GCPA

Oct, 2014

The Role of Shale Gas in North American and Global Power Markets

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Framing Conundrum

A majority of the educated public do not know how electricity is made… nor do they really care.

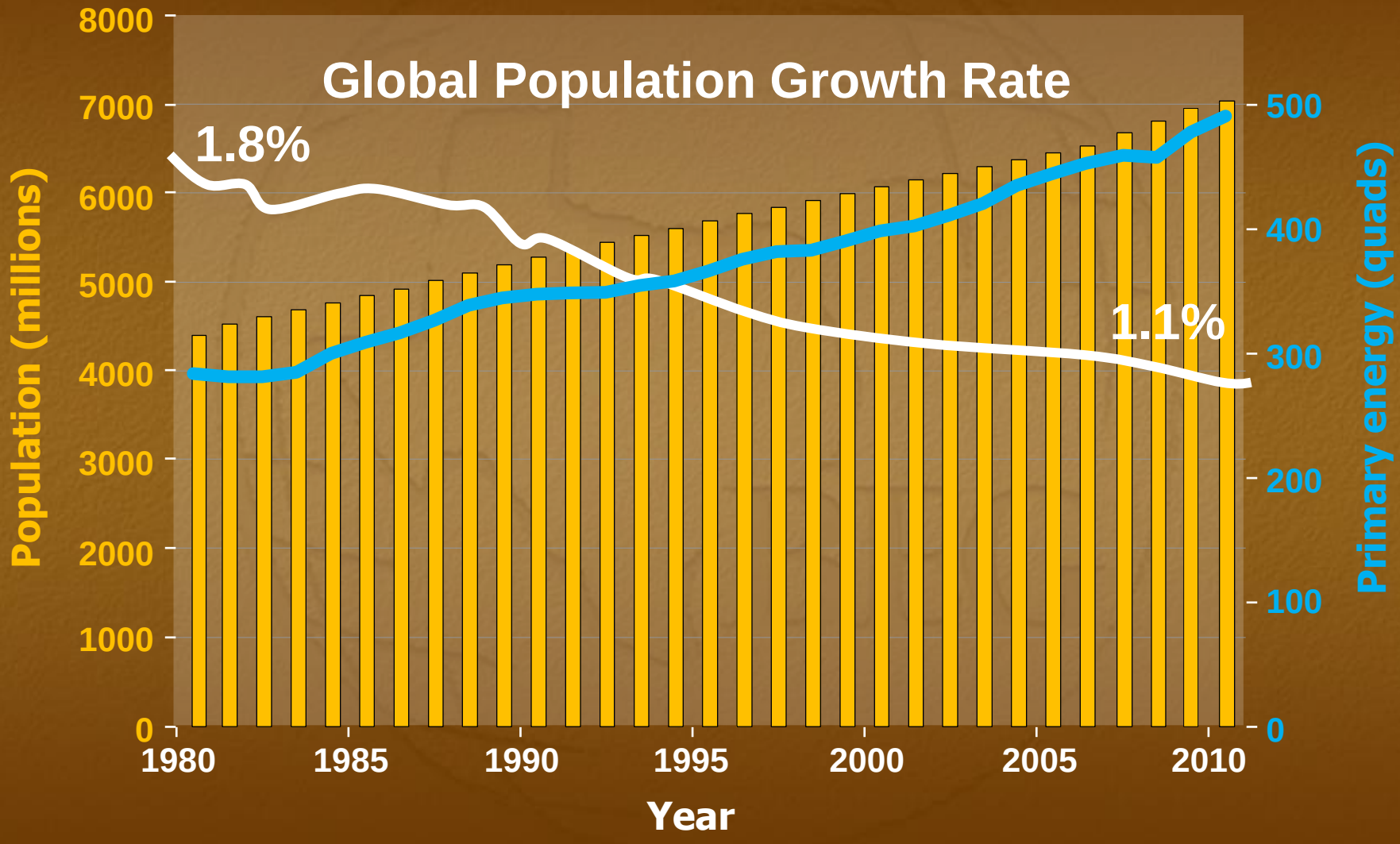
As a result, the public is free to "not like" everything.

We need to take the energy conversation to a different place.

Outline

- Global Demand
- Shale Gas and Electricity
- Market Implications

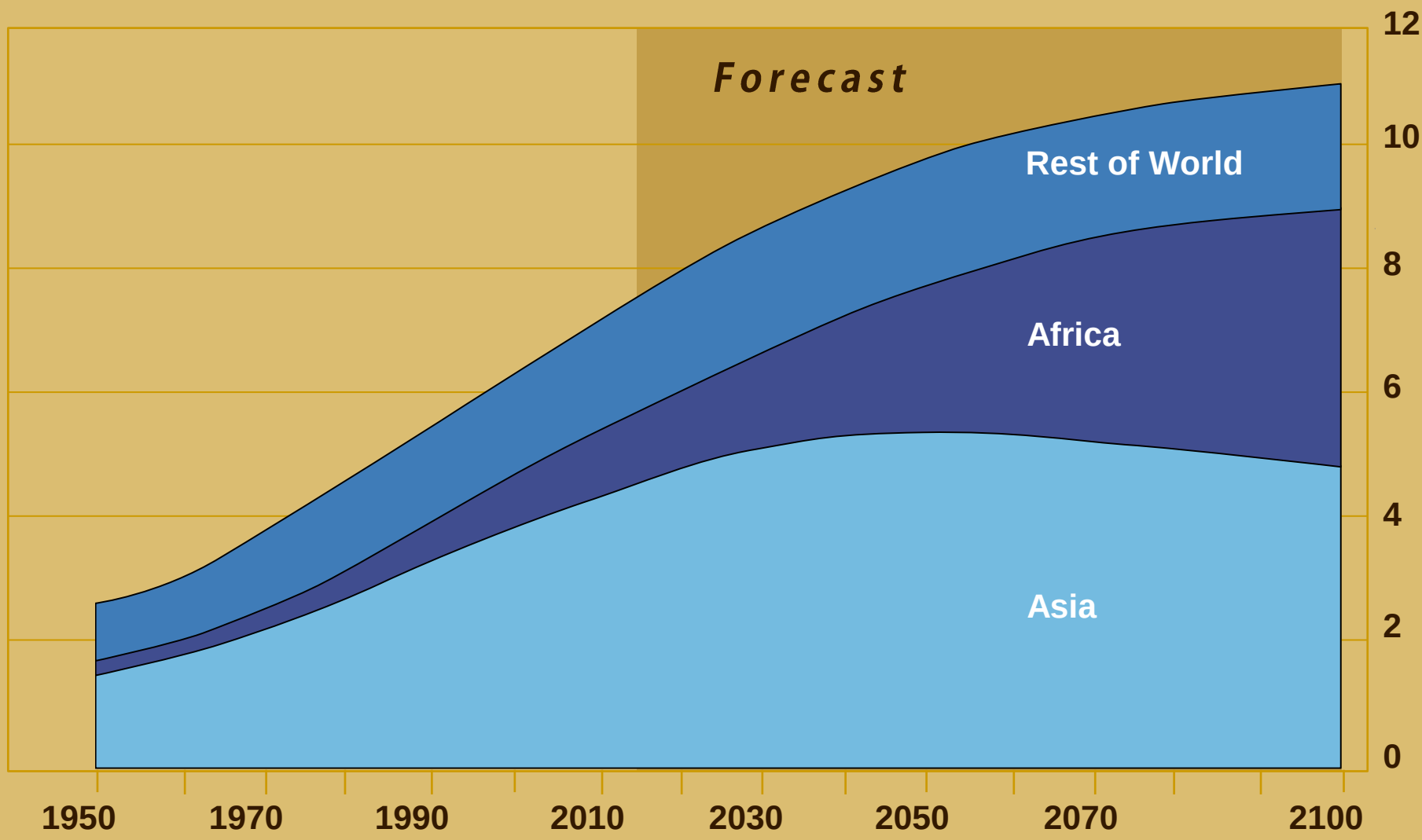
Global Population and Energy



Source: BP Statistical Review of World Energy, 2012
http://www.eia.gov/iea/wecbtu.html

Source: US Census Bureau Int'l Database, June 2011

Global Population and Energy

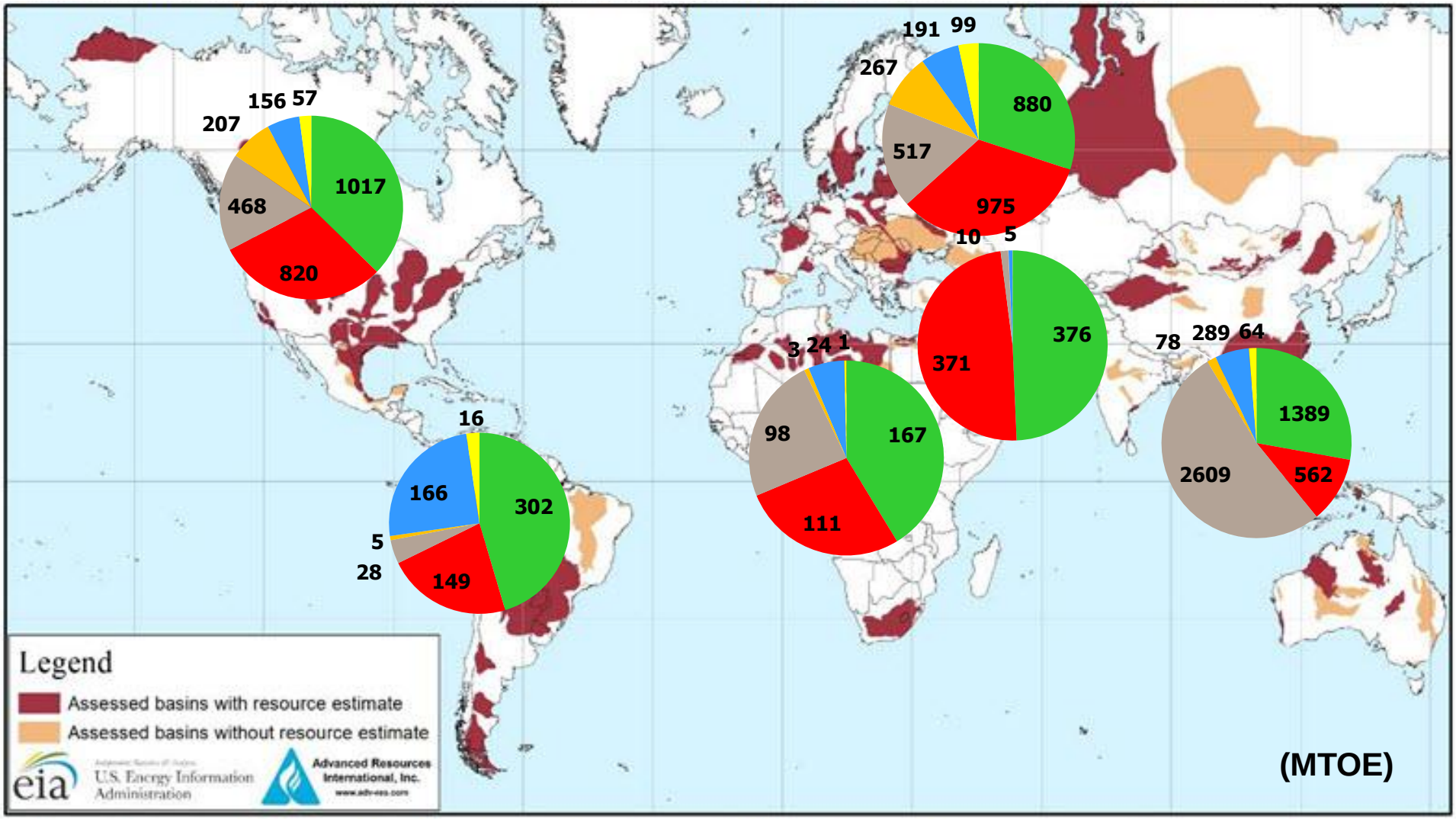


Source: From the UN, as appeared in *The Economist*, August 23, 2014

Population 2015

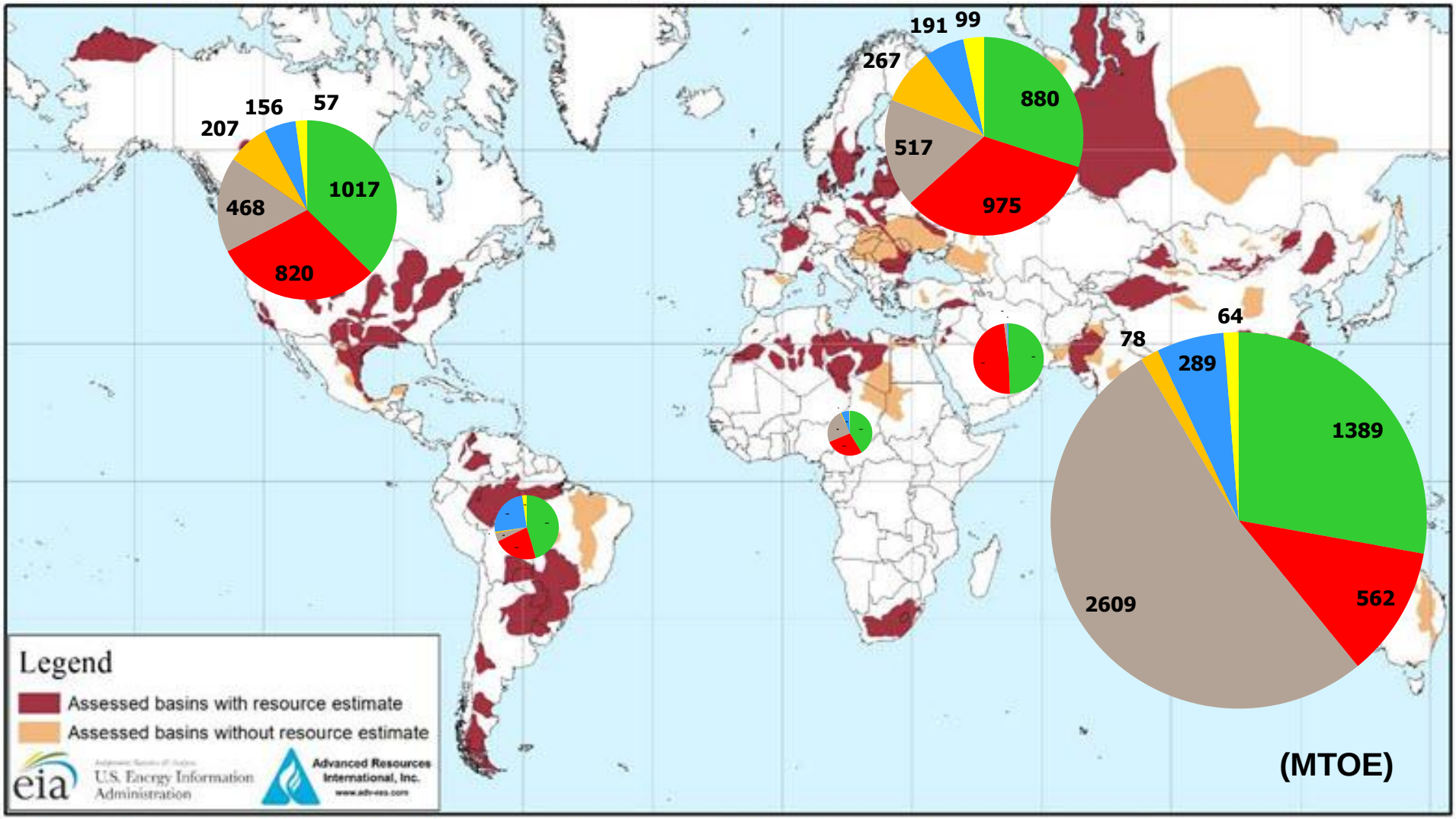
~1 billion people per color

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.

