Imperial College London

Oil Technology Centenary

September, 2013

The 21st Century Energy Mix

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Bureau of Economic Geology

Jackson School of Geosciences, The University of Texas at Austin

100 years is quite an accomplishment.

Congratulations!

The 21st Century Energy Mix
Framing Observation

A majority of "the public" do not know where electricity comes from or how it is made; nor do they particularly care.

Therefore, energy policy makers are free to do dumb things, even if well intended.

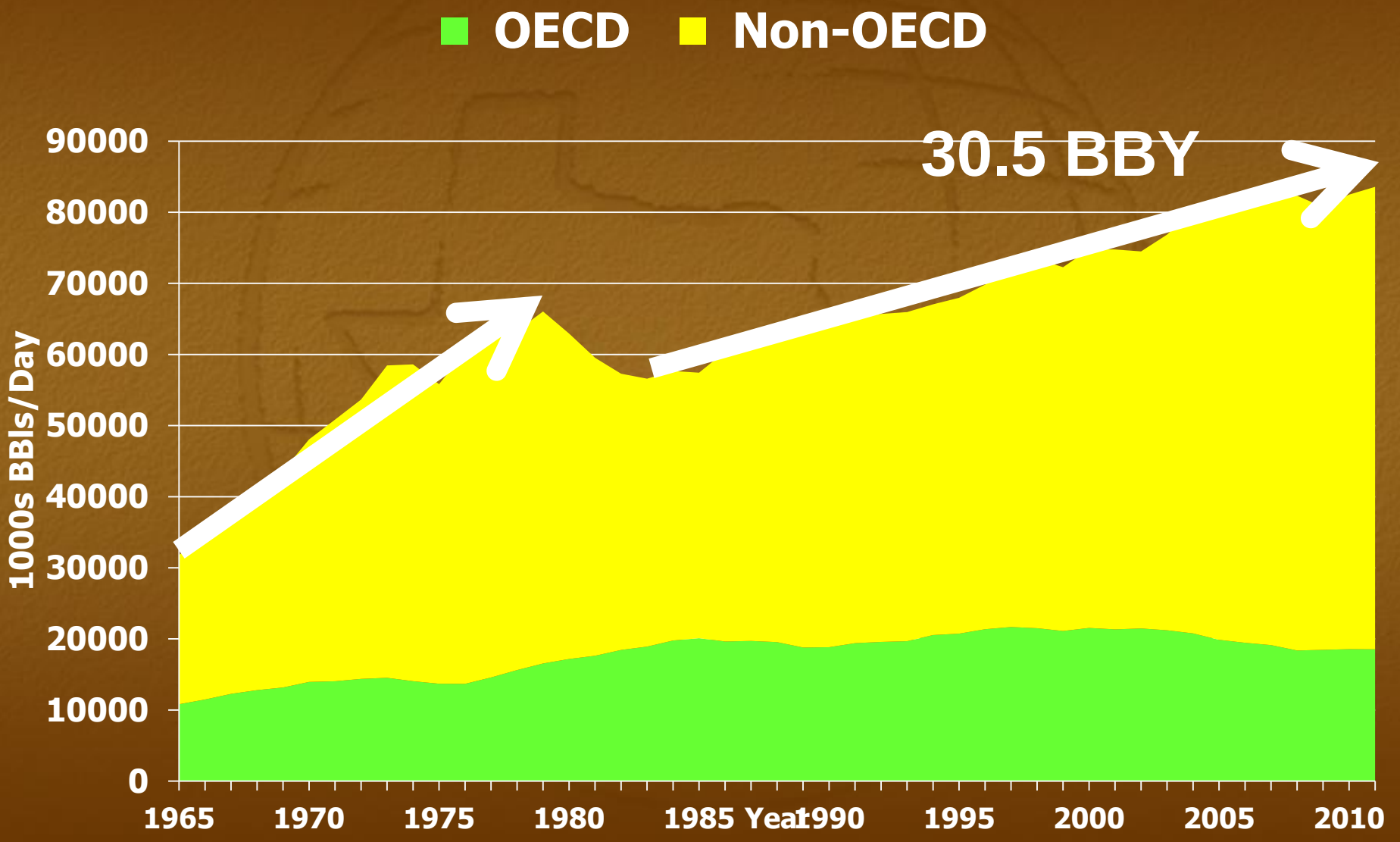
Energy education is imperative.

Outline

- An Anticipated Evolution
- Is it Real?
- The Global K's

Tinker, 2013

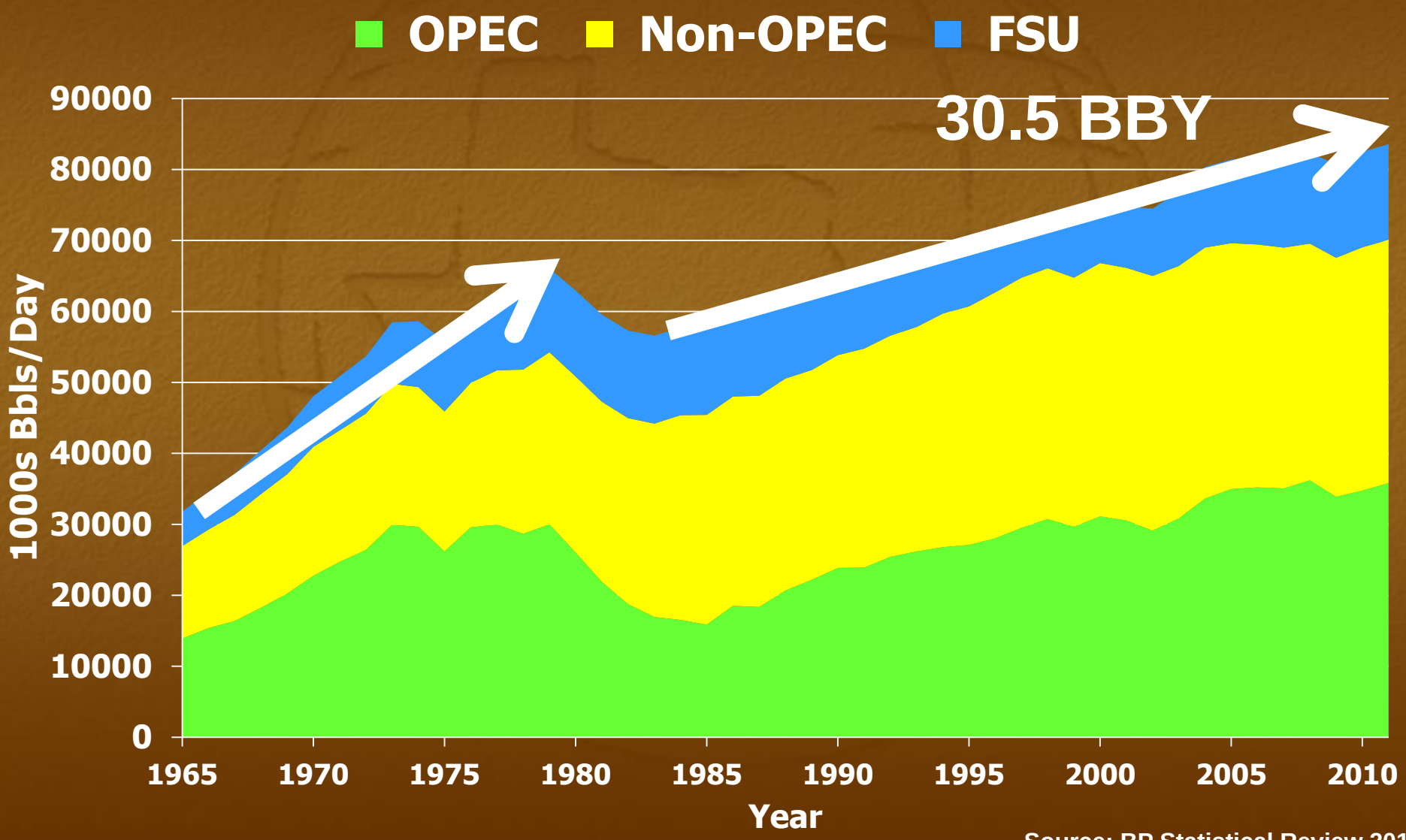
Global Oil Production



Source: BP Statistical Review 2012

Tinker, 2013

Global Oil Production



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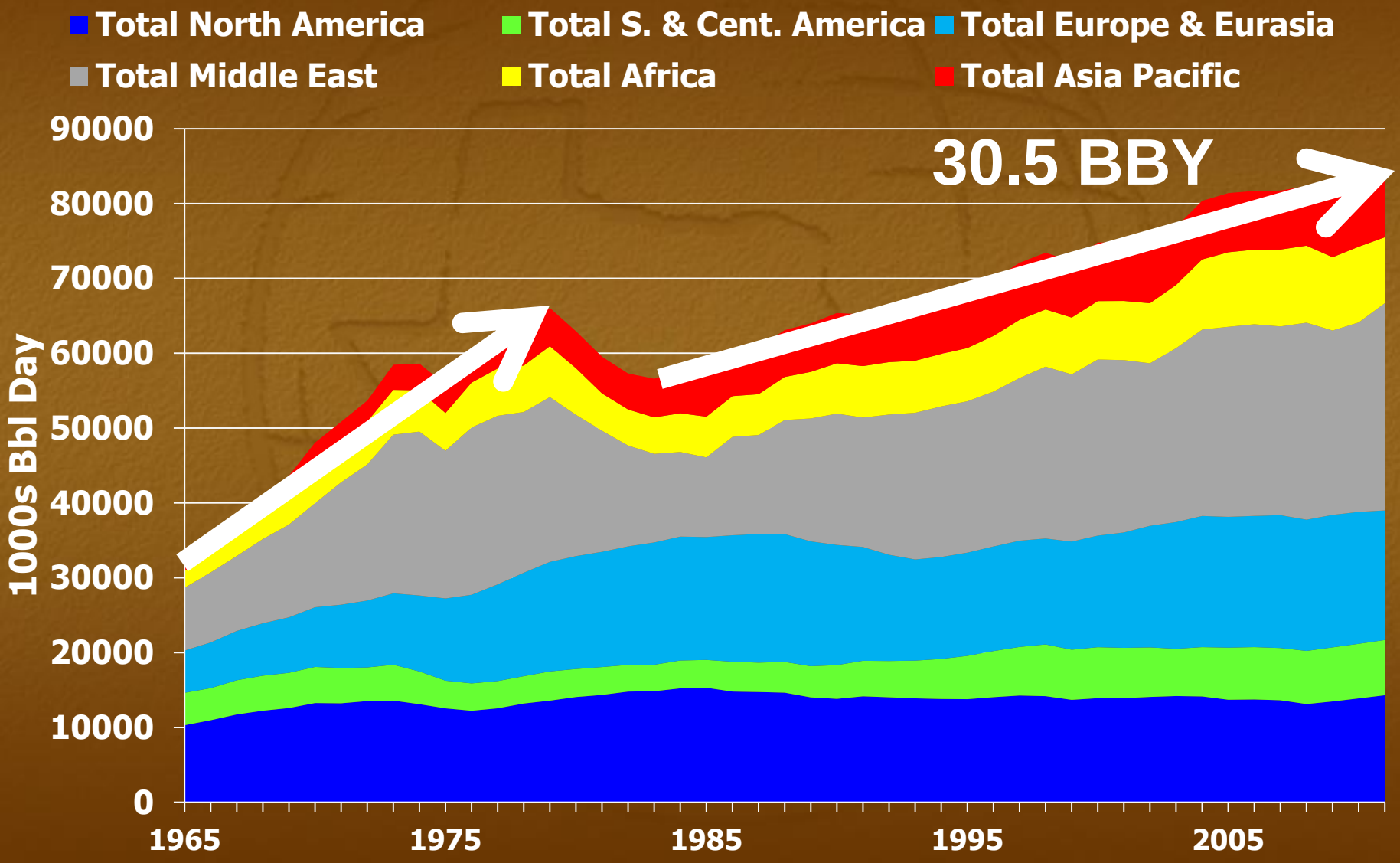
Tinker, 2013

Global Oil Production



Source: BP Statistical Review 2012

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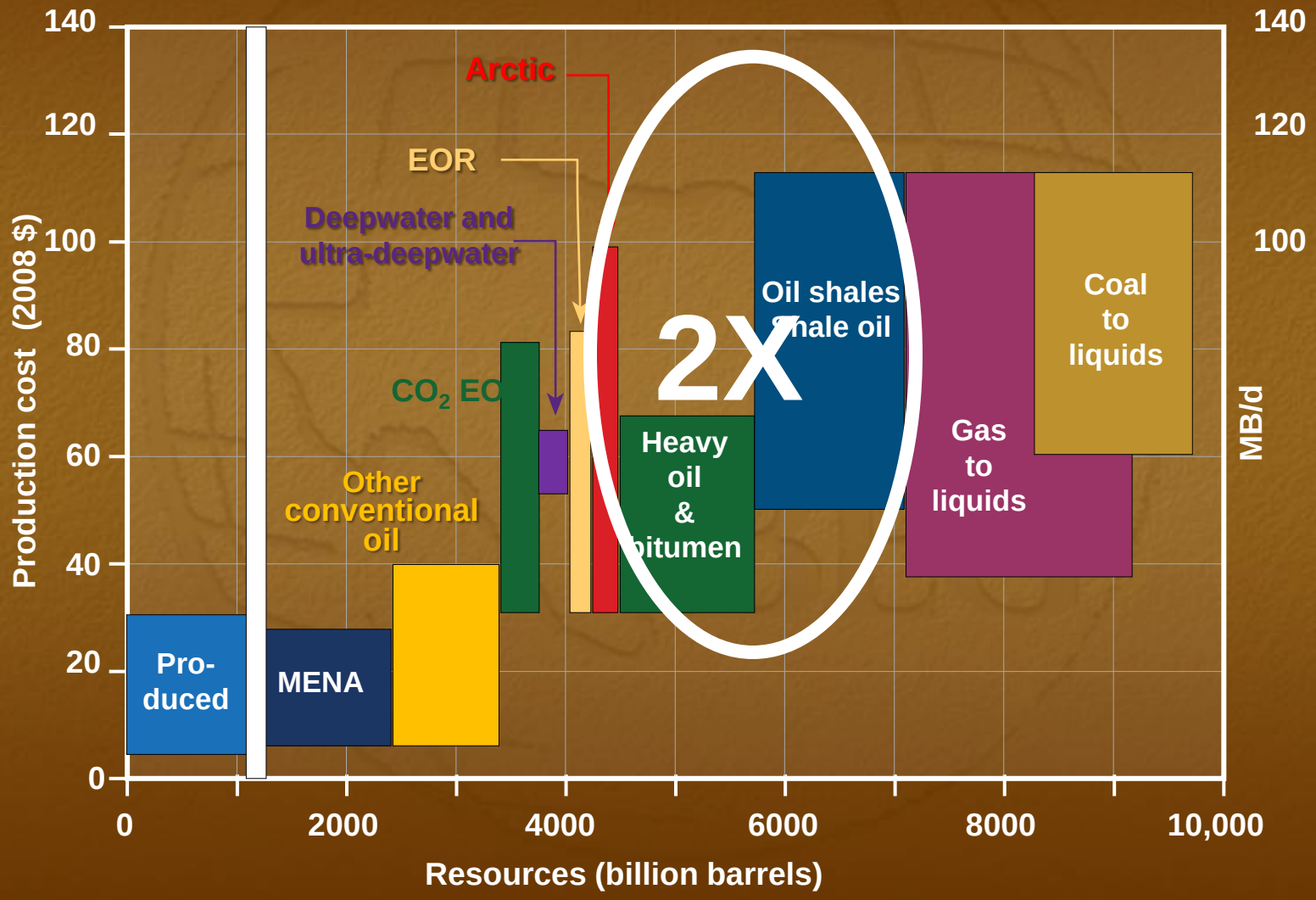
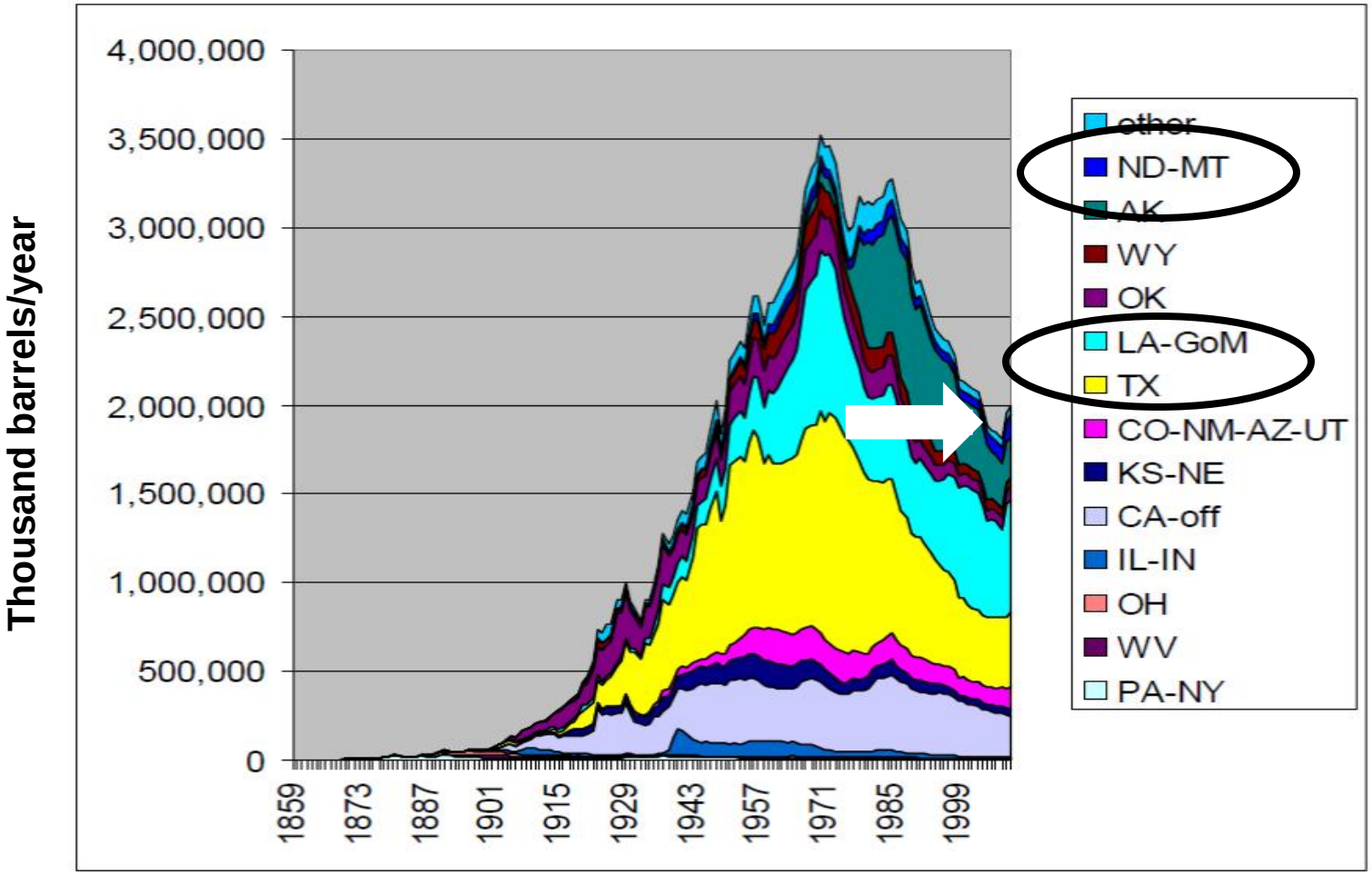
Long-Term Oil Supply

