Microseismic

February, 2014

US Shale Gas Reserve and Production Forecasts and Implications for Shale Oil

Scott W. Tinker

John Browning, Svetlana Ikonnikova, Gürcan Gülen, Eric Potter, Frank Male, Qilong Fu, Katie Smye, Susan Horvath, Tad Patzek, Ken Medlock, Forrest Roberts and William Fisher

Bureau of Economic Geology

Jackson School of Geosciences, The University of Texas at Austin

Outline

- U.S. Shale Gas Reserves and Production Forecasts
- The Impact of Shale on US and Global Gas and Oil Markets
- Above Ground Challenges and Implications

BEG 3-Year Study

Shale Gas Reserve & Production Forecasting

Goal: Objective understanding of the capability of U.S. shale gas to contribute to natural gas supply for the next 20 years

- 3-year project, funded by the Alfred P. Sloan Foundation
- Four plays: Barnett, Fayetteville, Haynesville, Marcellus
- Multidisciplinary team of geoscientists, engineers, and economists.

Framing Questions

- What is the *original resource base* in place?
- What portion of the resource is *technically recoverable?*
- What portion of the technically recoverable resource is *economically recoverable*?
- What impact will these levels of production have on infrastructure, roads, water, regulation, jobs, taxes…

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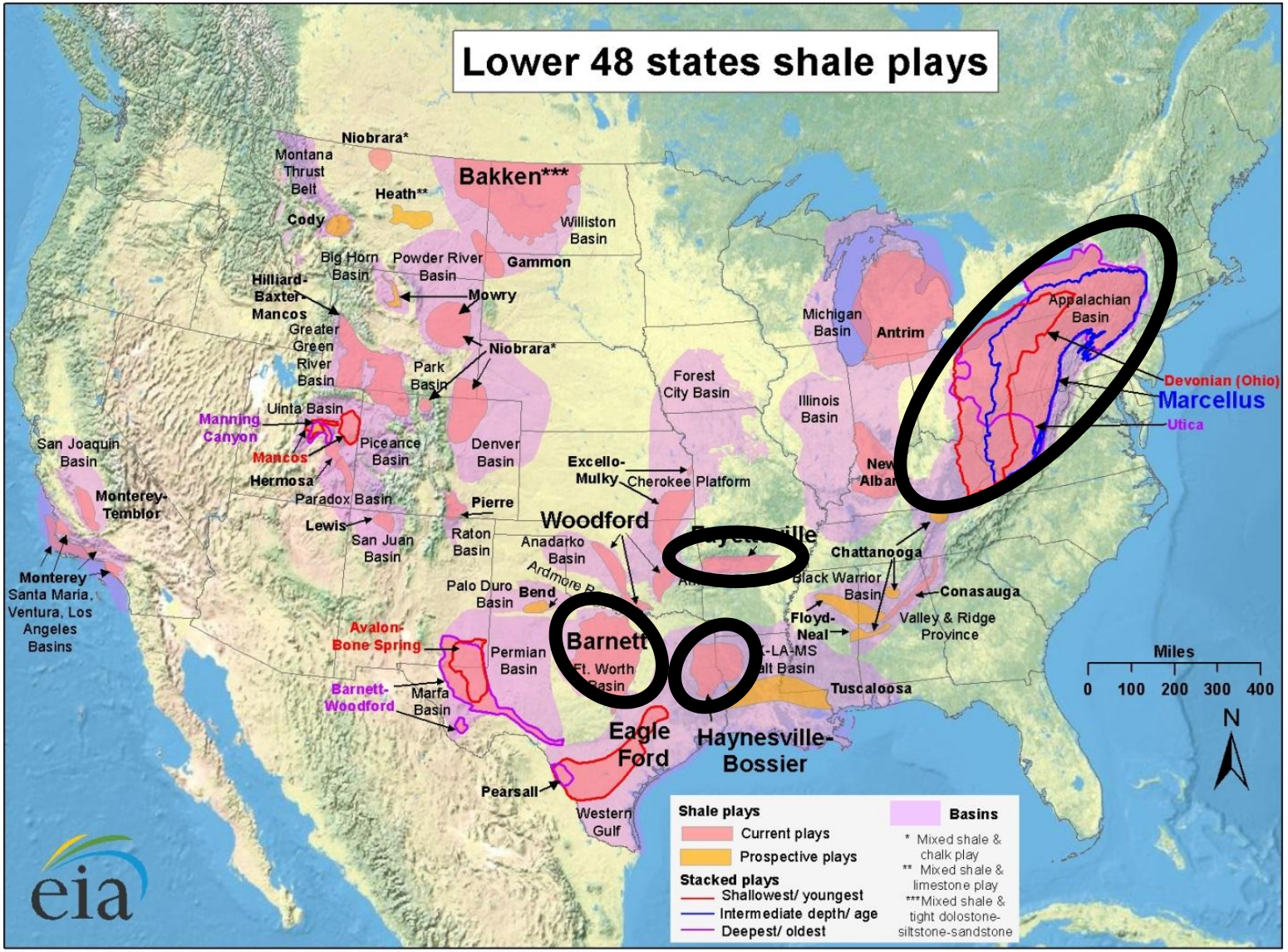
U.S. Shale Gas Plays



Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

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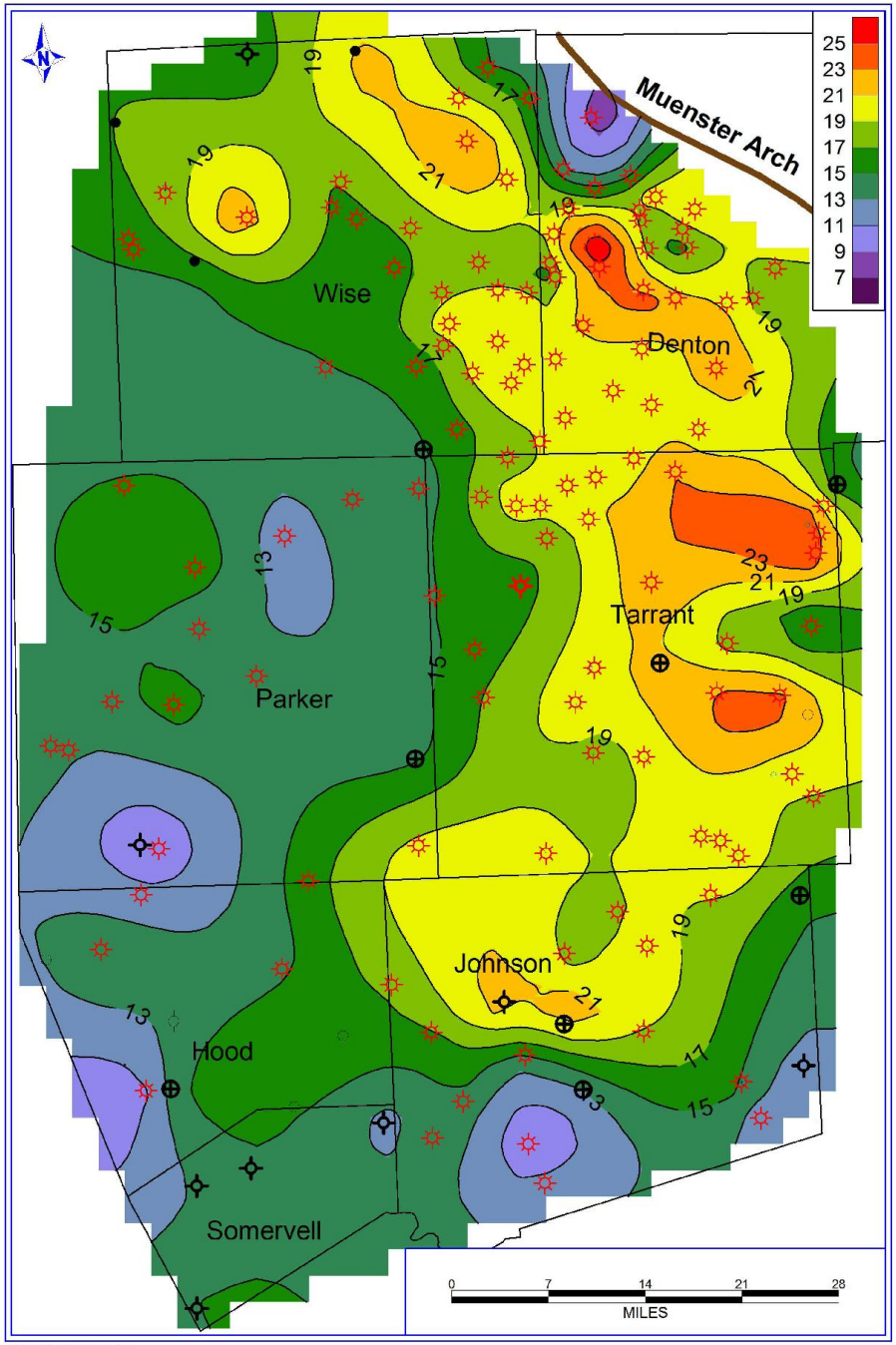

Barnett

DPhi * H

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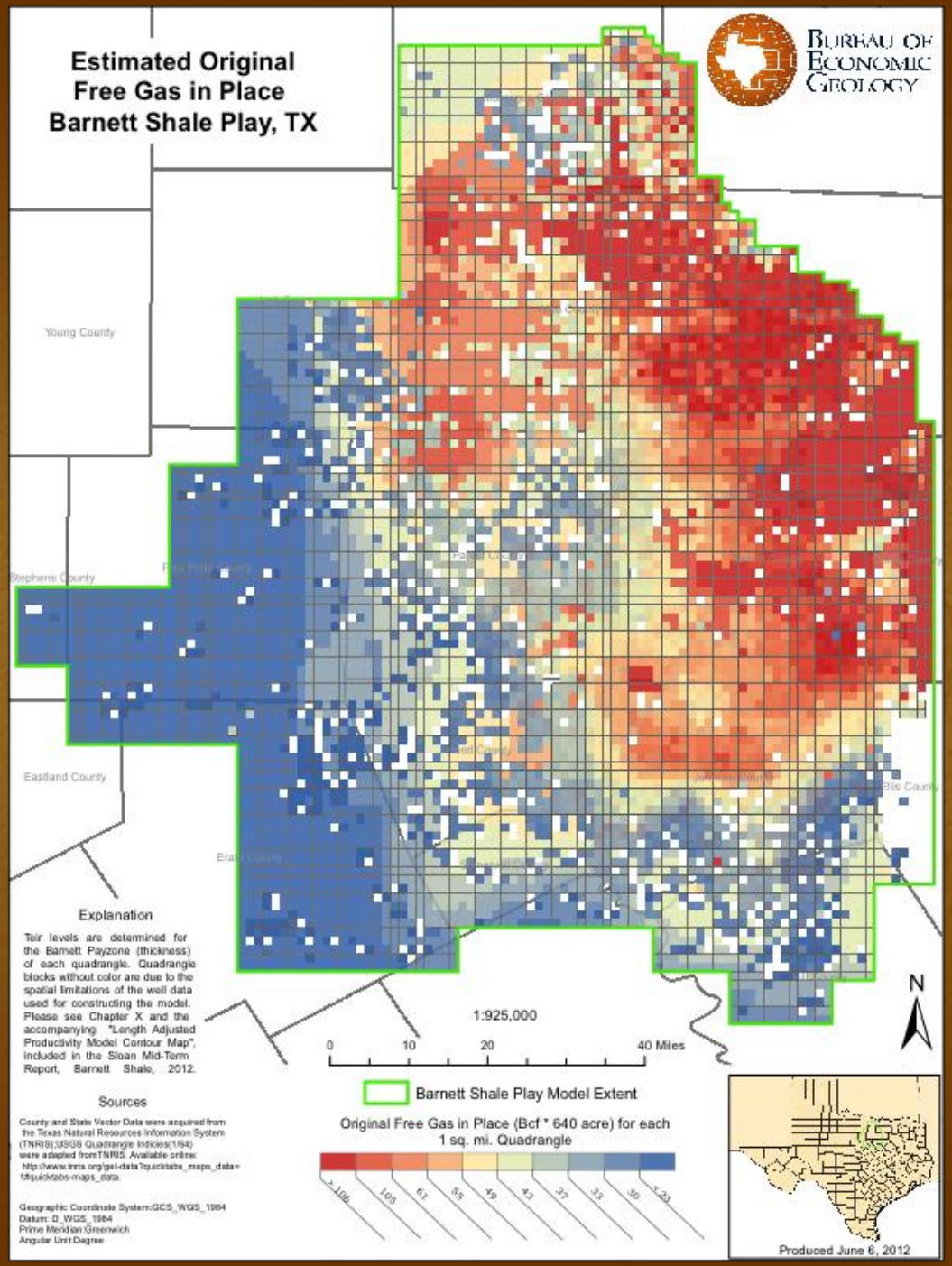
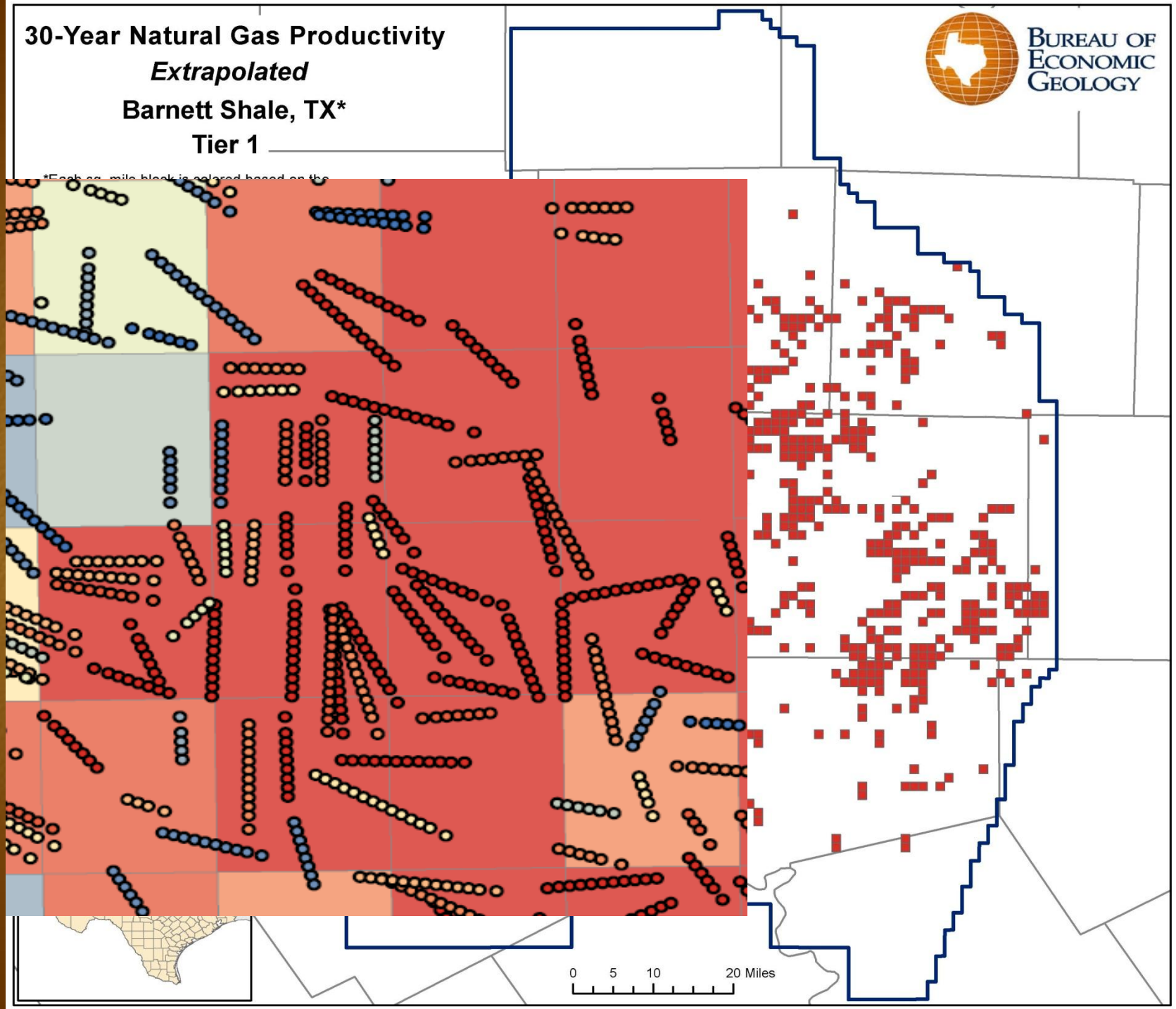
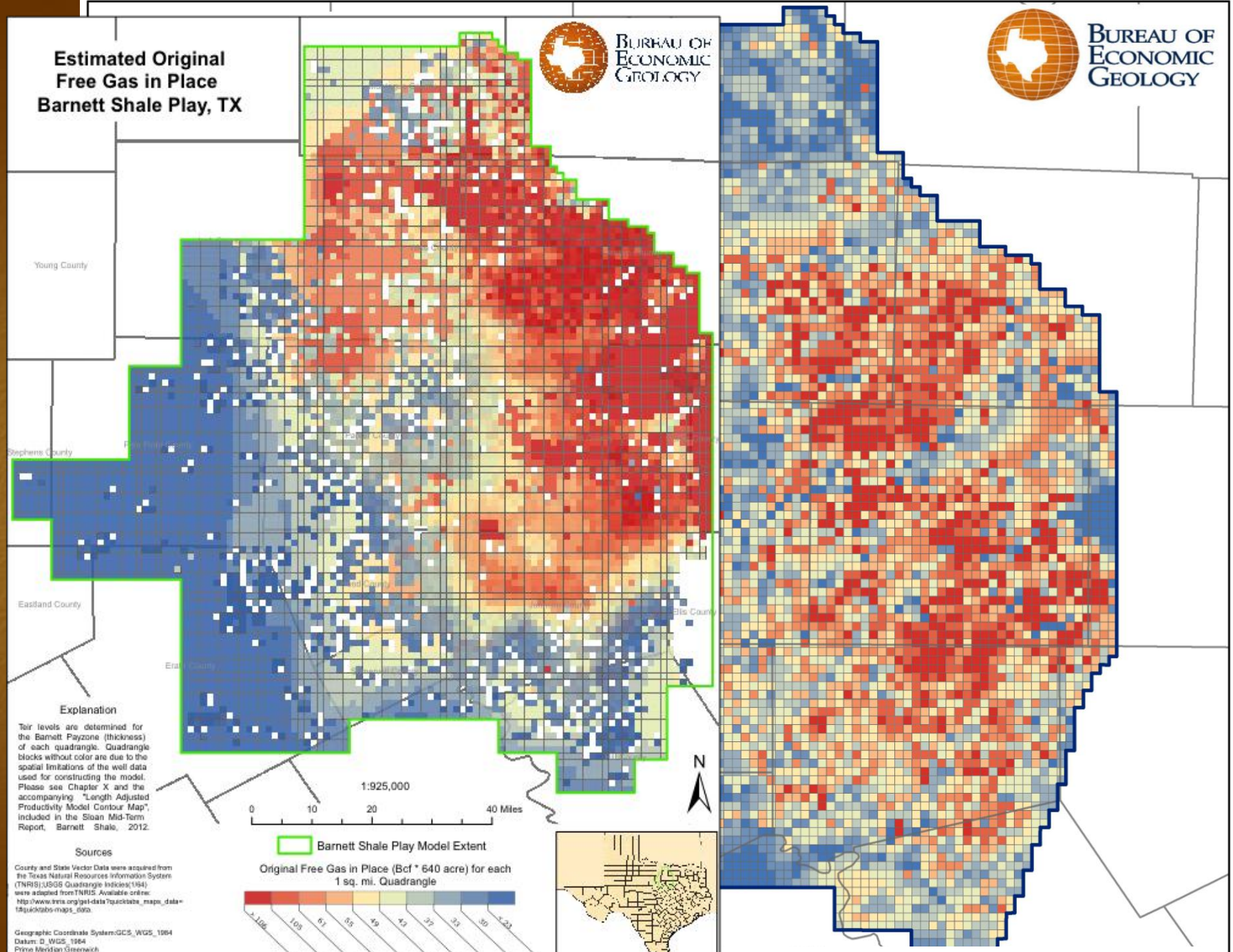