Energy Demand



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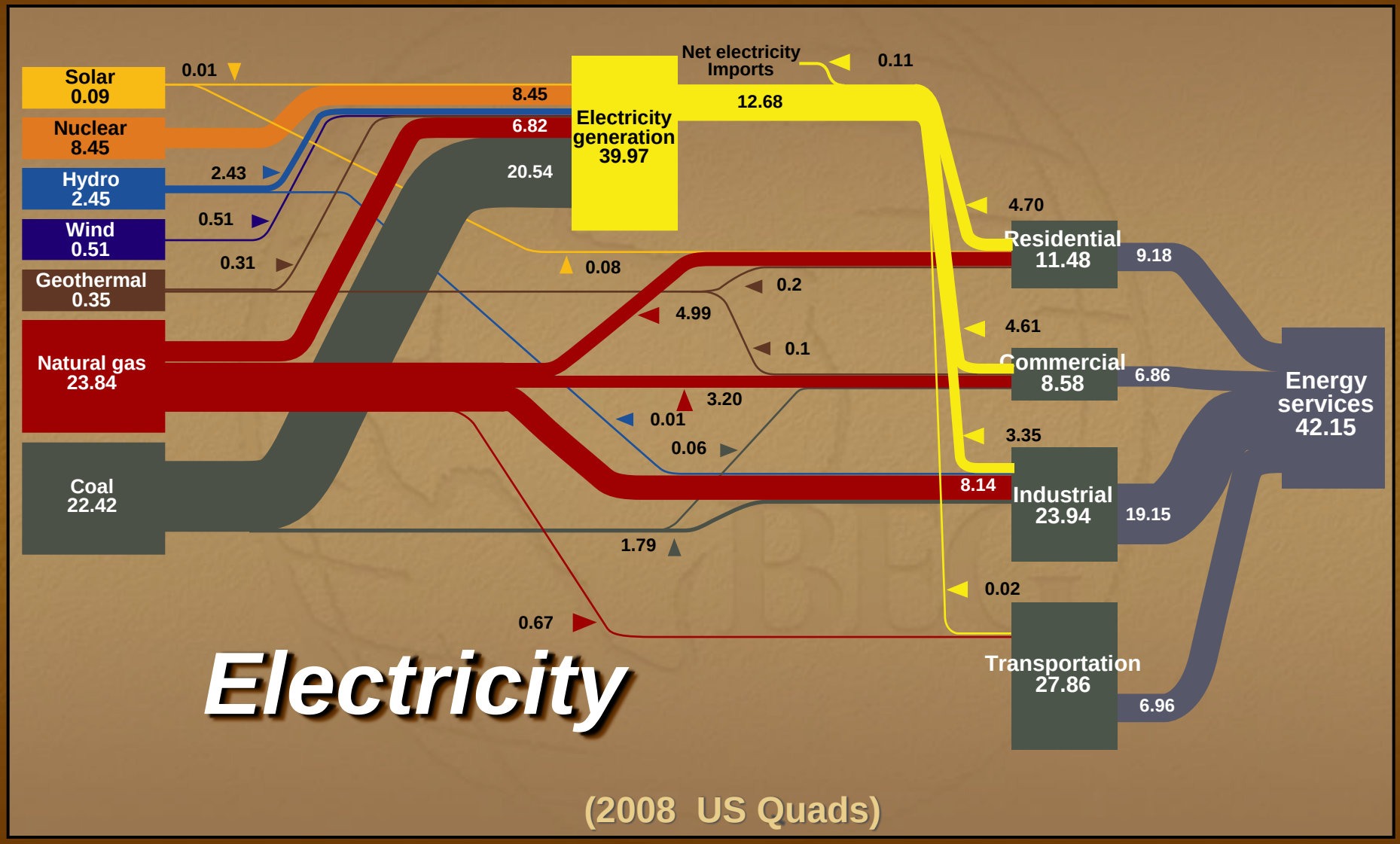
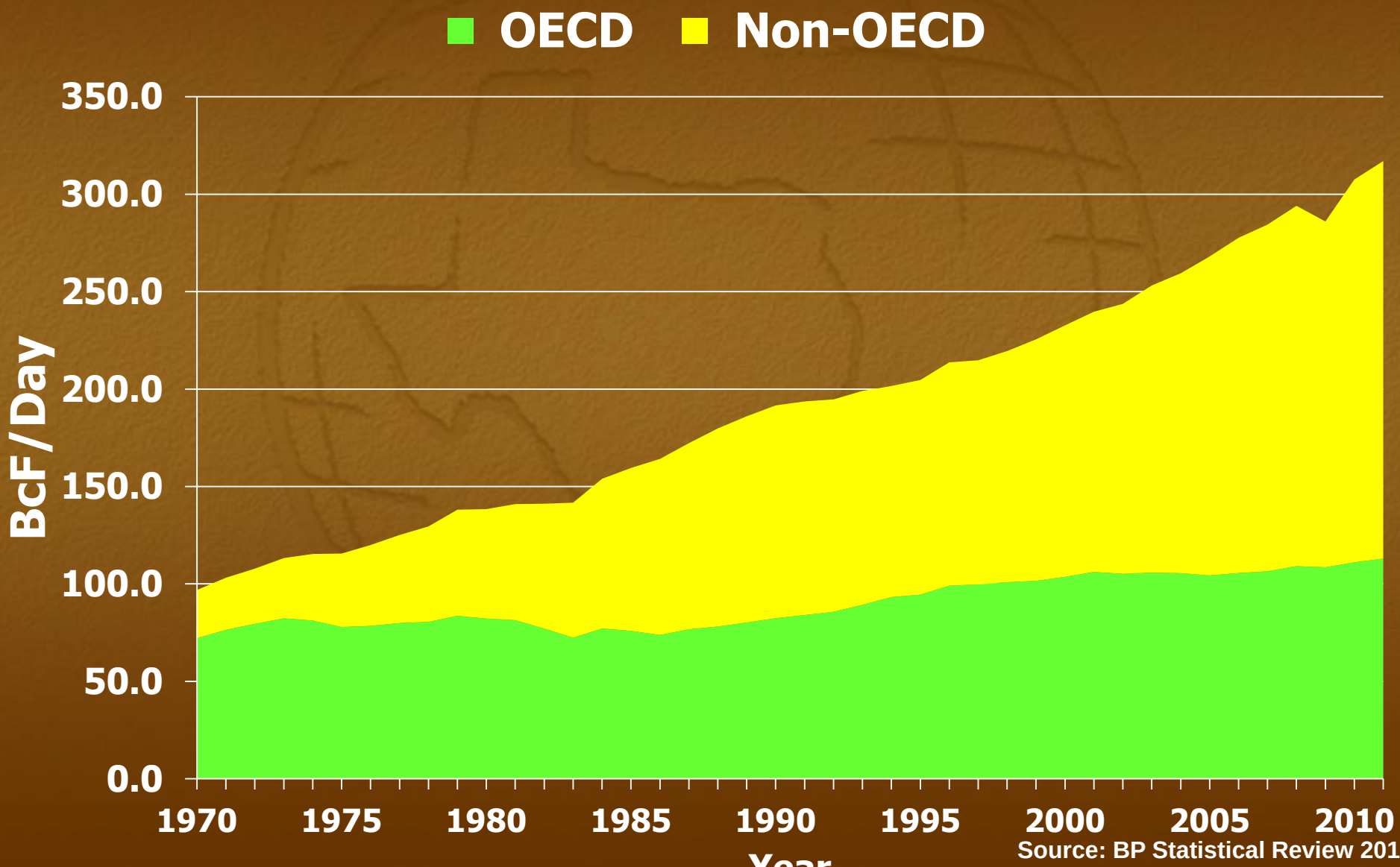
Energy Flows



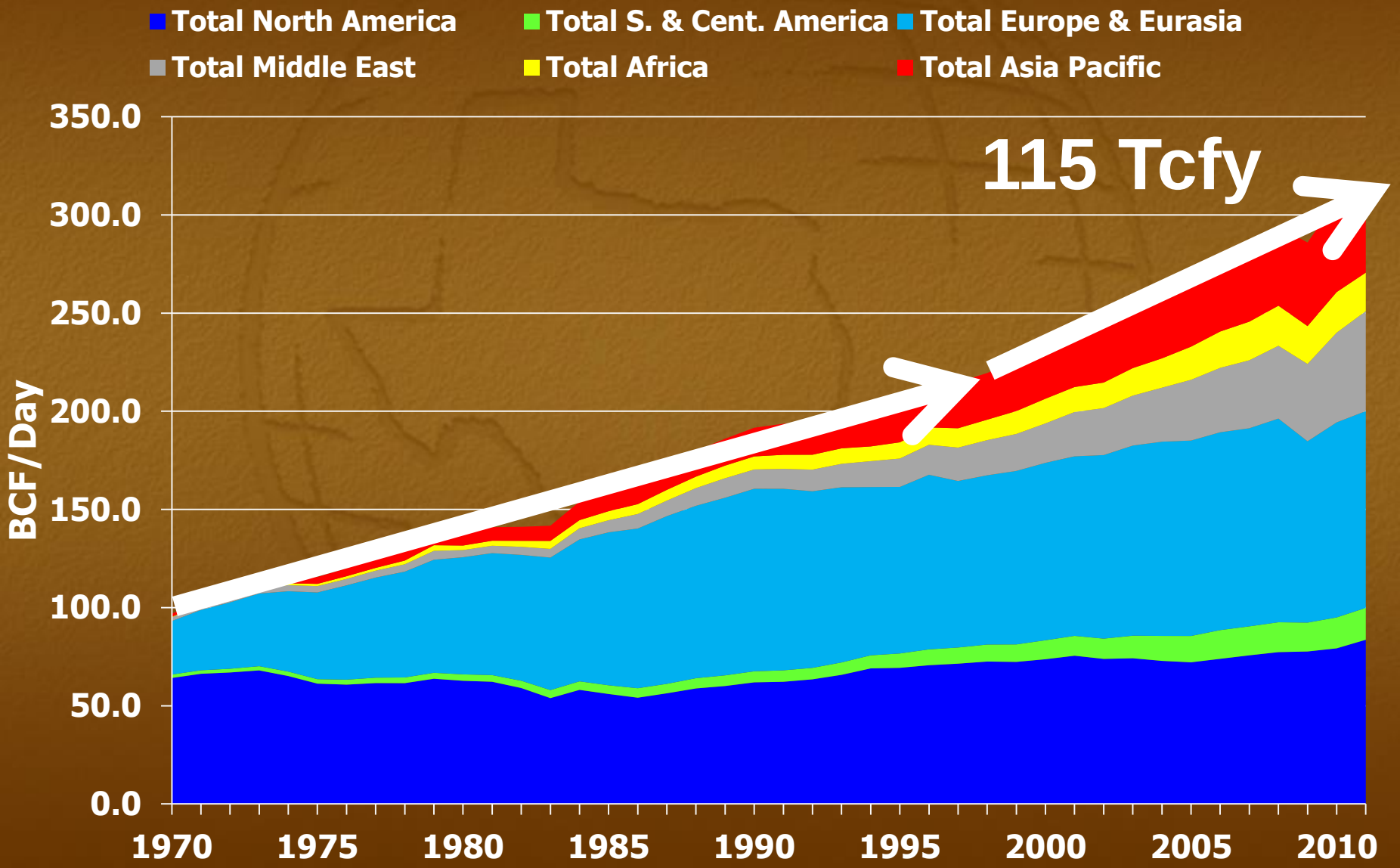
Source: Lawrence Livermore National Laboratory and U.S. DOE based on Annual Energy Review, 2008 (EIA, 2009)
From National Academies Press, *America's Energy Future*, 2009

Global Natural Gas Production



Source: BP Statistical Review 2012

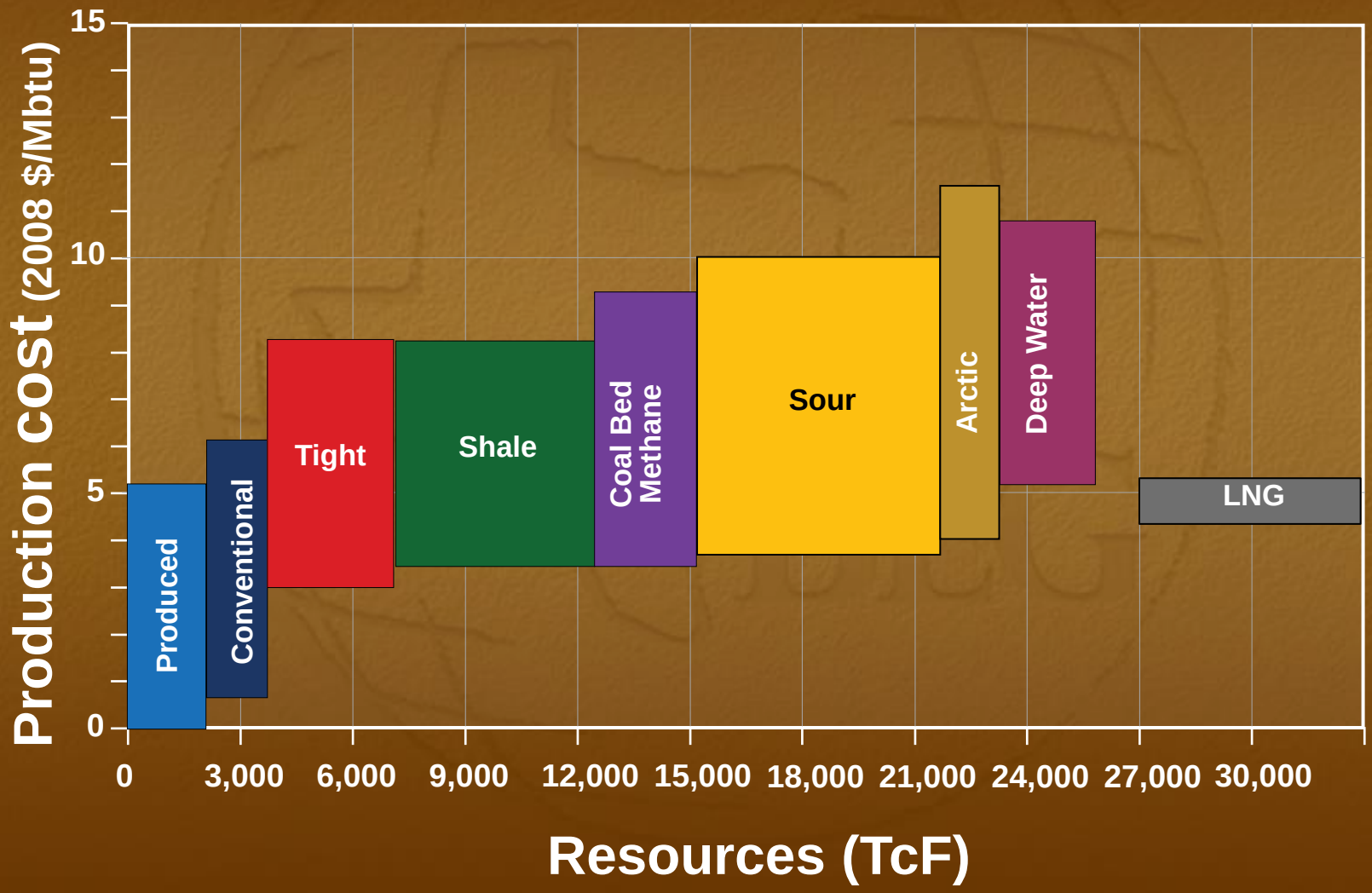
Global Natural Gas Production



Source: BP Statistical Review 2012

Global Natural Gas

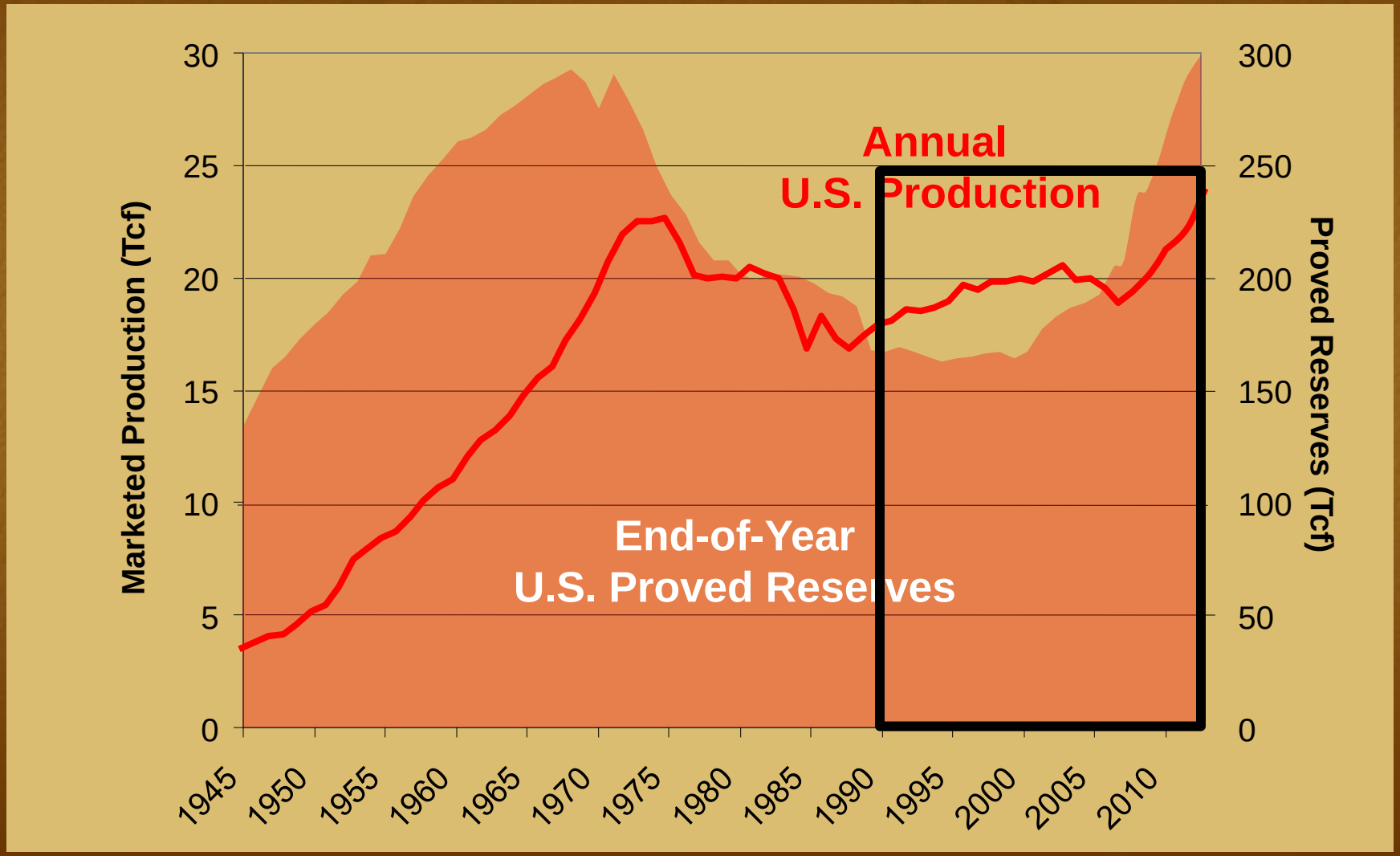
Resources v. Cost



Source: IEA World Energy Outlook (2009)

U.S. Natural Gas

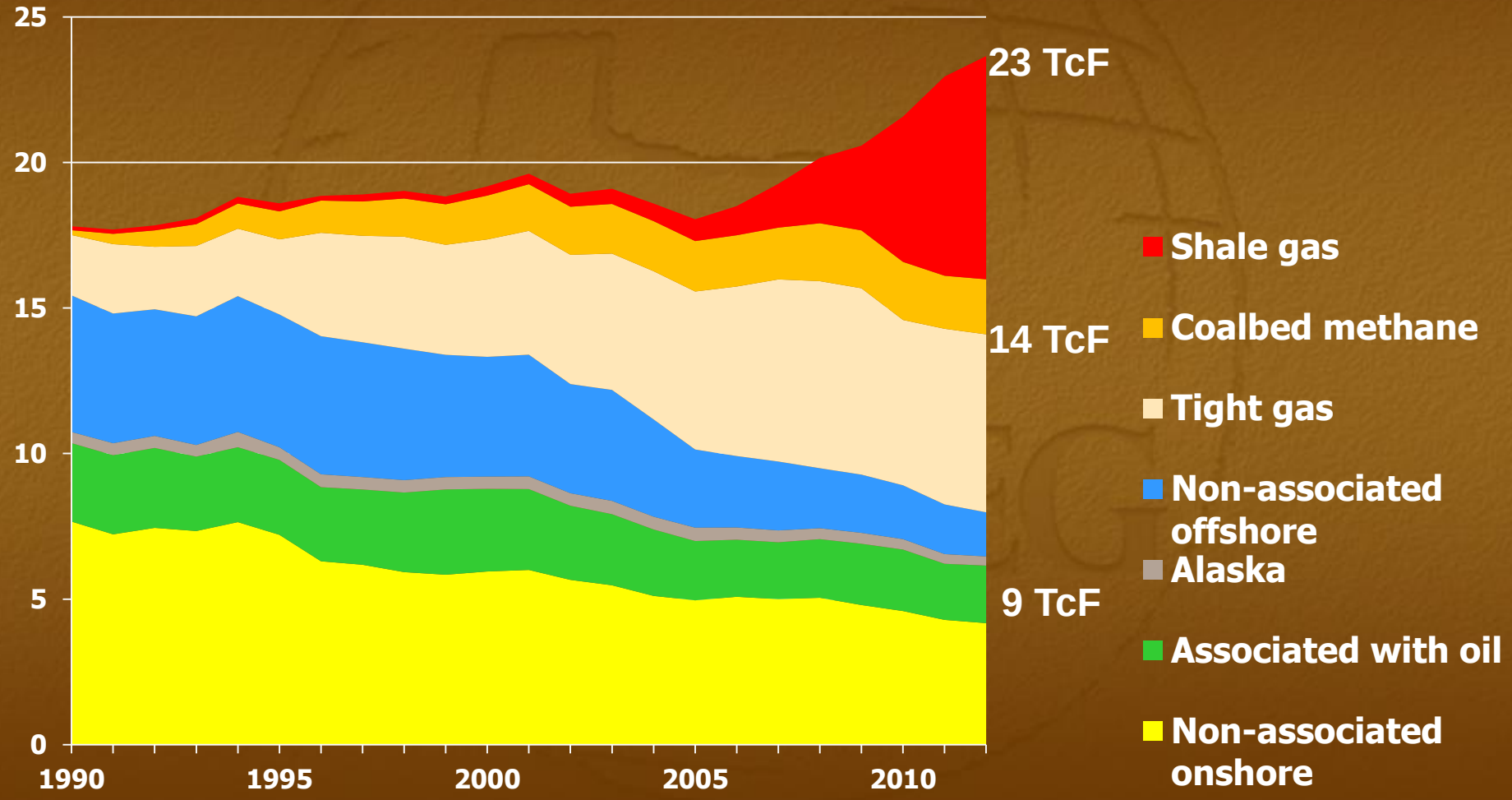
Production and Reserves



Data: BP World Energy 2012

U.S. Natural Gas

Production (TcF)