Resources and Cost



Source: IEA World Energy Outlook (2009)

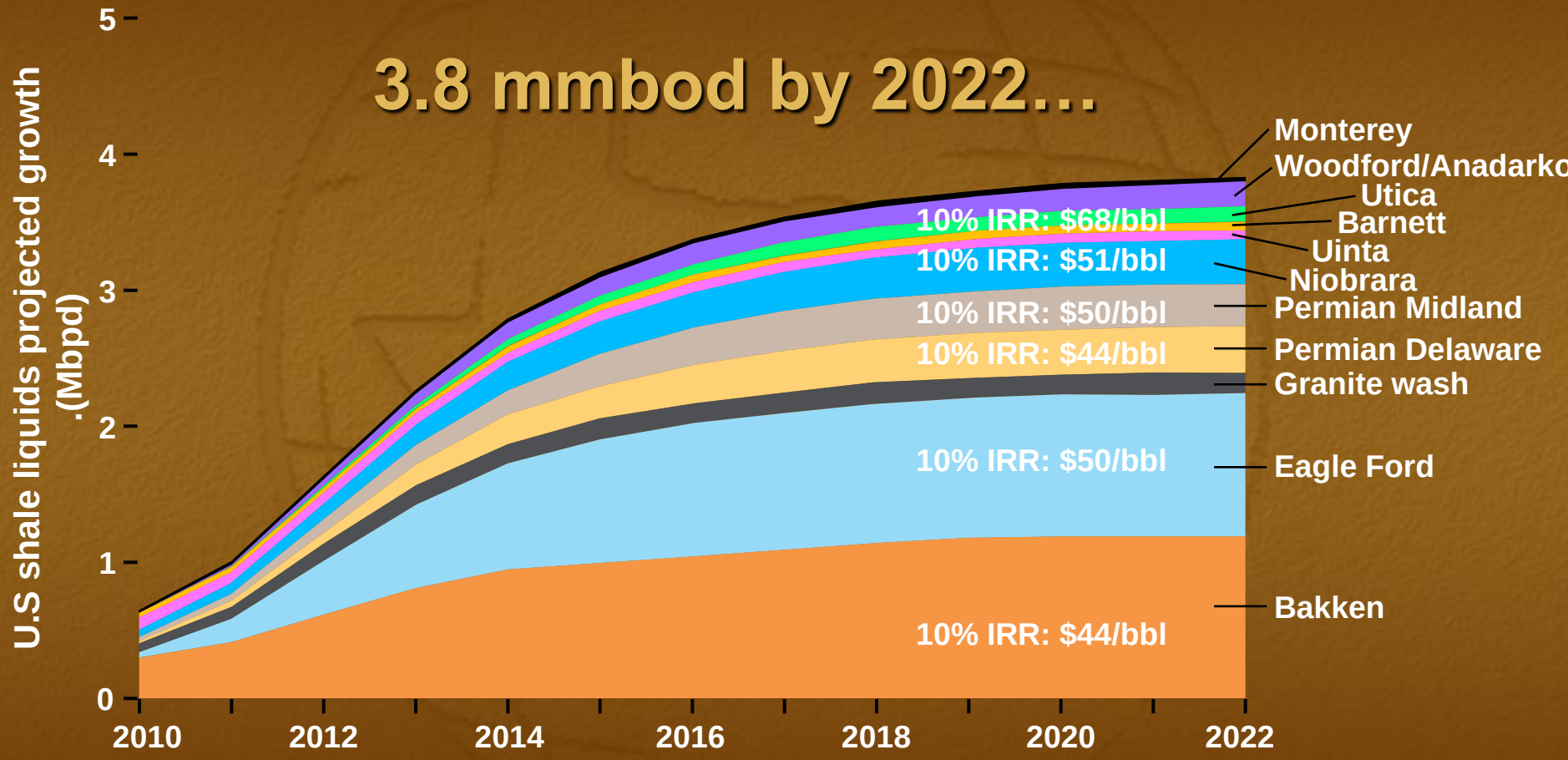
Annual US Oil Production



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

2010 U.S. SHALE LIQUIDS *PROJECTION*

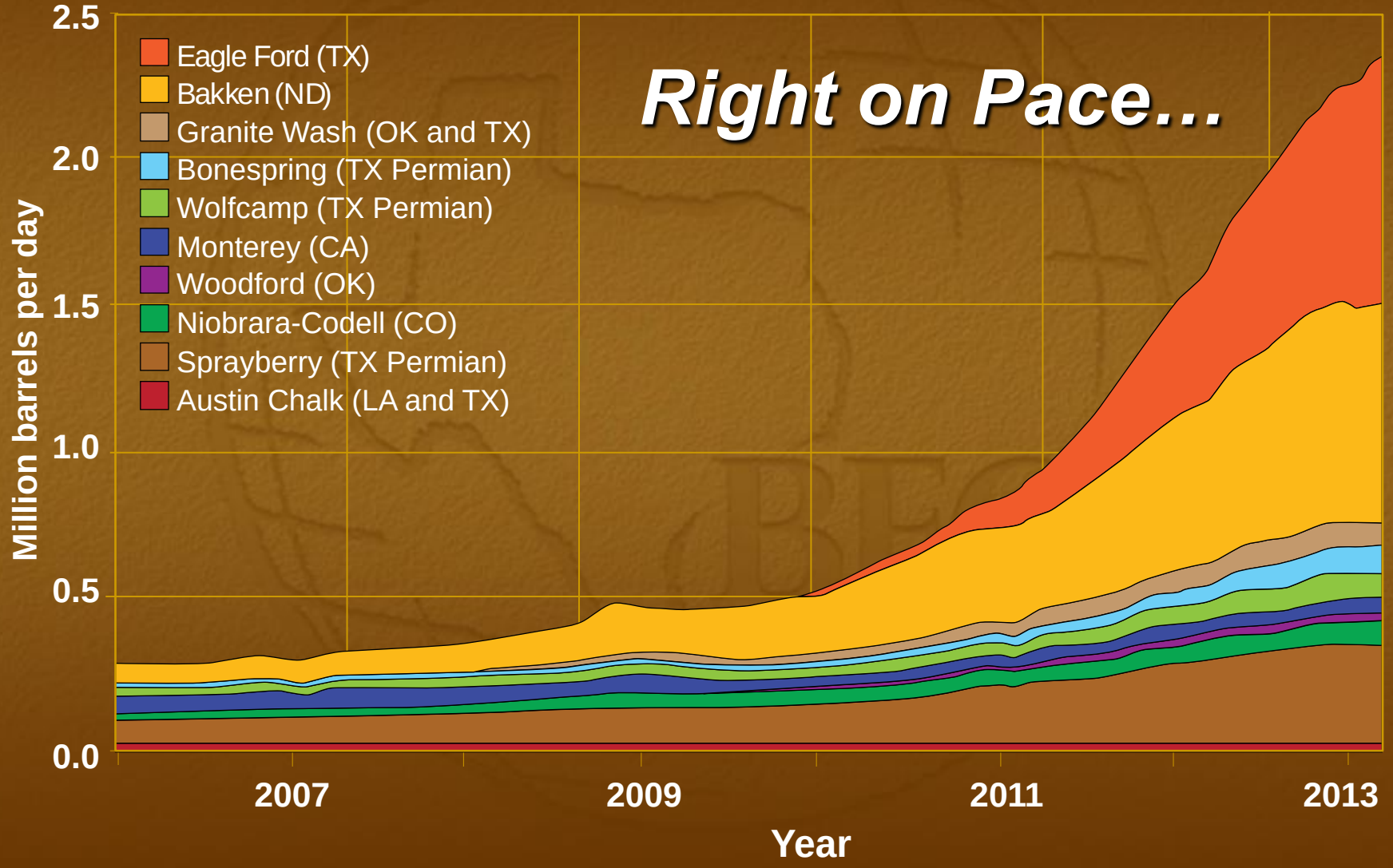
3.8 mmbod by 2022…



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

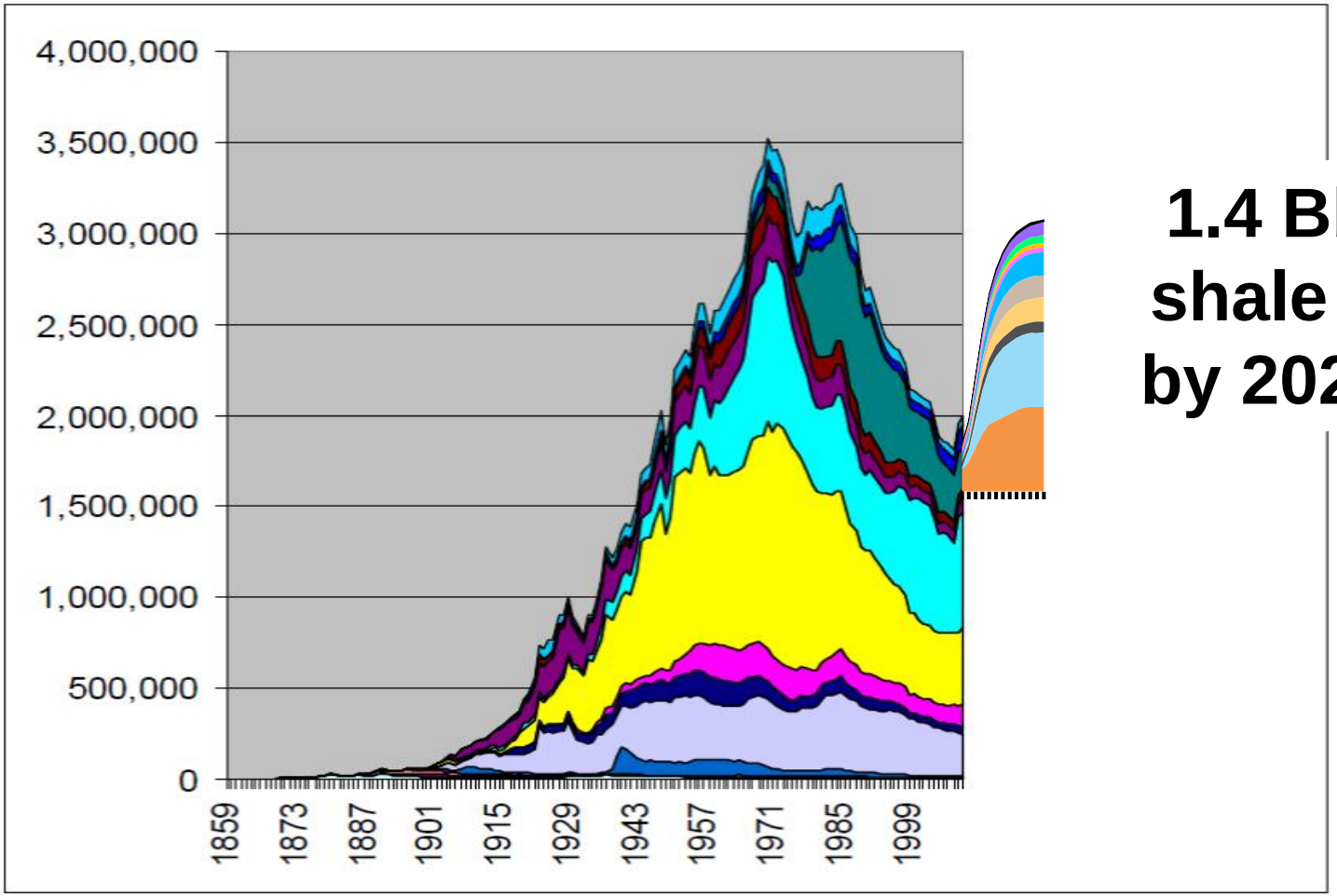
IRR Source: Rystad Energy

US Shale and Tight Oil Production



Source: U.S. Energy Information Administration

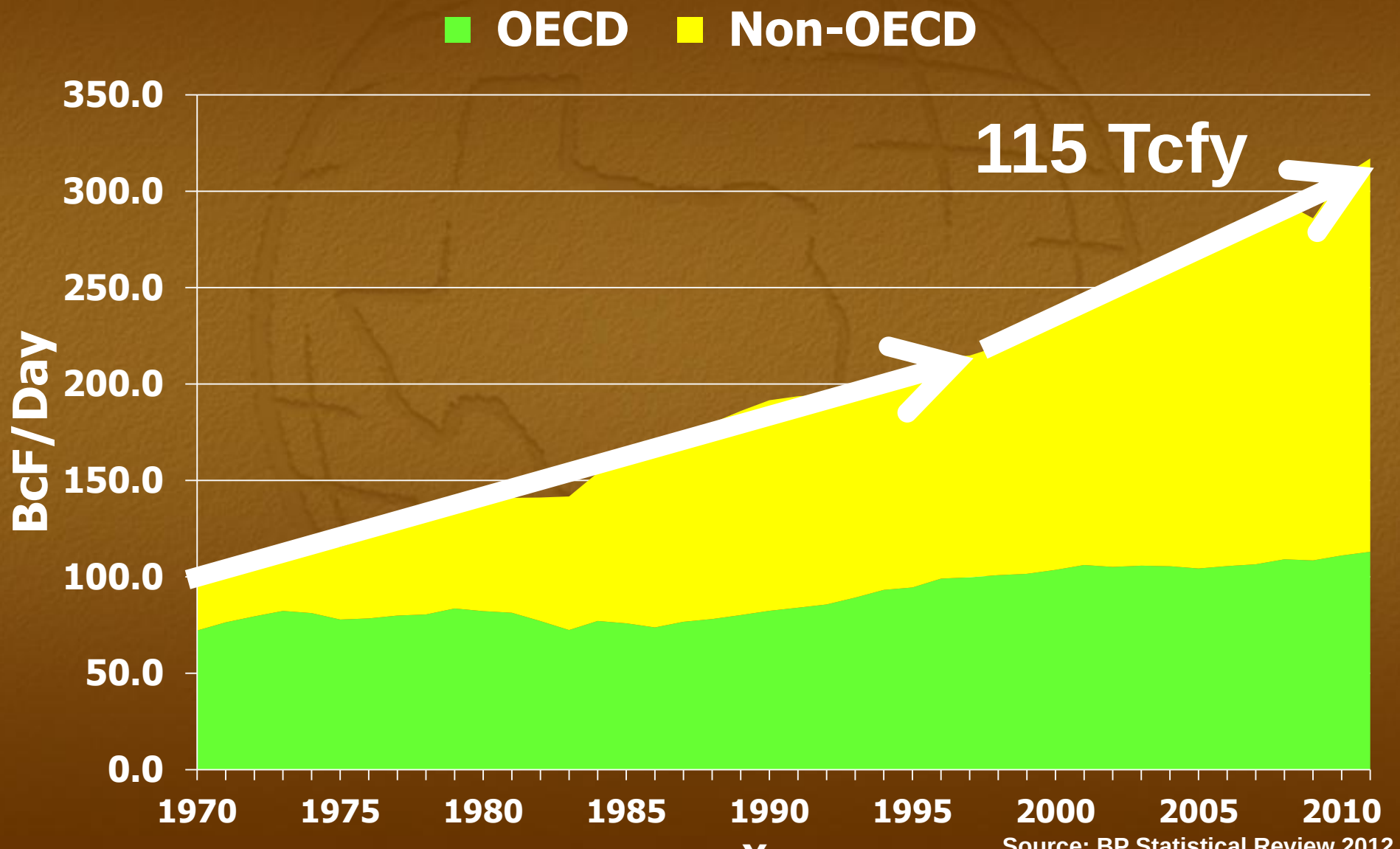
Annual US Oil Production



1.4 Bby shale oil by 2022?

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

