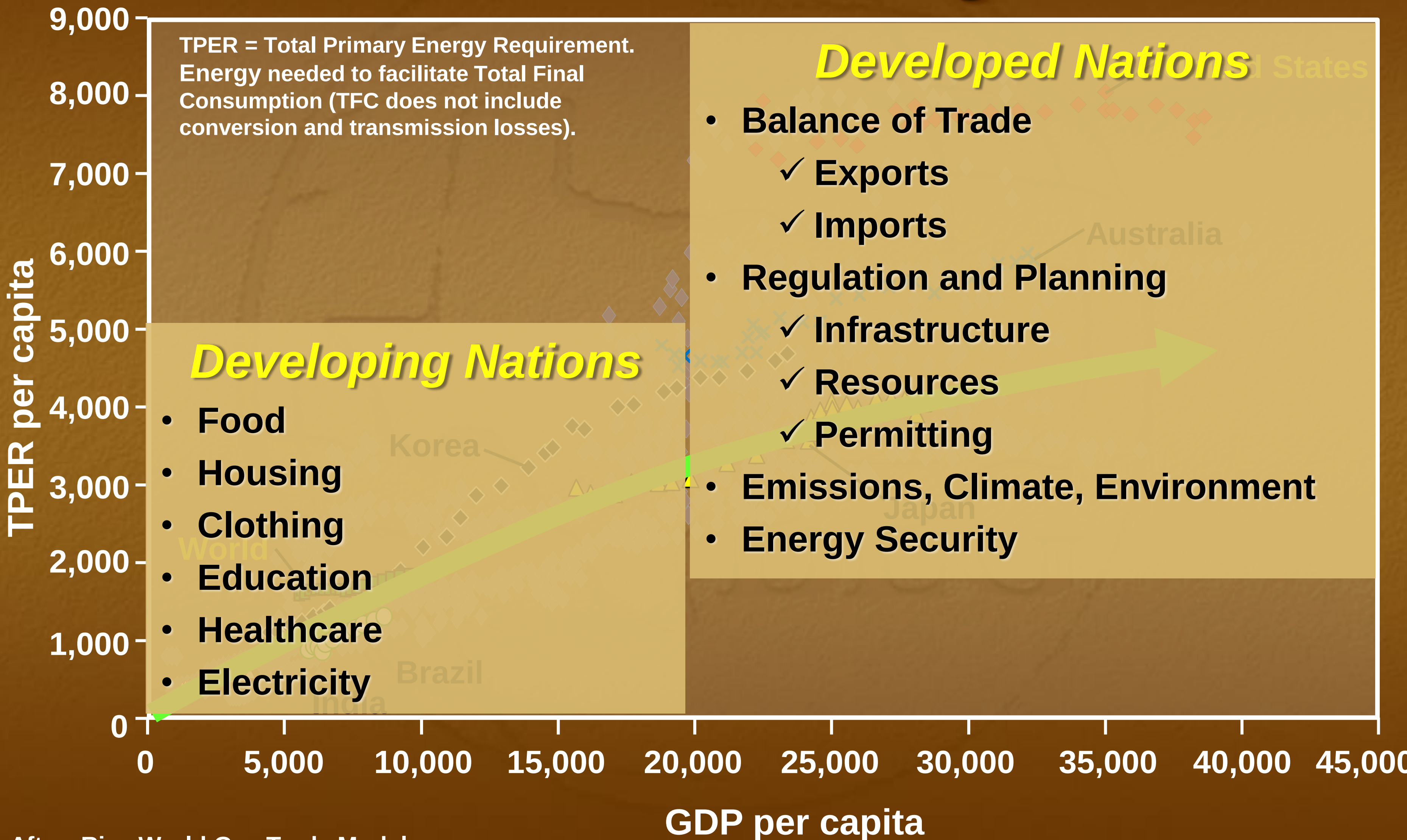
Energy and the Economy
A Global Challenge