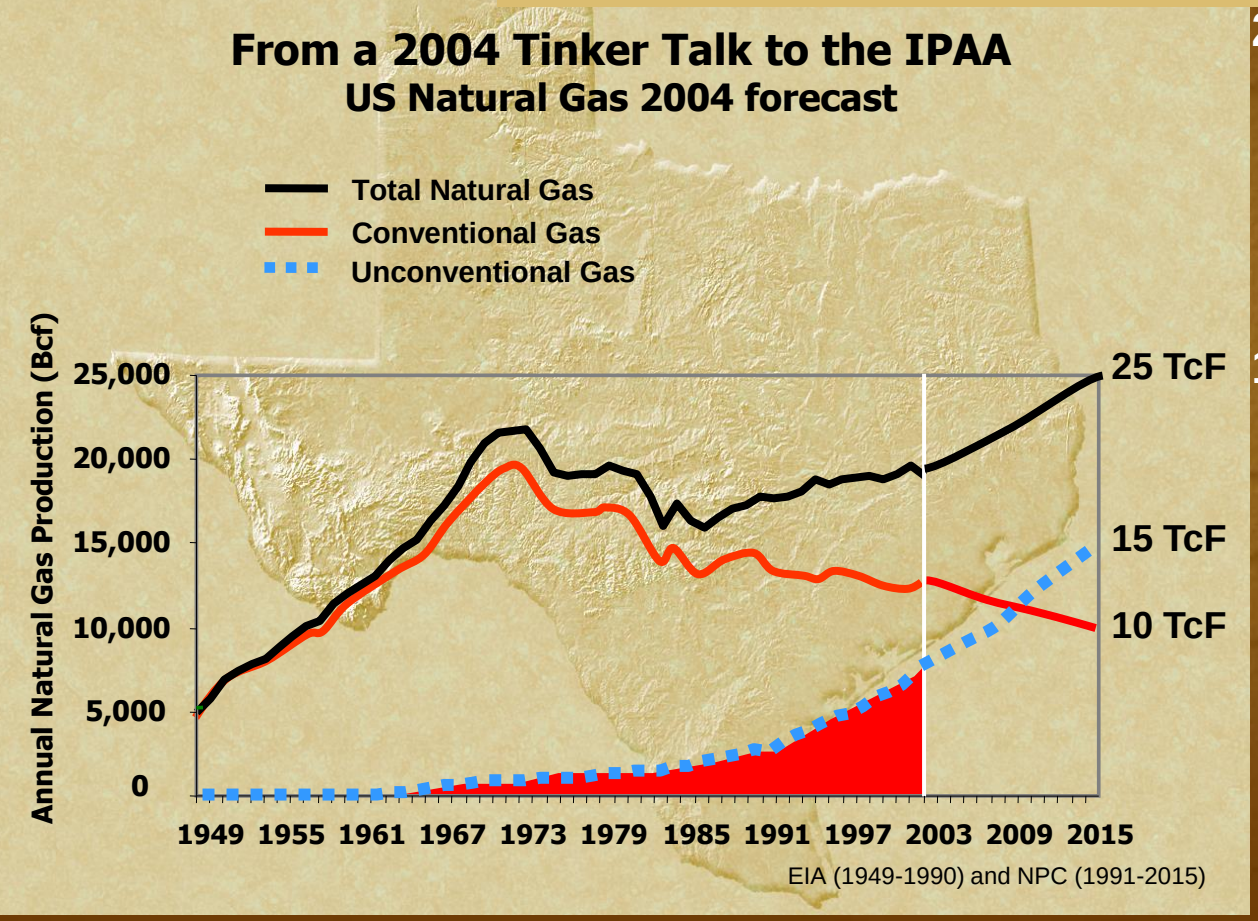


http://www.eia.gov/energy_in_brief/about_shale_gas.cfm

U.S. Natural Gas

Production (TcF)

An Anticipated Evolution



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

Hydraulic Fracturing
"Fracking"

Water

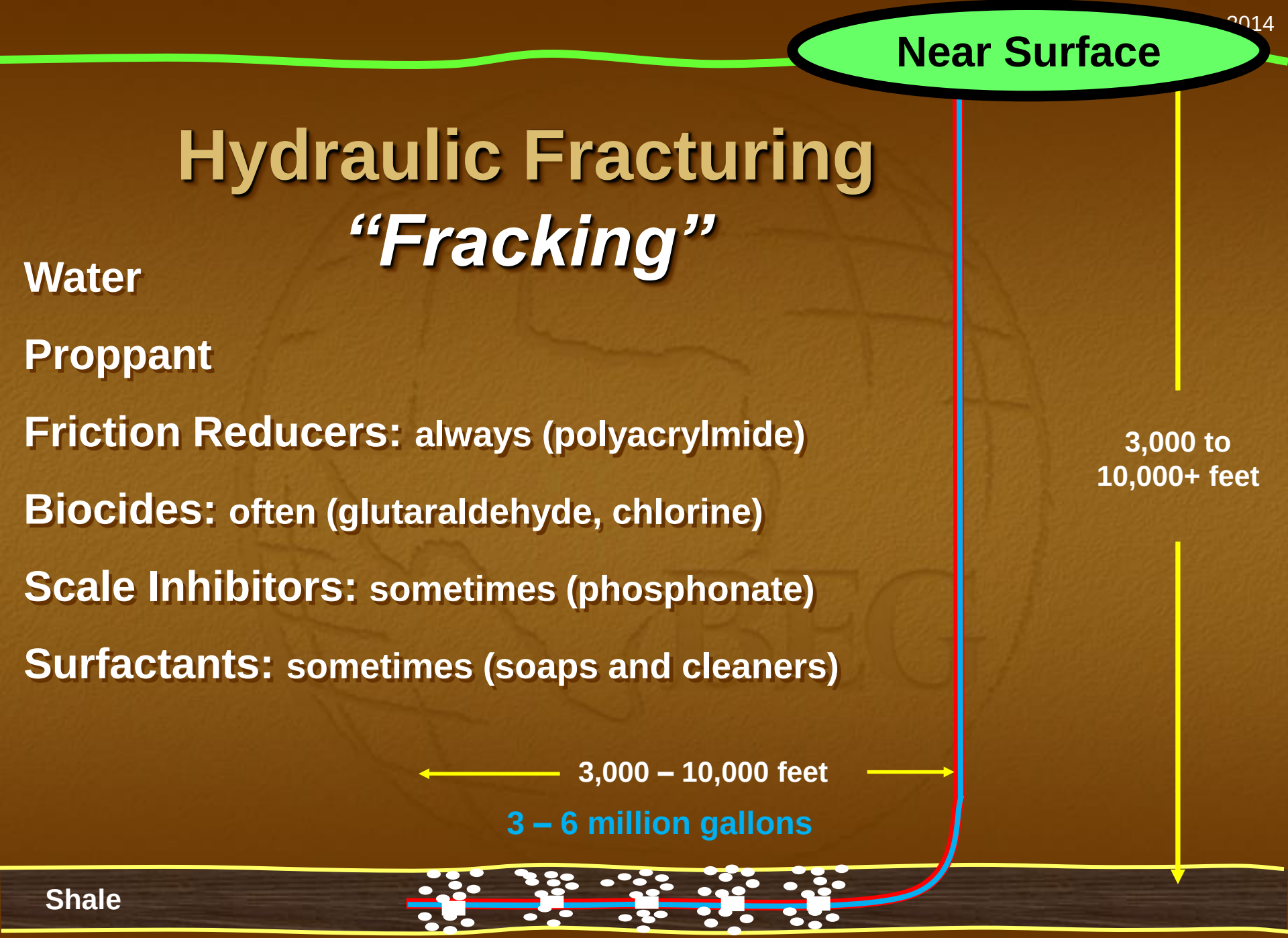
Proppant

Friction Reducers: always (polyacrylmide)

Biocides: often (glutaraldehyde, chlorine)

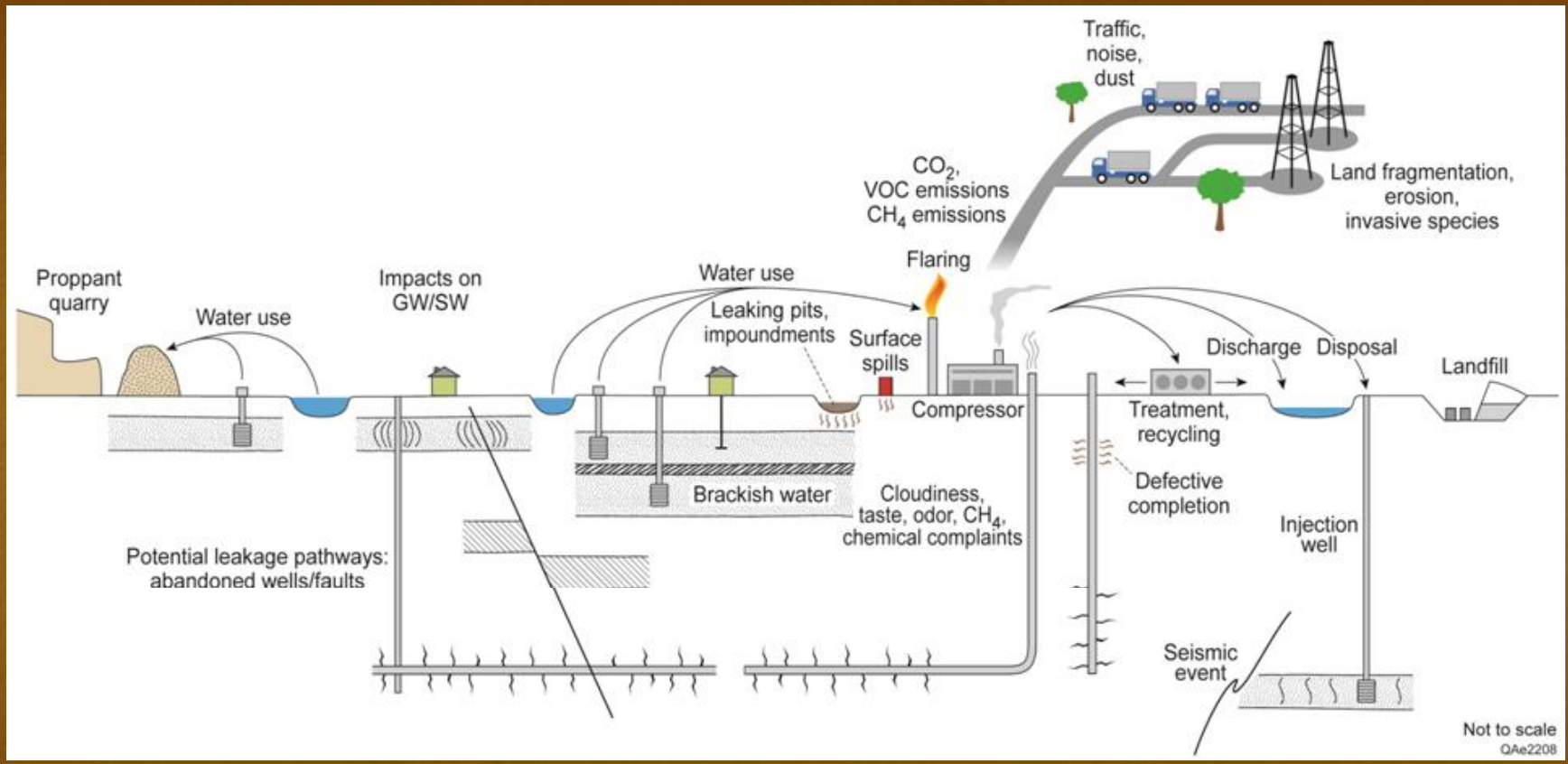
Scale Inhibitors: sometimes (phosphonate)

Surfactants: sometimes (soaps and cleaners)



Environmental Impact

Tinker, 2014



Not to Scale!

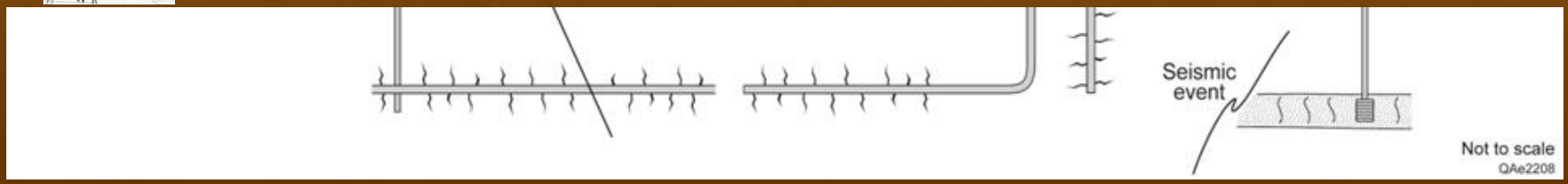
After JP Nicot, Bureau of Economic Geology

Environmental Impact

Tinker, 2014

1000's of Feet of Rock

Drawn to Scale



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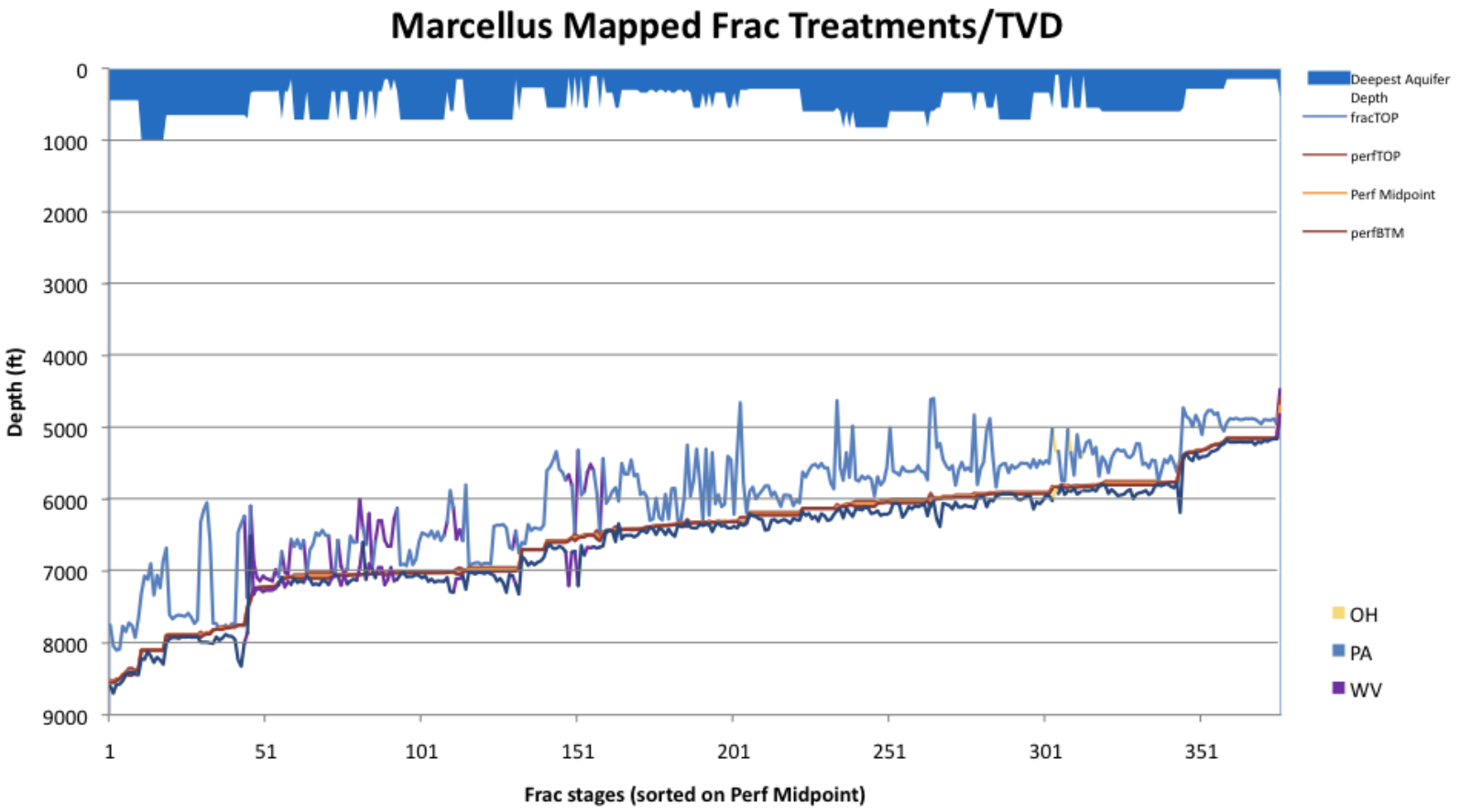