Global Natural Gas Production



Source: BP Statistical Review 2012

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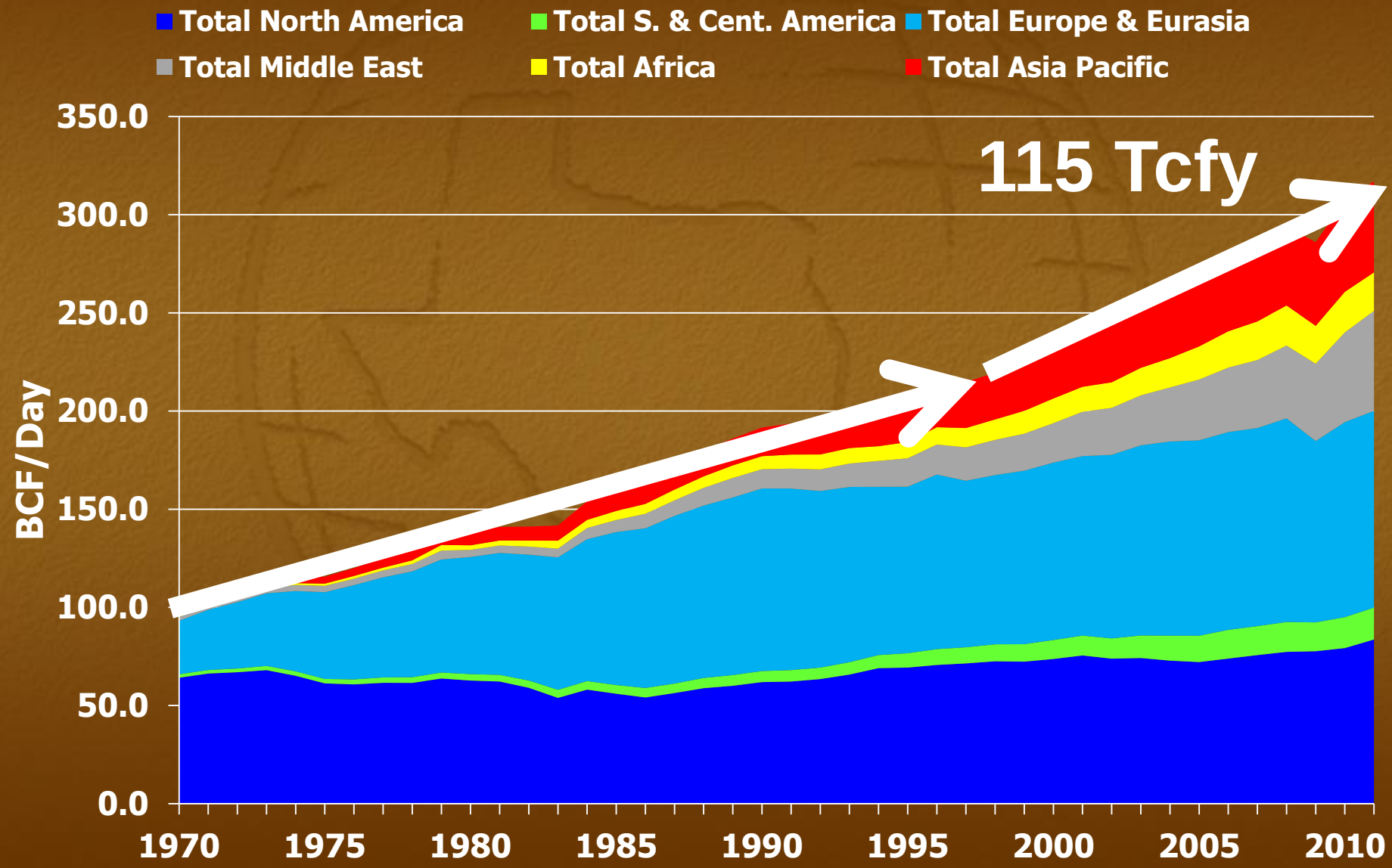
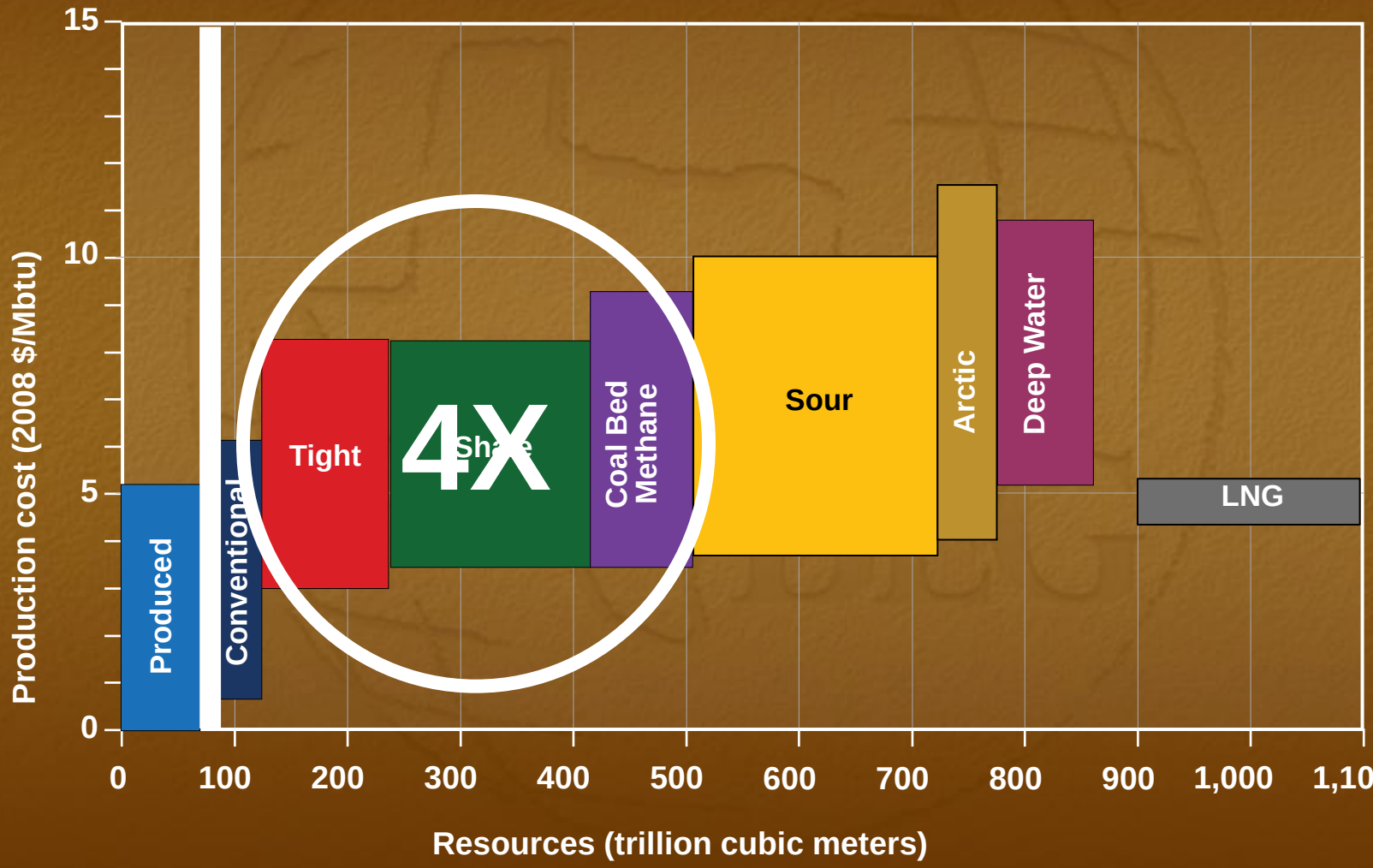
Global Natural Gas Production



Source: BP Statistical Review 2012

Natural Gas Supply

Resources and Cost



Source: IEA World Energy Outlook (2009)

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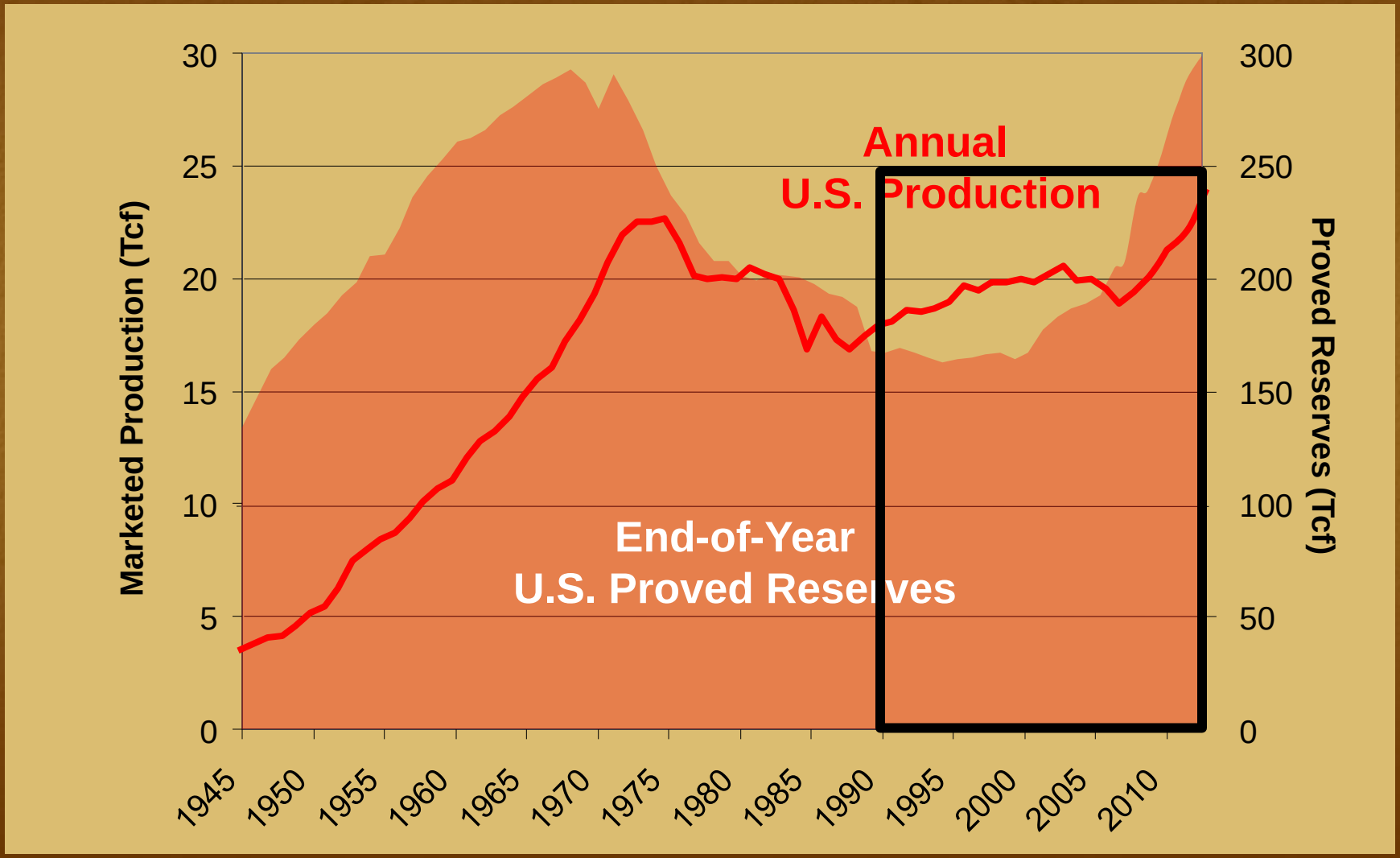
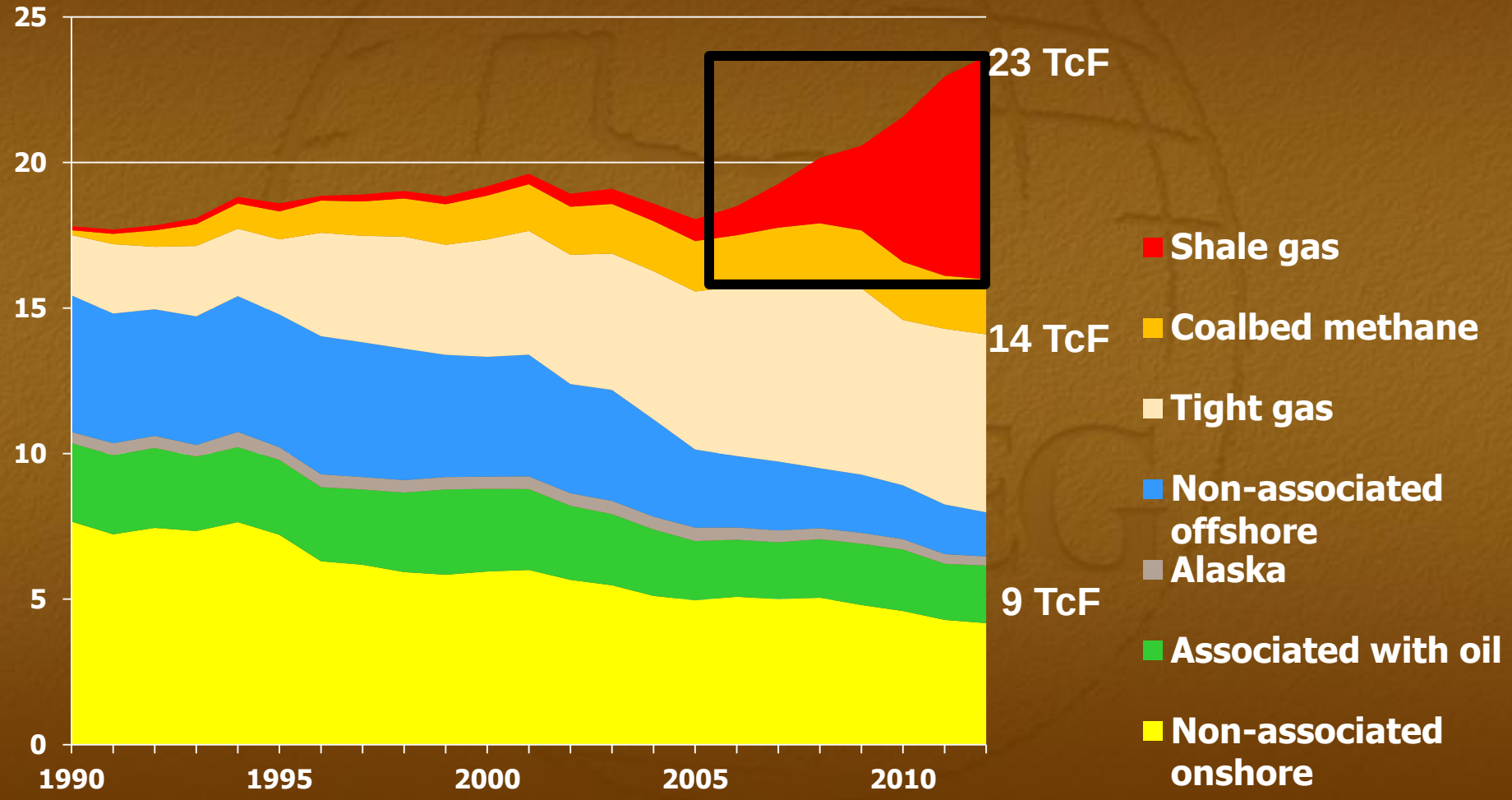
U.S. Natural Gas
Production and Reserves



Data: BP World Energy 2012

U.S. Natural Gas

Production (TcF)