Barnett

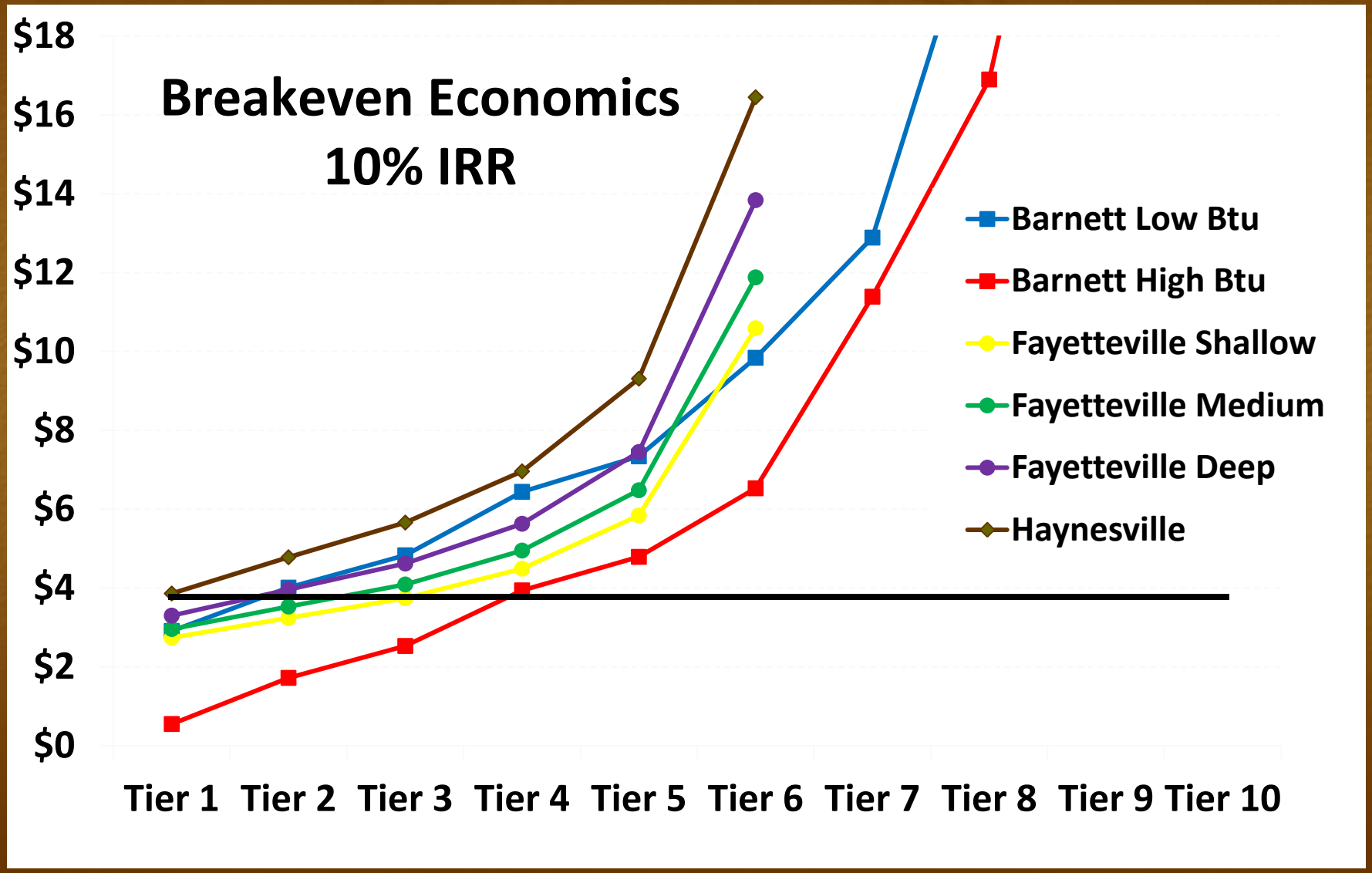
OGIP Free


30-Year Natural Gas Productivity
Extrapolated
Barnett Shale, TX*
Tier 1
Bureau of Economic Geology
0 5 10 20 Miles

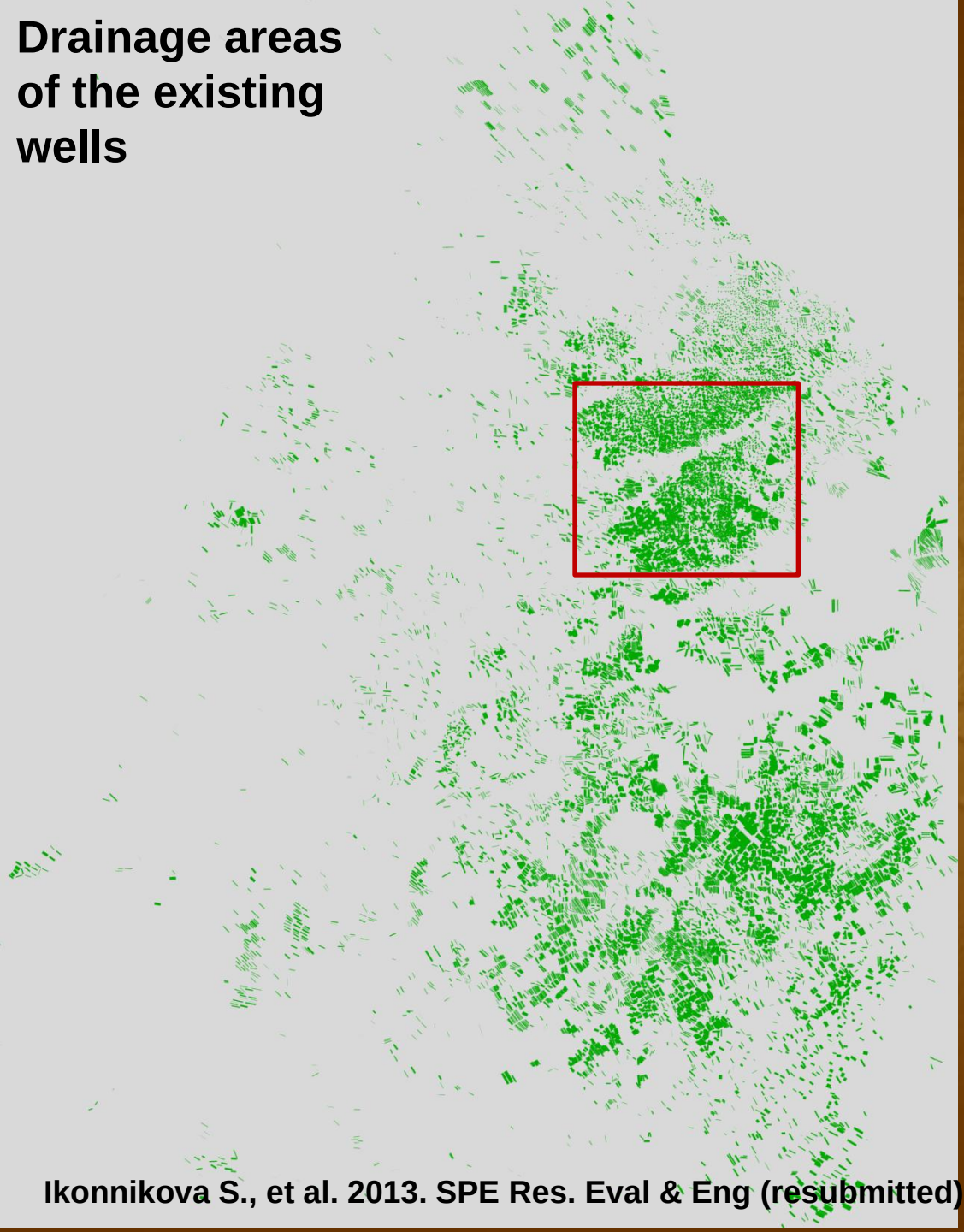


Ikonnikova S., et al. 2013. SPE Res. Eval & Eng (resubmitted)

Economics by Tier (Bcf)



Drainage areas of the existing wells



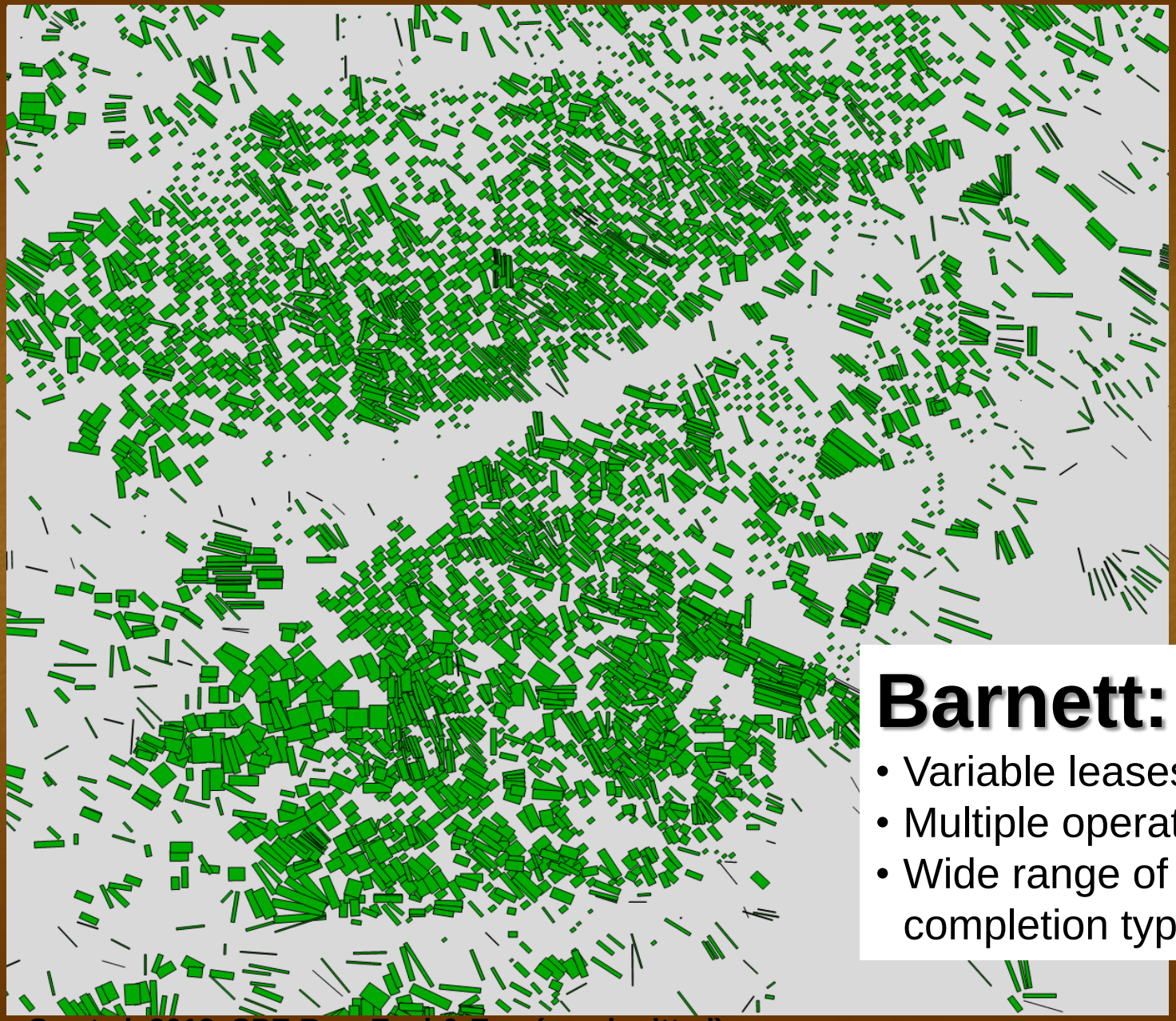
Ikonnikova S., et al. 2013. SPE Res. Eval & Eng (resubmitted)