Pinnacle
A HALLIBURTON SERVICE

Environmental Issues

Regulatory Considerations

1. **Mandatory baseline data**
2. **Cement all gas producing zones**
3. **Full disclosure of chemicals**
4. **Minimize fresh water use on the front end**
5. **Handle flowback and produced water**
6. **Manage potential induced seismicity**
7. **Minimize methane emissions and flaring**
8. **Minimize surface impact**

after Rao, 2012

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after Rao, 2012

Tinker, 2014

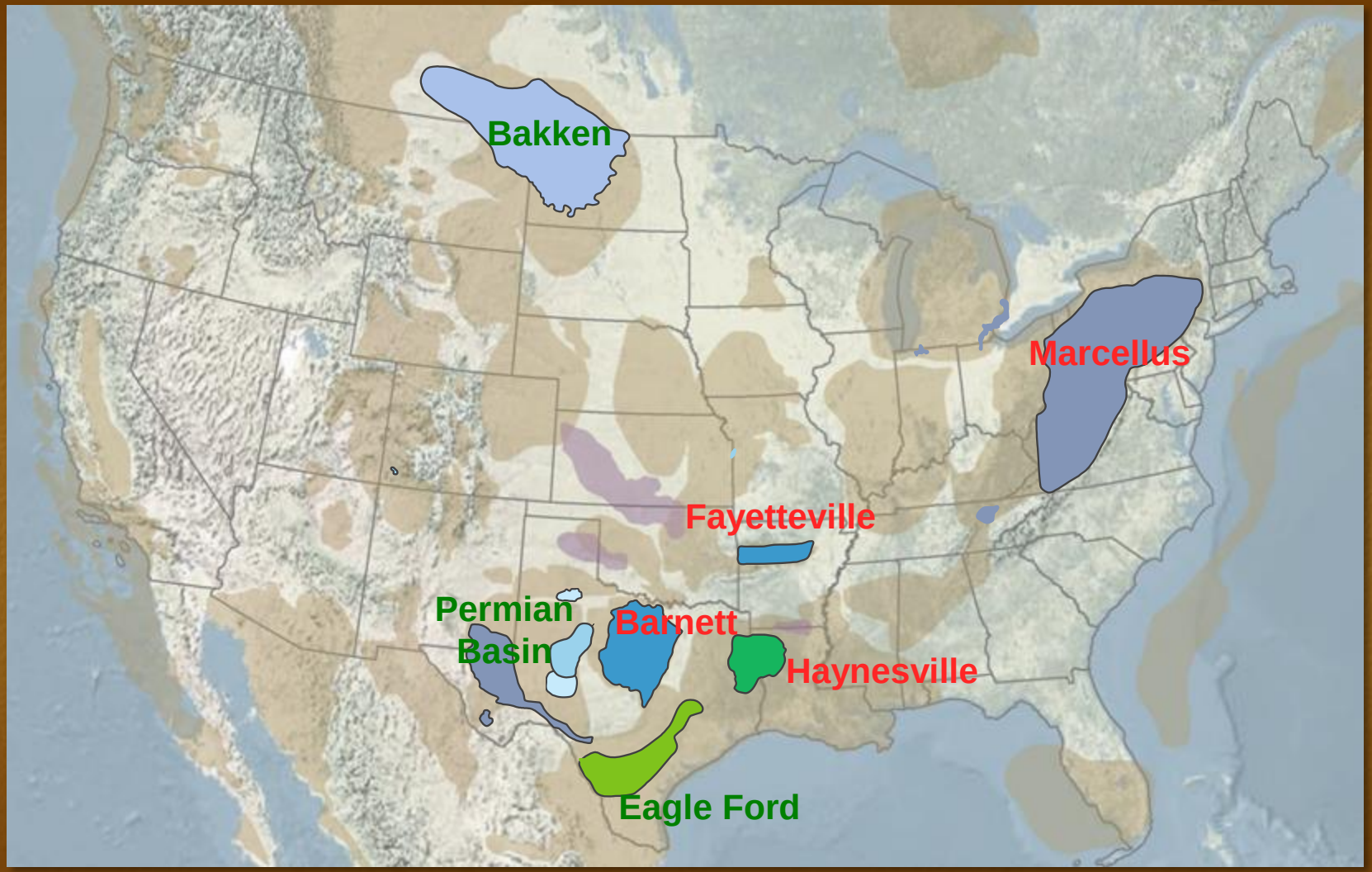
Unconventional Resource Plays

Cenozoic	Mesozoic	Paleozoic		
Miocene	Cretaceous	Permian	Mississippian-Devonian	Tight sands
Miocene-Oligocene	Jurassic	Pennsylvanian	Devonian	Basins
Eocene	Trassic	Mississippian-Pen	Ordovician	
		Mississippian	Cambrian	

Modified from: EIA and National Geographic

Unconventional Resource Plays

Tinker, 2014



Cenozoic
- Miocene
- Miocene-Oligocene
- Eocene

Mesozoic
- Cretaceous
- Jurassic
- Trassic

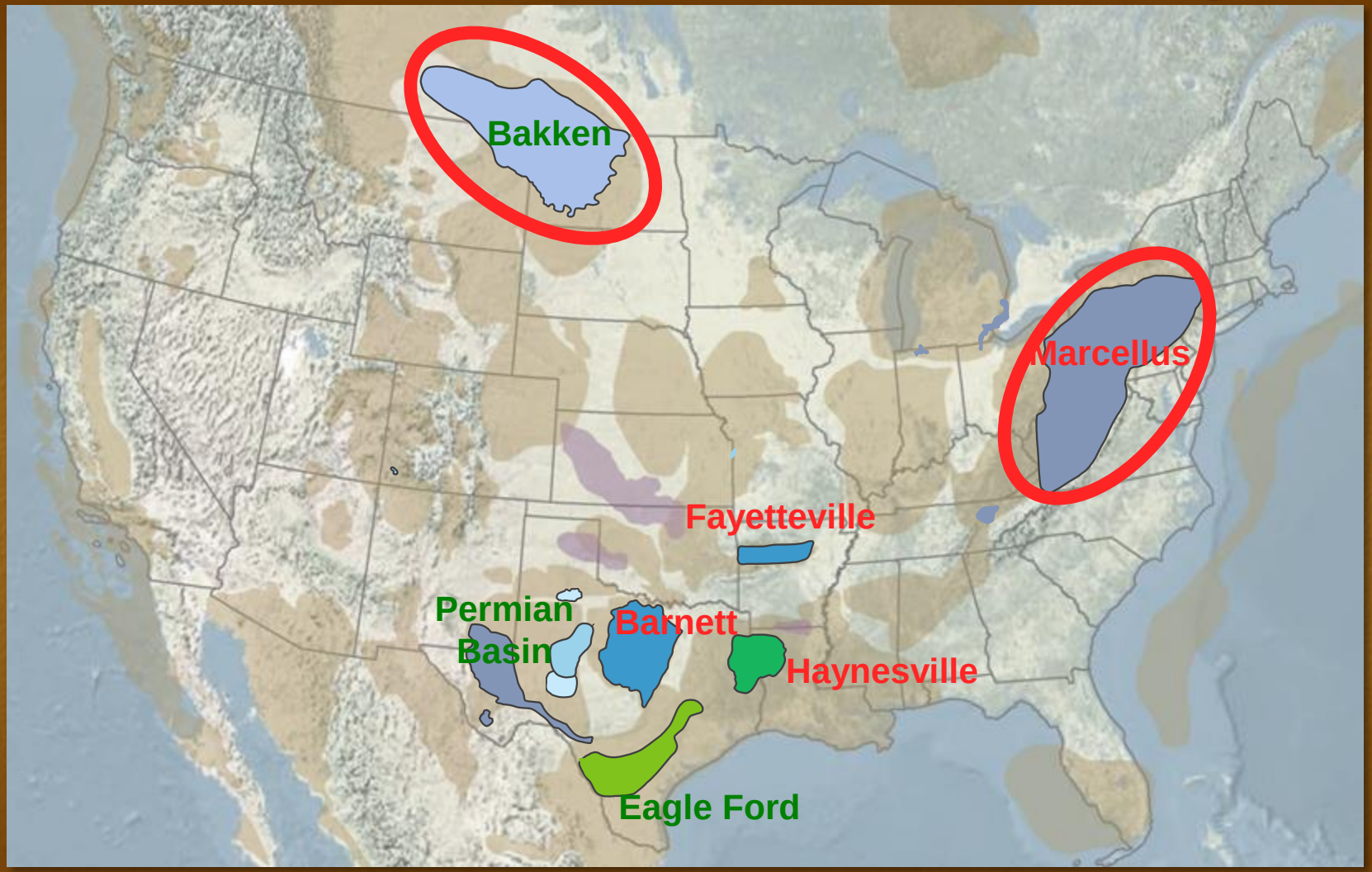
Paleozoic
- Permian
- Pennsylvanian
- Mississippian-Pen
- Mississippian
- Mississippian-Devonian
- Devonian
- Ordovician
- Cambrian

- Tight sands
- Basins

Modified from: EIA and National Geographic

QAei2915

Unconventional Resource Plays



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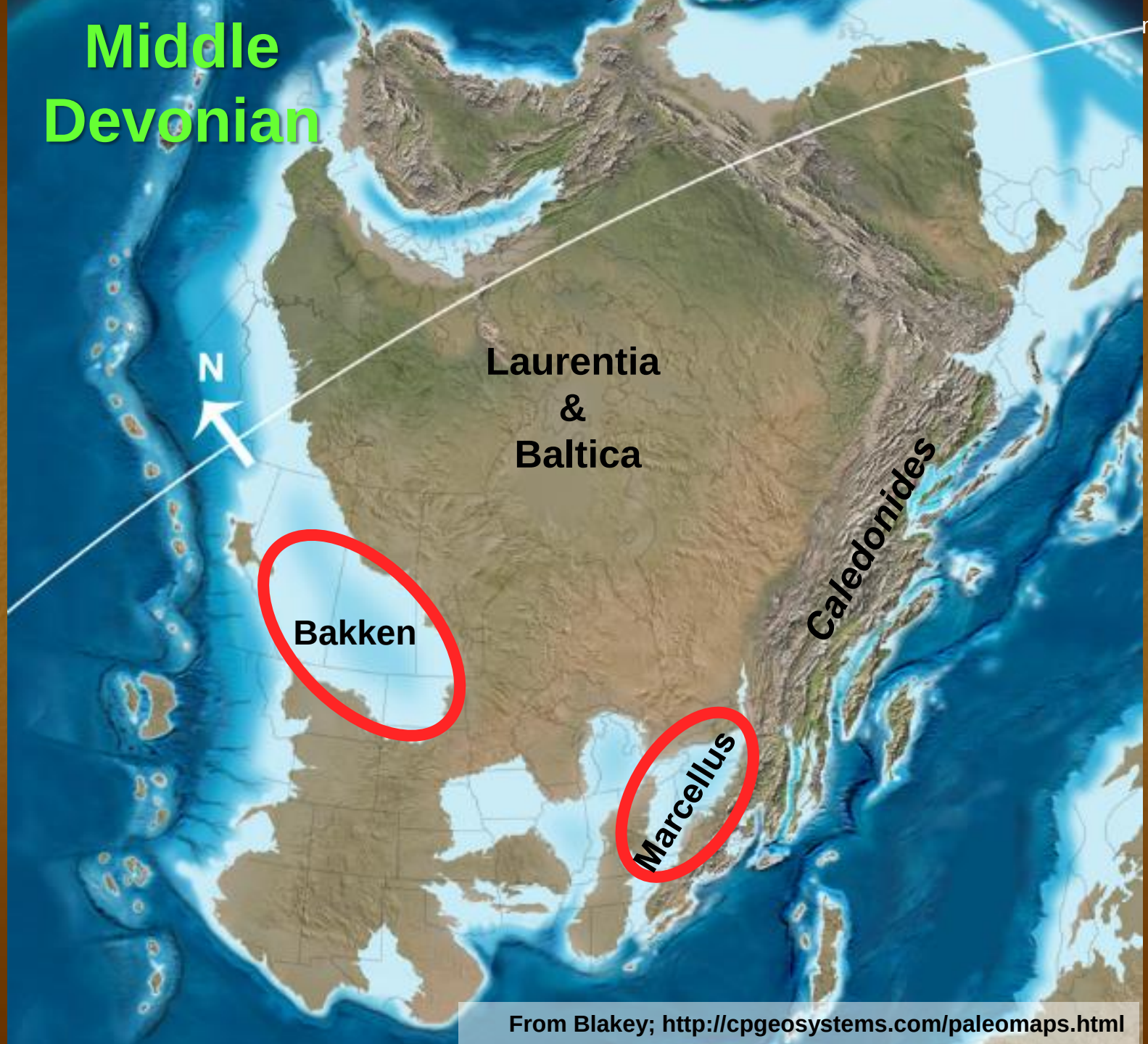

Middle Devonian
N
Laurentia & Baltica
Caledonides
Bakken
Marcellus
From Blakey; http://cpgeosystems.com/paleomaps.html

nker, 2014

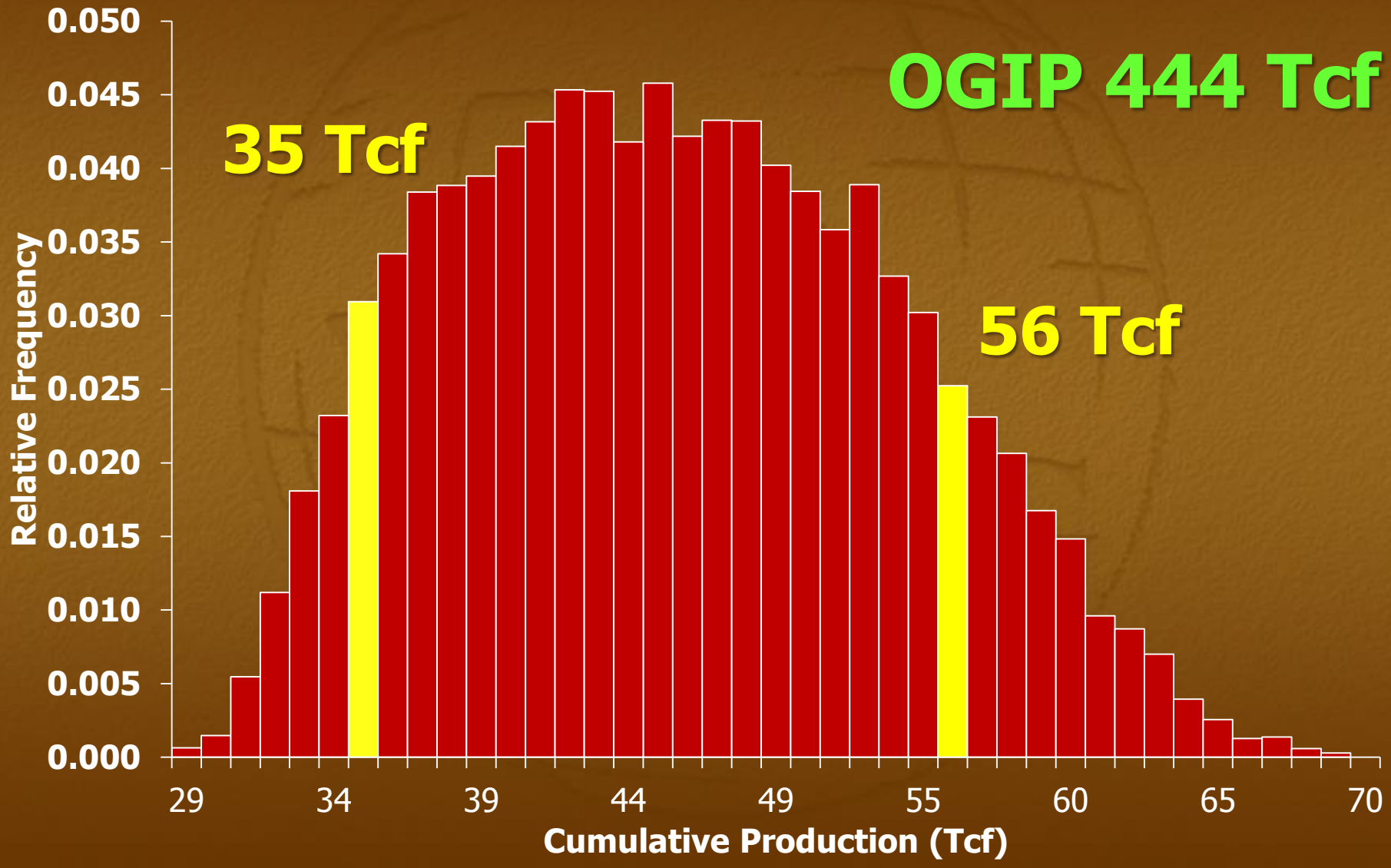
Bureau of Economic Geology
U.S. Shale Gas Study