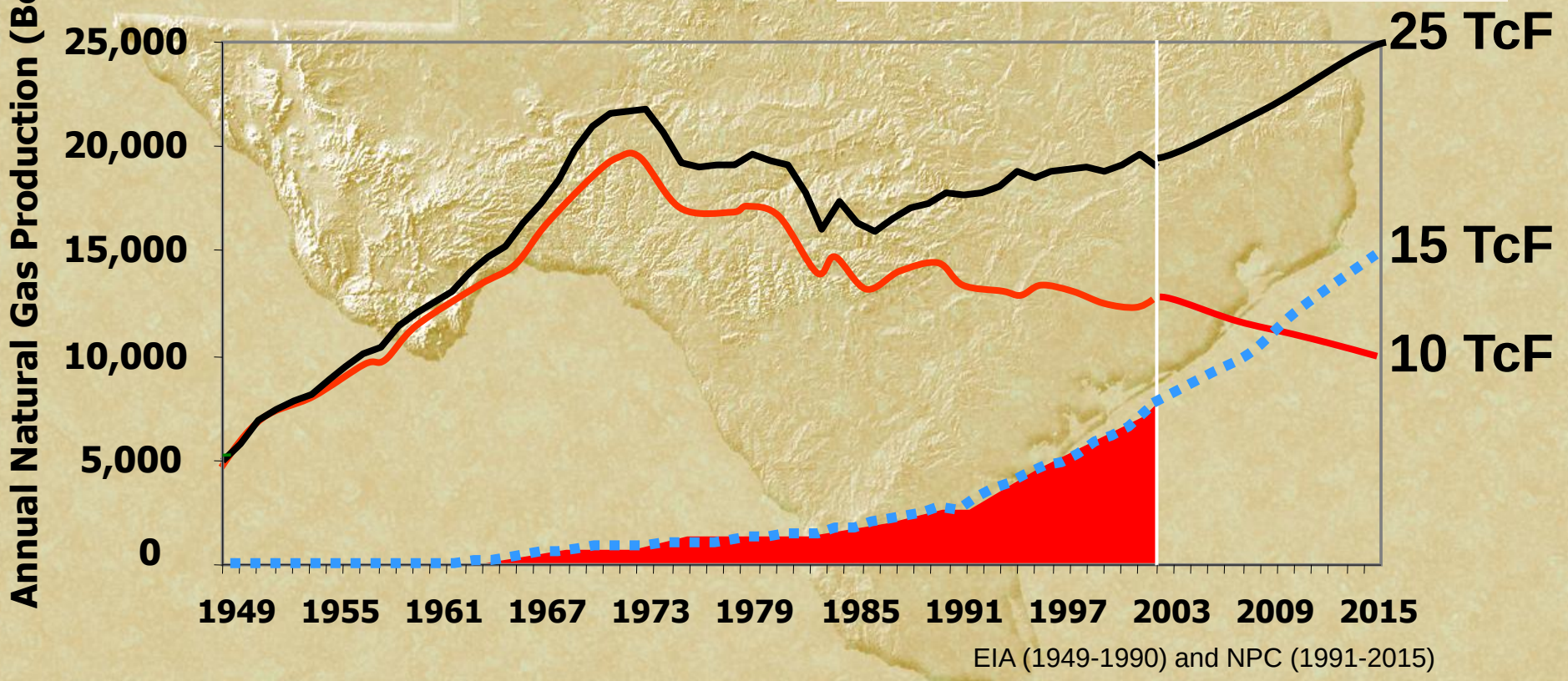


http://www.eia.gov/energy_in_brief/about_shale_gas.cfm

From a 2004 Tinker Talk to IPAA

US Natural Gas 2004 forecast

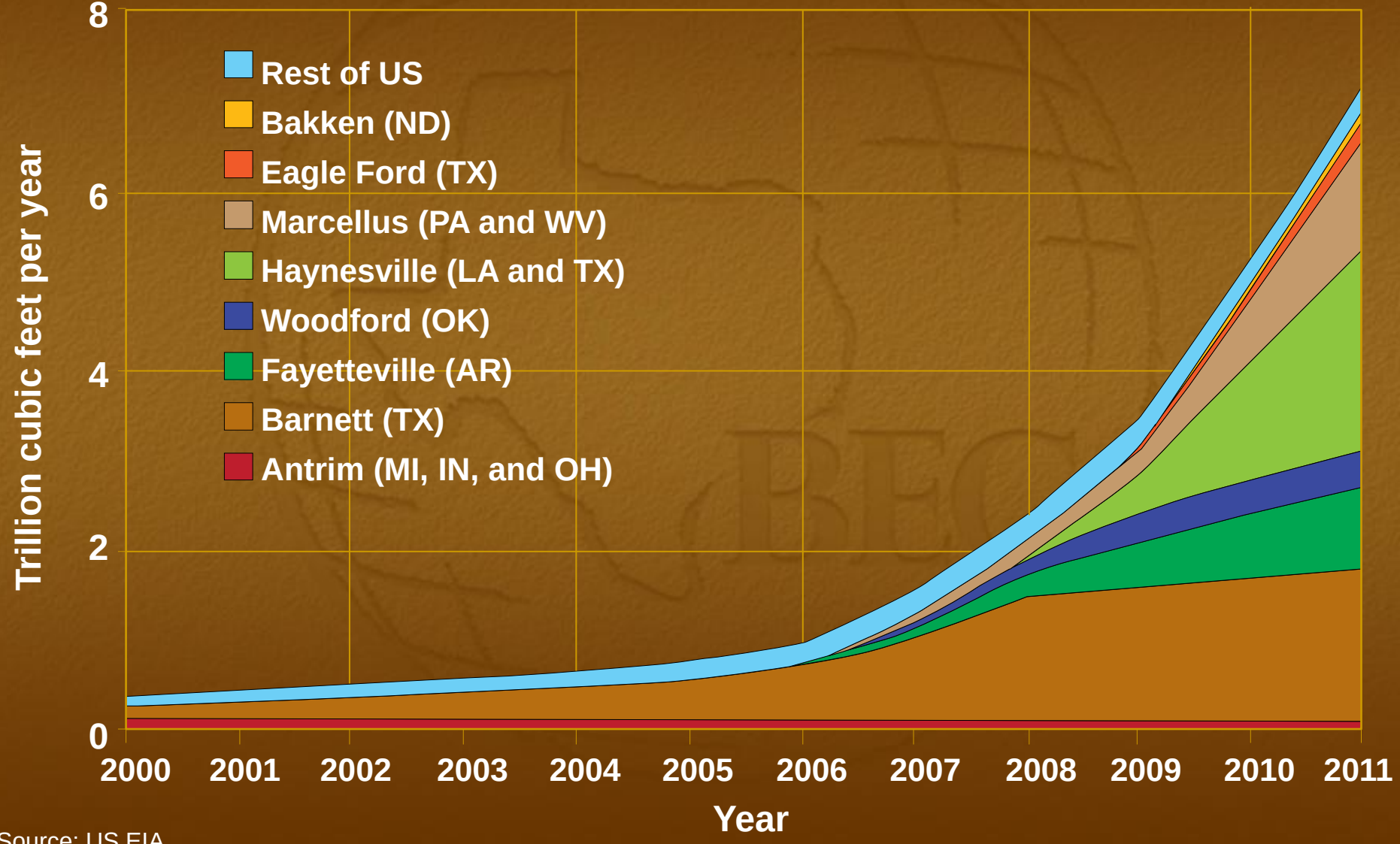
An Anticipated Evolution



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

Tinker, 2012

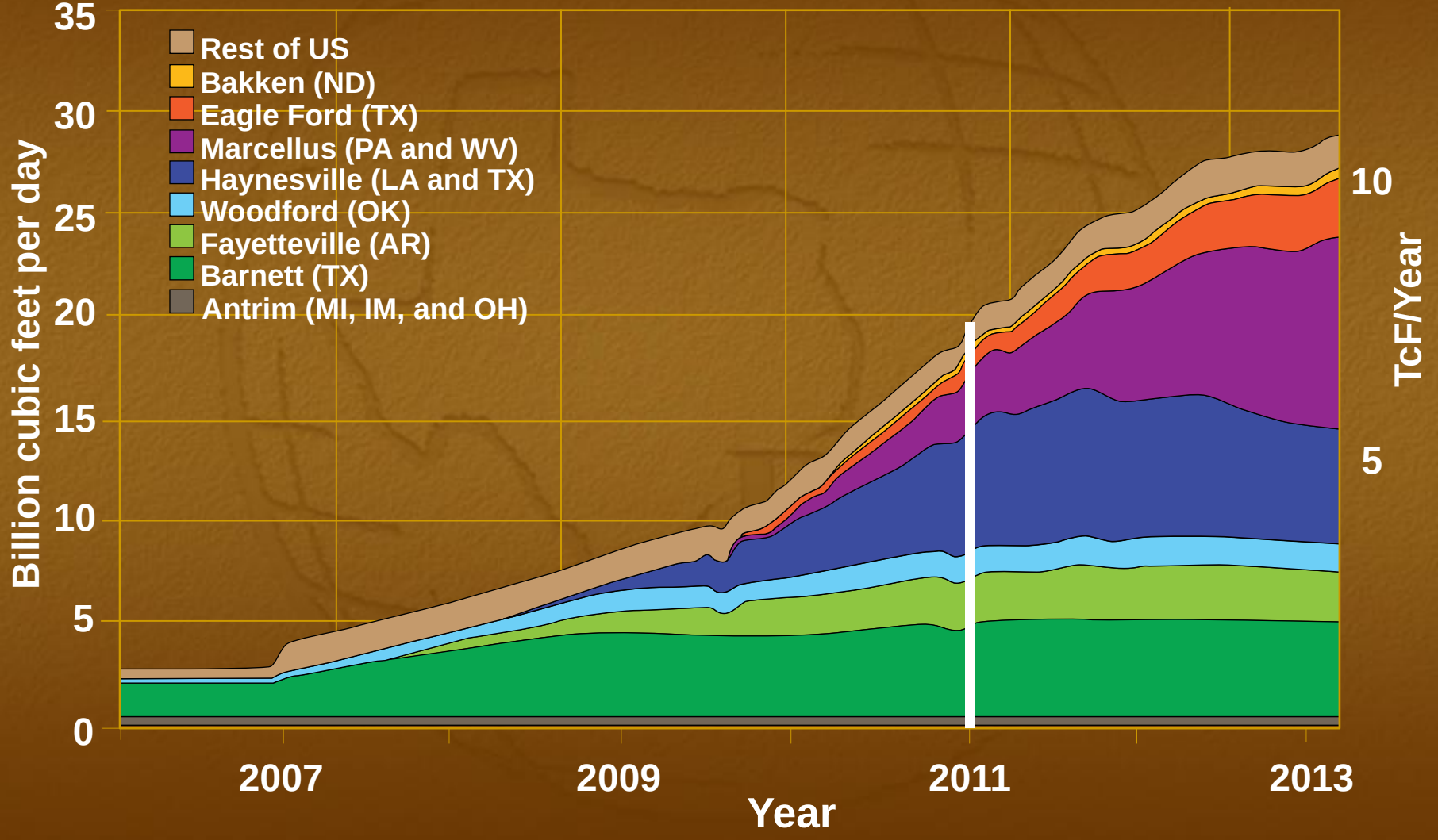
Estimated Annual US Shale
Dry Natural Gas Production, 2000-2011



Source: US EIA

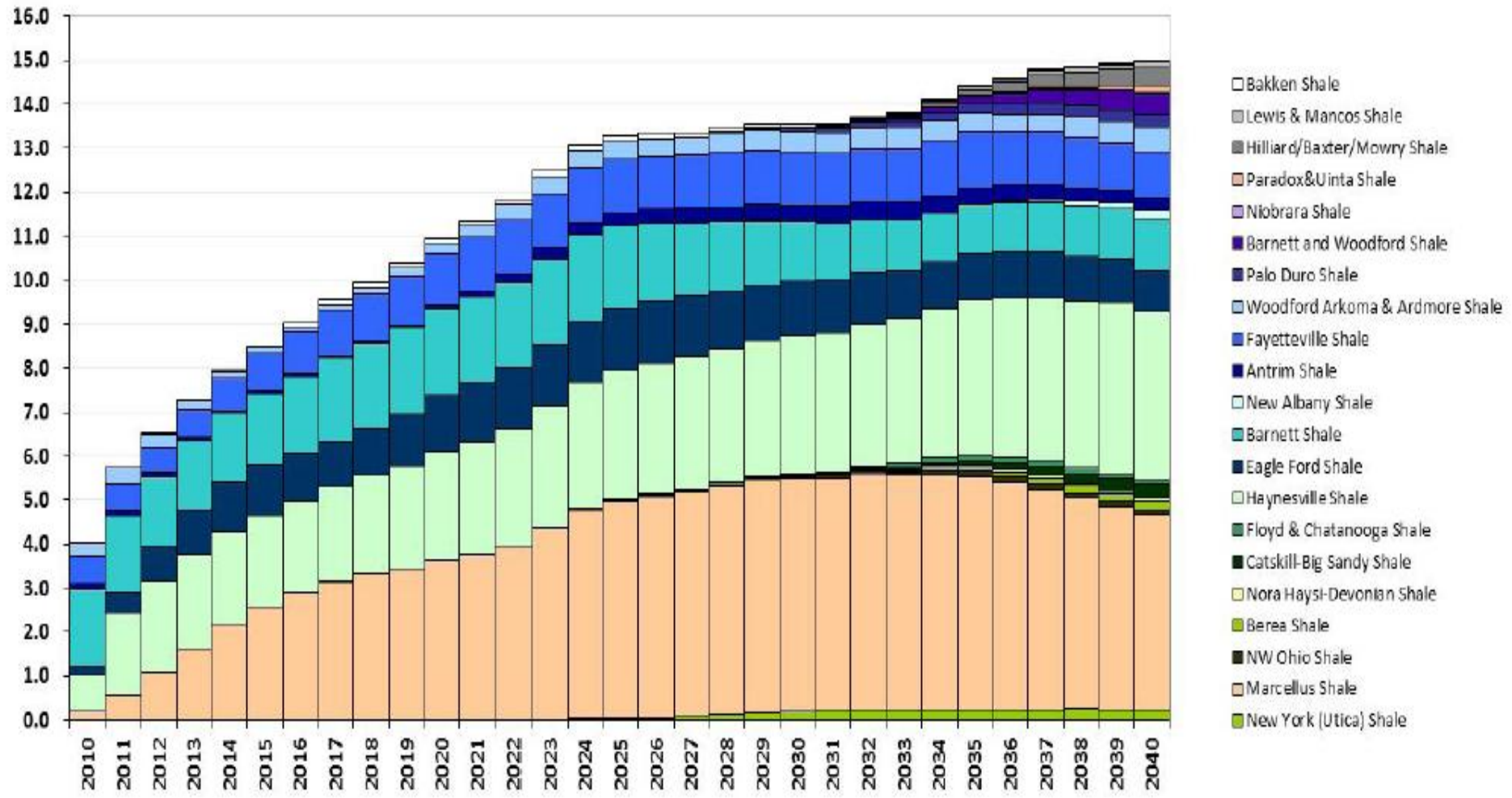
QAe1978

2013 Dry Shale Gas Production



Source: U.S. Energy Information Administration

US Dry Shale Natural Gas Production



Source: US EIA

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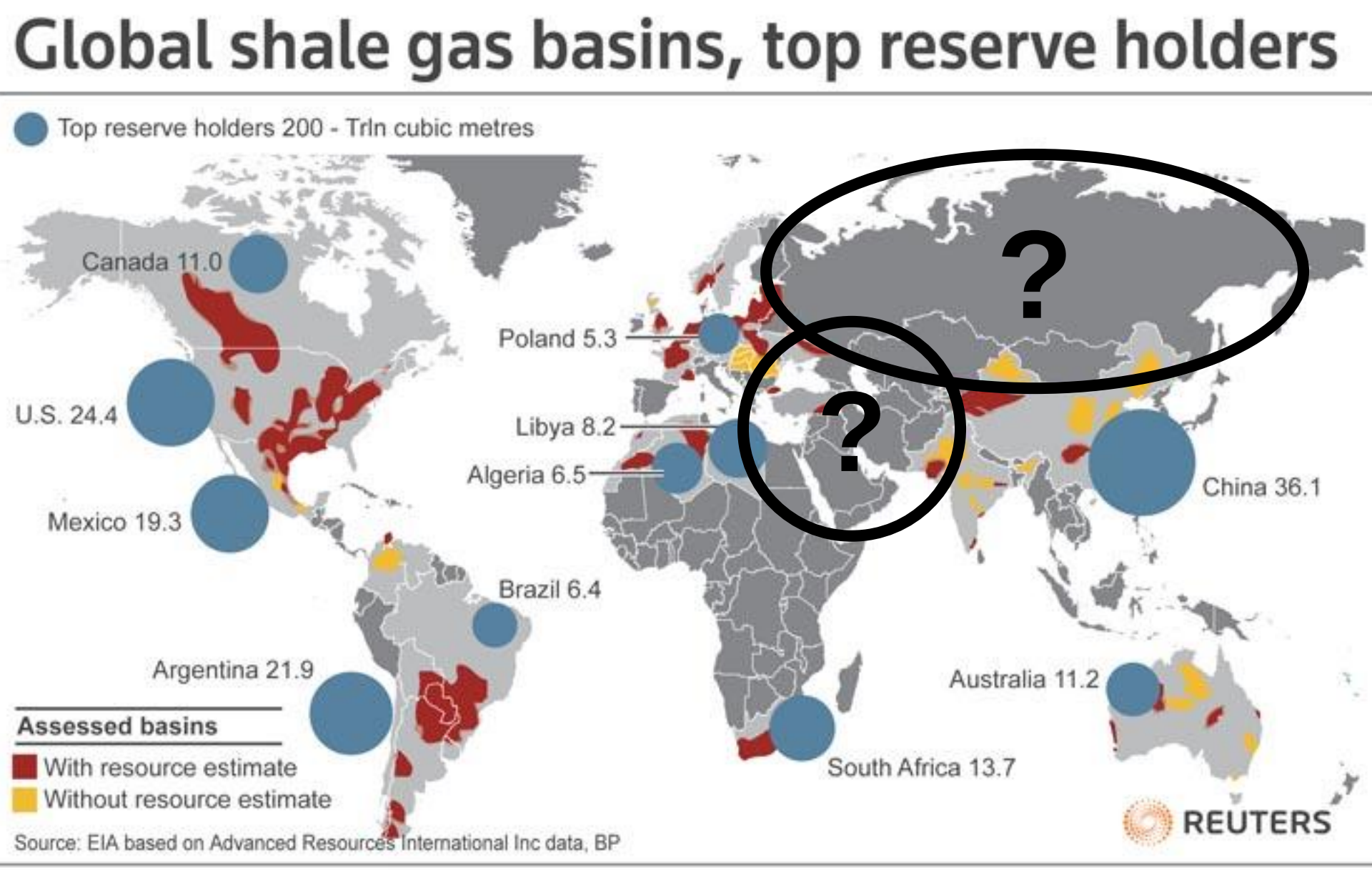
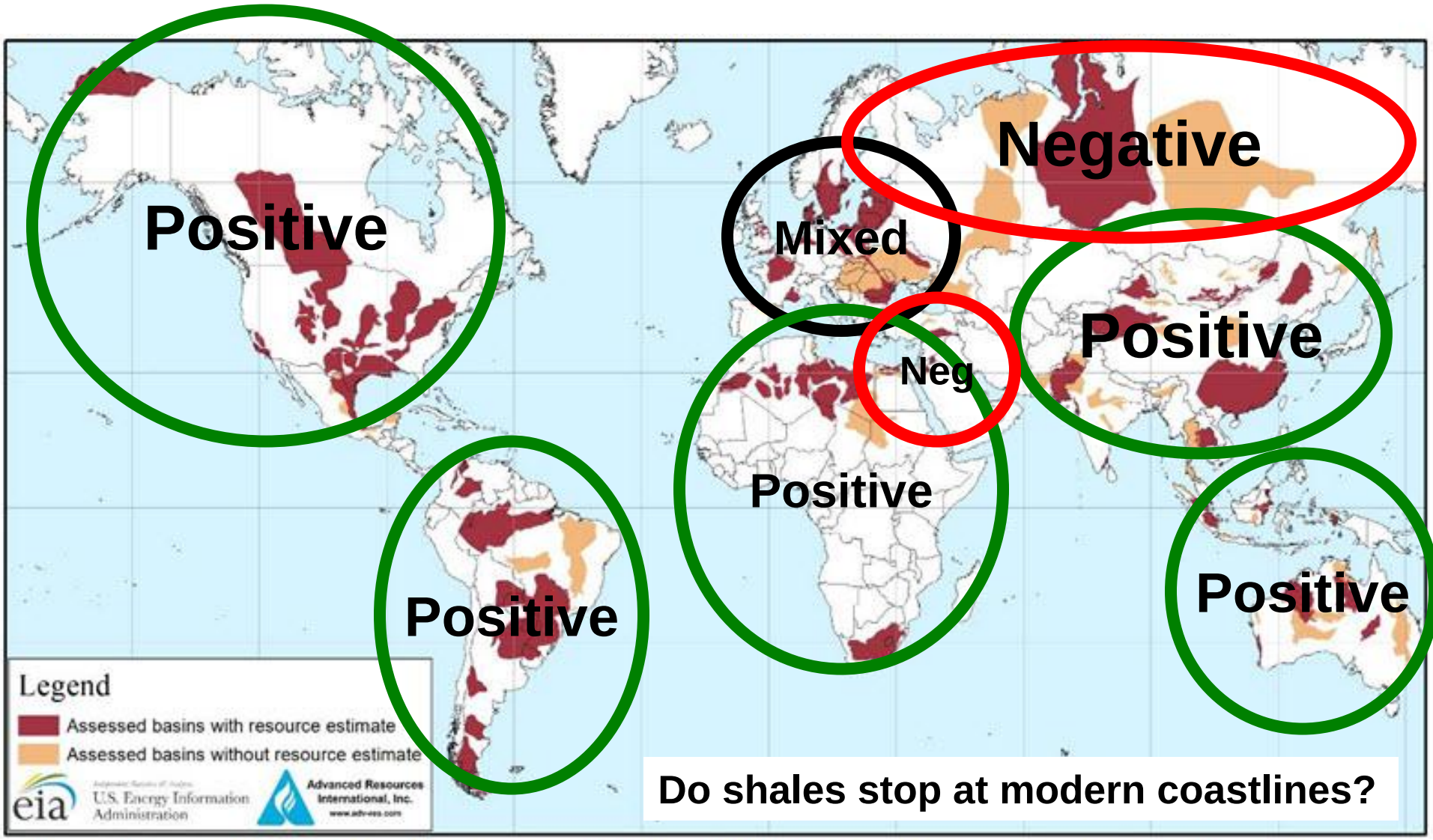
Global Shale Gas



Global Shale Politics



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.