“Bottom Up”

Well Recovery

Drainage Areas

Infill Drilling Potential



Barnett:

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

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

Parameters Considered

- Economic Well Life Limit (mmcf/d)
- Basis to Henry Hub ($/mmbtu)
- Royalty Rate (%)
- Severance Tax Rate (%)
- Marginal Tax Rate (%)
- Inflation Rate (%)
- Drilling Cost (CAPEX)
- Related CAPEX Factor (%)
- Expense/Well/Year
- Gathering, Compression, Treatment
- NGL Transport Cost
- Water Cut (bbl/mcf)
- Water Disposal Cost
- Oil Yield
- GPL Yield
- Gas Shrinkage
- Processing Fee
- Lease Cost/acre
- Spacing (ac)
- Depletion Cost
- Abandonment Cost
- Basis to Henry Hub
- WTI Price
- GPL/WTI Ratio
- Developable Acreage Ceiling
  - Partly Drained
  - Undrilled
- Annual Technology Improvement
- Annual Well Cost Improvement
- Minimum Completions in a Year
- Attrition

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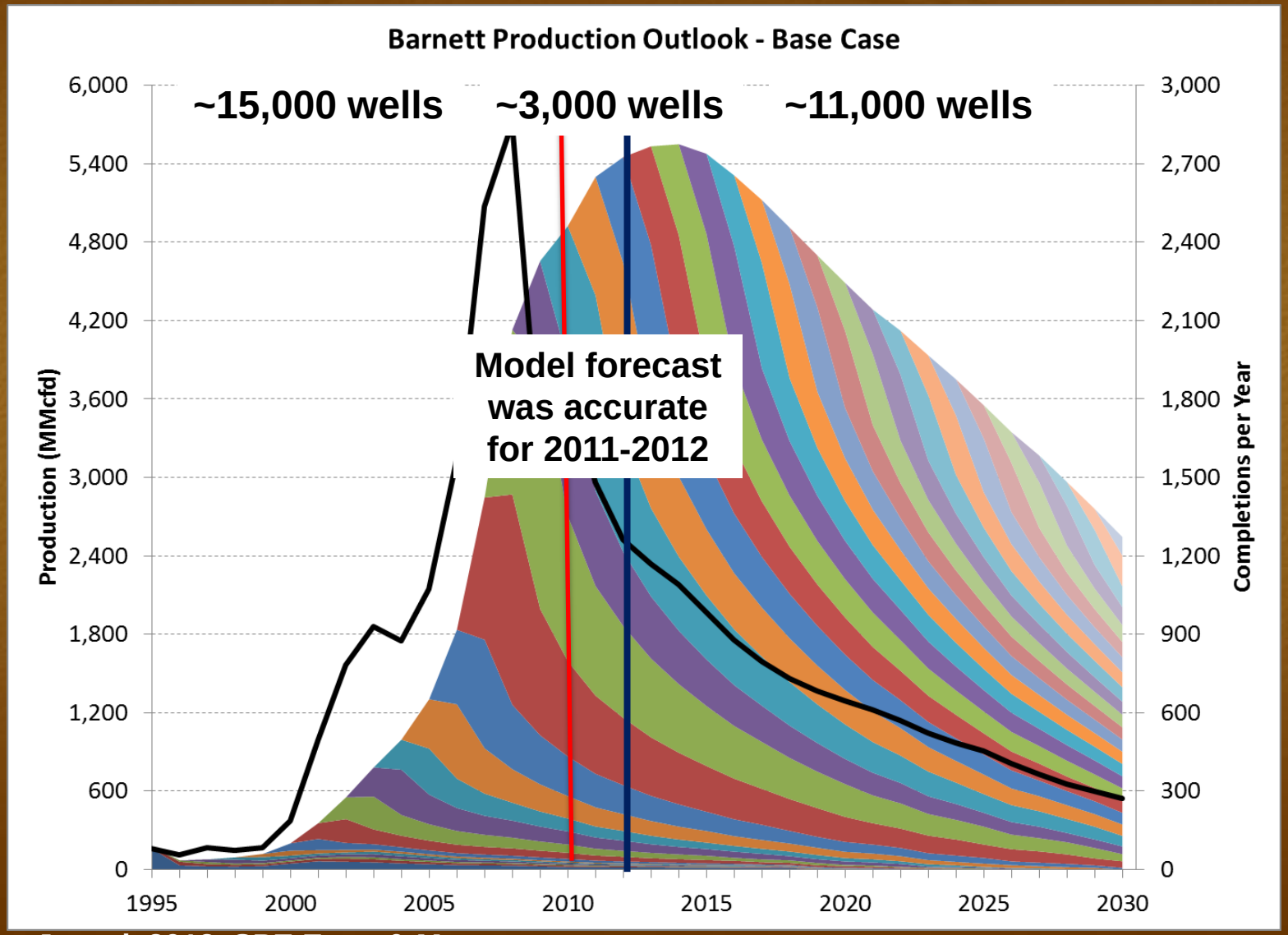
Barnett
Production Outlook



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

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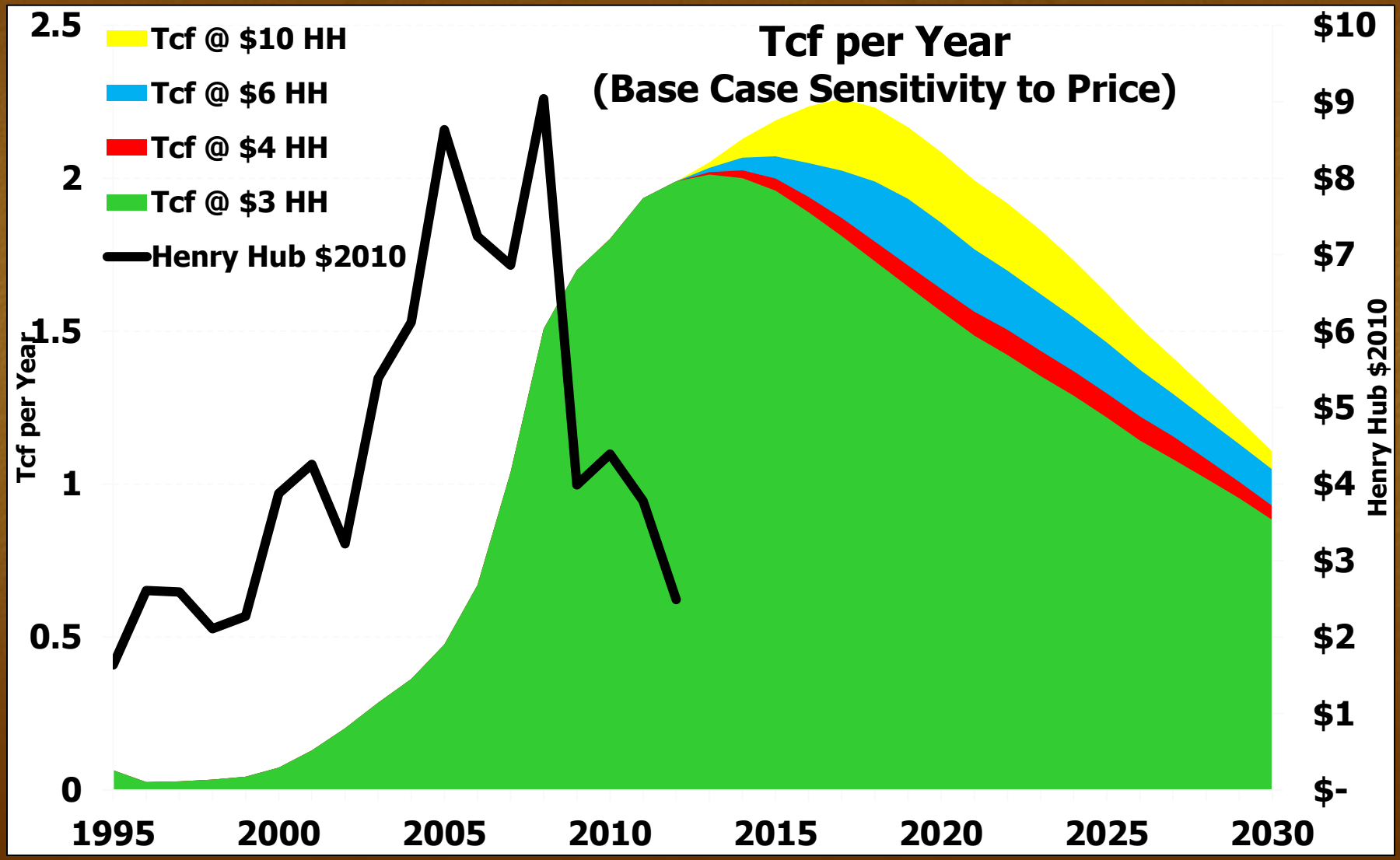
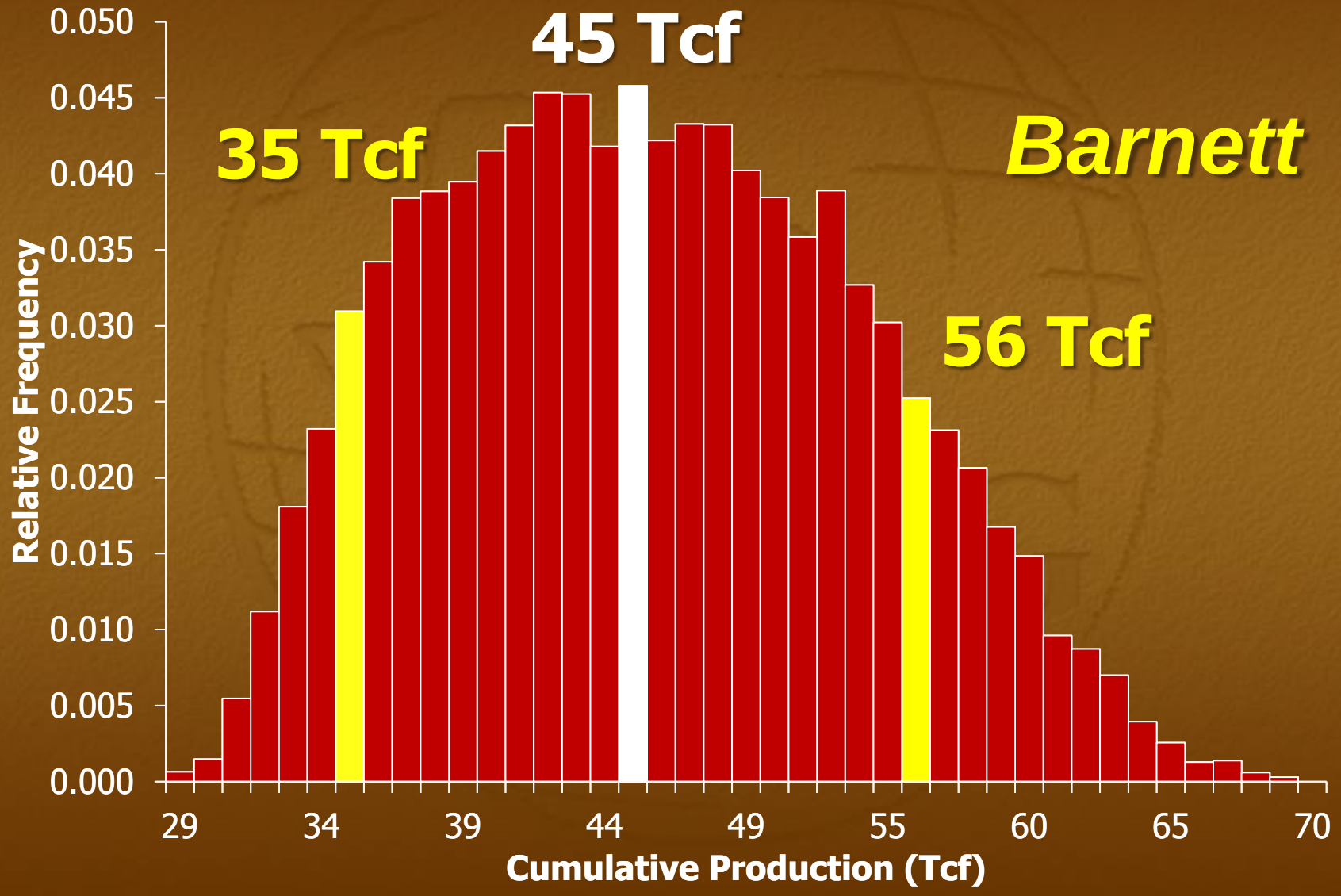
Barnett
Production Forecast