- 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

Tinker, 2014

Monte Carlo Production Distribution

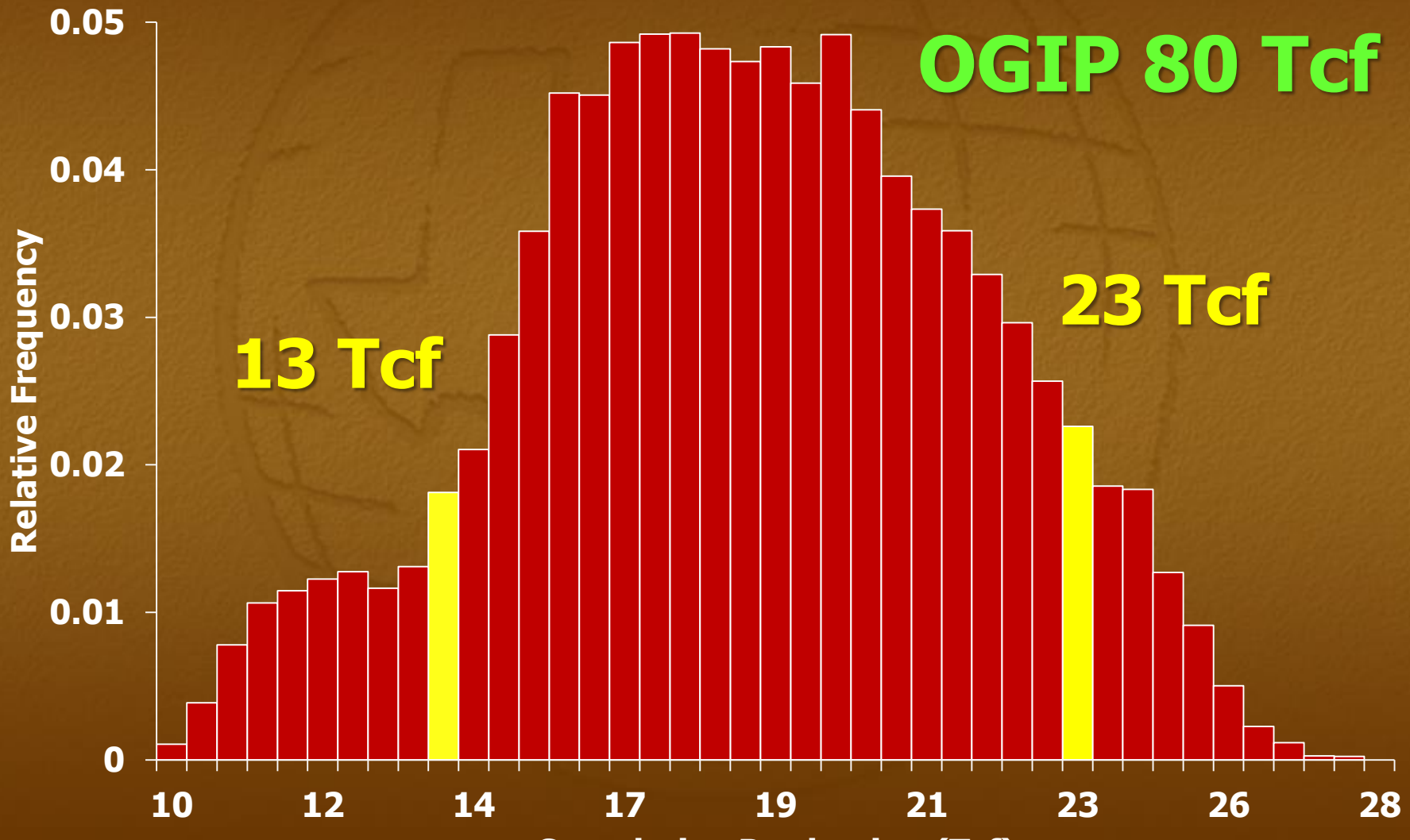


Browning, J. et al. 2013. SPE Econ & Mgmt

Tinker, 2014

Fayetteville

Monte Carlo Production Distribution



BEG Shale Reserves and Production Project

Haynesville

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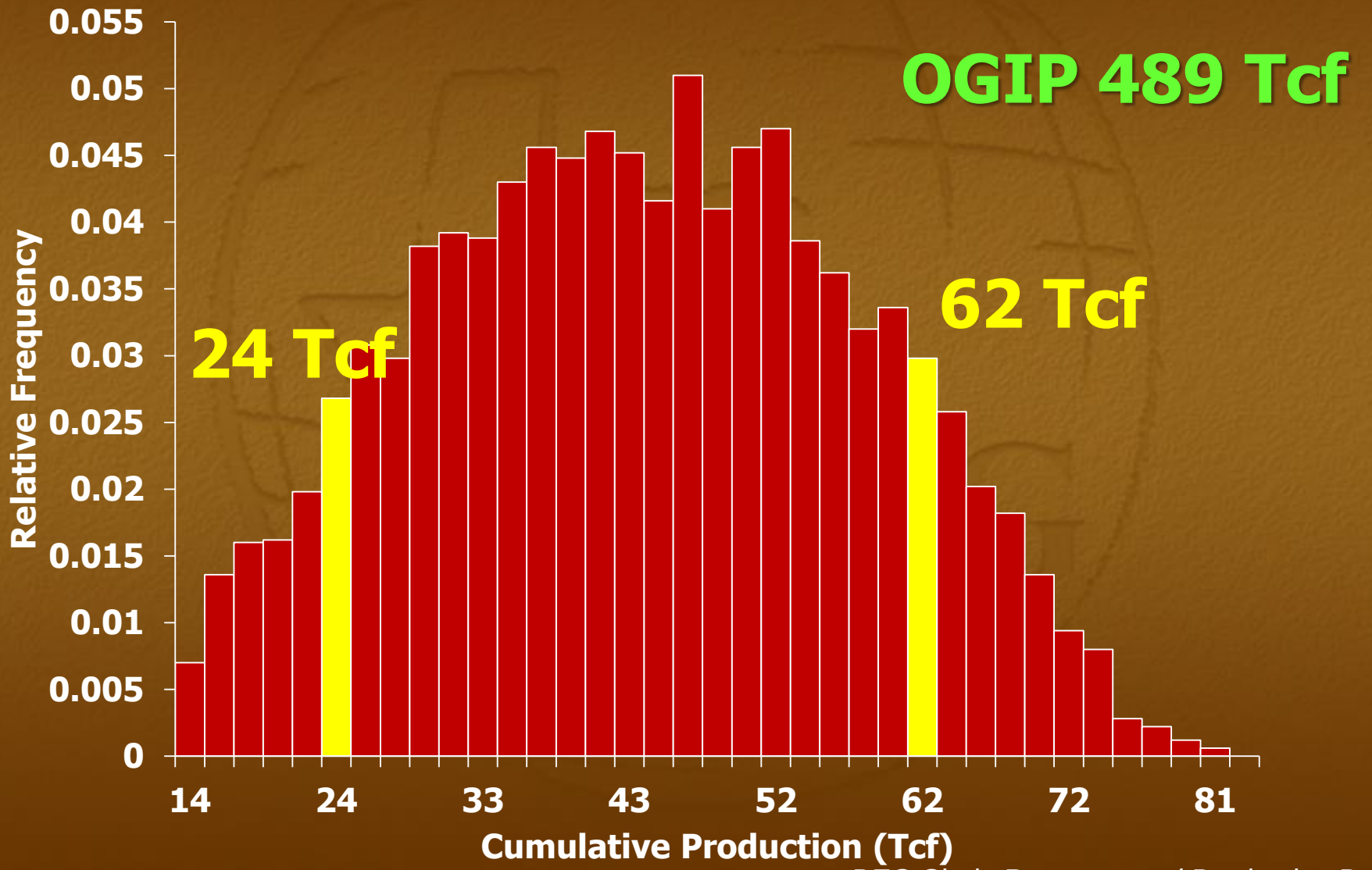
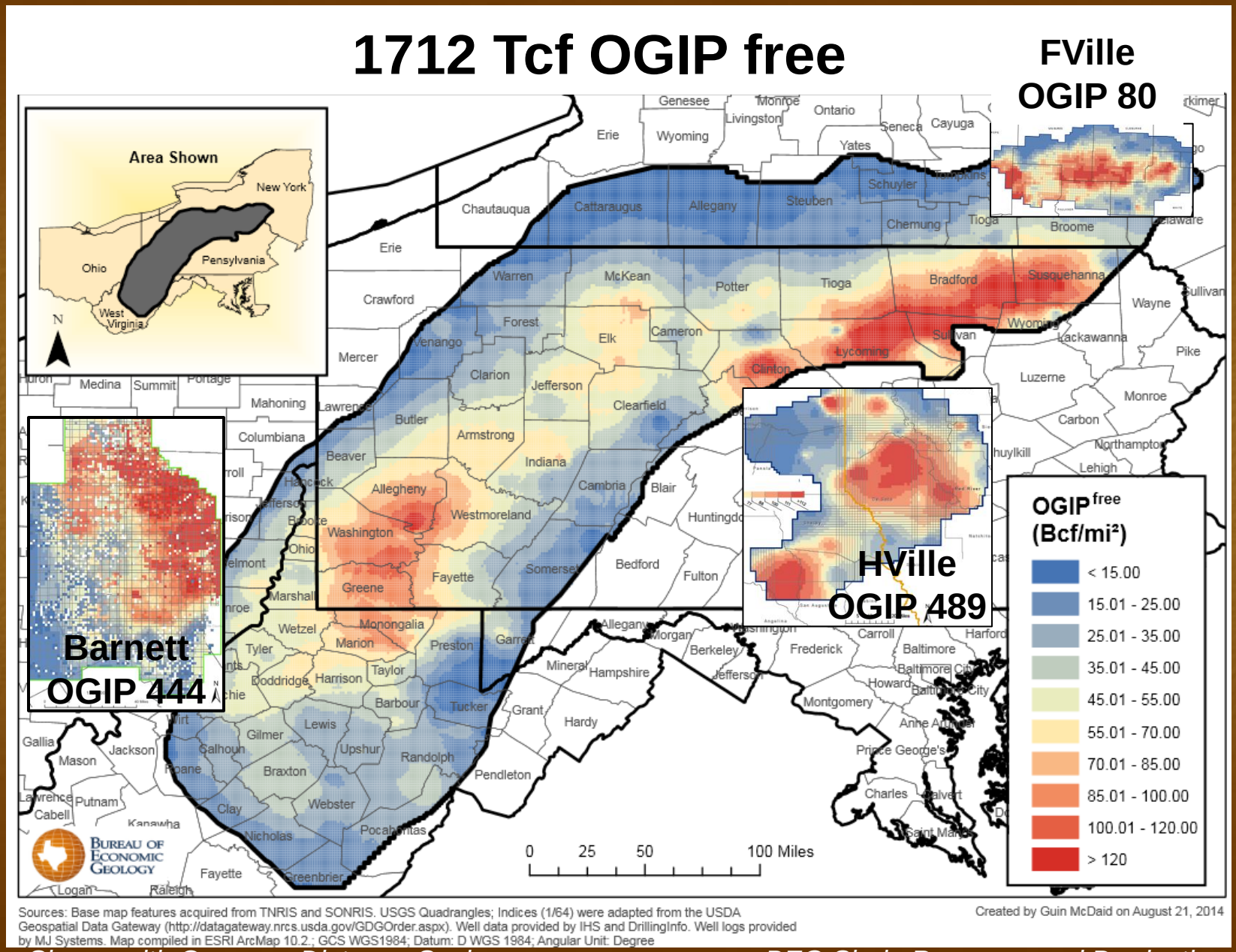
Monte Carlo Production Distribution