Outline

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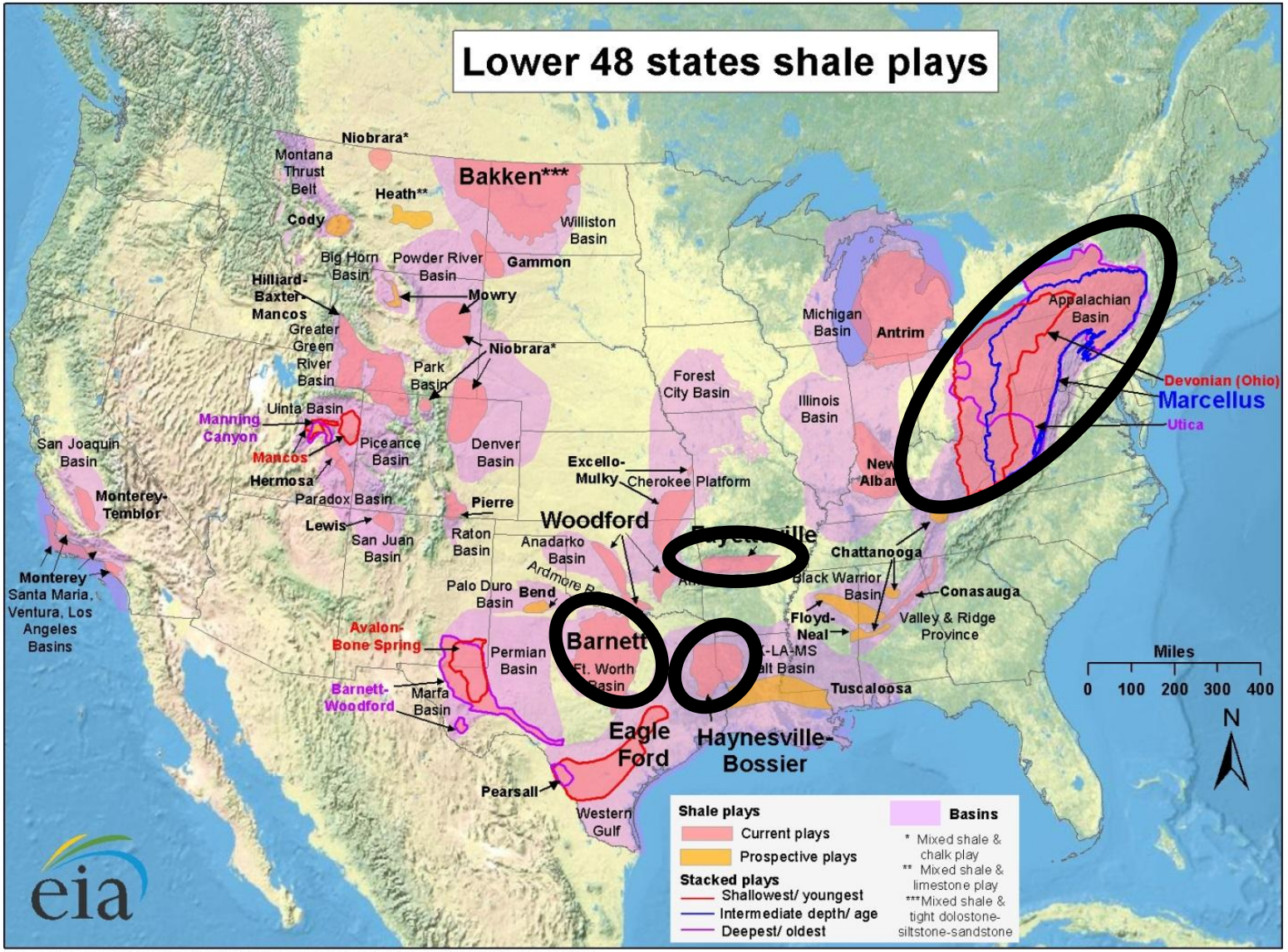
U.S. Shale Gas Plays



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

Key Elements of Bureau Study

- Highly integrated team
- Productivity tiers
- New per-well production decline approach
- Per well drainage area
- Bottom-up field development by tier with full economics integration
- Monte Carlo simulation of future production and reserves

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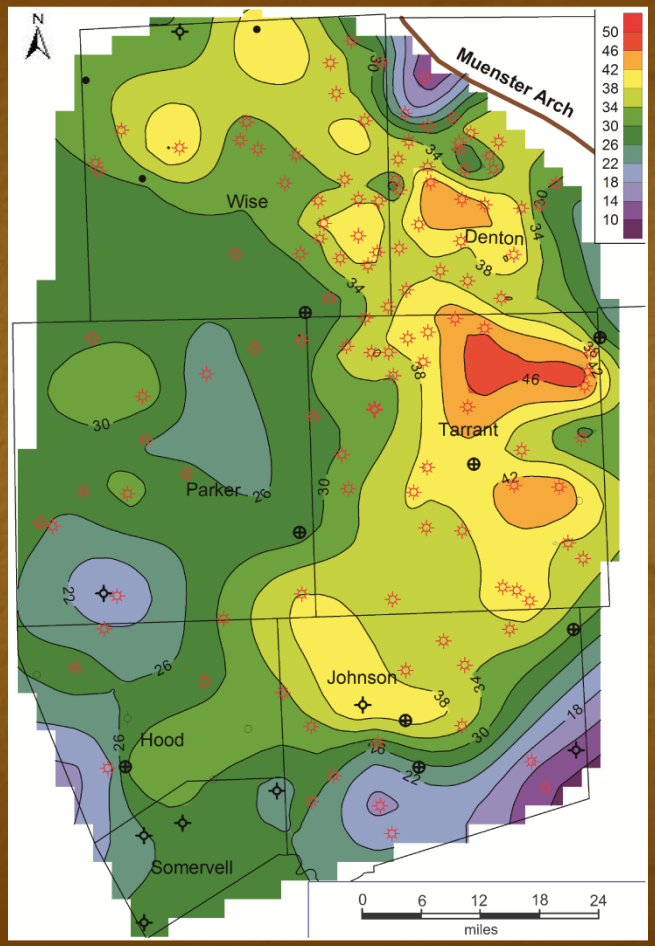
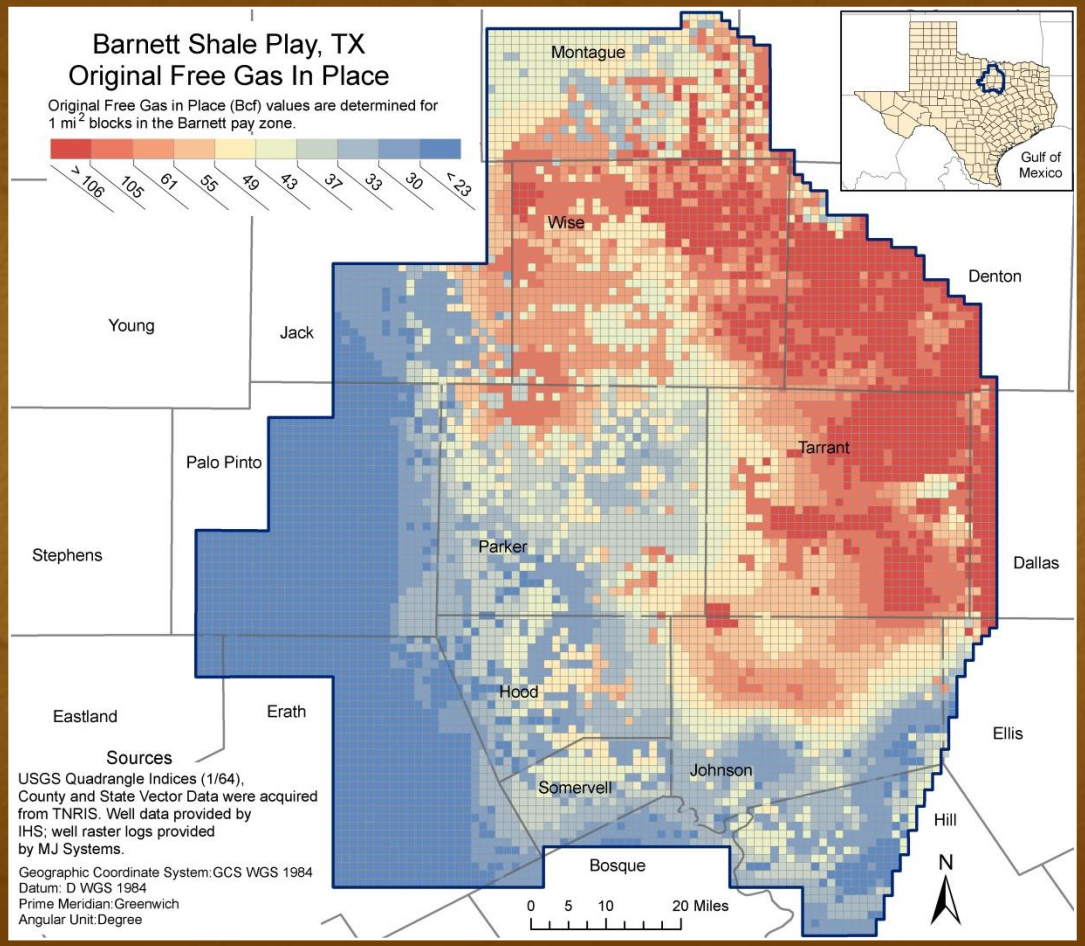
Barnett Shale

Phi * H



OGIP^{free}



Fu et al. 2013 (AAPG Bulletin *in press*)

Barnett Productivity Tiers

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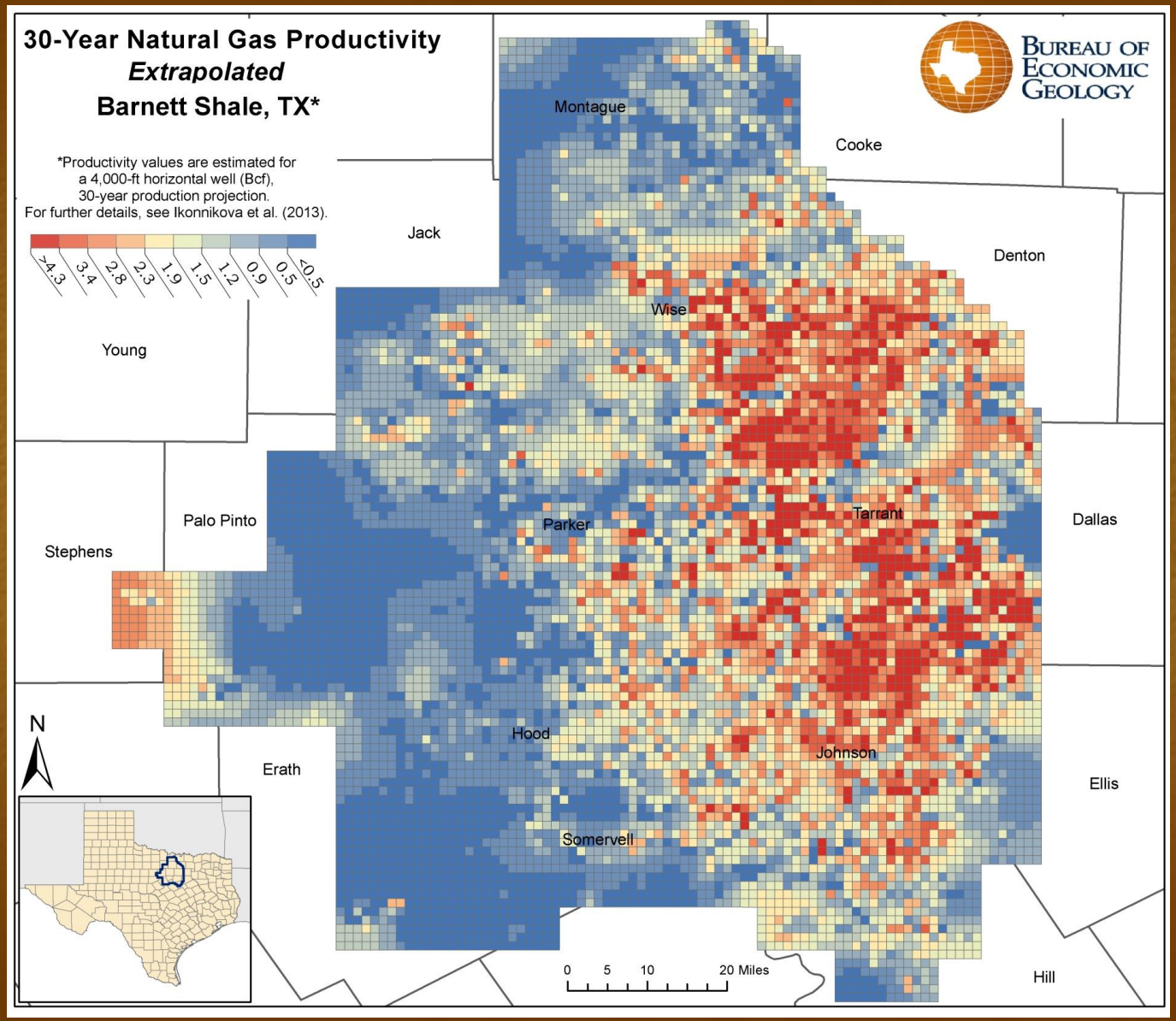

Ikonnikova S., et al. 2013. SPE Res. Eval & Eng (resubmitted)

Barnett Production Outlook

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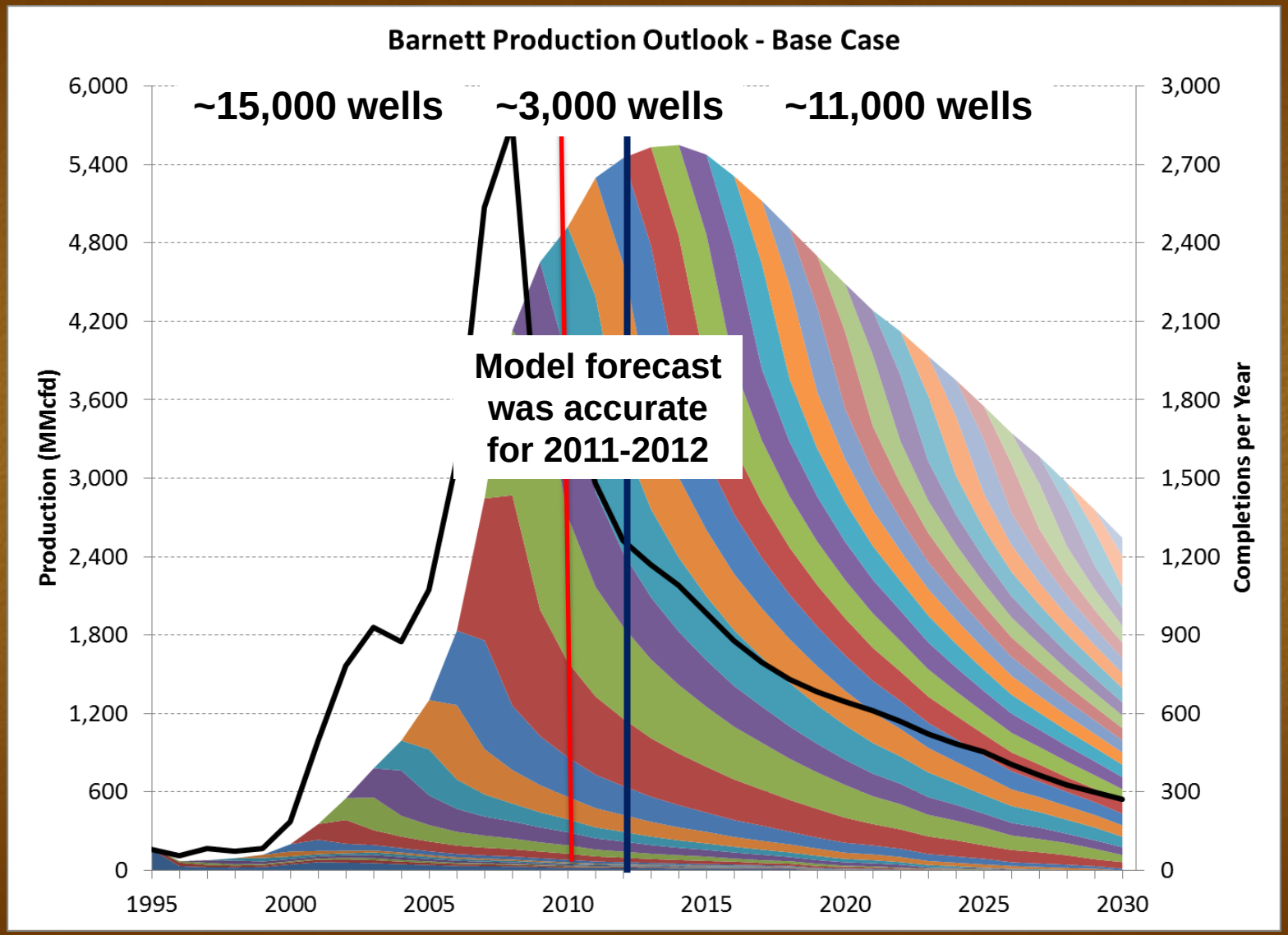
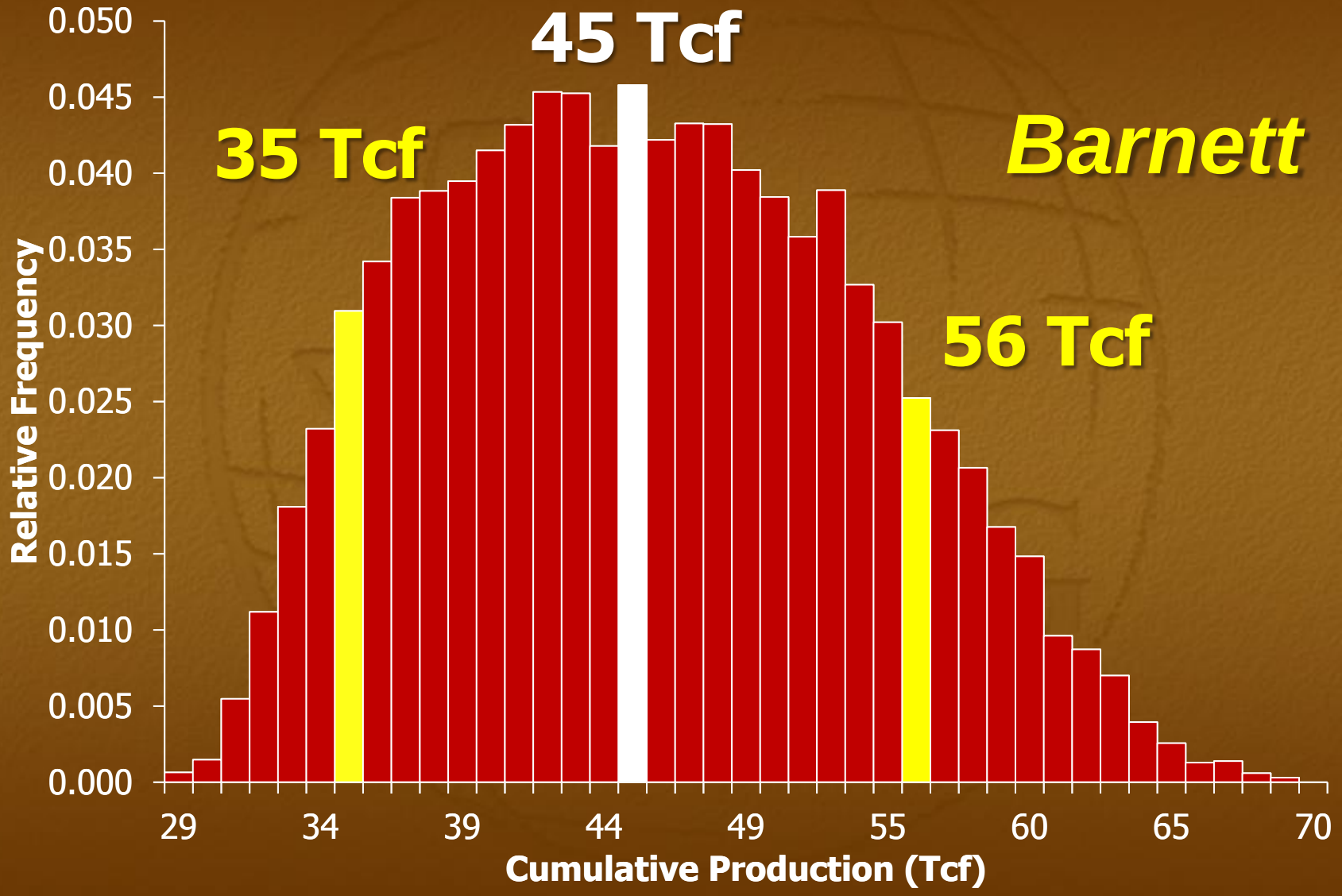