Economic Production Distribution



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

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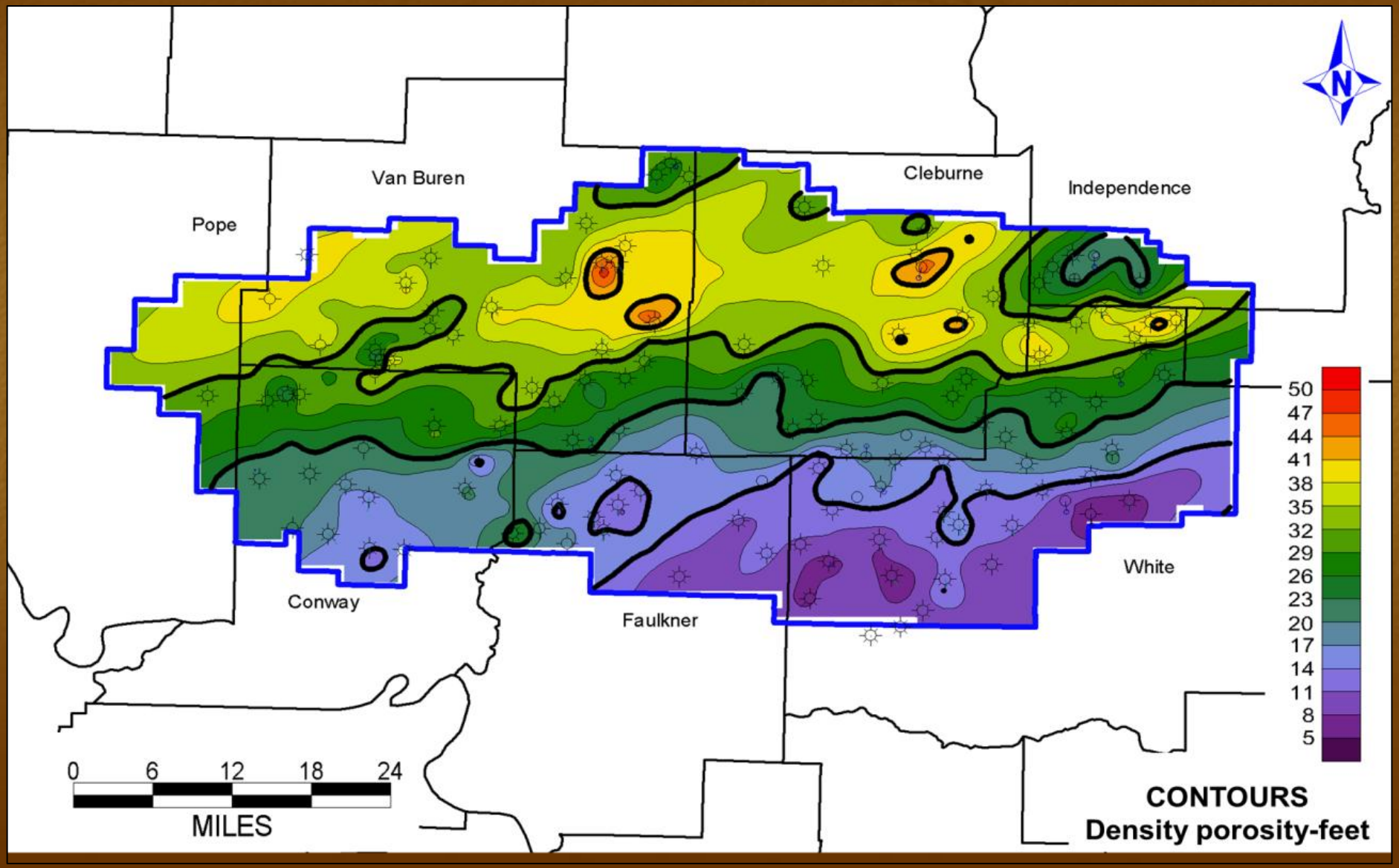
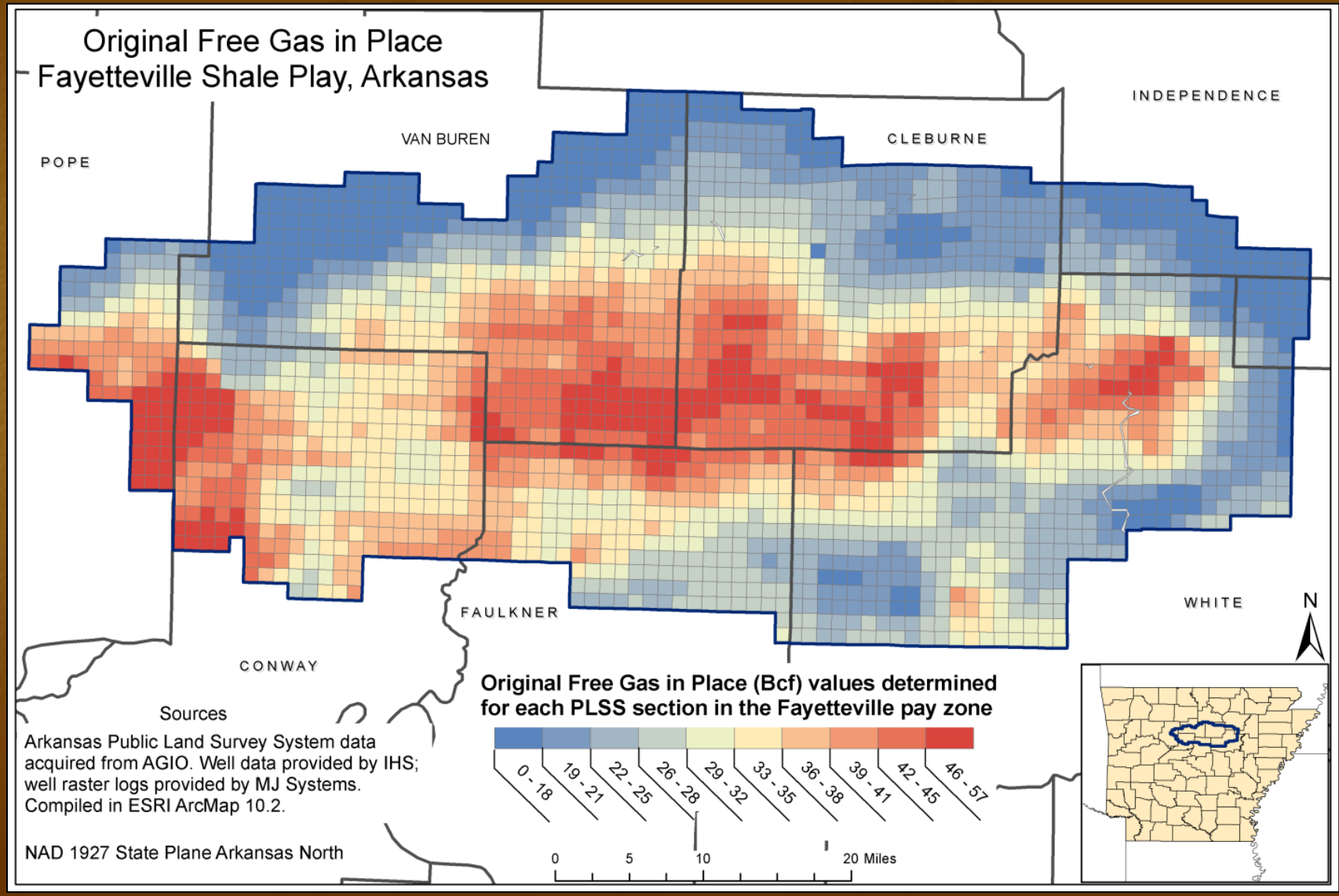
Fayetteville

DPhi * H



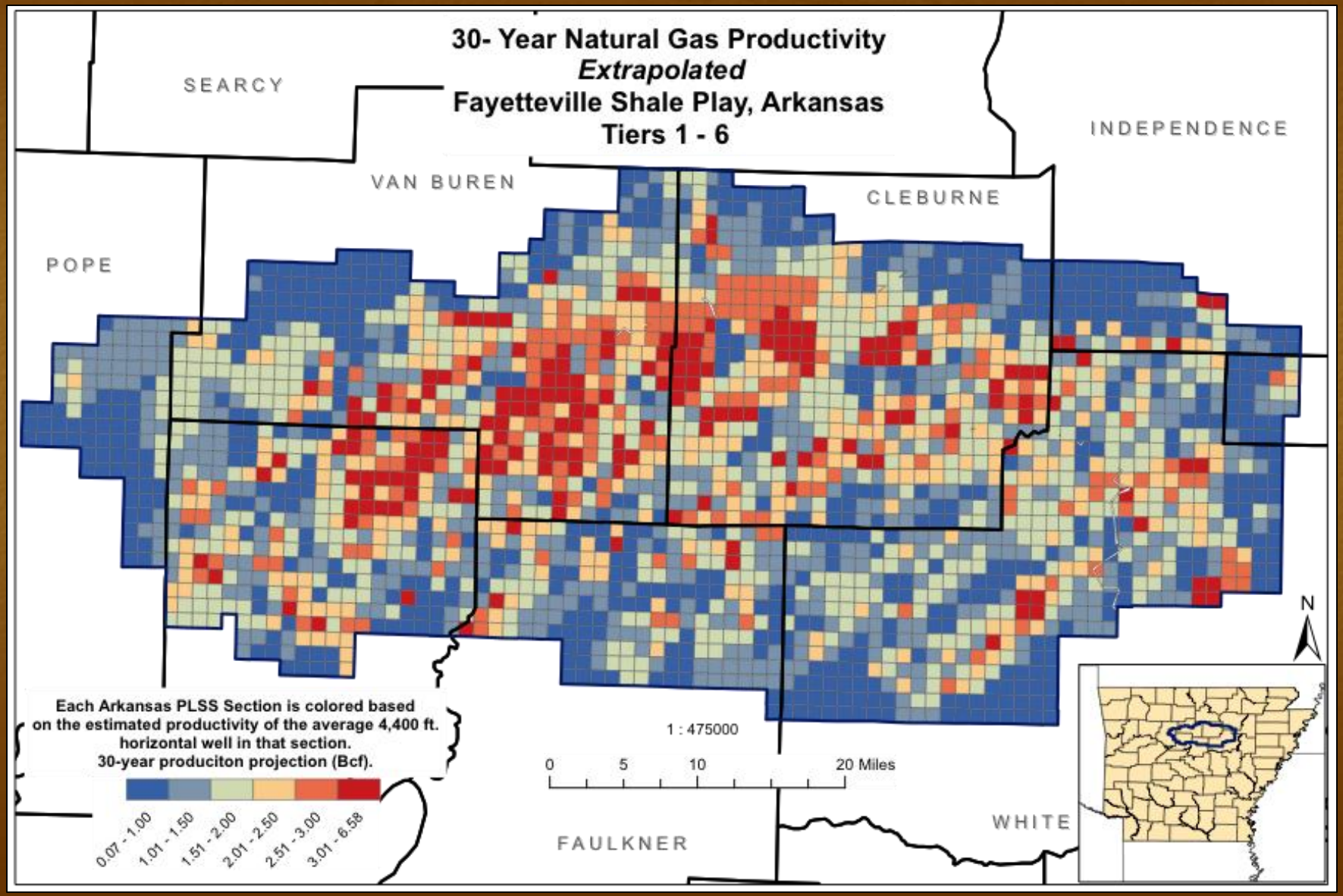
Fayetteville

OGIP Free



Fayetteville
Tiers

Tinker, 2014



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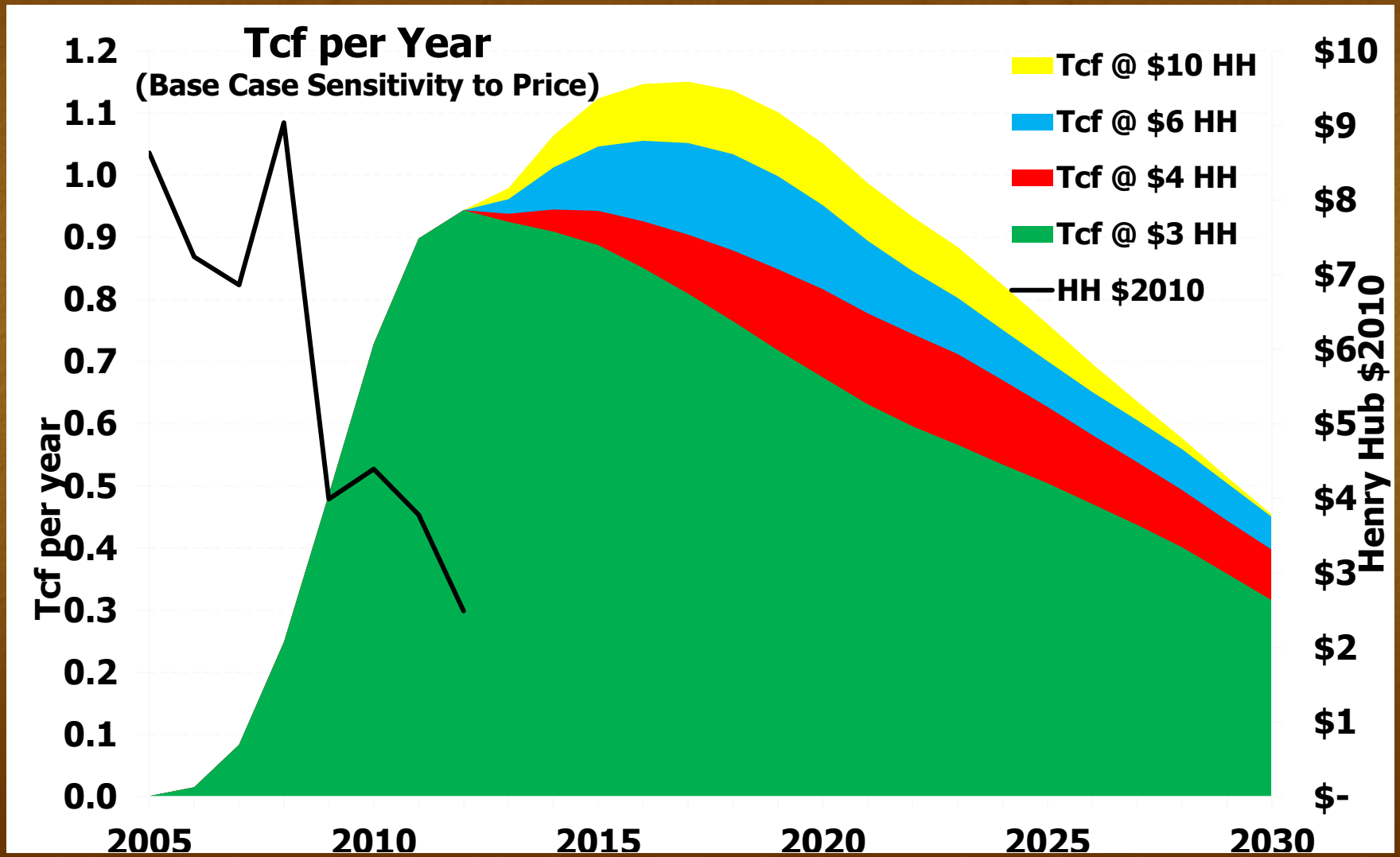
Fayetteville
Production Forecast



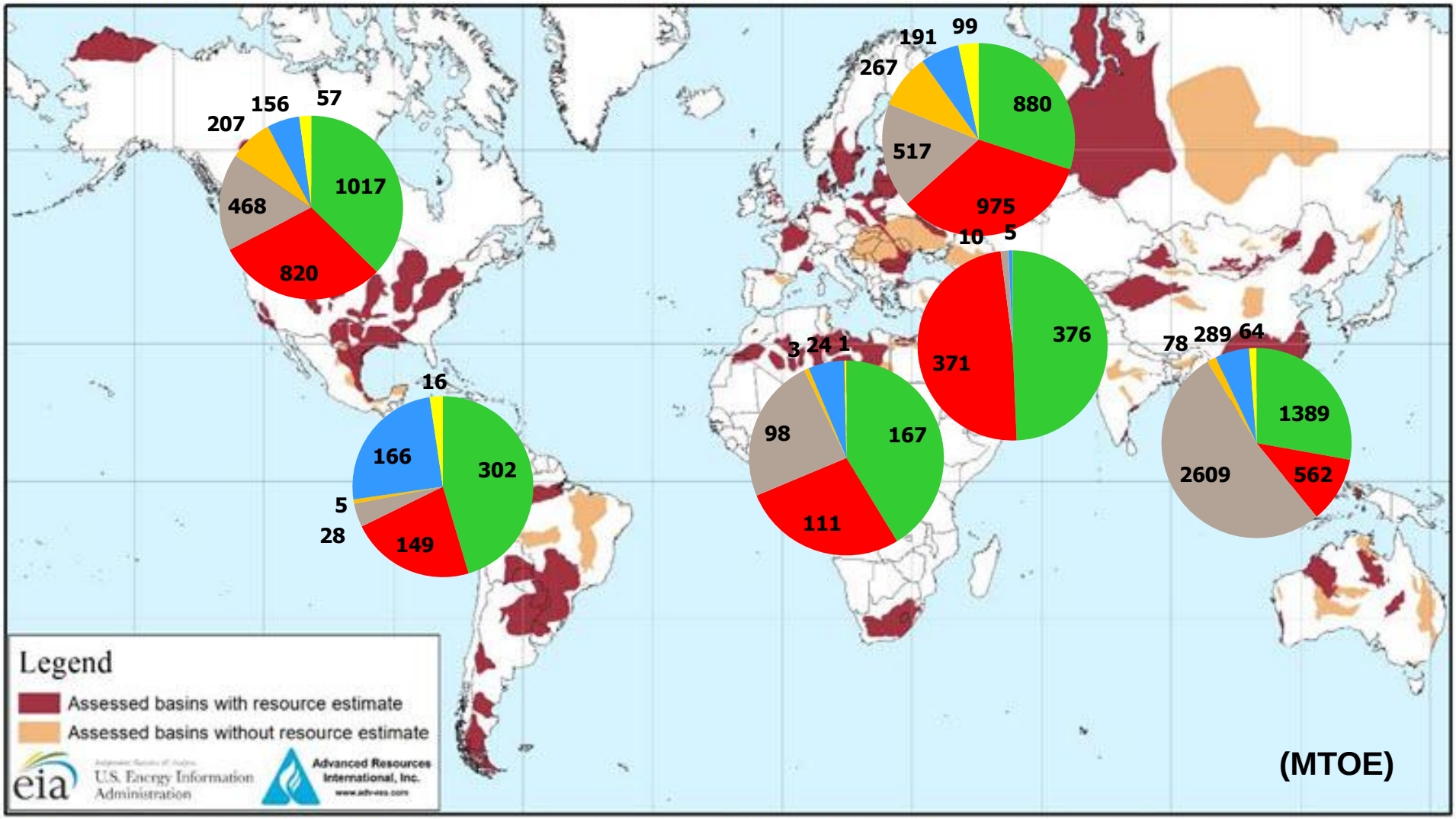
Outline

- U.S. Shale Gas Reserves and Production Forecasts
- The Impact of Shale on US and Global Gas and Oil Markets
- Above Ground Challenges and Implications