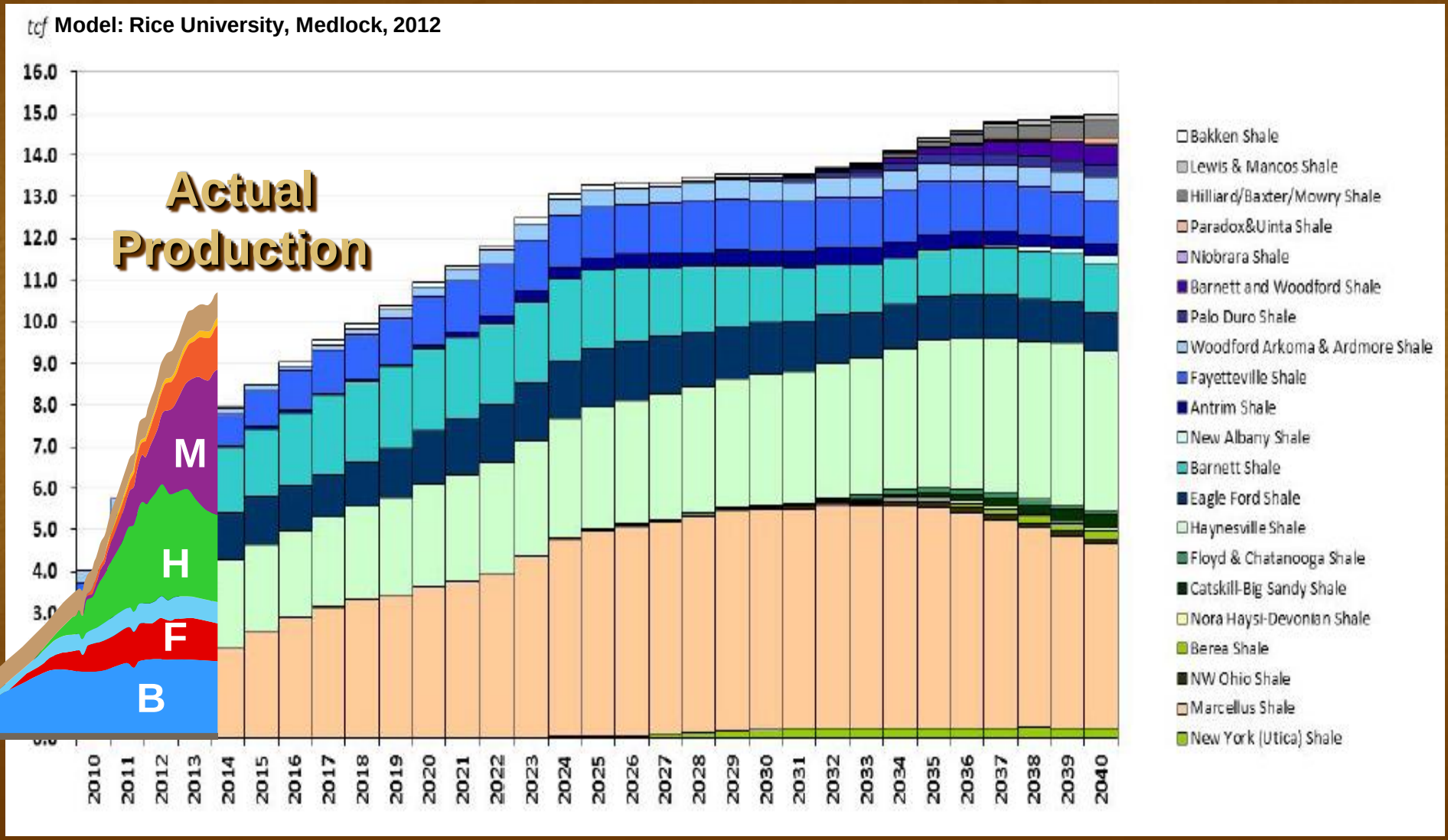


BEG Shale Reserves and Production Project

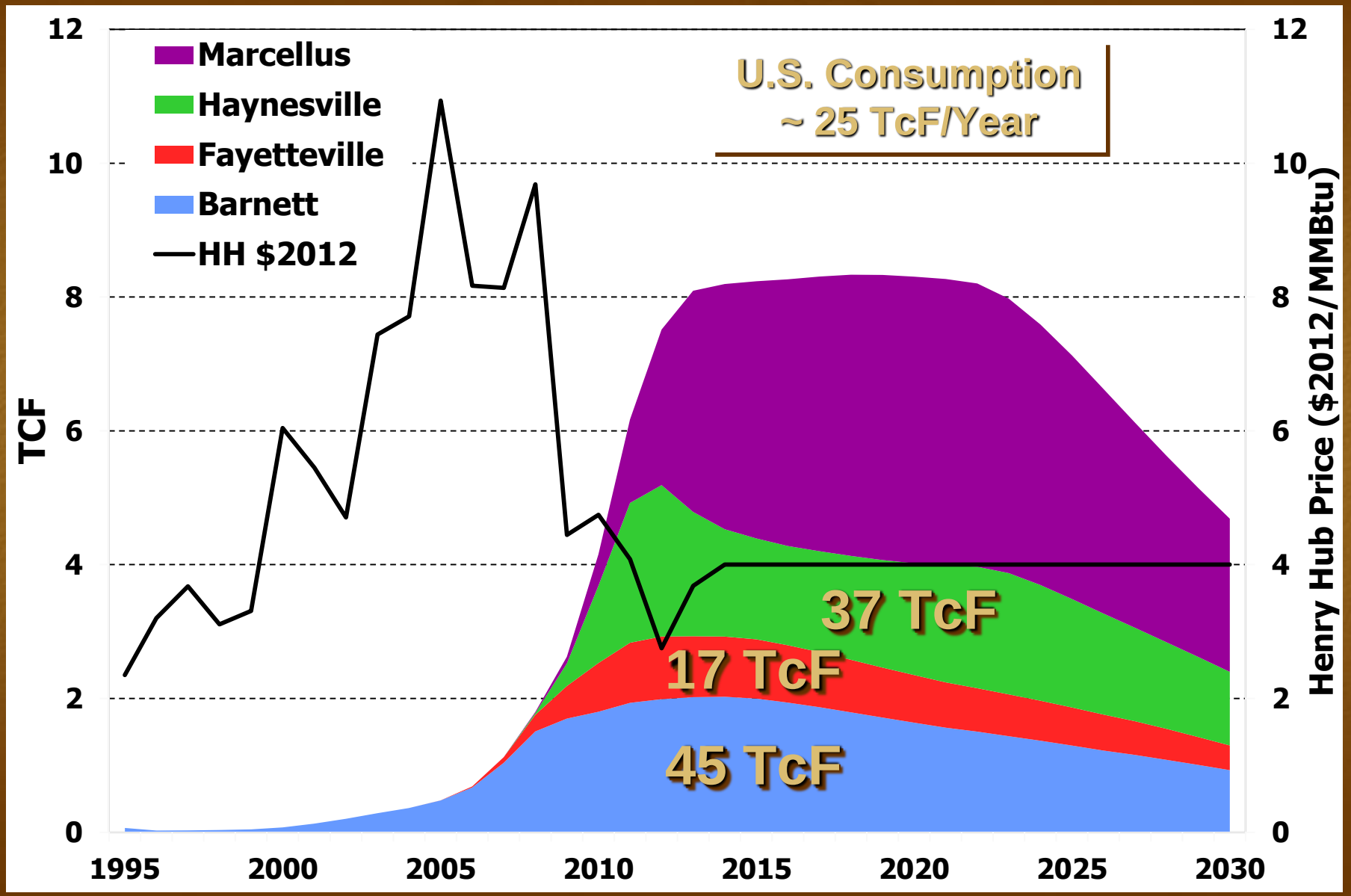
Marcellus OGIP



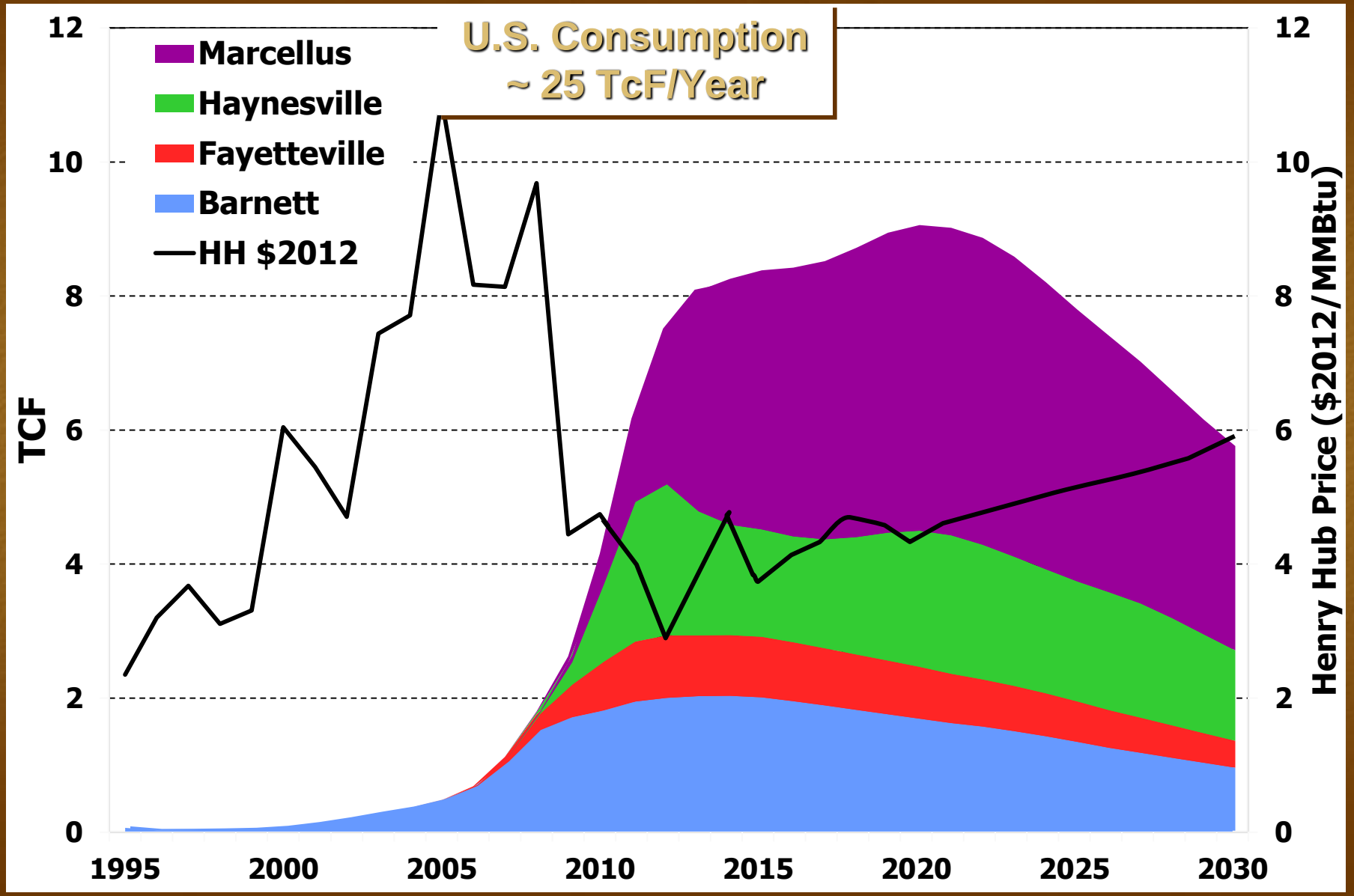
Shale Gas Forecast vs. Actual



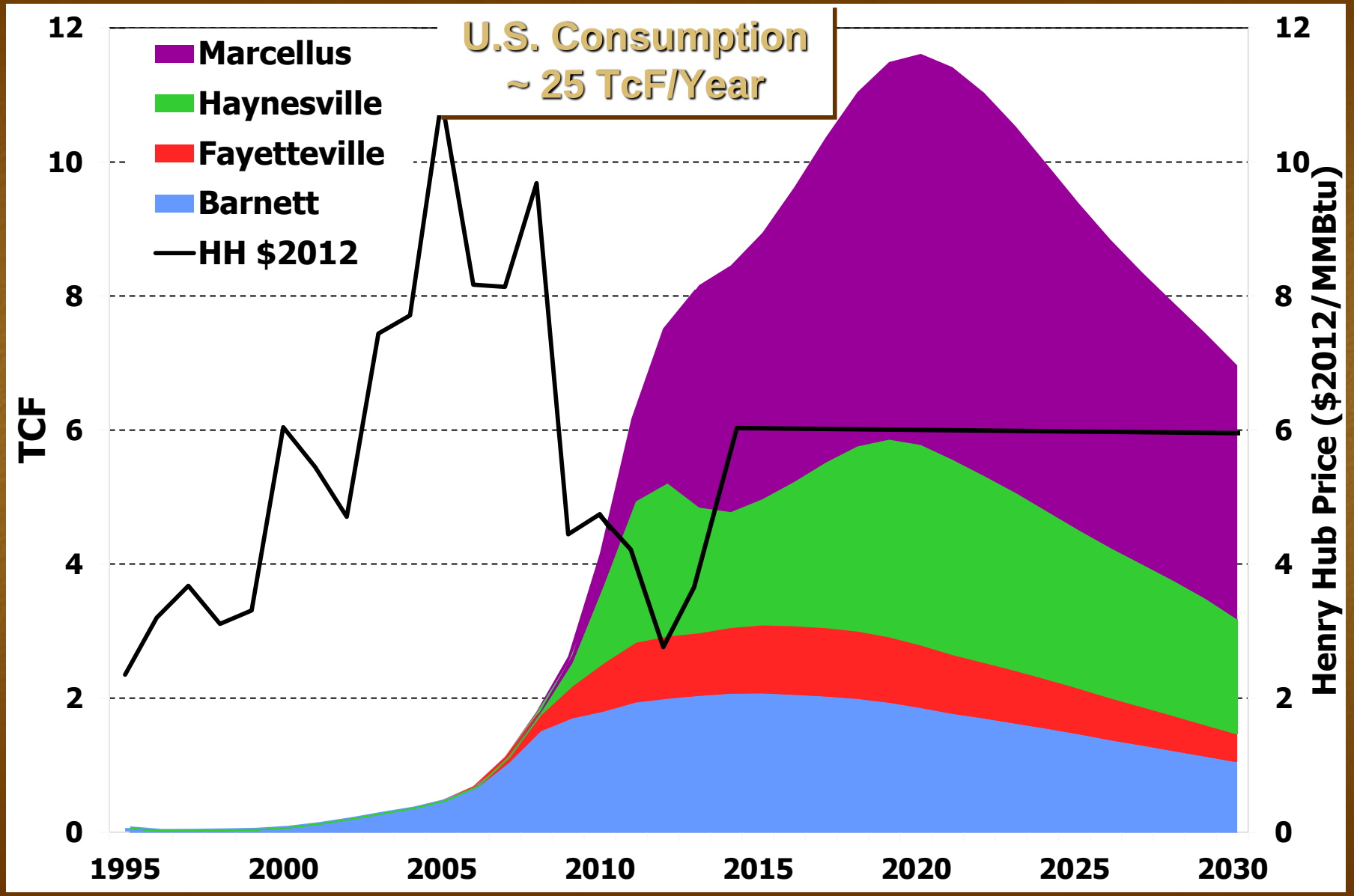
Base Case ($4) Stacked Production



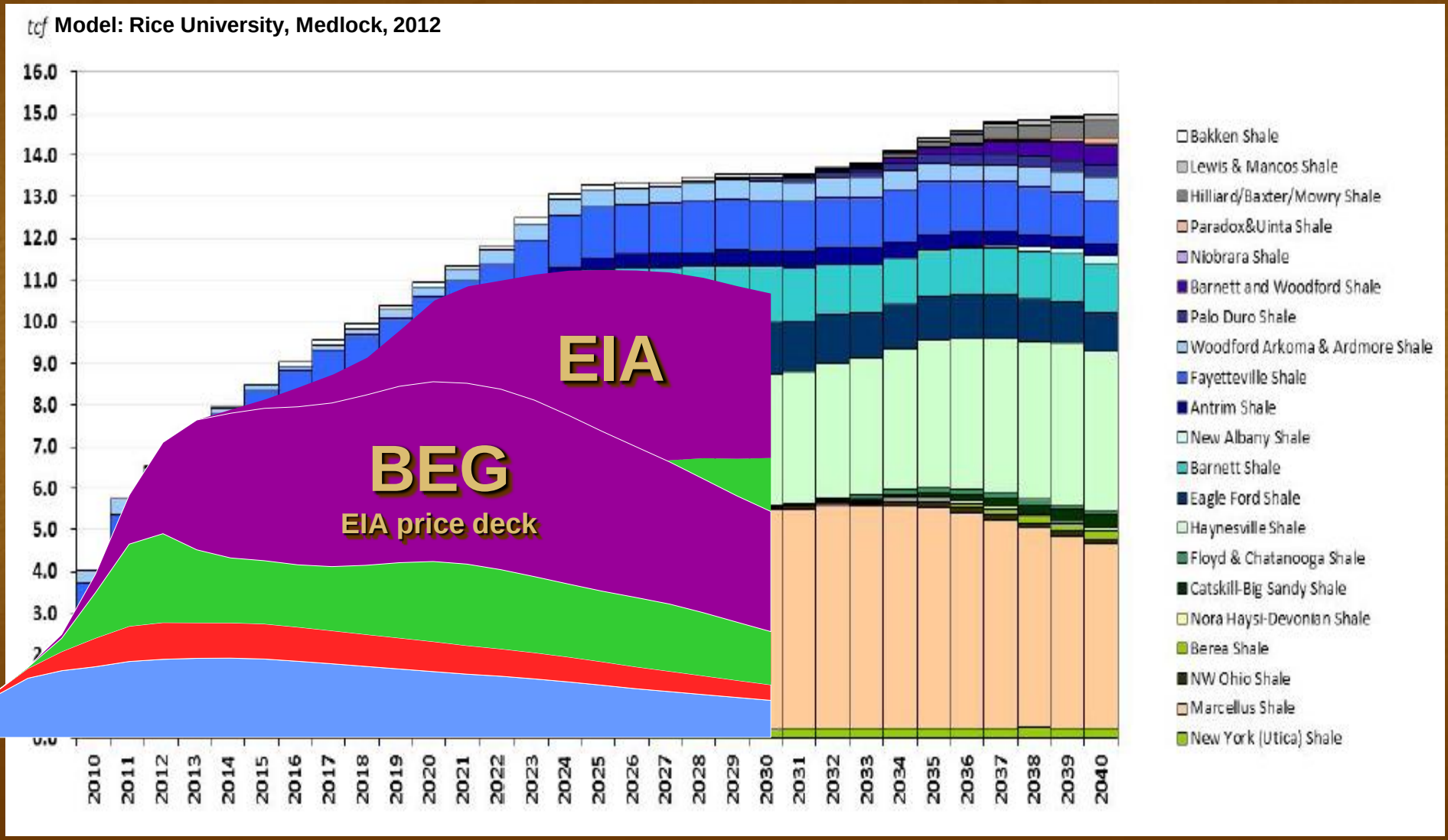
EIA Price Case Stacked Production



$6 Case Stacked Production



Forecast vs. Actual



Outline

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Natural Gas Prices

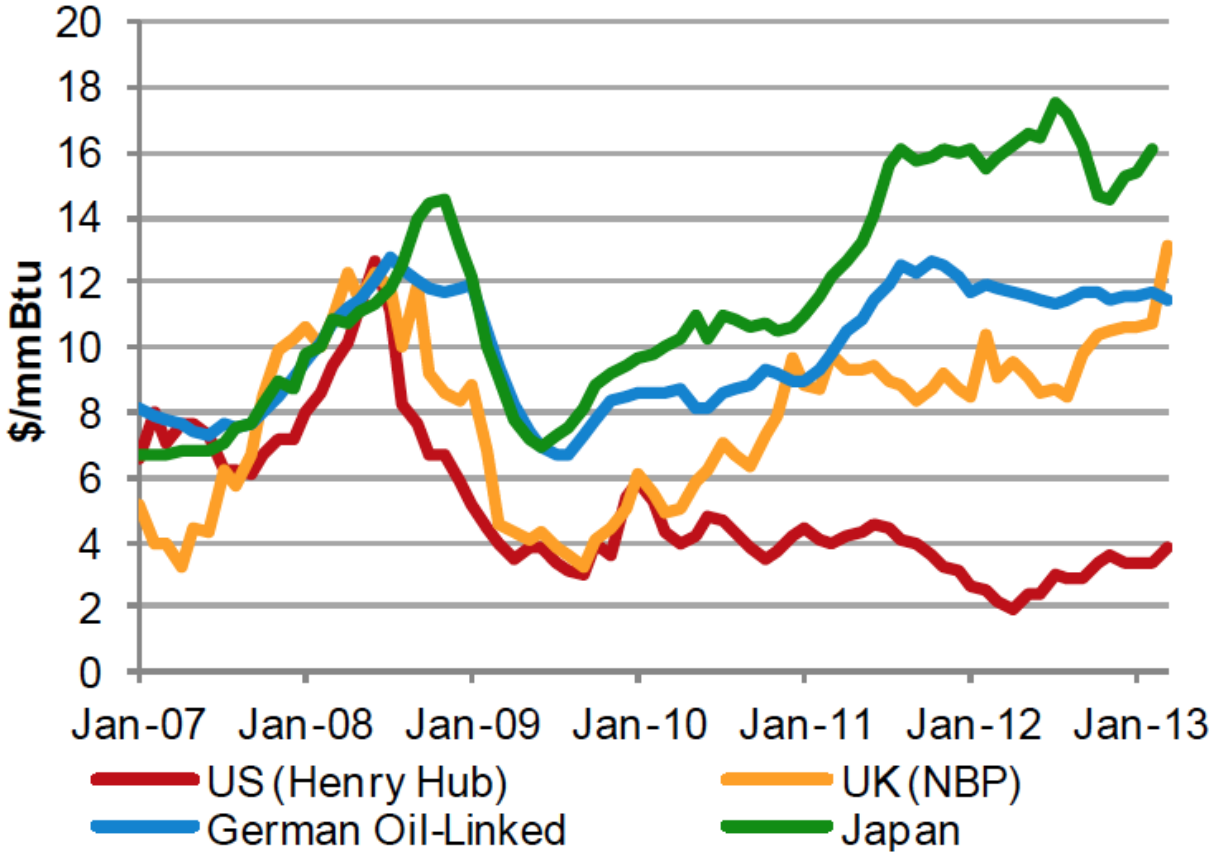
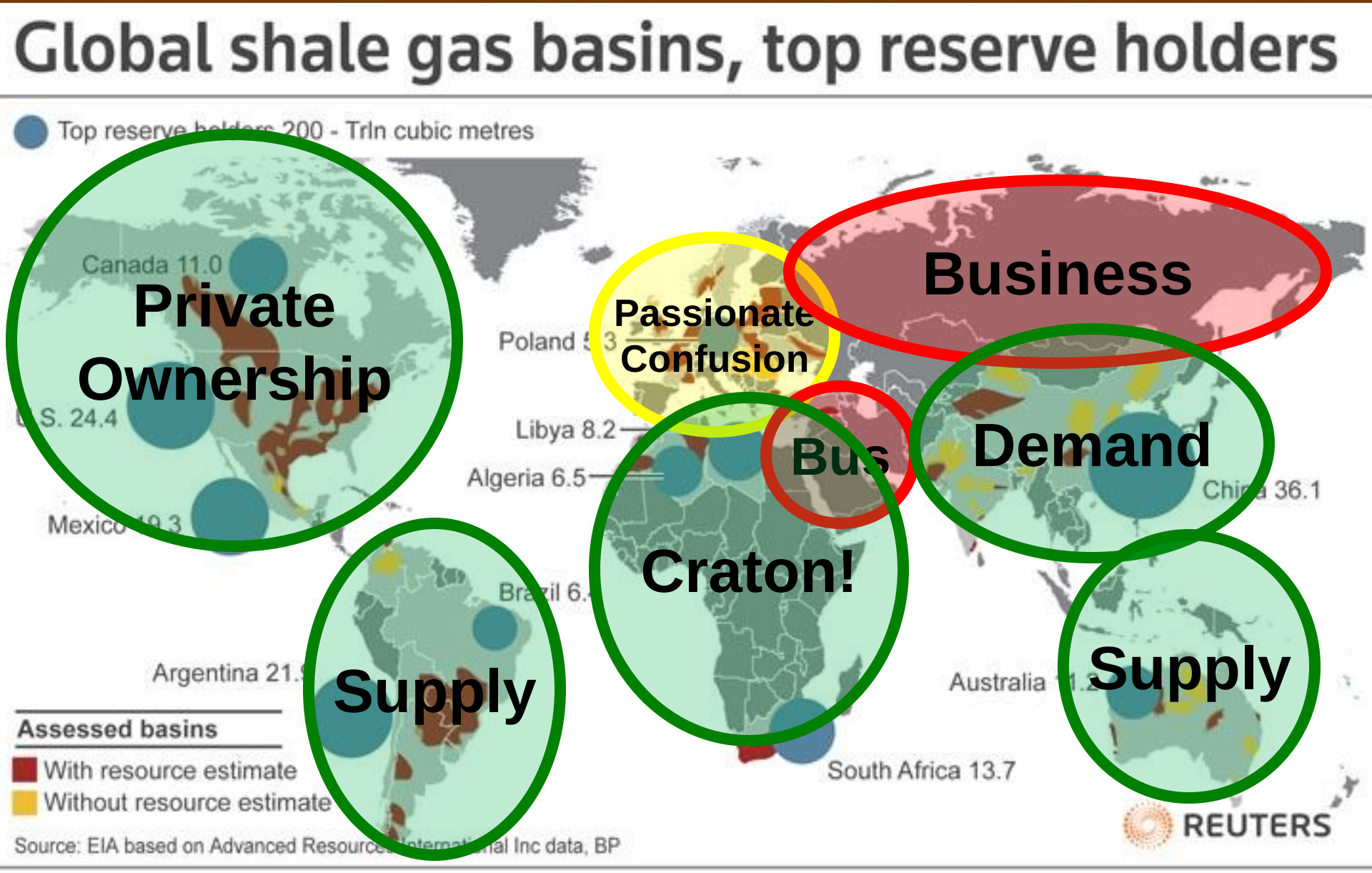


Figure 3.12: Monthly Global Gas Prices, 2007-Q1 2013

Sources: Sources: Cedigaz, GIIGNL, Waterborne LNG Reports, US DOE, PFC Energy Global LNG Service