After: Rice World Gas Trade Model
Medlock, 2012

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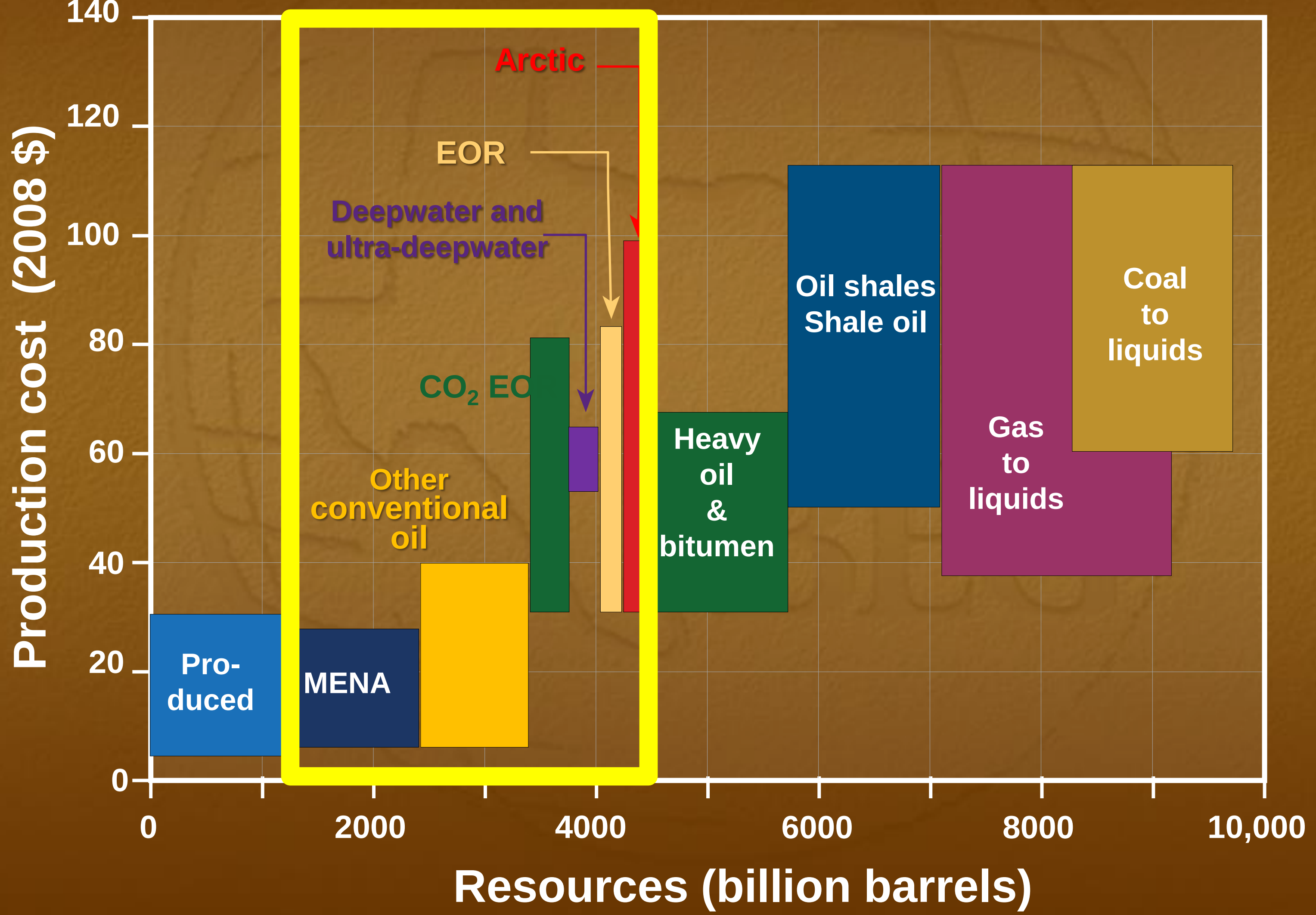
Oil "Frontiers"

Unconventional Technology for Conventional Reservoirs



Source: IEA World Energy Outlook (2009)

Tinker's Top Ten

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1. Governments, industry and academe must work together; we all play a role in objective, balanced energy education.
2. The scale of energy demand is difficult to comprehend; energy transitions take many, many decades.
3. Energy security — affordable, available, reliable, sustainable — drives the energy mix and should be the goal of energy policy.
4. Energy efficiency is underappreciated; individuals matter!
5. Diverse energy portfolios are inevitable and healthy.
6. Renewables are growing but will remain regional supplements until major advances are made in energy storage.
7. Shale will play a global role in the energy future; "above ground" challenges are as important as "below ground."
8. Natural gas and nuclear are the new foundational energies.
9. Oil and coal are abundant at the right price, and difficult to replace as transportation and electricity fuels.
10. Energy, the economy and the environment are linked.