Browning, J. et al. 2013. SPE Econ & Mgmt

Economic Production Distribution



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

Unconventional Reservoirs

Implications

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

Outline

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Hydraulic Fracturing
"Fracking"

Water

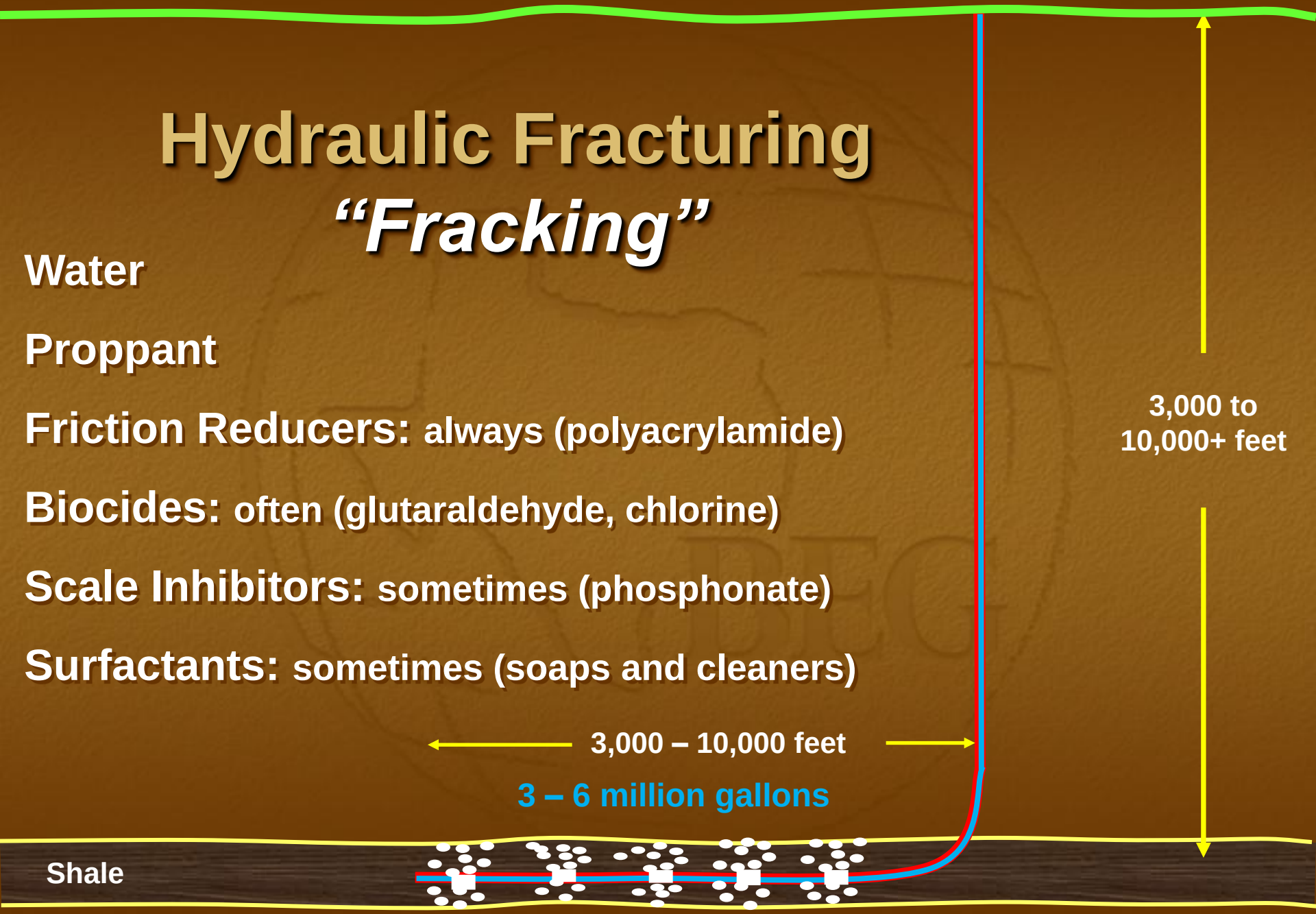
Proppant

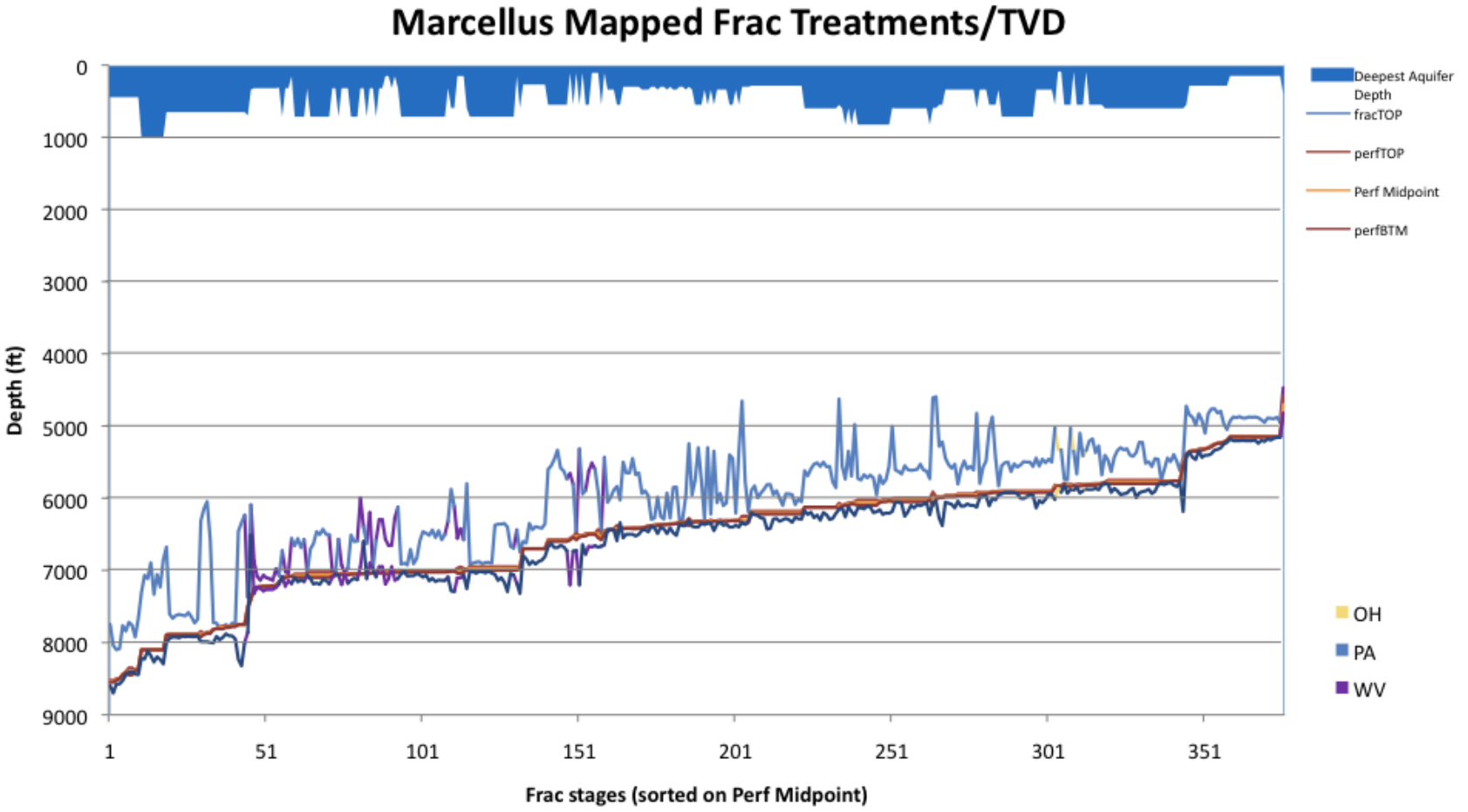
Friction Reducers: always (polyacrylamide)

Biocides: often (glutaraldehyde, chlorine)

Scale Inhibitors: sometimes (phosphonate)

Surfactants: sometimes (soaps and cleaners)





Pinnacle
A HALLIBURTON SERVICE

Unconventional Reservoirs

Implications

- Environmental
  - Traffic/noise/light
  - Land
  - Groundwater
  - Quakes
  - NORM
  - Methane and Carbon
- Security
  - Available
  - Affordable
  - Reliable

Not mutually exclusive…

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Environmental Issues
Regulatory Considerations

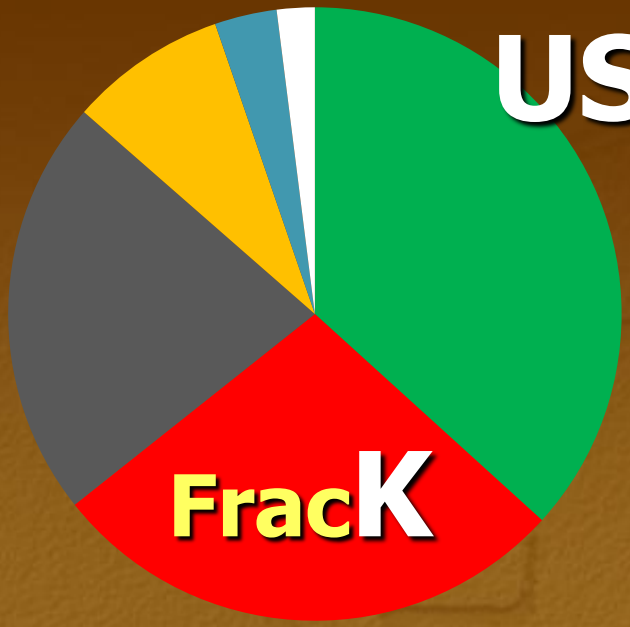
I. **Mandatory baseline data**
II. **Cement all gas producing zones**
III. **Minimize fresh water use on the front end**
IV. **Full disclosure of chemicals**
V. **Handle flowback and produced water**
    a. **Treat and reuse**
    b. **Dispose: characterize for faults**
VI. **Minimize methane emissions**
VII. **Minimize surface impact**