Population

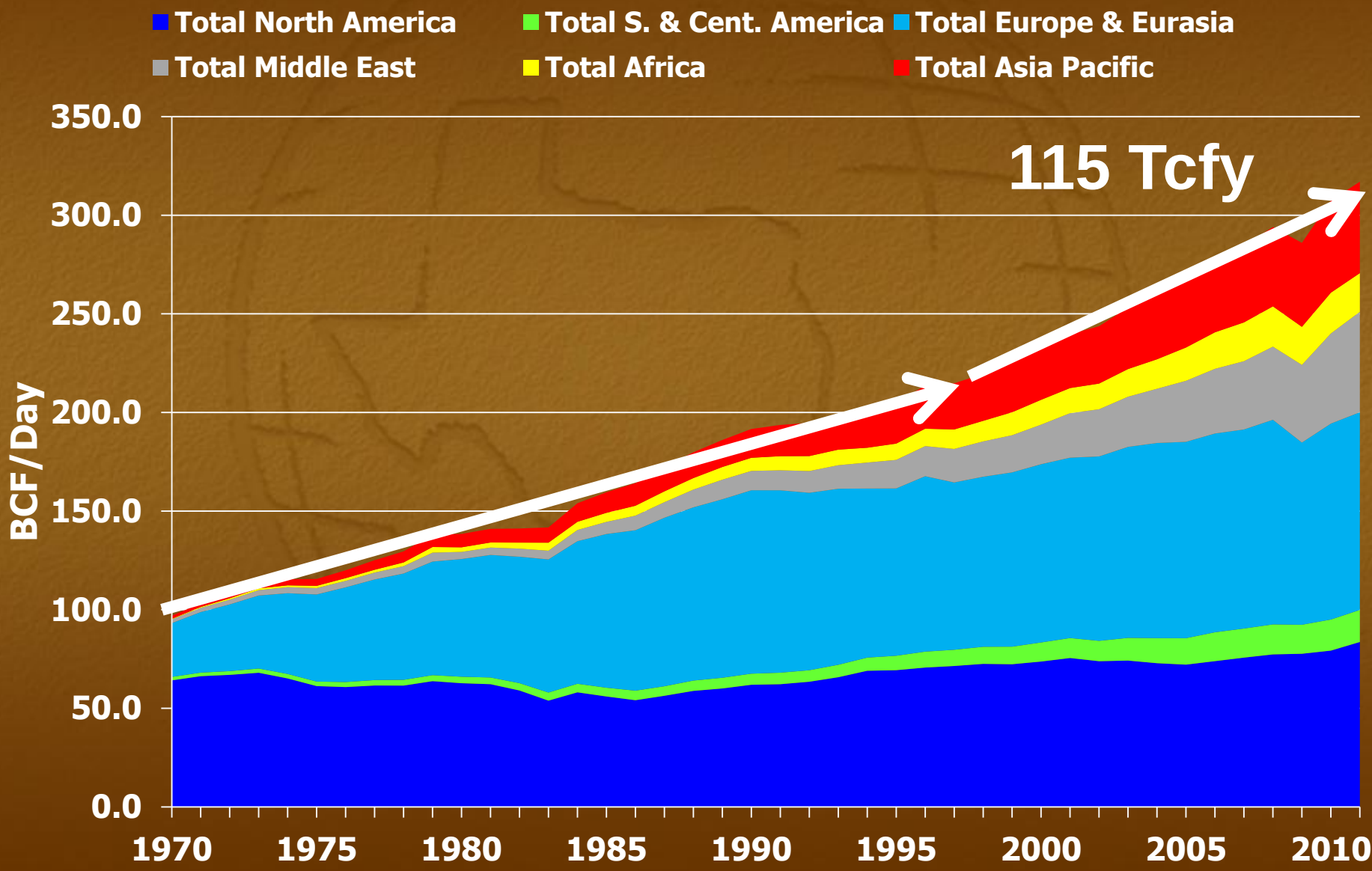
~1 billion people per color

Global Energy Mix and Demand



Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.

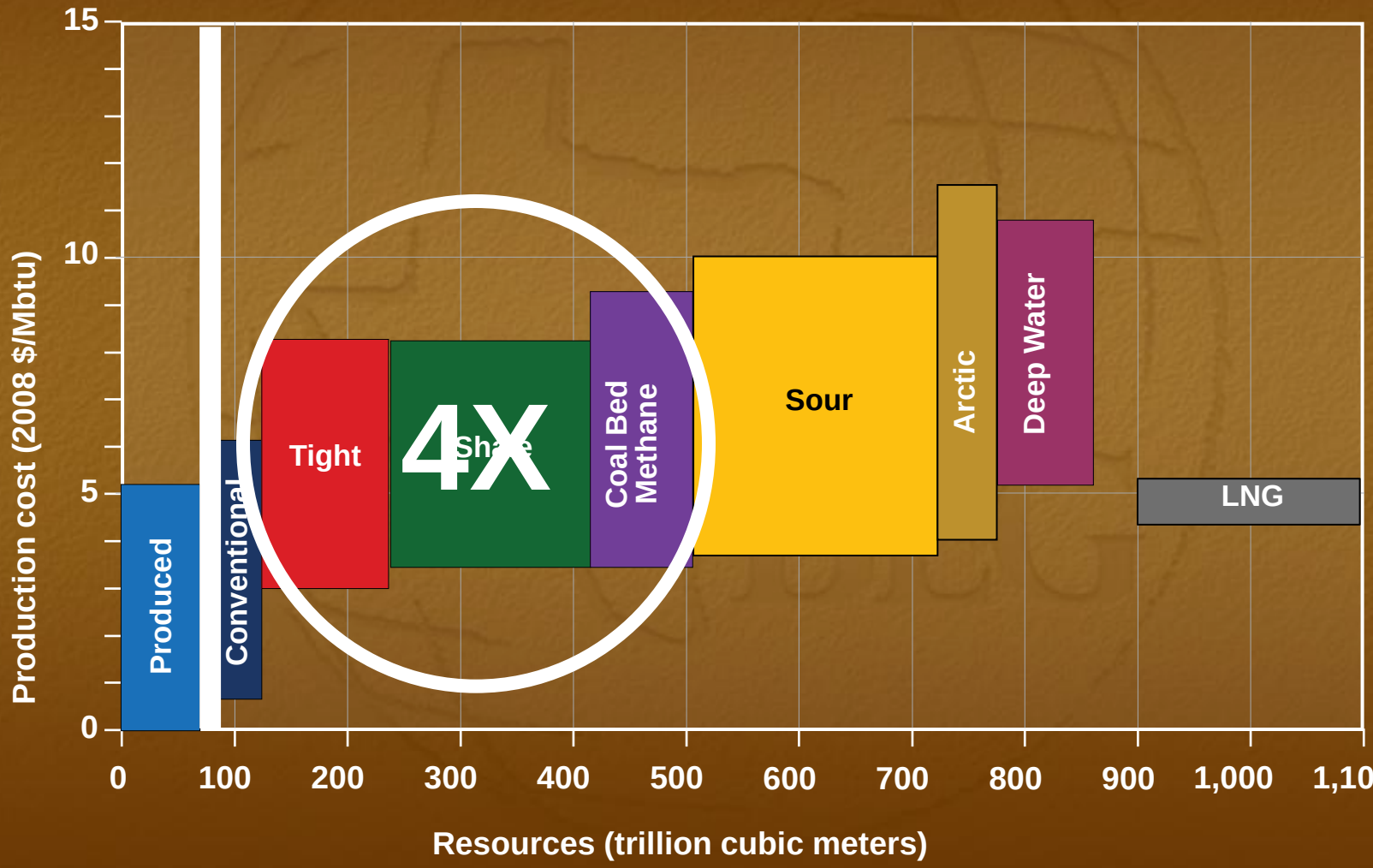
Global Natural Gas Production



Source: BP Statistical Review 2012

Natural Gas Supply

Resources and Cost



Source: IEA World Energy Outlook (2009)

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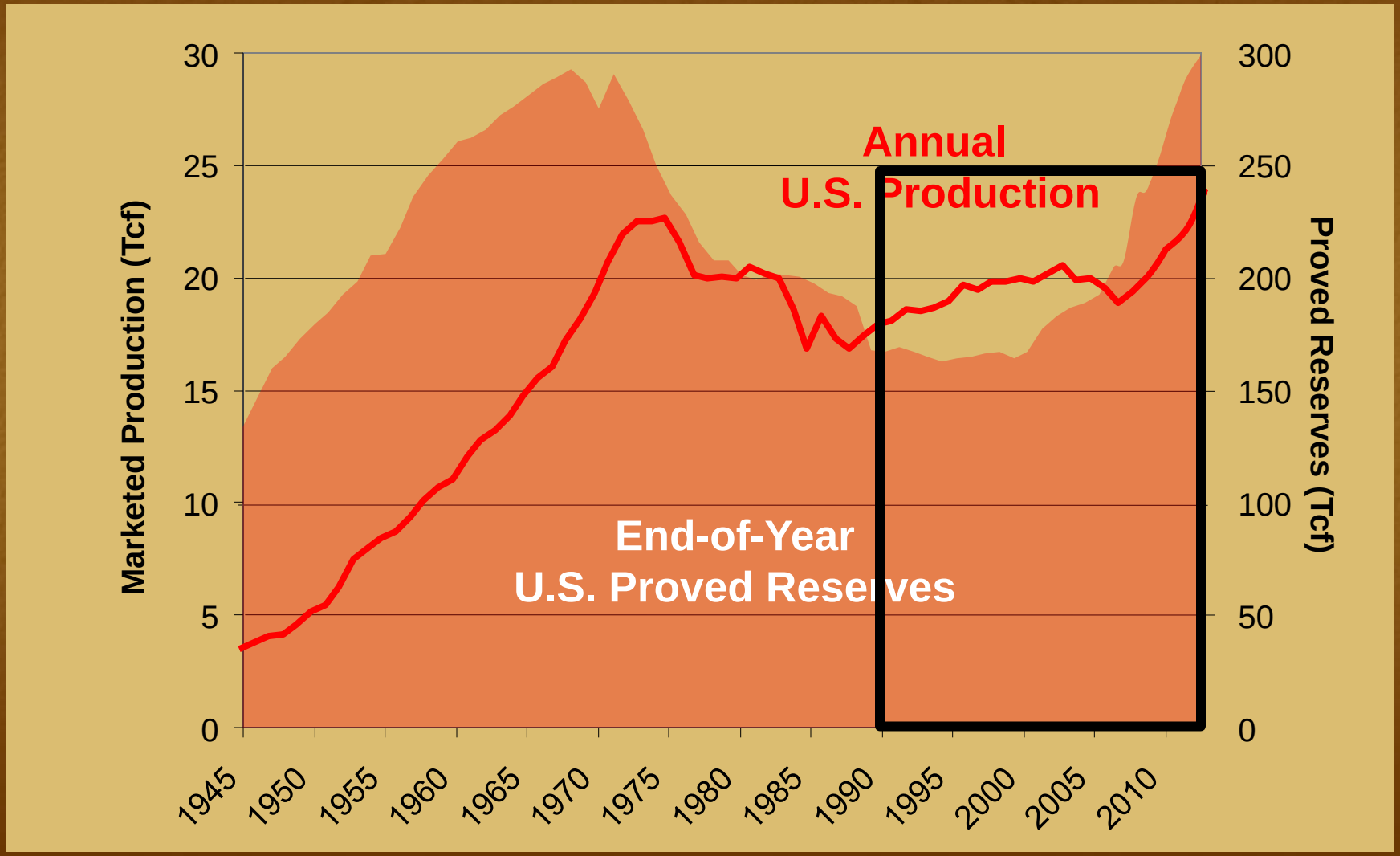
U.S. Natural Gas
Production and Reserves



Data: BP World Energy 2012

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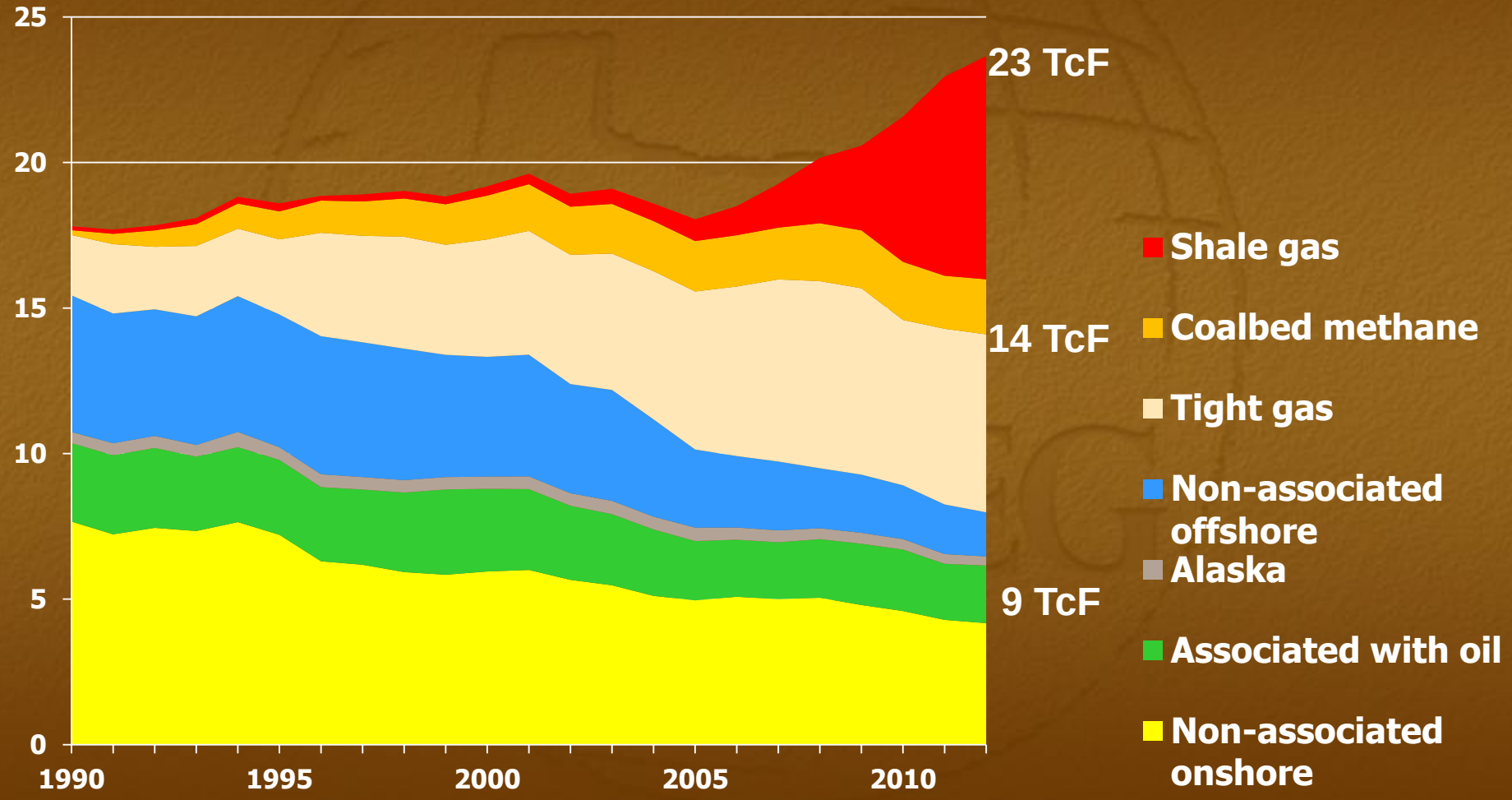
U.S. Natural Gas

Production (TcF)