Tinker, 2014

Shale Drivers



Reuters graphic/Catherine Trevethan

Options to Natural Gas 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

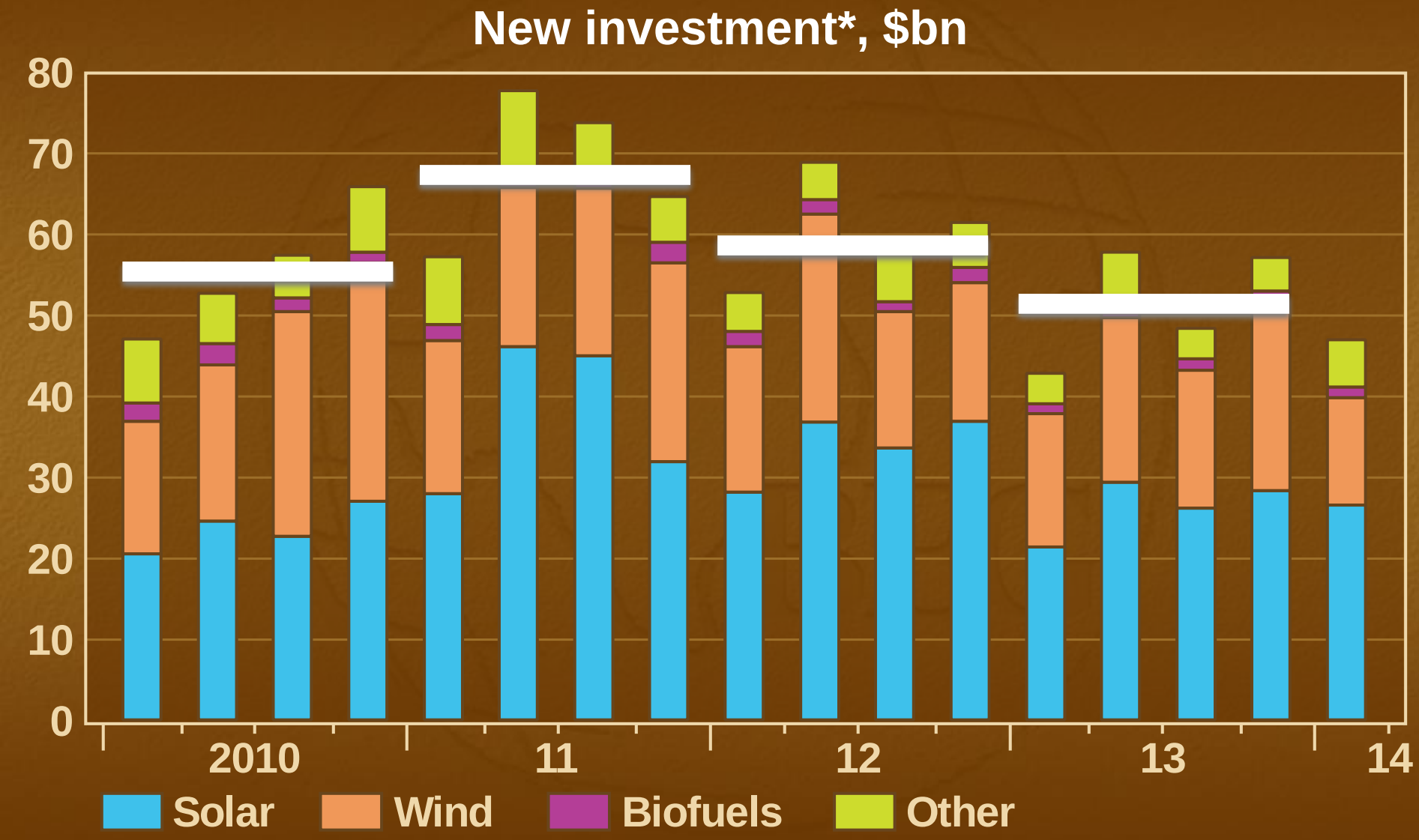
III. **Wind**
   - Simple, affordable, no emissions
   - Intermittent, land and visual, transmission

IV. **Solar**
   - Simple, no emissions, local
   - Intermittent, land, transmission

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

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

Global Investment in Clean Energy

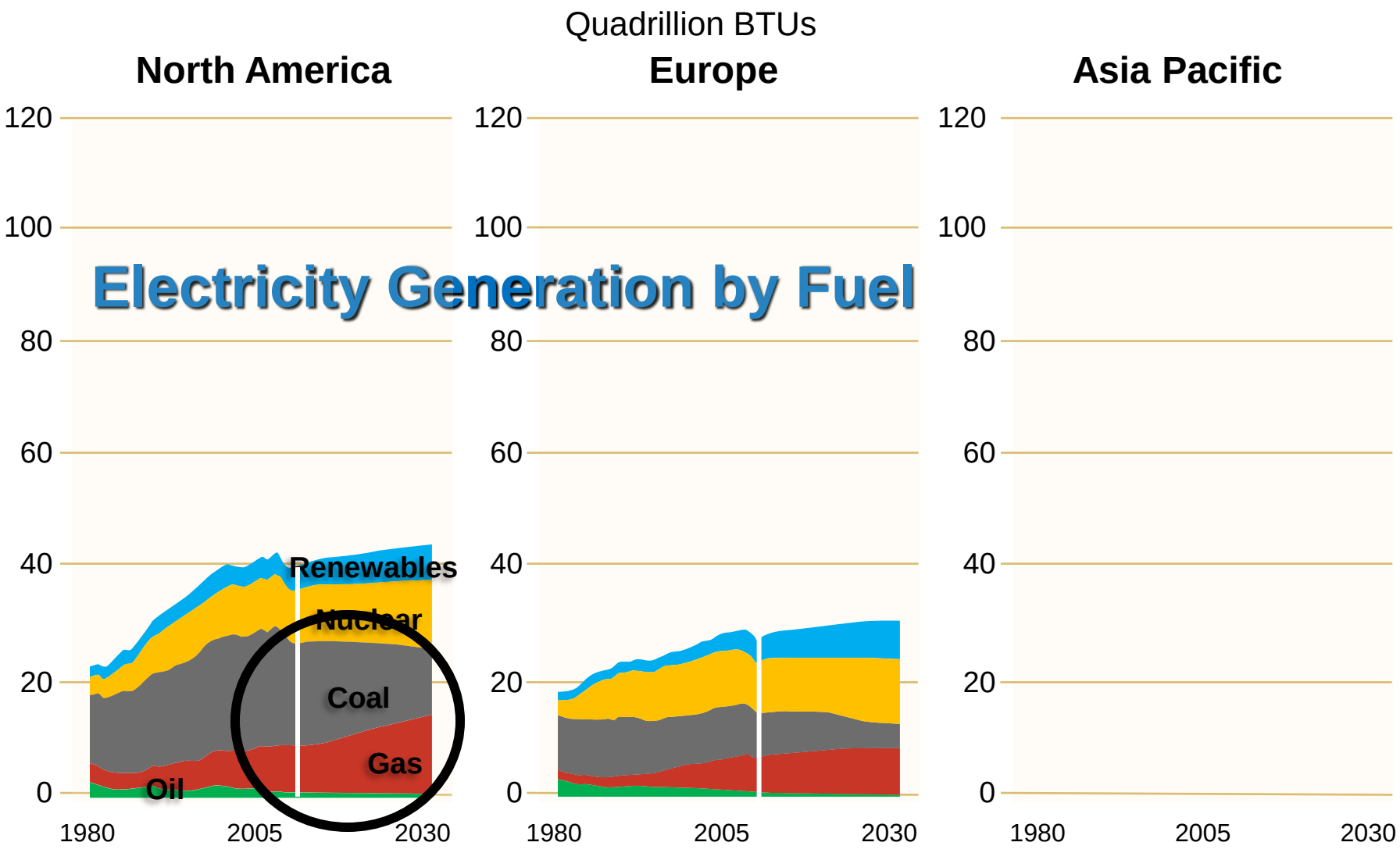


*Excludes corporate and government R&D

Source: Bloomberg New Energy Finance, The Economist, April 26, 2014

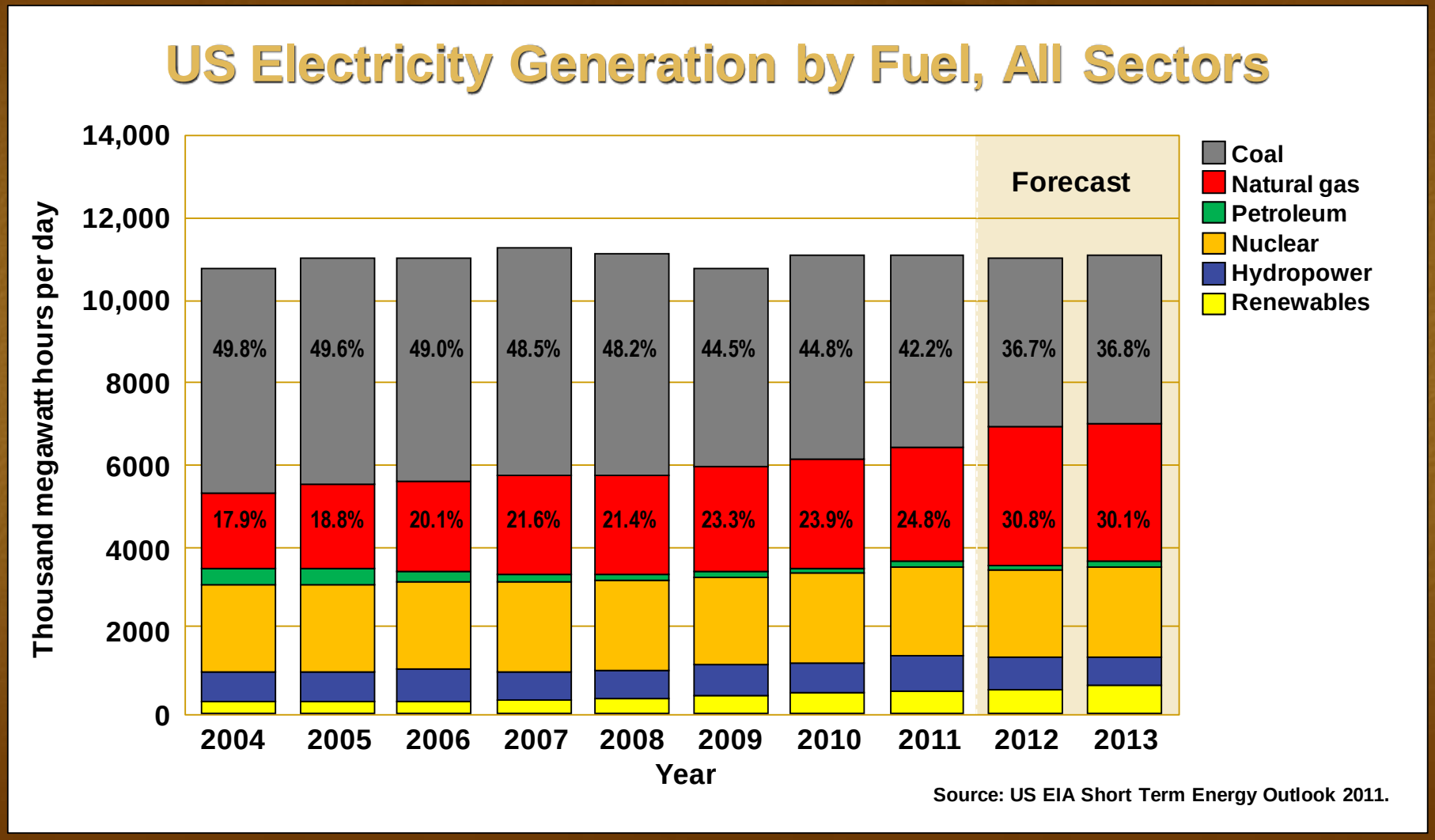
QAe2822

The Future Electricity Mix



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

The Future Electricity Mix



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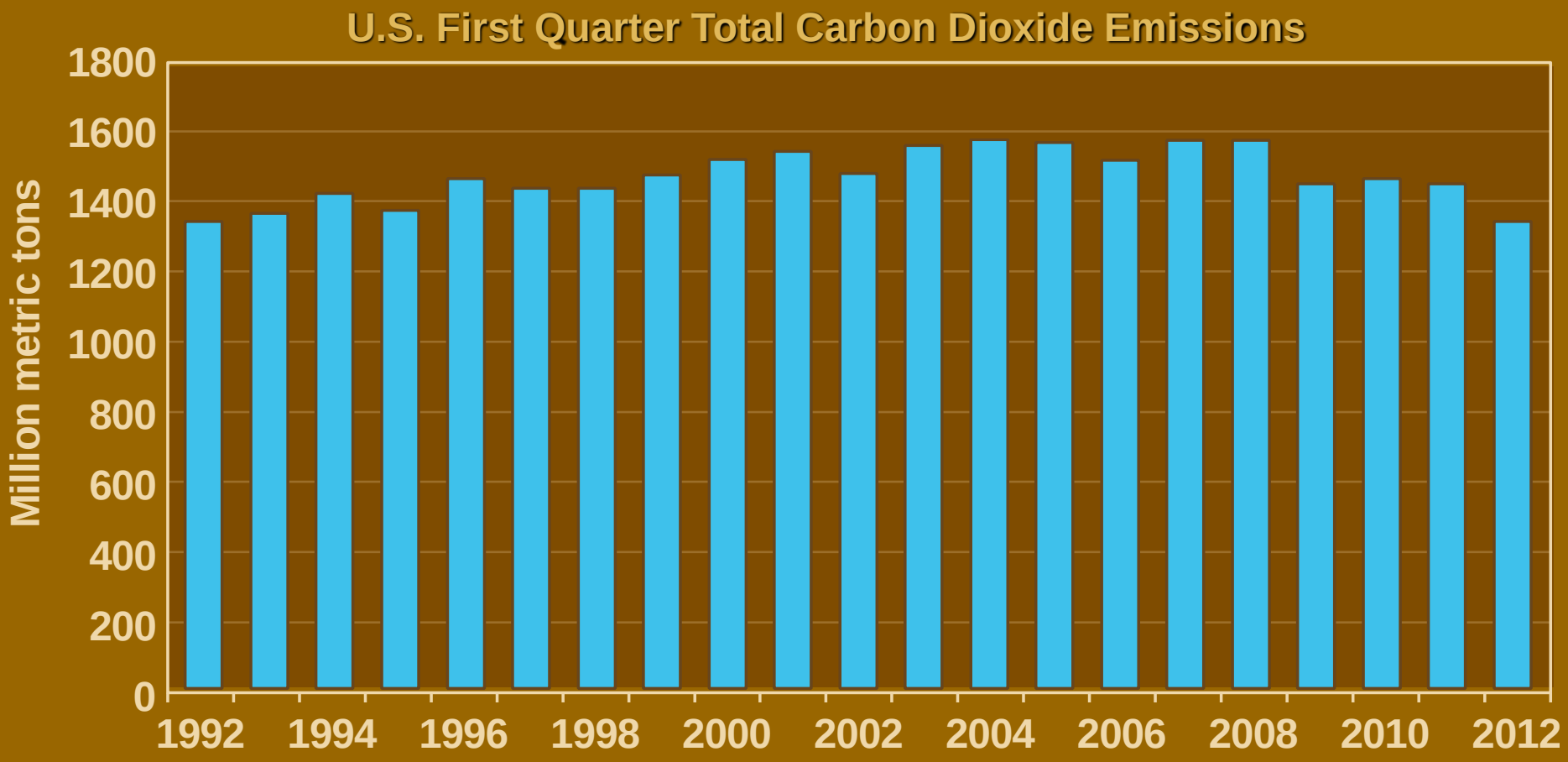

Source: EIA

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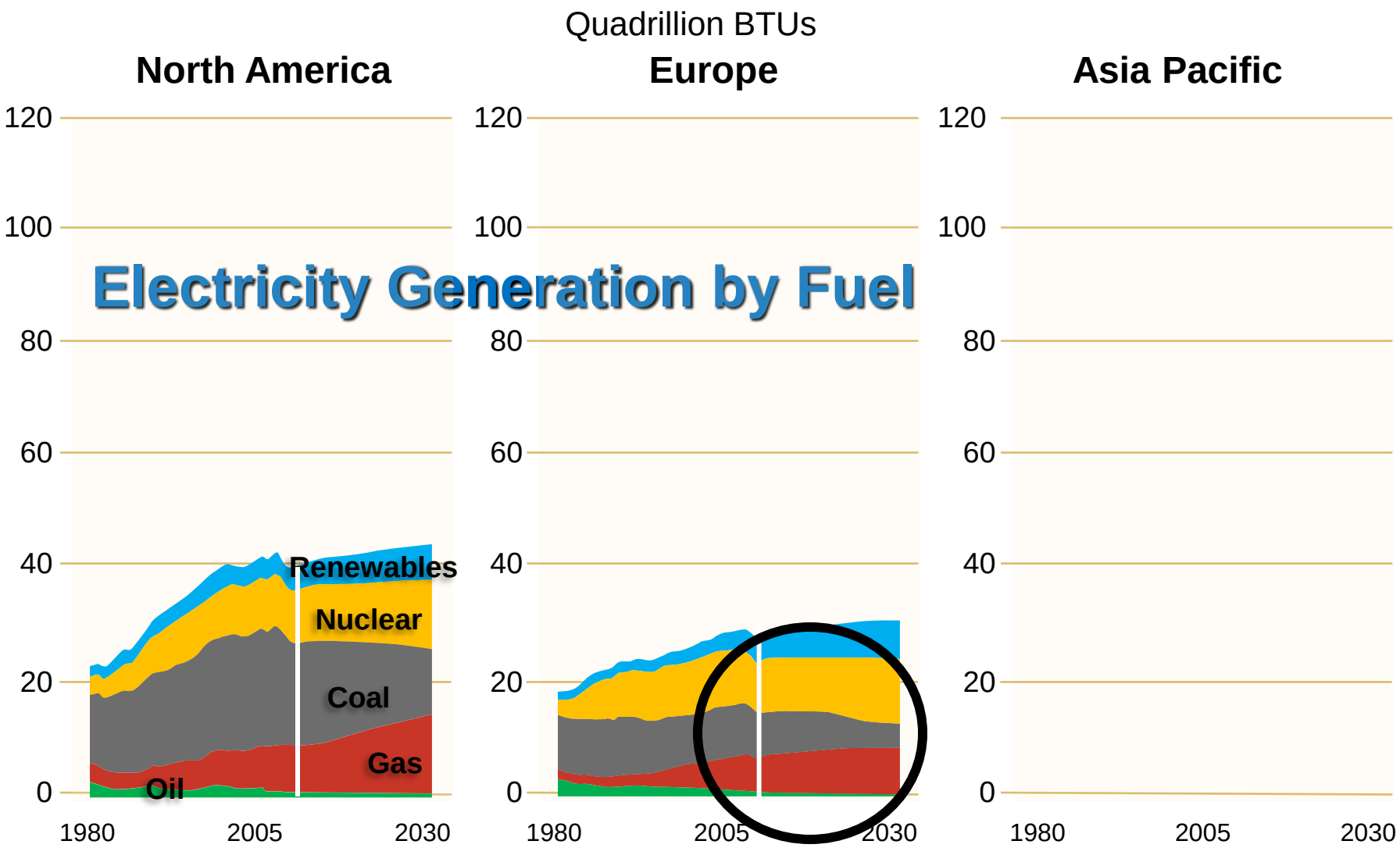
The Future Electricity Mix