after Rao, 2012

Tinker, 2013

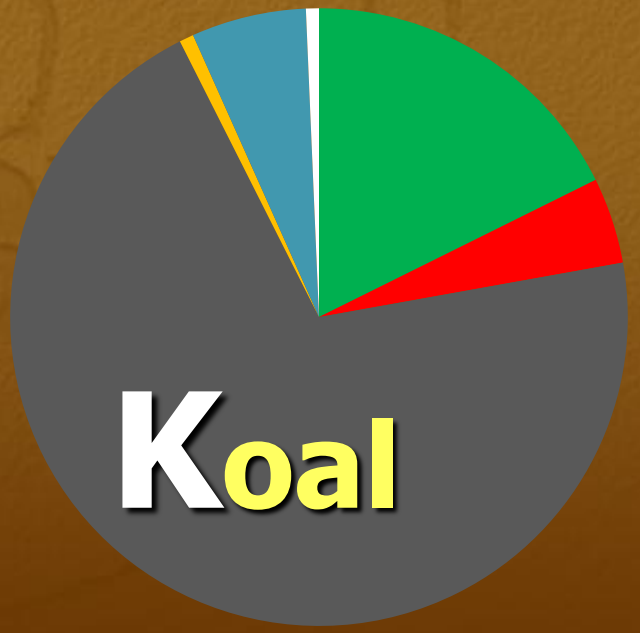
"K" is for…

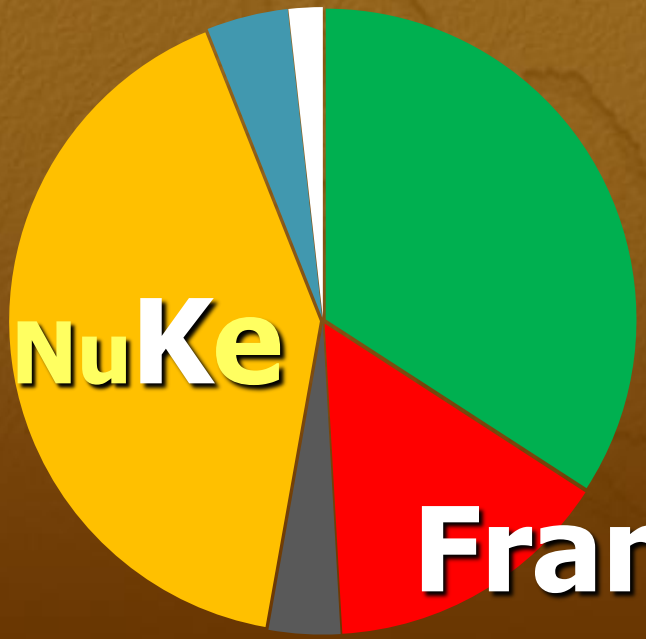
US



Oil
Natural gas
Coal
Nuclear energy
Hydro electricity
Renewables

China

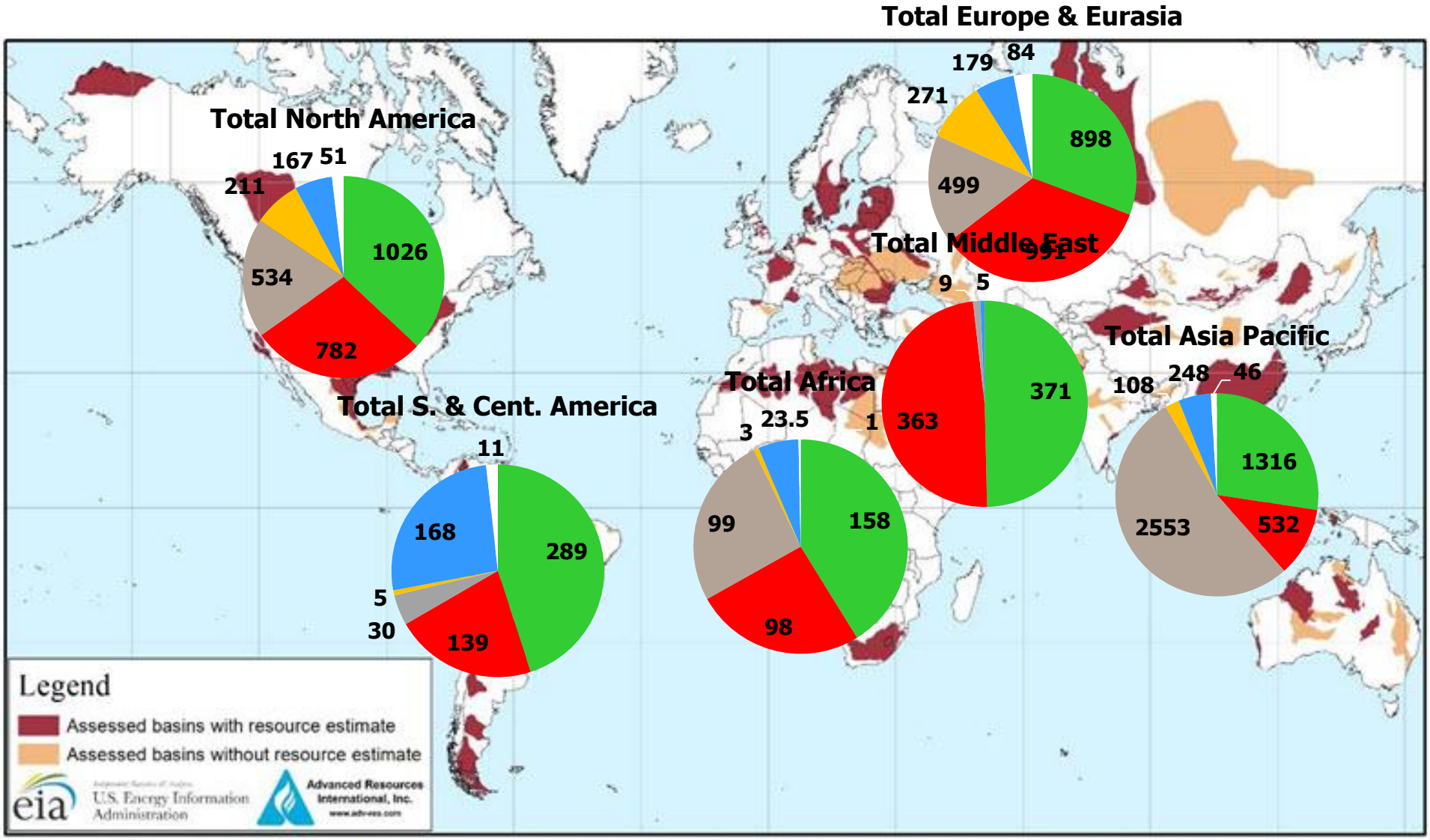




France

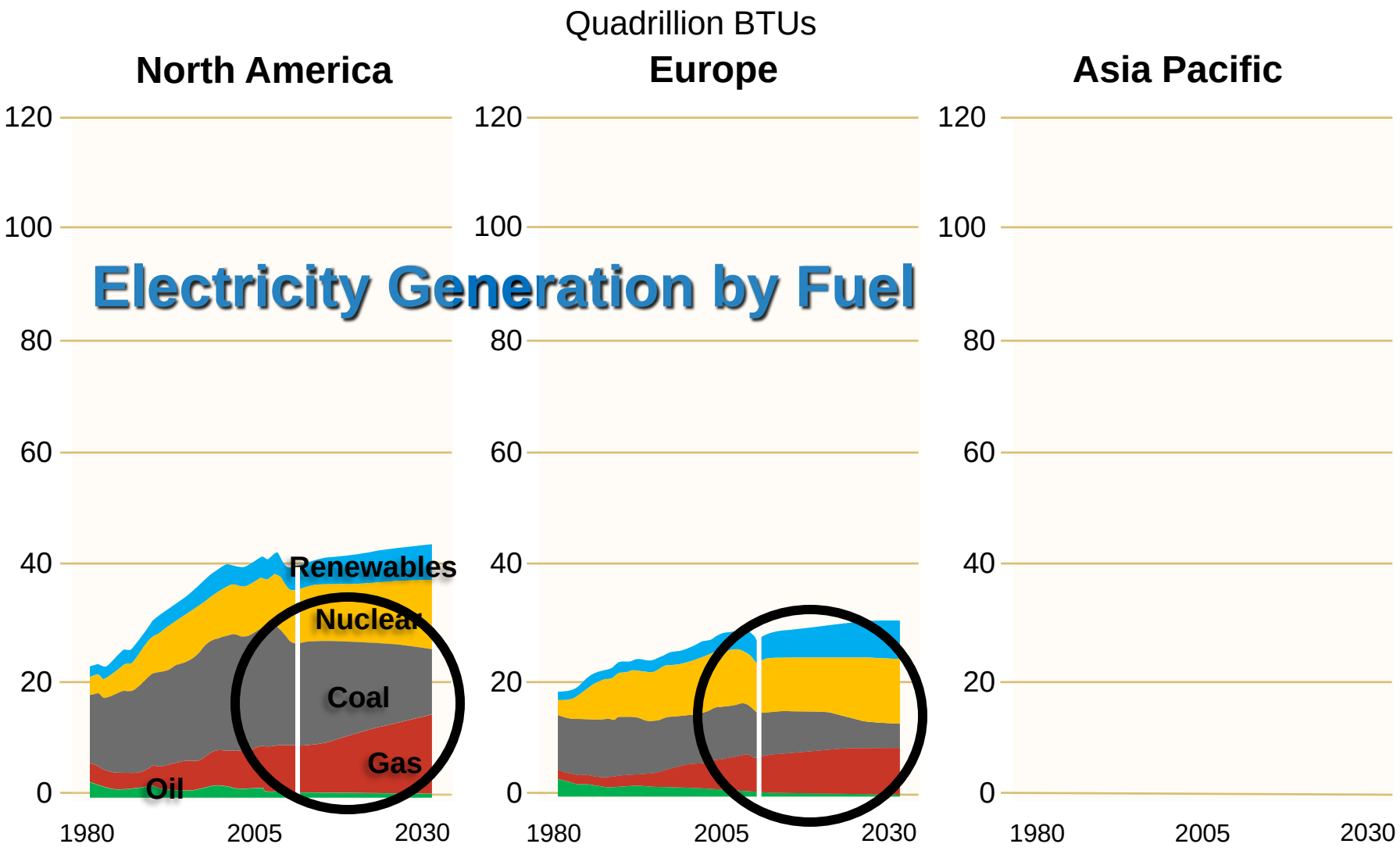
Tinker, 2013

Global Energy Mix



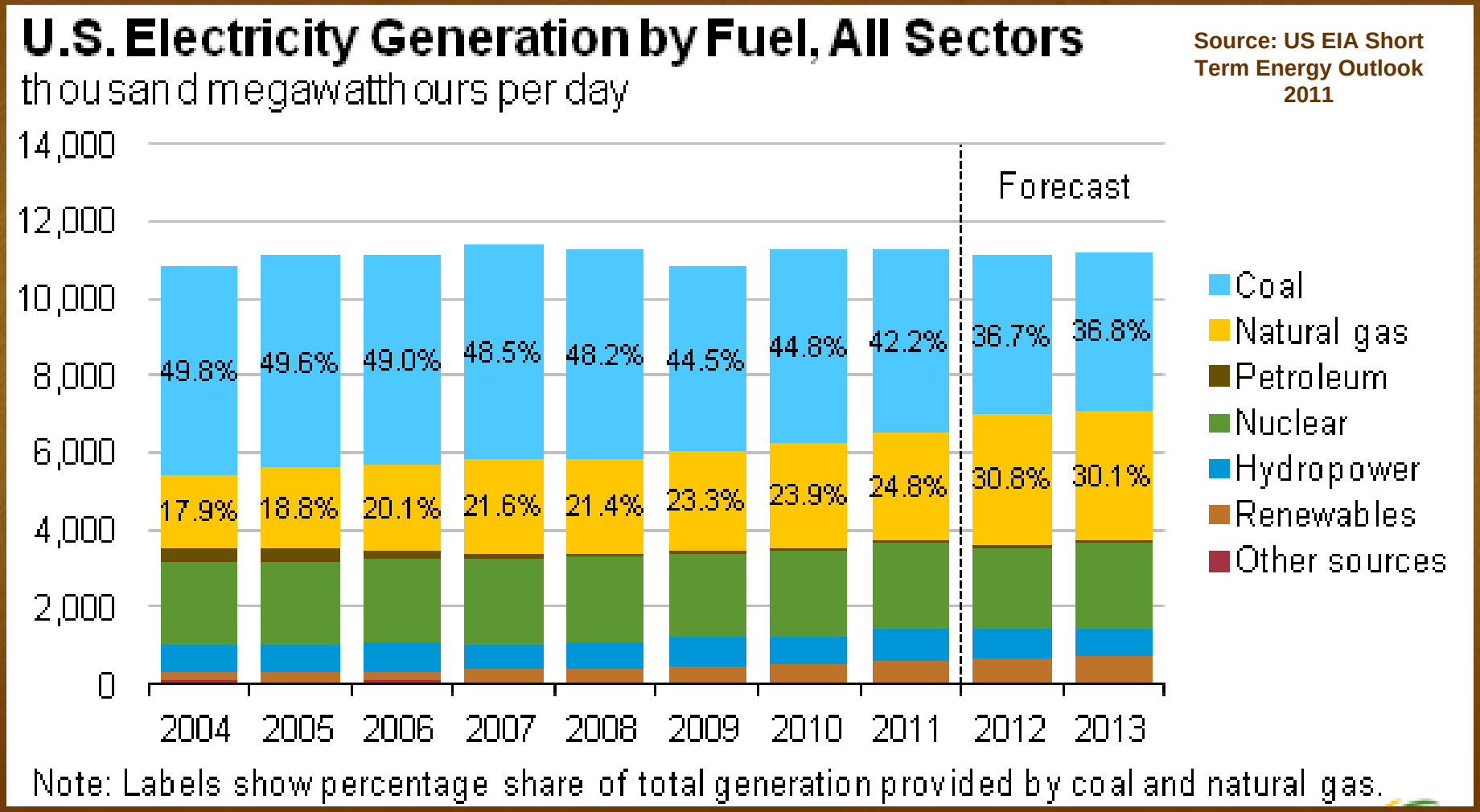
Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.

The Future Mix



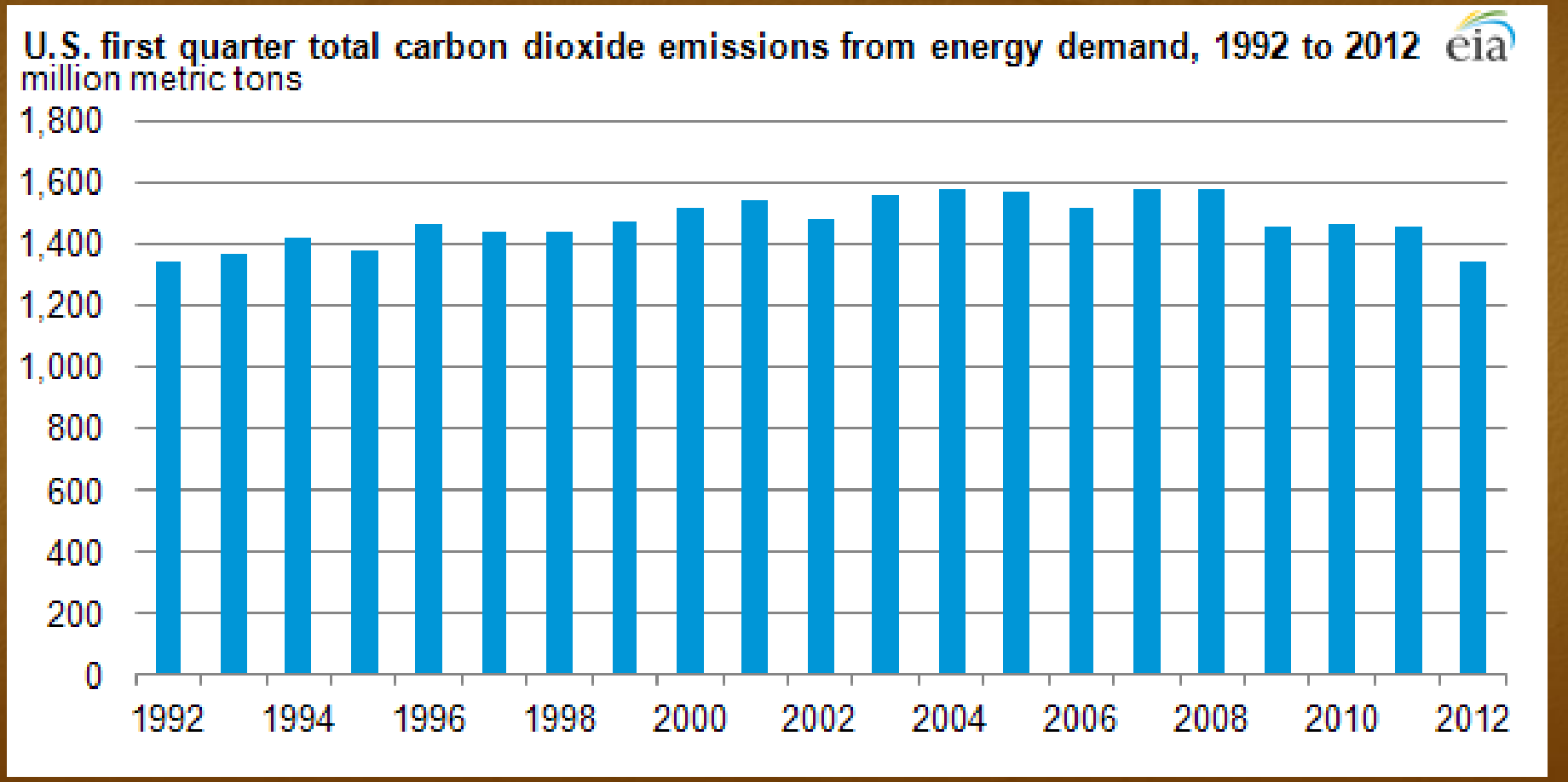
ExxonMobil Corporation, 2010, The outlook for energy: a view to 2030: ExxonMobil report, 53 p.

US Electricity Energy Mix



Tinker, 2013

US CO2 Emissions



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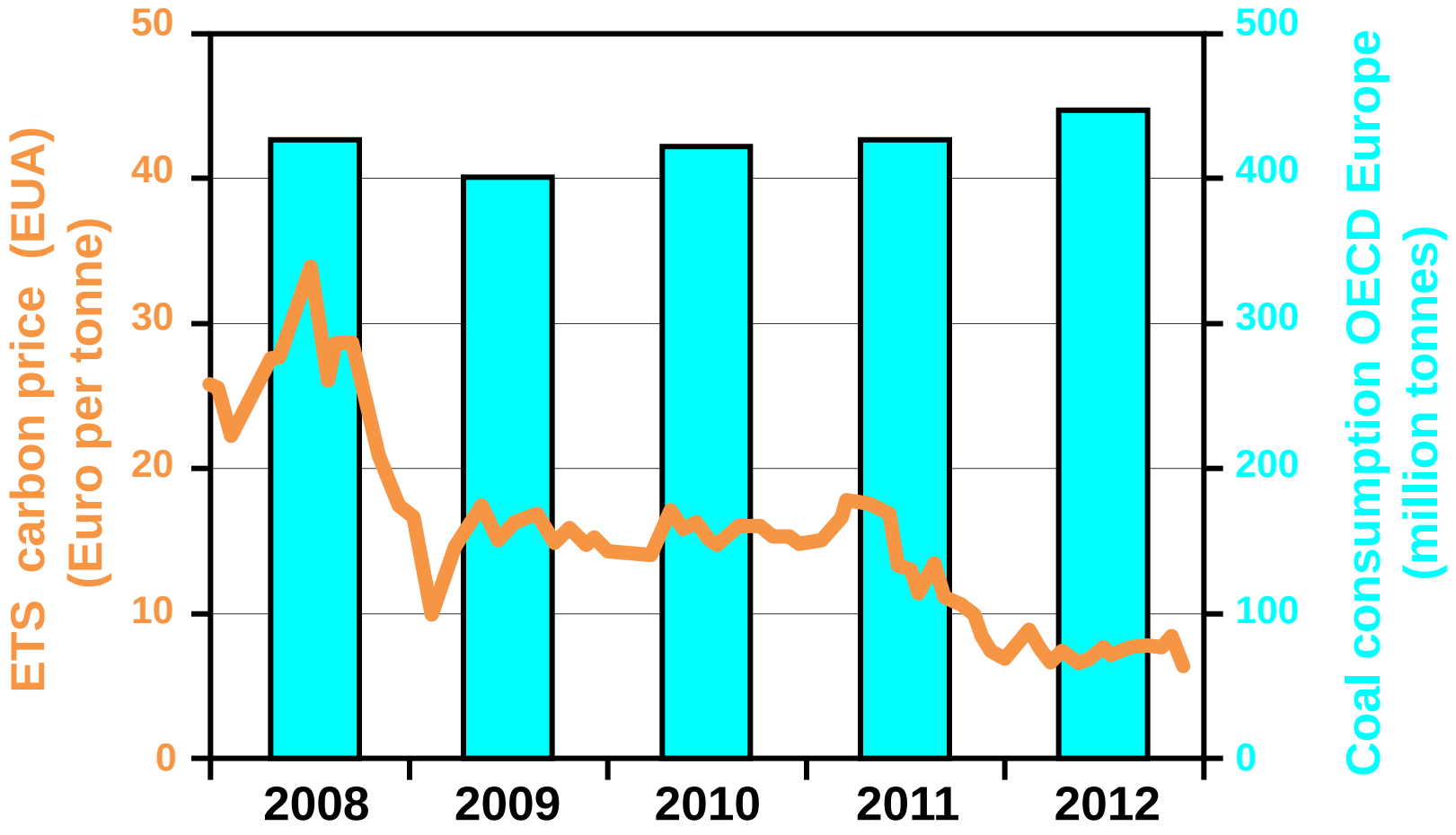
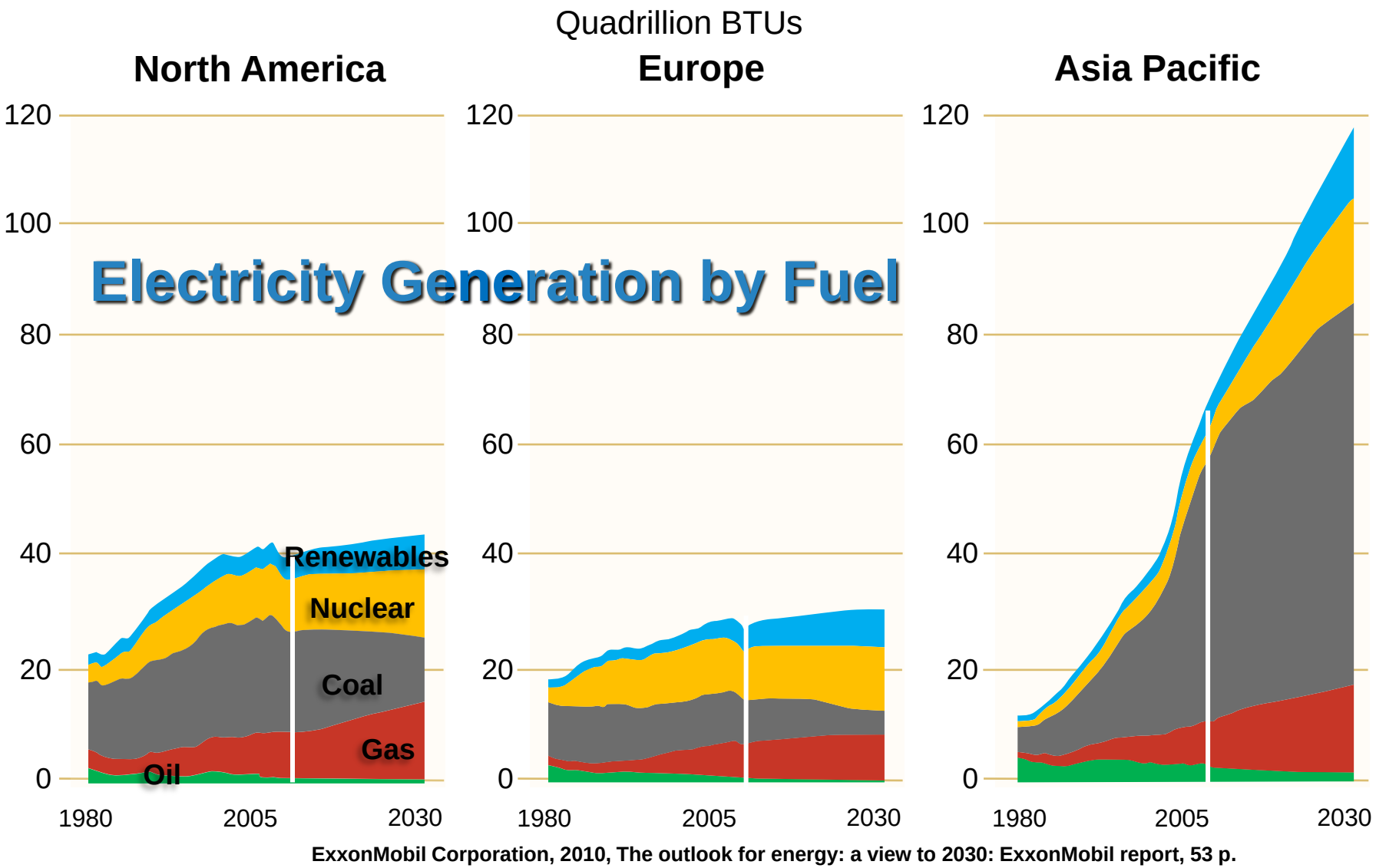
Coal Consumption in Europe