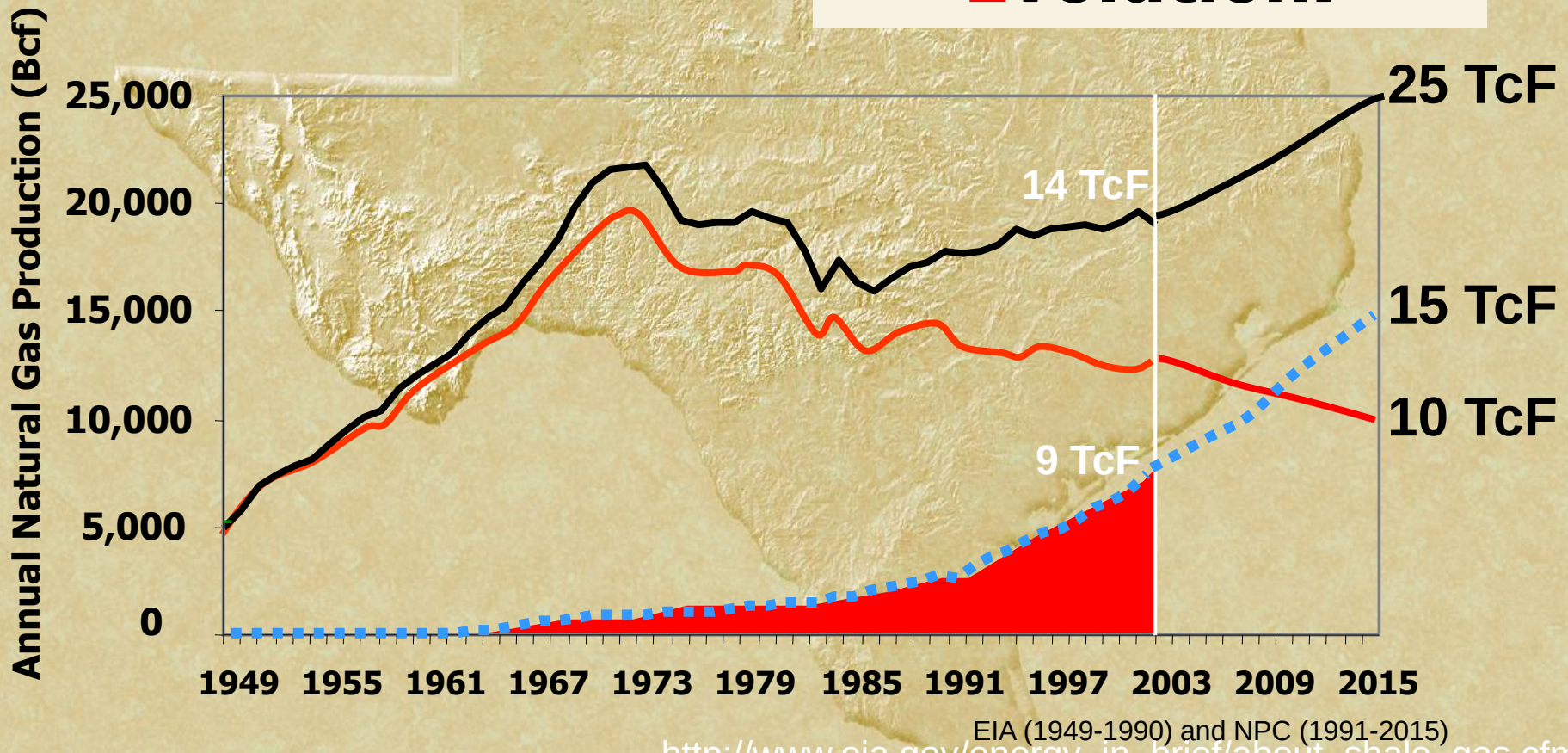


http://www.eia.gov/energy_in_brief/about_shale_gas.cfm

From a 2004 Tinker Talk to the IPAA

US Natural Gas 2004 forecast

An Anticipated Evolution!

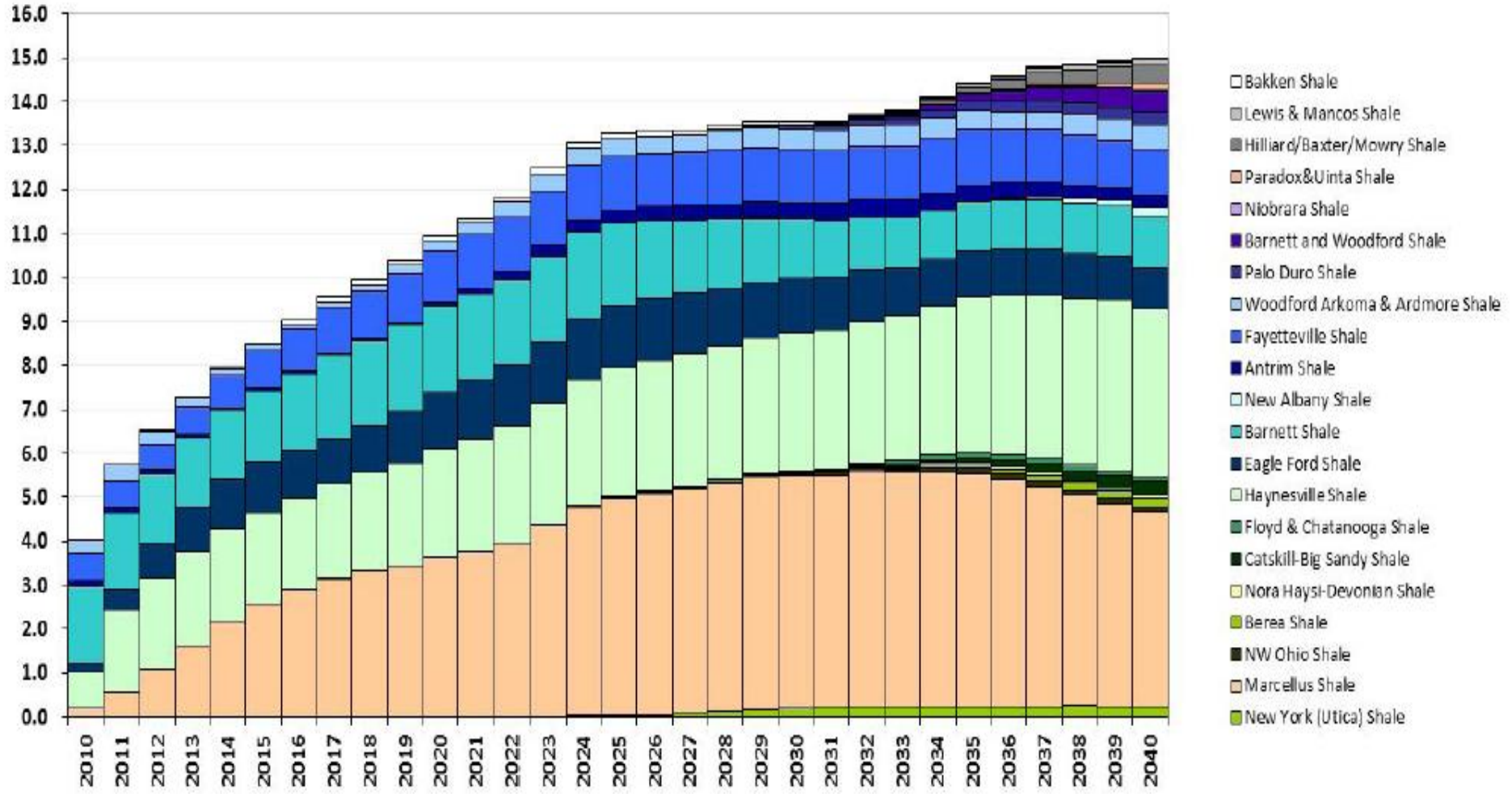


EIA (1949-1990) and NPC (1991-2015)

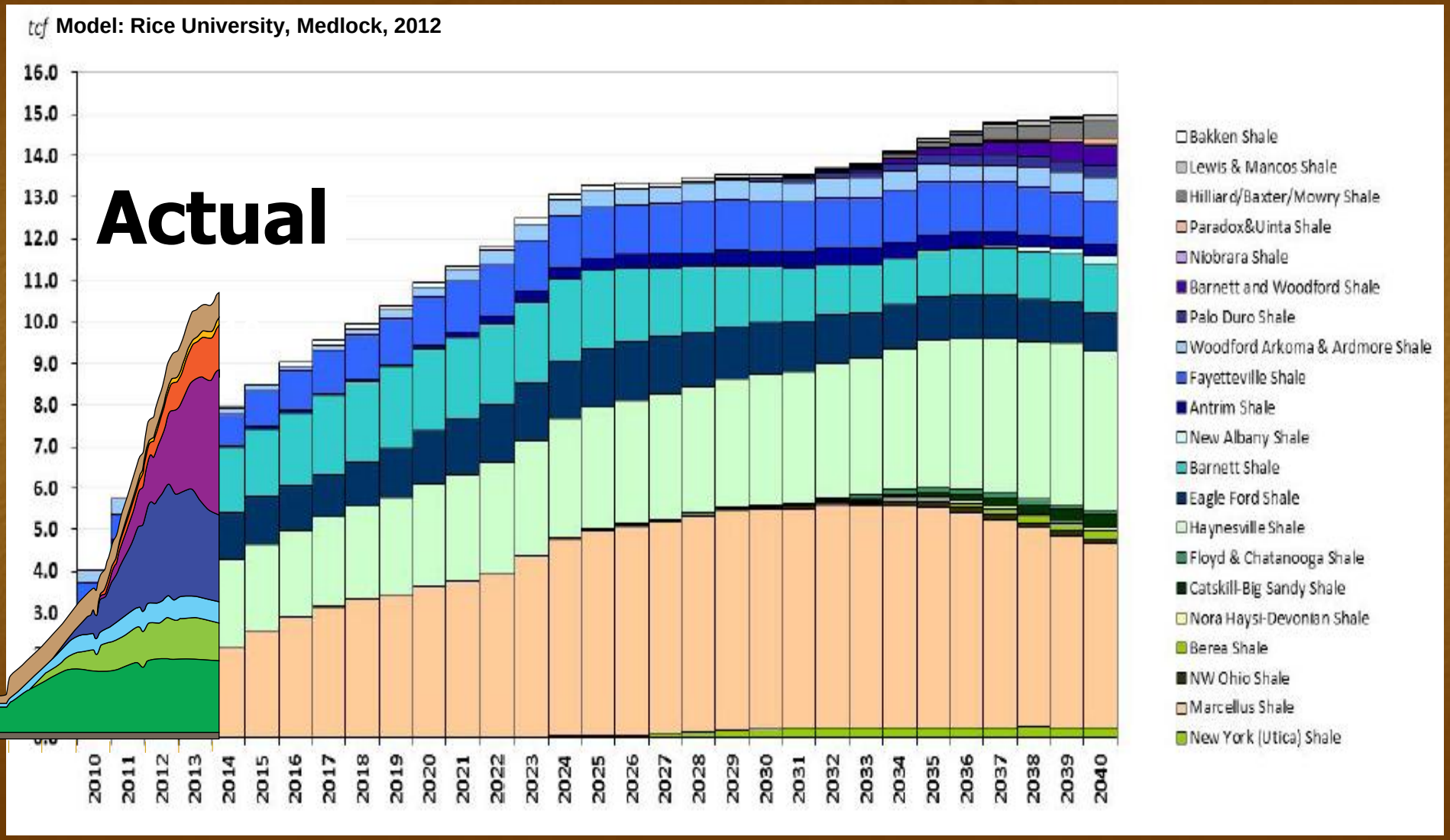
http://www.eia.gov/energy_in_brief/about_shale_gas.cfm

2013 Dry Shale Gas Production

tcf **Model: Rice University, Medlock, 2012**



2013 Dry Shale Gas Production



Source: U.S. Energy Information Administration

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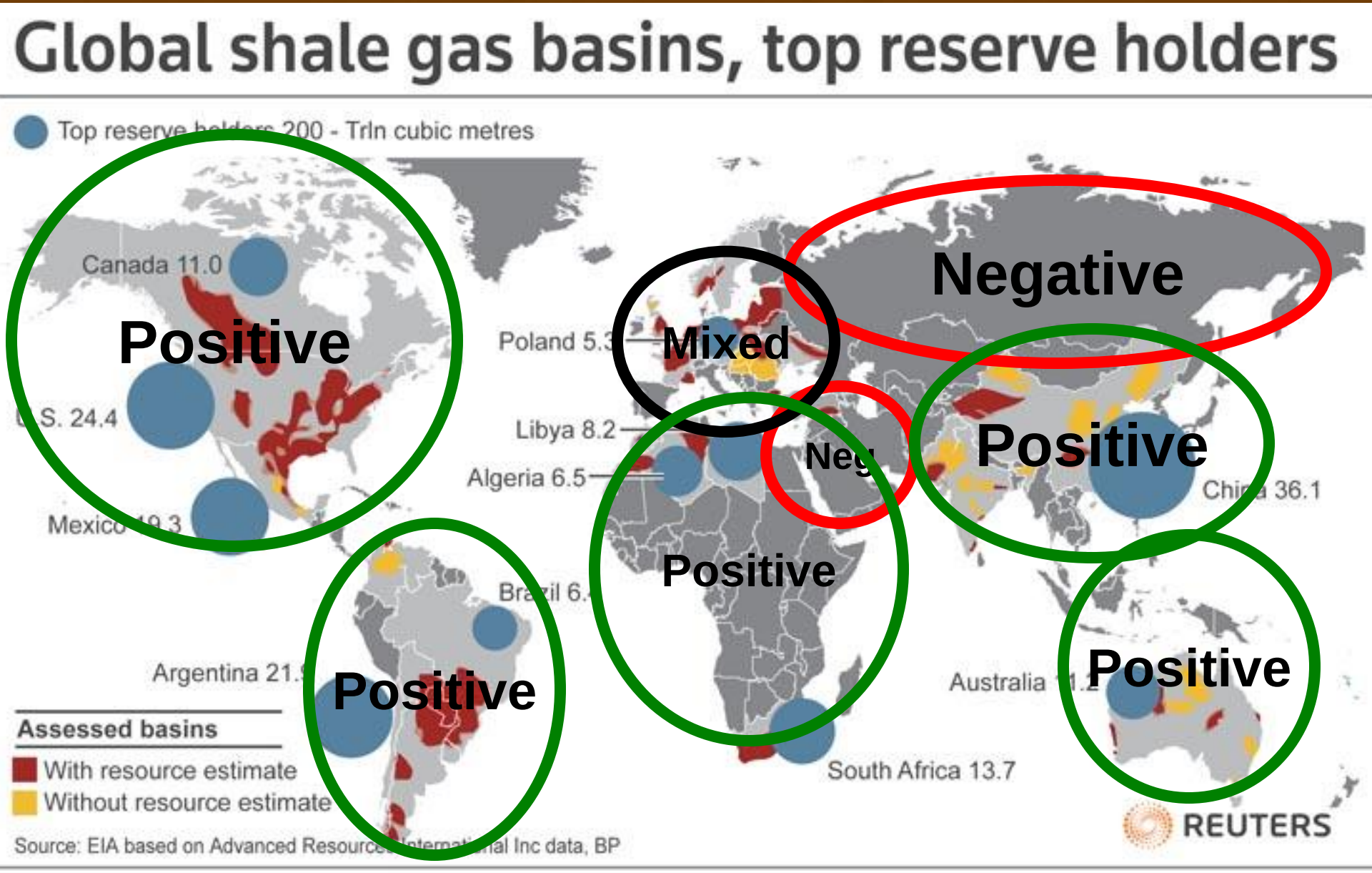
Global Shale Gas