The Future Mix



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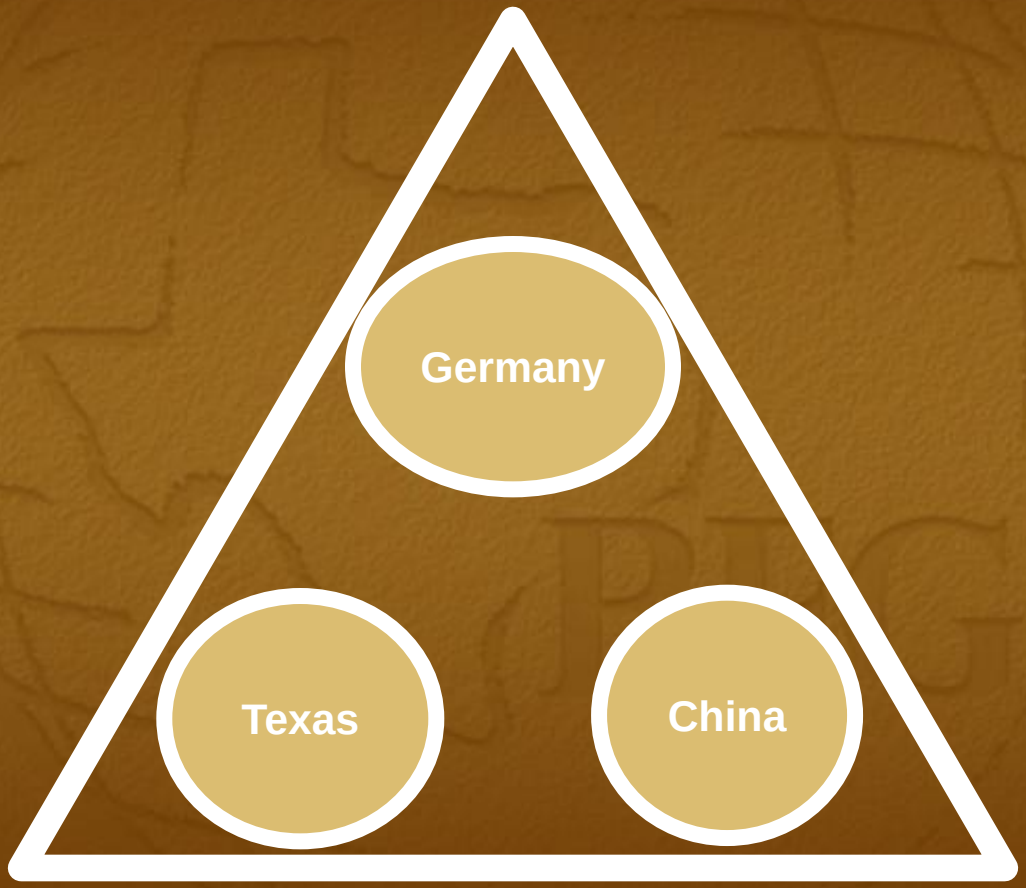
Tinker, 2013

The 3E Waltz



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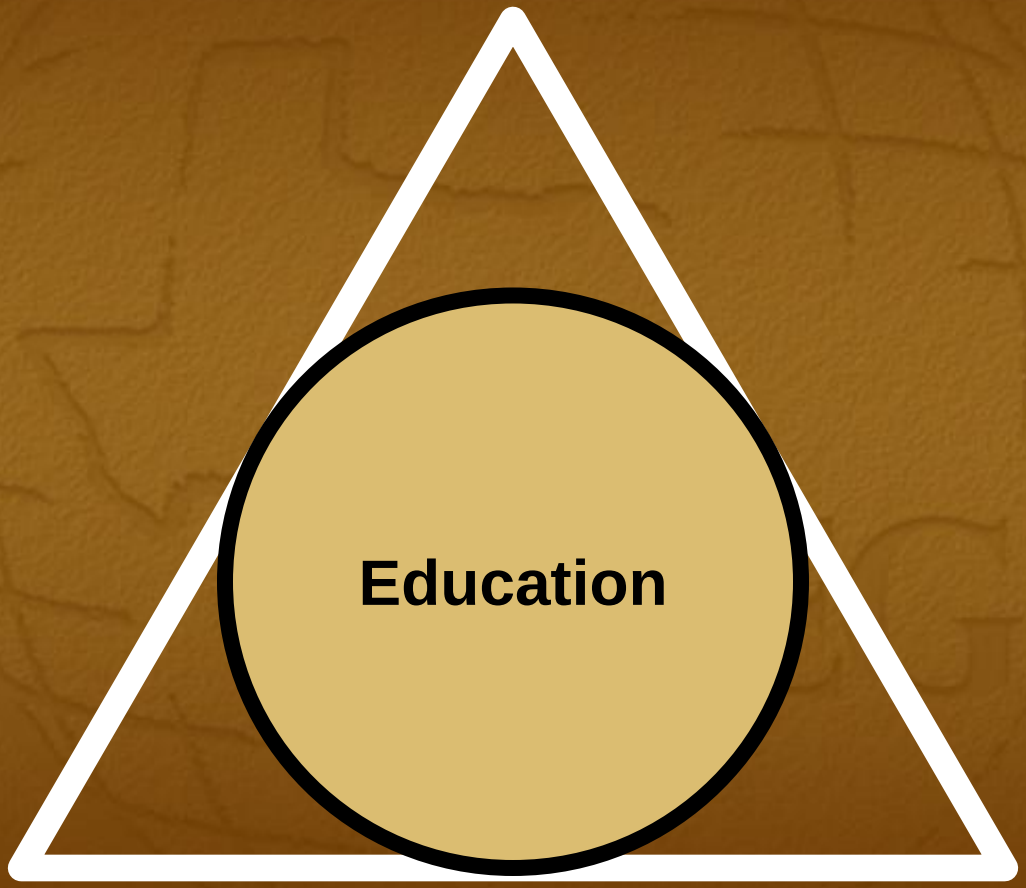

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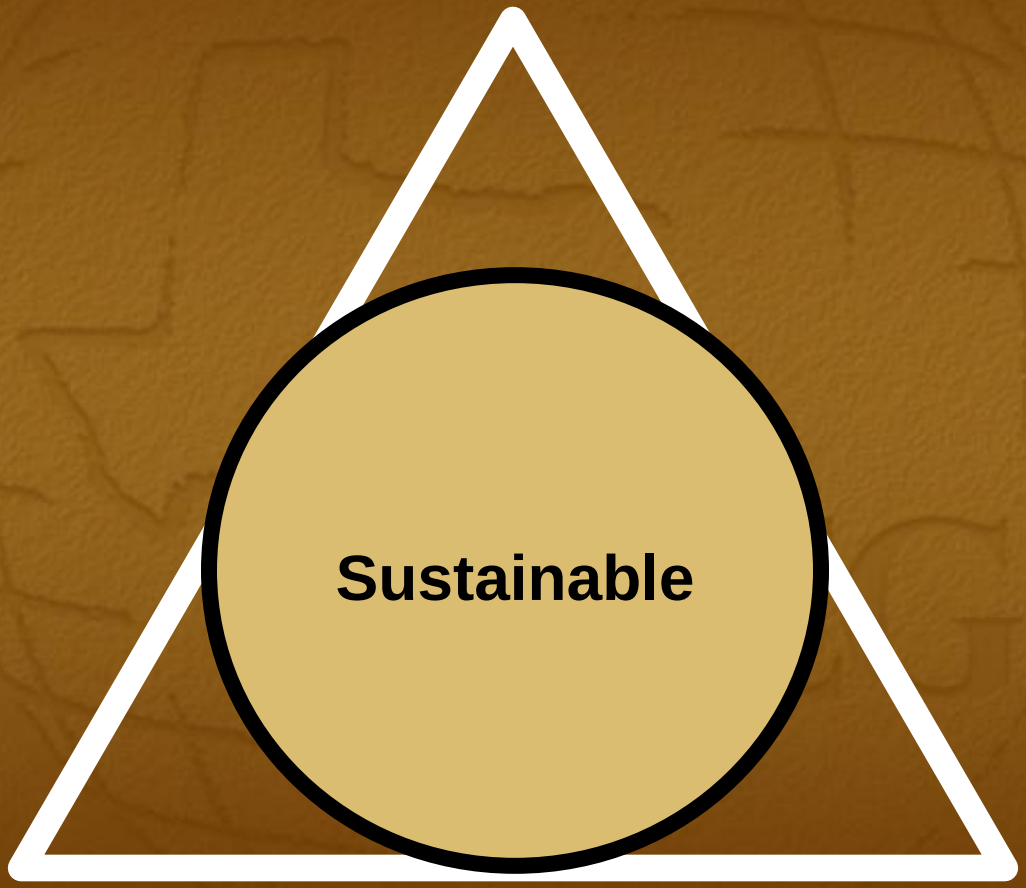
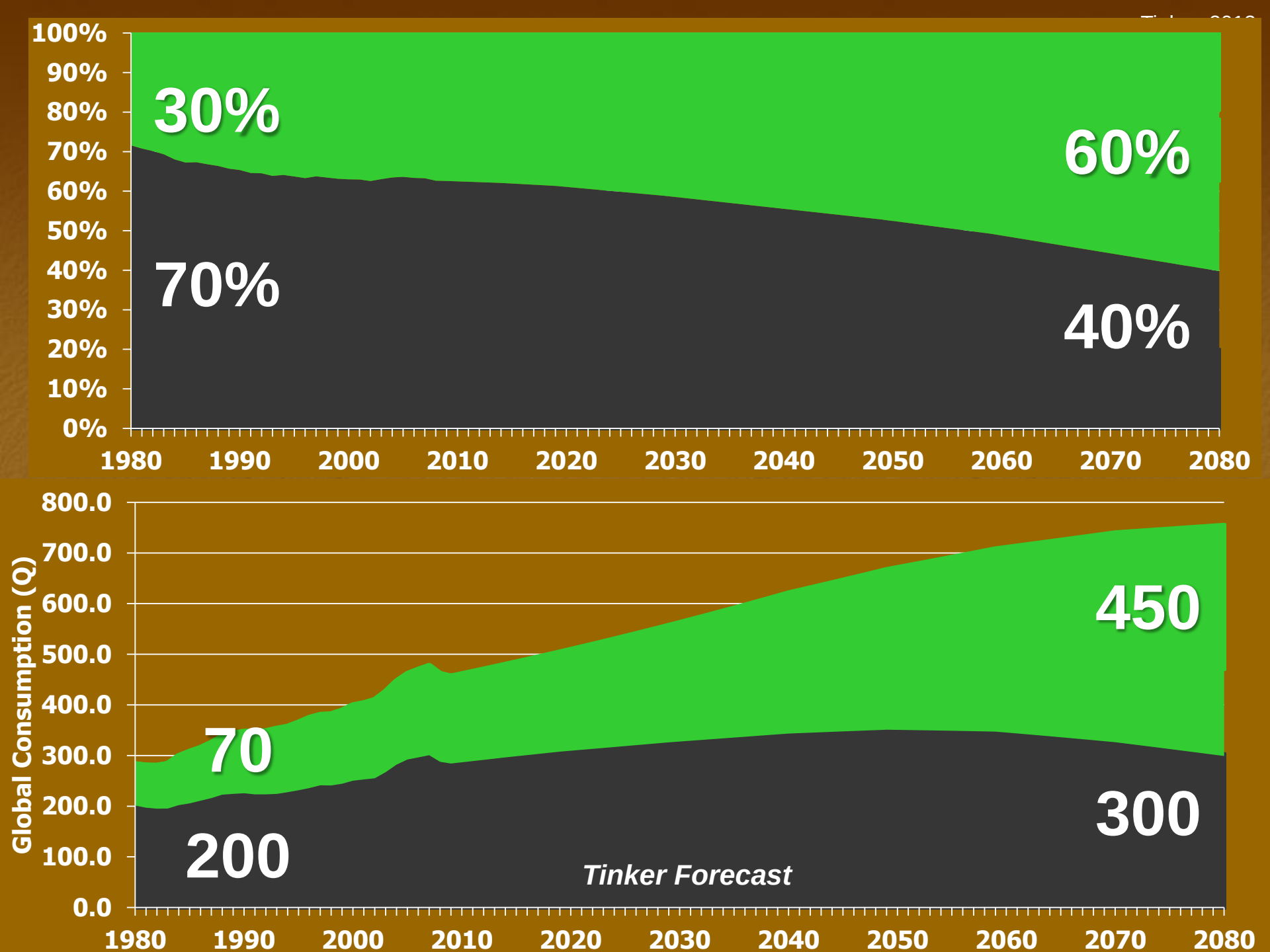
Secure Energy




100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
30%
70%
60%
40%
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
Global Consumption (Q)
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
70
200
450
300
Tinker Forecast
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080

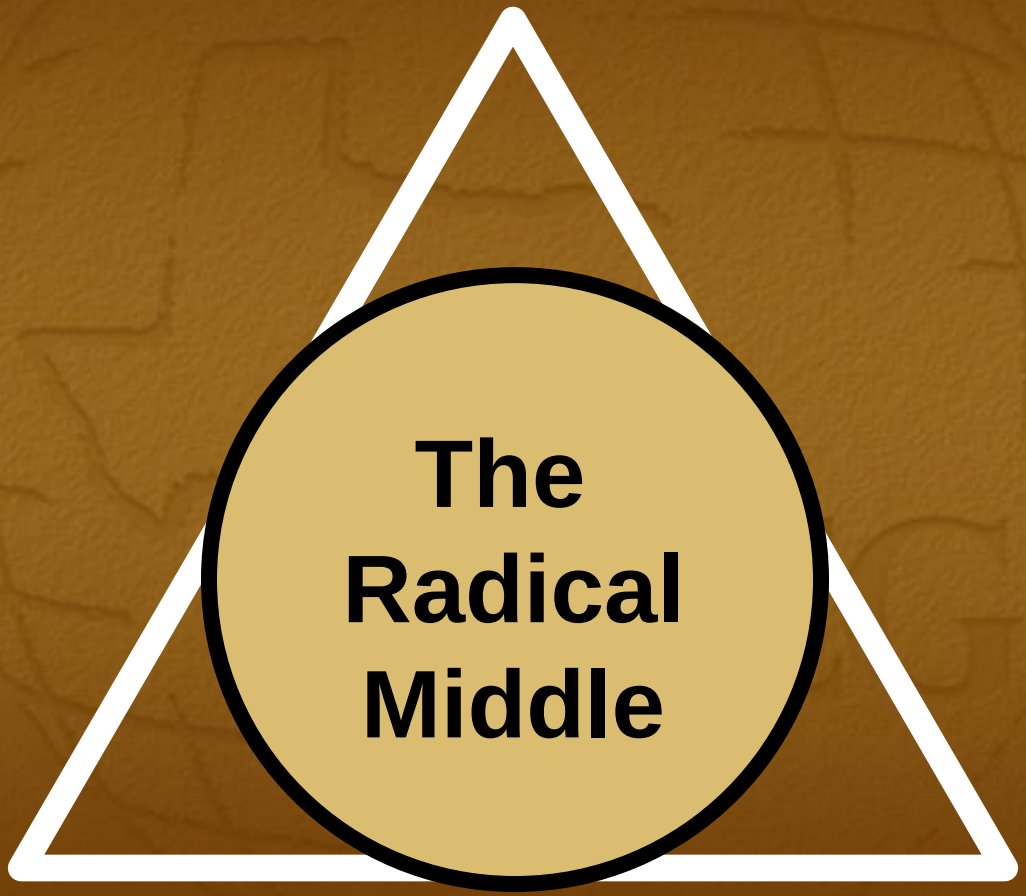
What Can Be Learned

1) Above ground regulatory and perception issues are as important as below ground technical challenges.
2) Diverse energy portfolios are inevitable, and for the most part desirable, but there are consequences.
3) Energy mix is driven by energy security, and policy attempts to force an energy transition usually have unintended 3E consequences.
4) The global energy transition will take time, but regional transitions can happen quickly!

Tinker, 2013

Leaving our Corners

Government



Academia/NGO

Industry

Imperial College London

Oil Technology Centenary

September, 2013

Happy 100th Birthday

Congratulations from Texas!