Options to "Fracking" for Power

I. **Coal**
   - Available, affordable to generate, reliable
   - Dirty, expensive to build

II. **Nuclear**
   - Efficient, no emissions, affordable generation
   - Expensive to build, waste, safety

III. **Wind**
   - Simple, affordable, no emissions
   - Intermittent, land and visual, transmission

IV. **Solar**
   - Simple, no emissions, local
   - Expensive, intermittent, land

V. **Hydro**
   - Efficient, affordable to generate, no emissions
   - Water, land, drought

VI. **Geothermal**
   - Affordable where concentrated, no emissions
   - Geology

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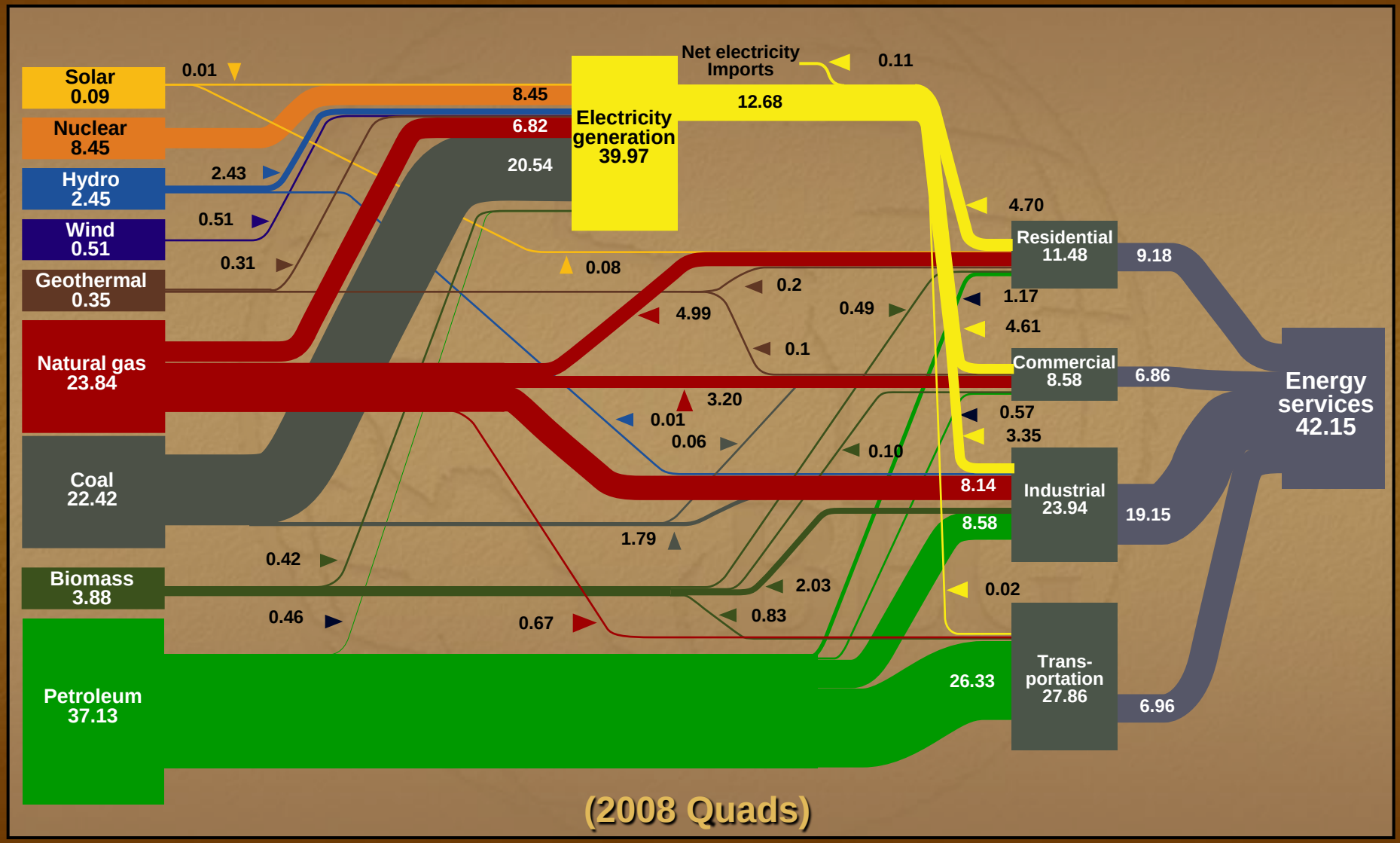
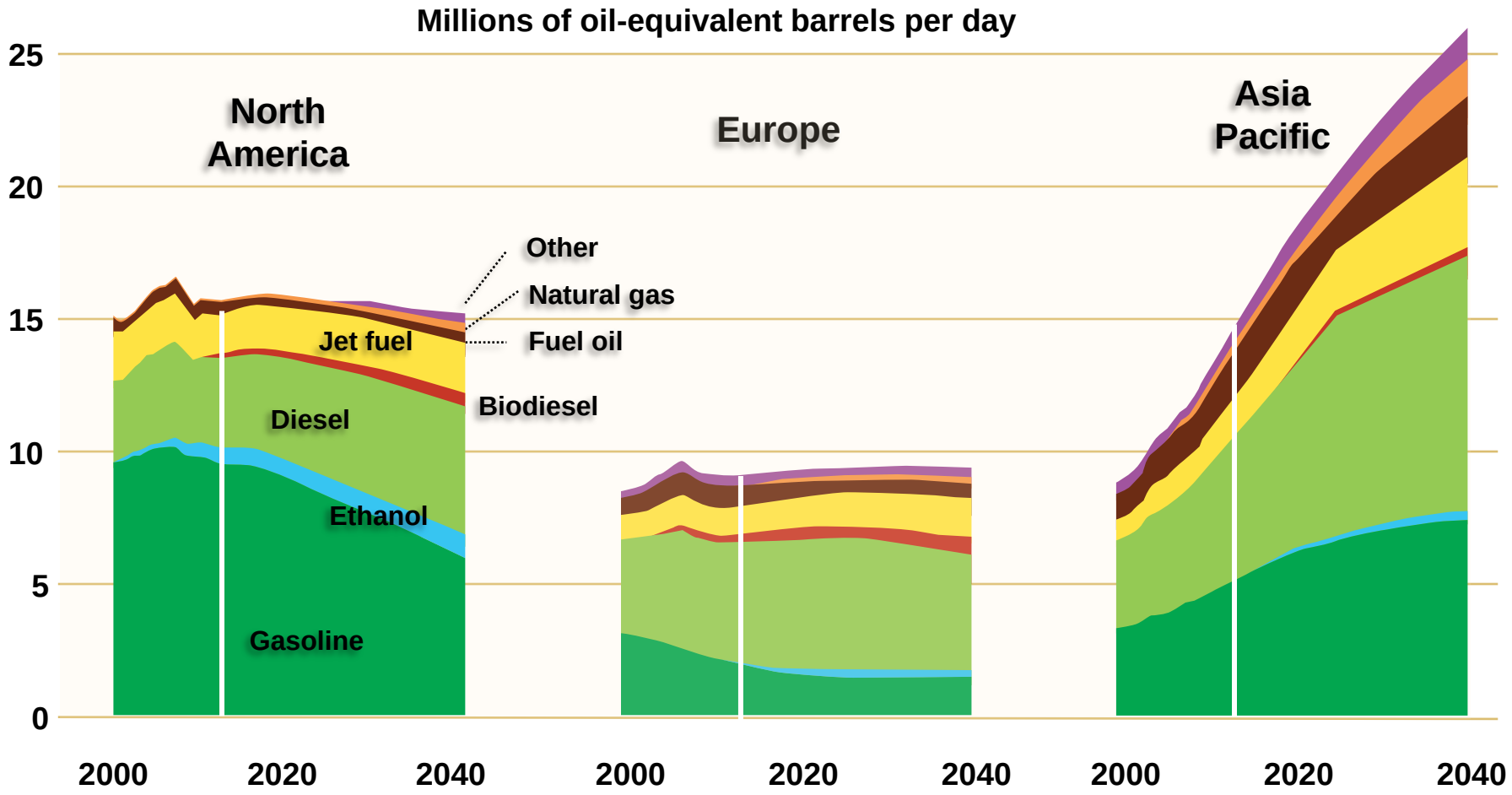
U. S. Energy Flows



Source: Lawrence Livermore National Laboratory and U.S. DOE based on Annual Energy Review, 2008 (EIA, 2009)
From National Academies Press, *America's Energy Future*, 2009

QAd8174

The Future Transportation Mix



ExxonMobil Corporation, 2013 The Outlook for Energy: A View to 2040, page 20.

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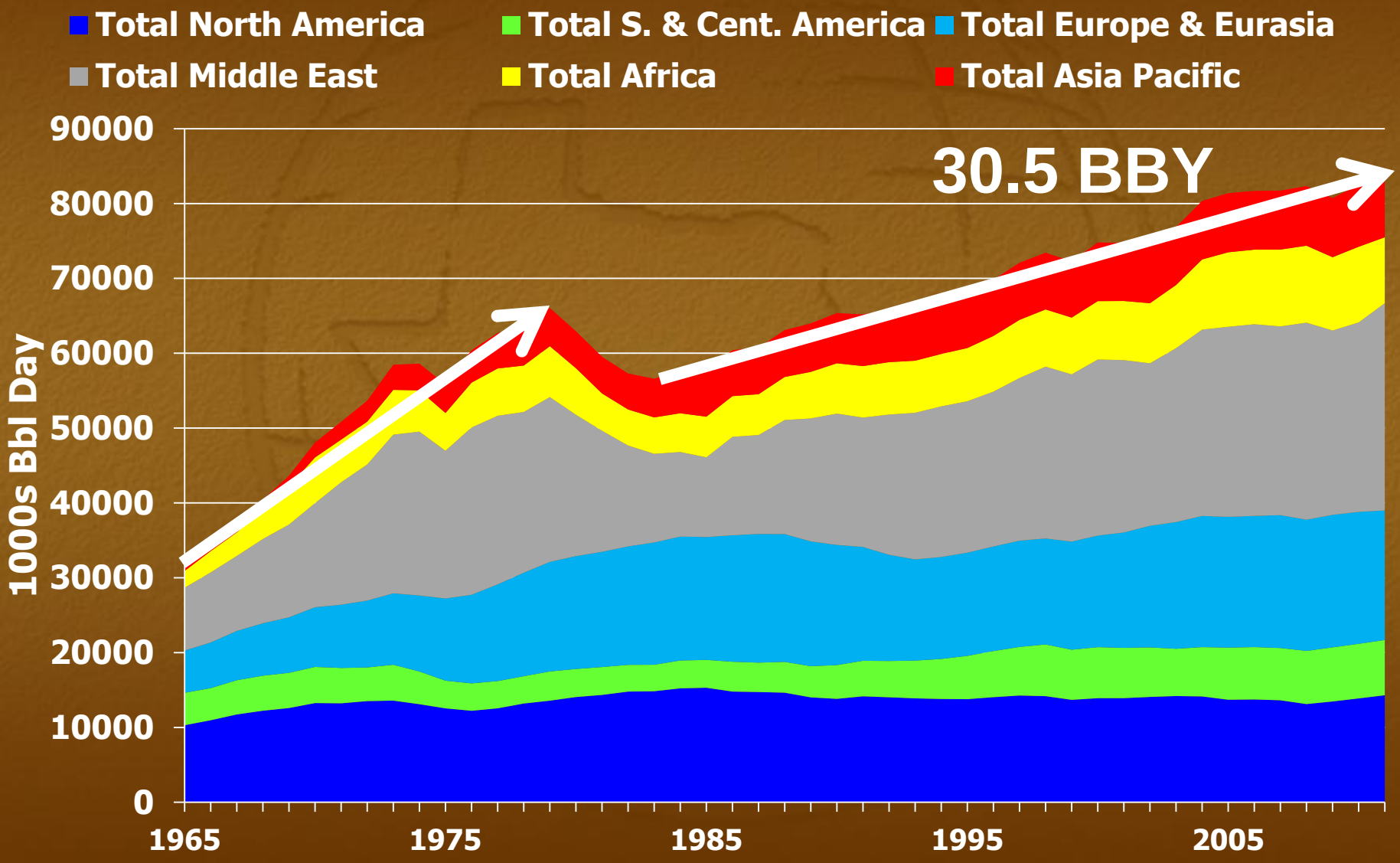
Global Oil Production



Source: BP Statistical Review 2012

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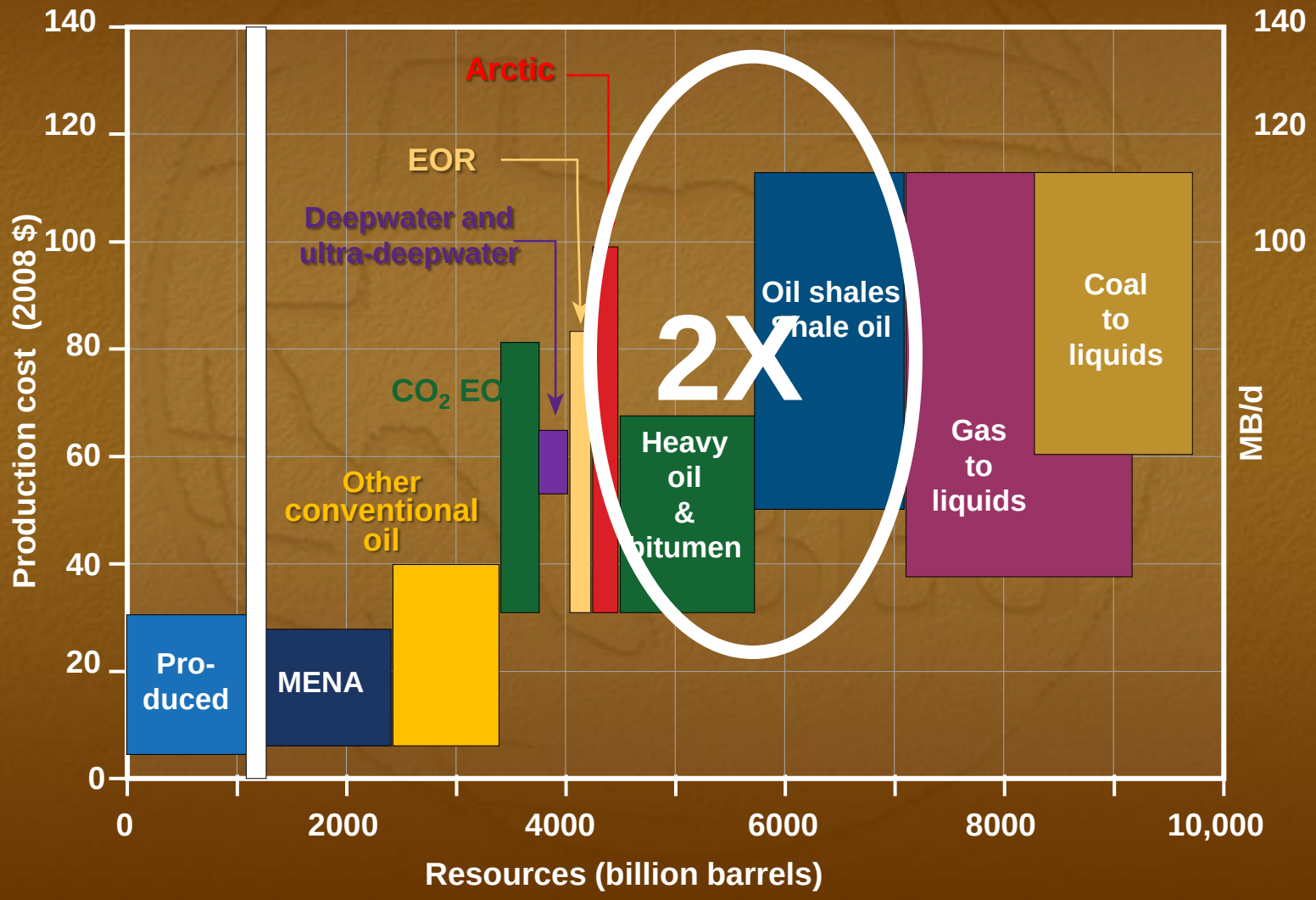
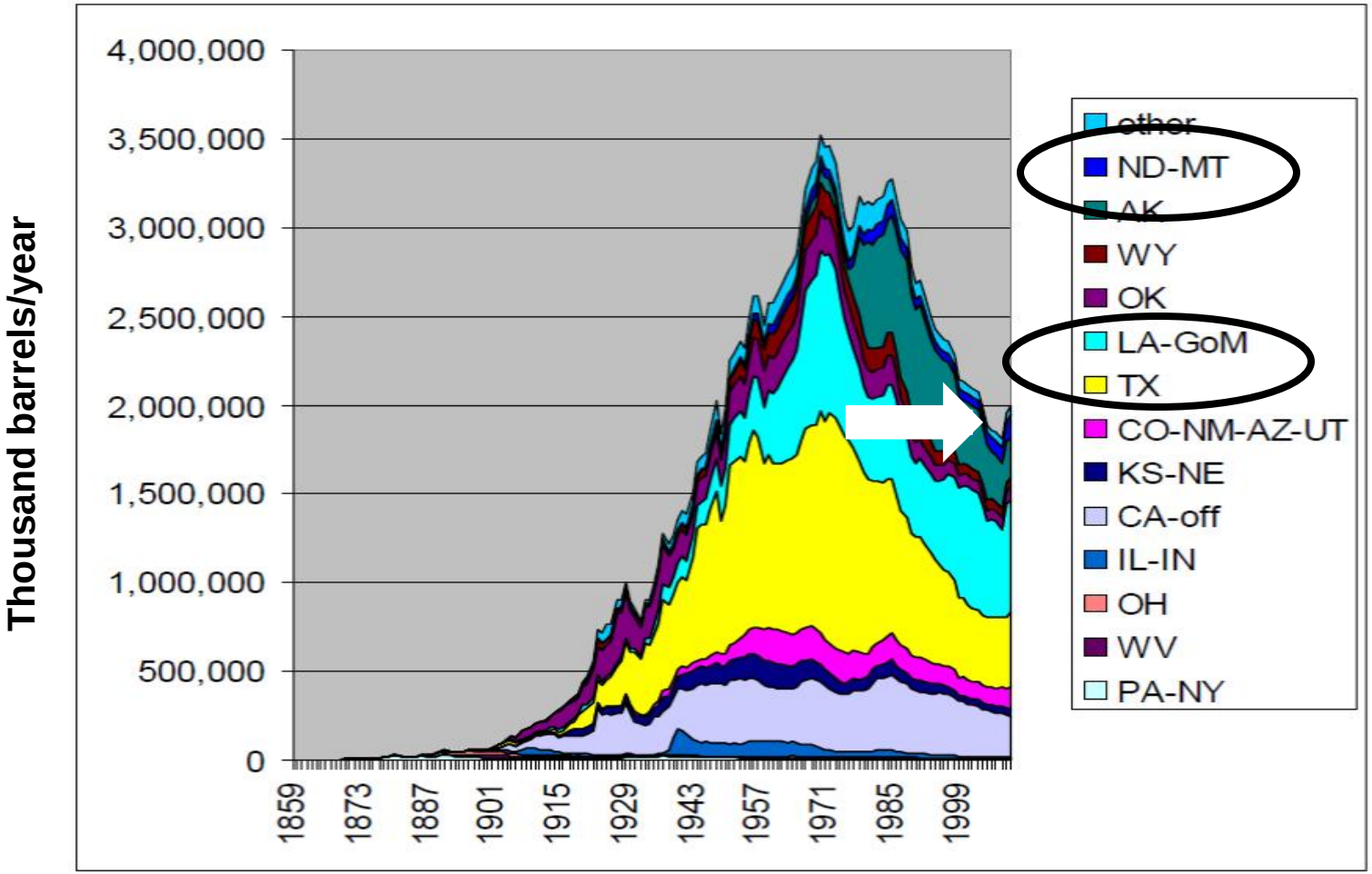
Long-Term Oil Supply

Resources and Cost



Source: IEA World Energy Outlook (2009)

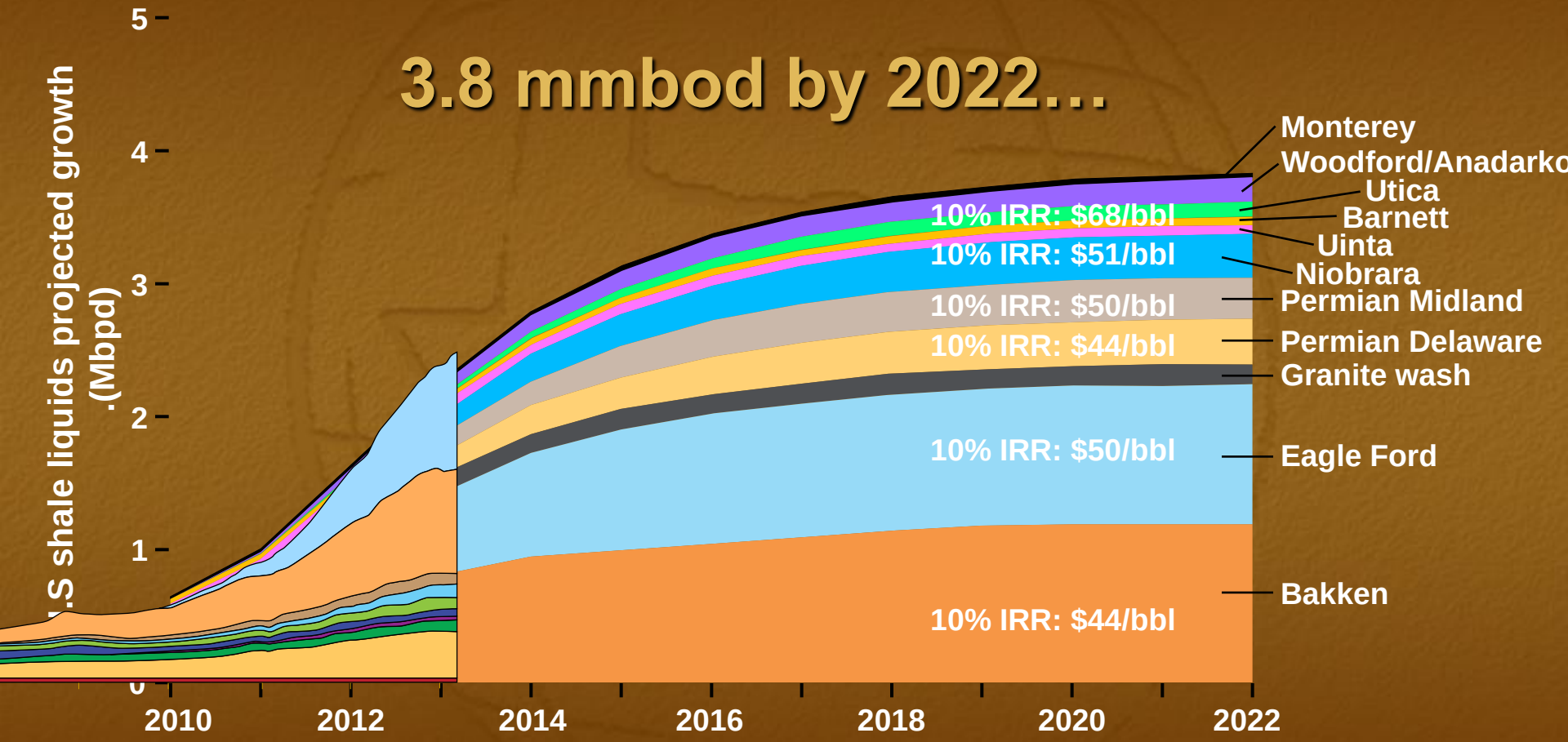
Annual US Oil Production



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

2010 U.S. SHALE LIQUIDS *PROJECTION*

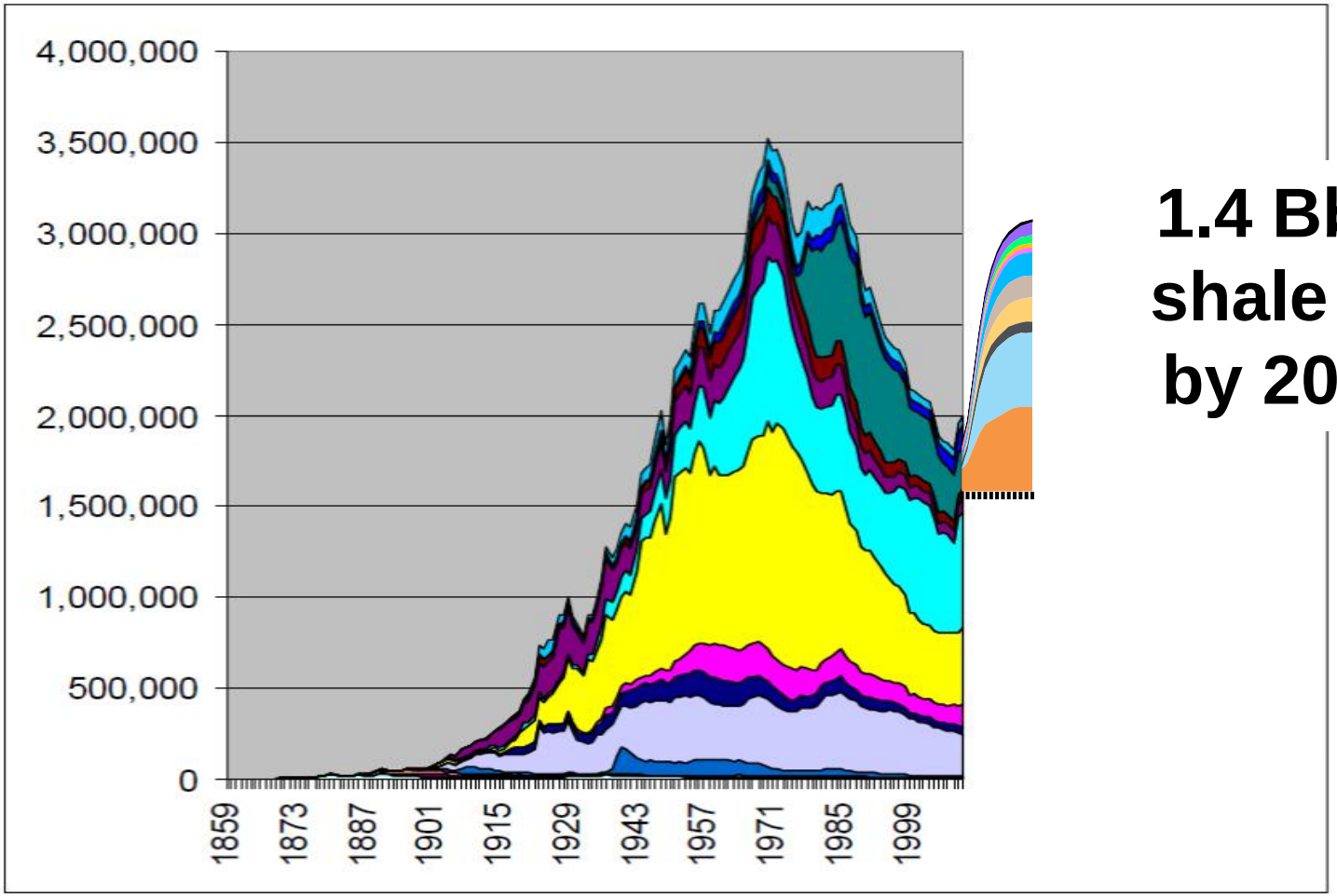
3.8 mmbod by 2022…



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

Annual US Oil Production



1.4 Bby shale oil by 2022

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

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- **Above Ground Challenges and Implications**

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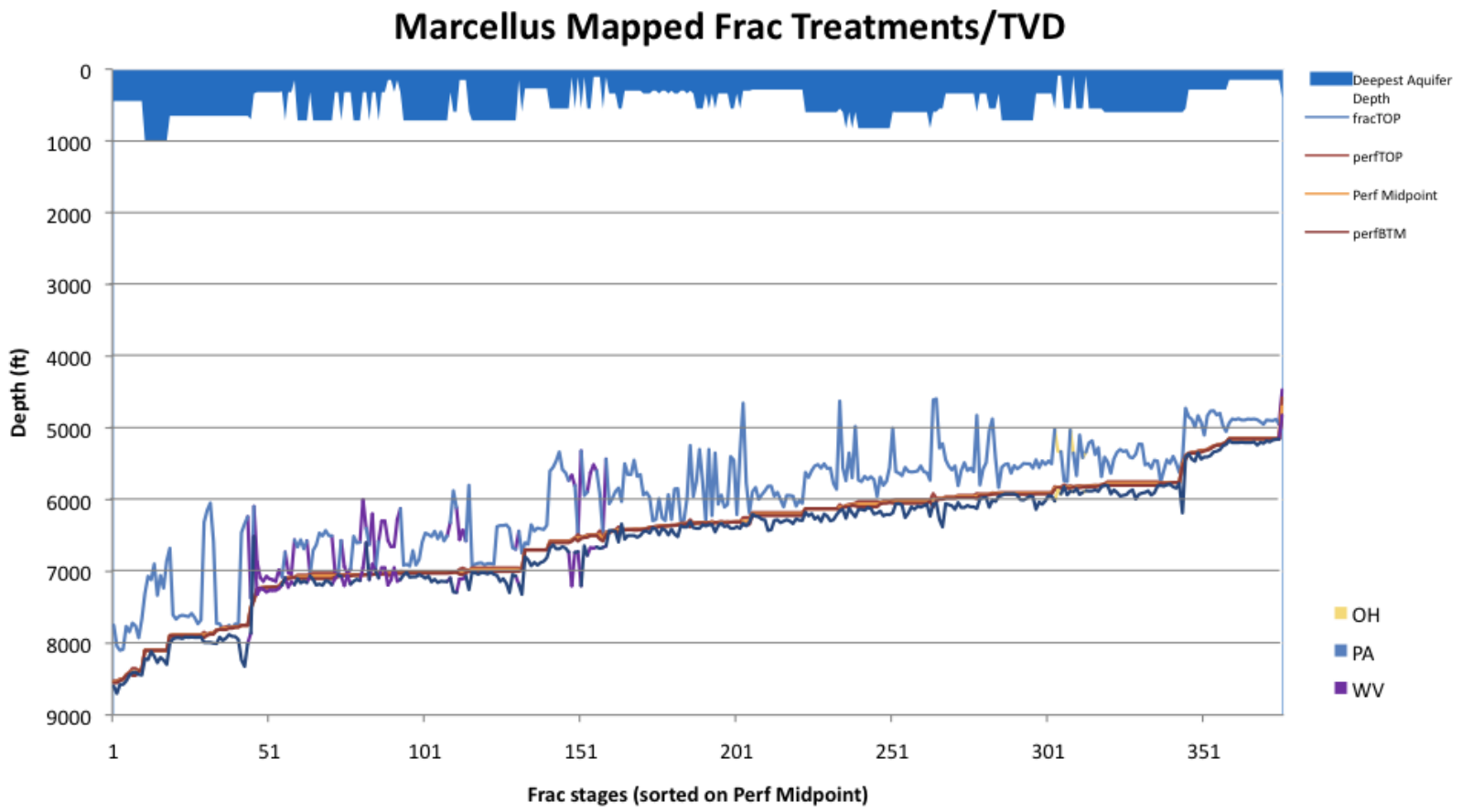
Unconventional Reservoirs



Pinnacle
A HALLIBURTON SERVICE

Unconventional Summary "Trade Offs"

- Environmental Risks and Impacts
  - Traffic/noise/light
  - Surface
  - Groundwater
  - Quakes
  - Health
  - Local and atmospheric emissions
- Energy Security and Economic Benefits
  - Available
  - Affordable
  - Reliable
  - Jobs and Taxes

These are not mutually exclusive!

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Environmental Issues

Regulatory Considerations

I. **Mandatory baseline data**

II. **Cement all gas producing zones**

III. **Minimize fresh water use on the front end**

IV. **Full disclosure and adaptation of chemicals**

V. **Handle flowback and produced water**

   a. **Treat and reuse**

   b. **Induced seismicity**

VI. **Minimize methane emissions**

VII. **Minimize surface impact**

after Rao, 2012

Unconventional Reservoirs

Implications

- **Balance of Trade**
  - ✓ **Exports: Natural gas, liquids, products**
  - ✓ **Imports: Oil**
- **Regulation and Planning**
  - ✓ **Infrastructure**
  - ✓ **Resources**
  - ✓ **Permitting**
- **Emissions**
- **Energy Security**

Global Context

- **Shale will be a big part of the future and "*above ground*" challenges must be addressed.**
- **Diverse energy portfolios are inevitable, and for the most part desirable; *efficiency* is part of the energy portfolio.**
- **Energy security — *affordable, available, reliable, sustainable* — drives energy mix.**
- **The global energy transition will take time; let's come out of our corners to *The Radical Middle*, where things get done.**

Thanks!