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Tinker, 2014

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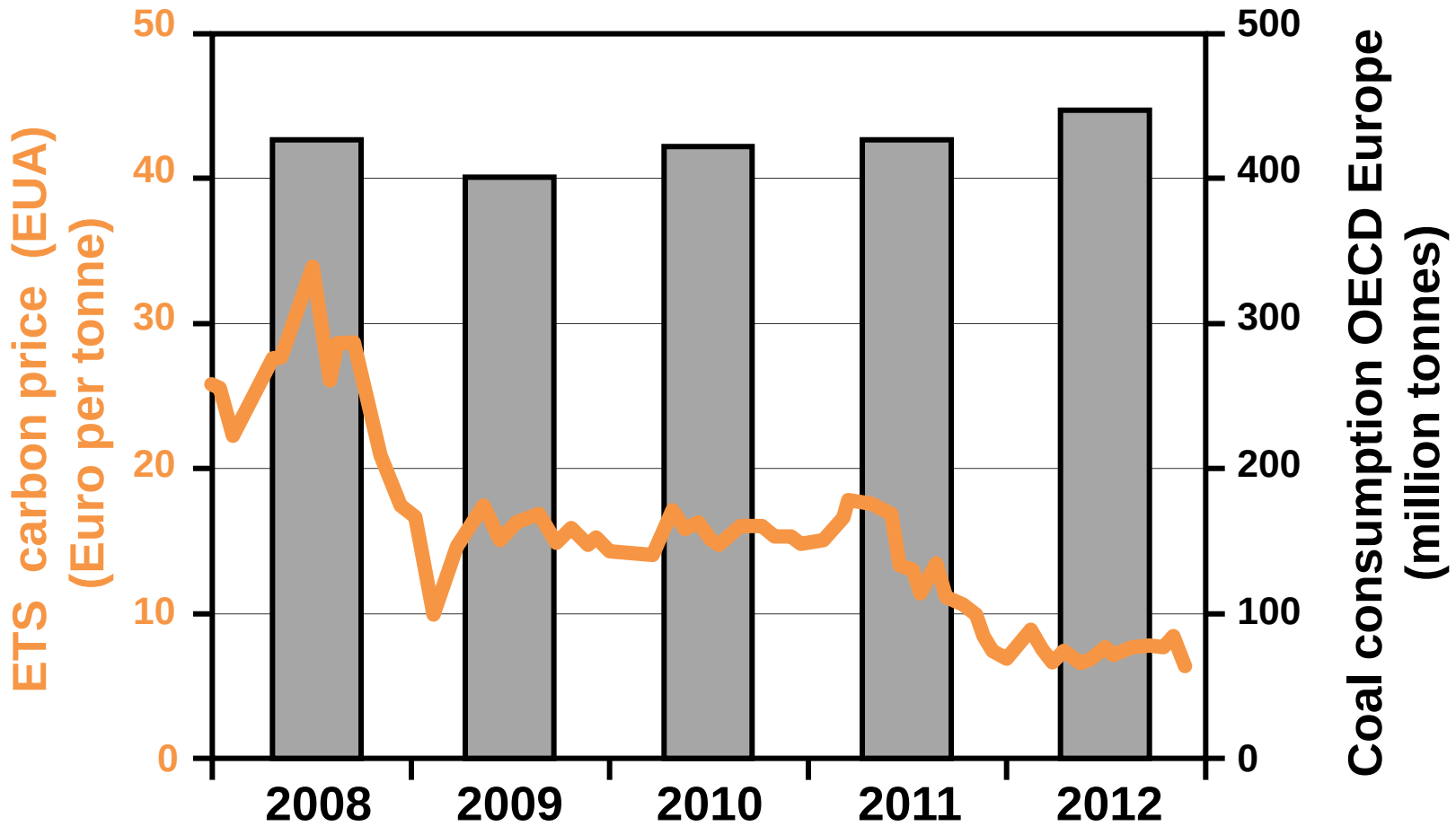

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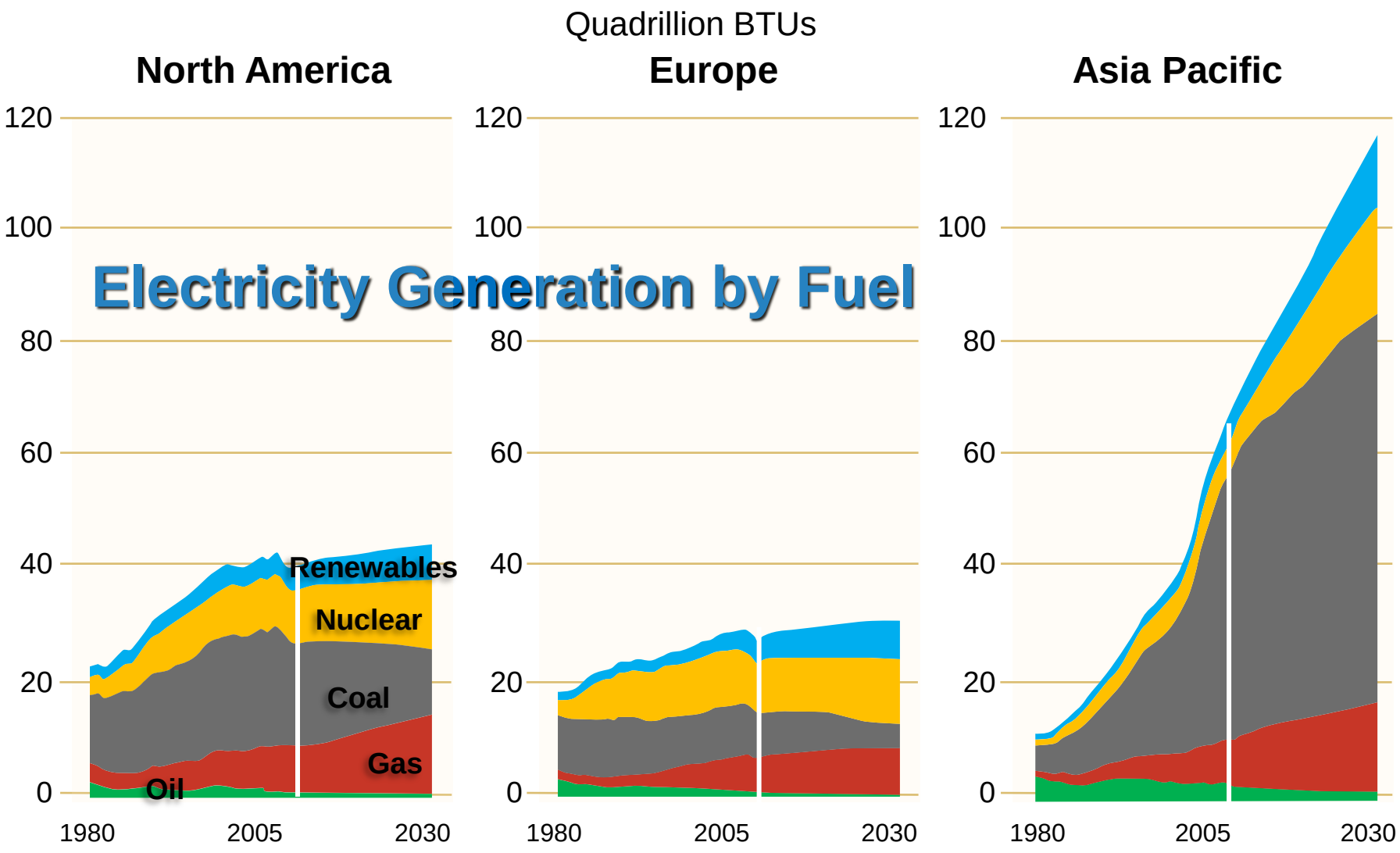
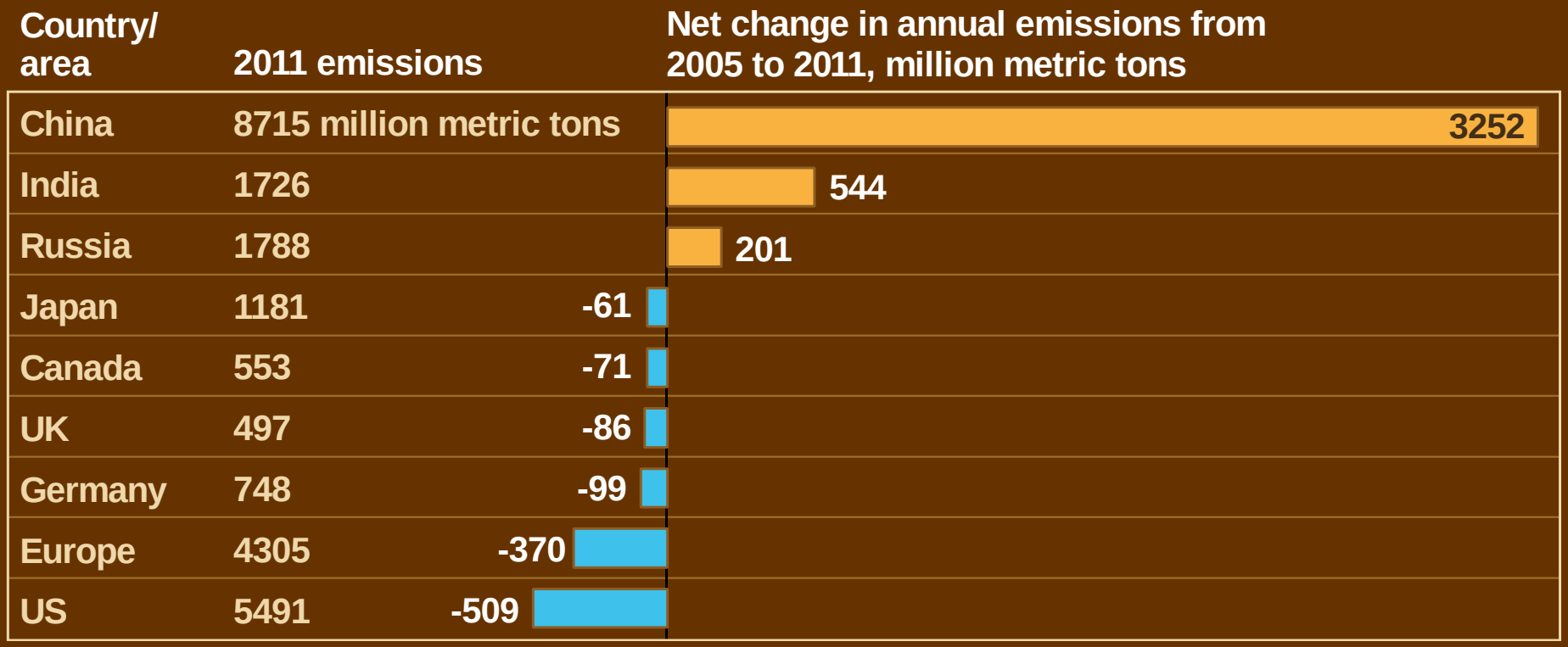


ExxonMobil Corporation, 2010, The outlook for energy: a view to 2030: ExxonMobil report, 53 p.

The Future Electricity Mix

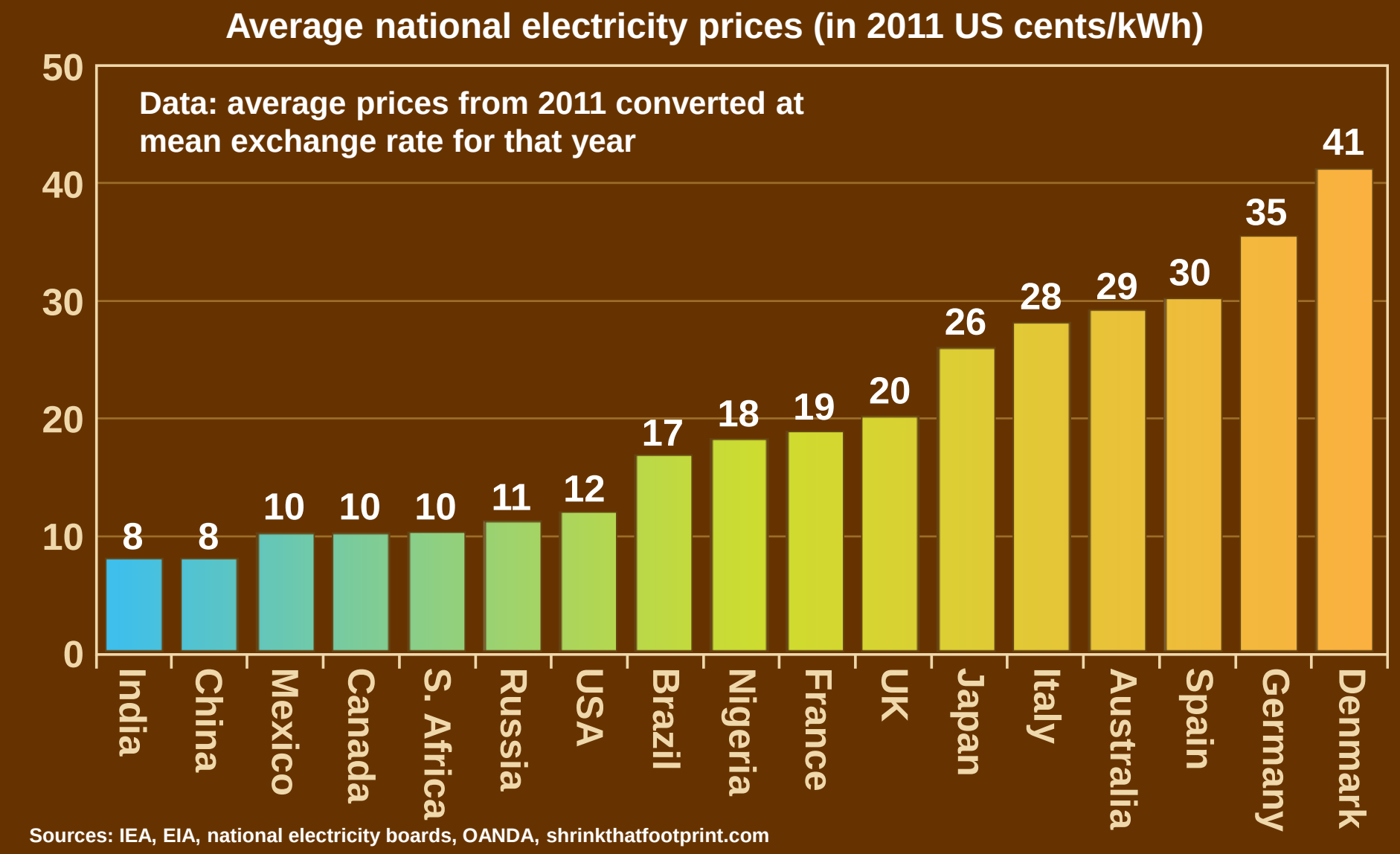
Energy-related carbon-dioxide emissions by geography, and net change since 2005



Sources: US DOE, The Wall Street Journal

Tinker, 2014

The Future Electricitv Mix



Sources: IEA, EIA, national electricity boards, OANDA, shrinkthatfootprint.com

Energy Security

Affordable	**Cost**
	Price Volatility: stable or fluctuating
	Infrastructure: Cost to build the plant
Available	**Access: substantial resources**
Reliable	**Intermittent: source consistent or variable**
	Safe: natural/human causes
Sustainable	**Clean: air and atmospheric emissions**
	Dense: land footprint
	Dry: fresh water use/risk

Energy Security

Affordable

Cost

Economy

Price Volati… …ctuating

Infrastructure: Cost to build the plant

Available

A…

The Three Es

Reliable

In… …iable

Safe: natural/human causes

Sustainable

Clean: a… …ssions

Environment

Dense: land footprint

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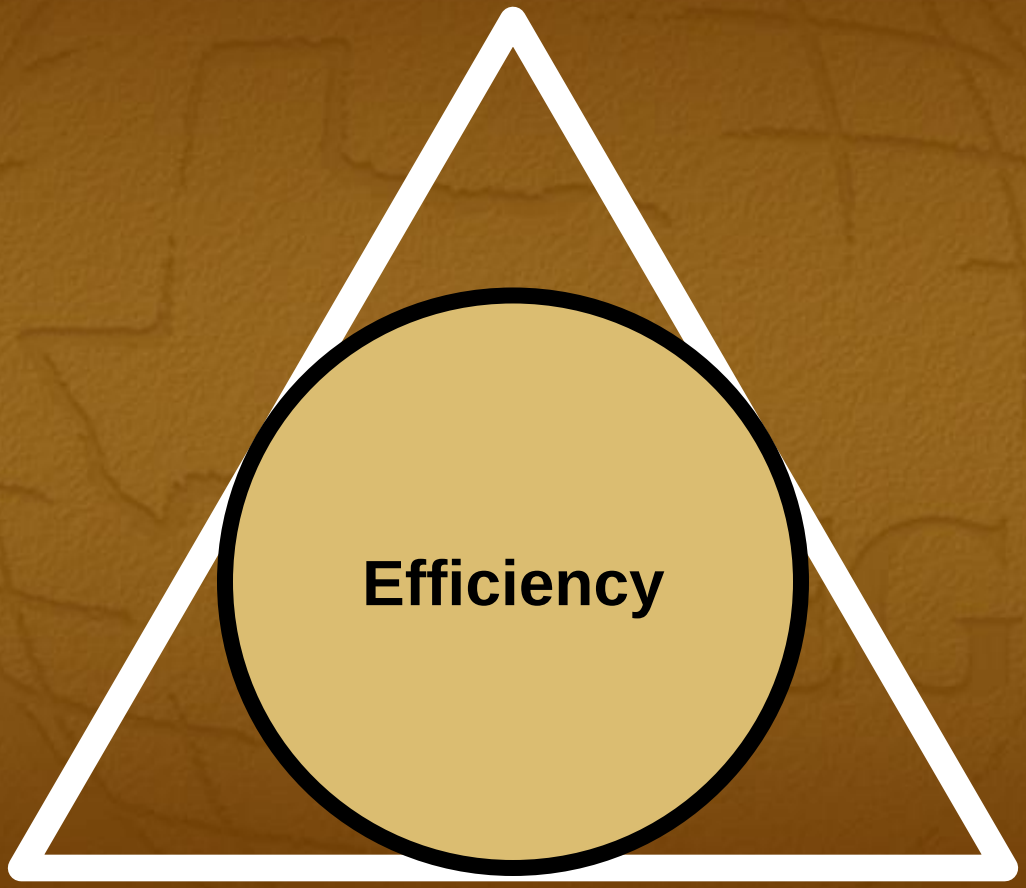
The 4th E



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Efficiency

Benefits

- Save energy
- Lower emissions
- Less water
- Less infrastructure
- Less land
- Save $

Challenges

- Incentivize producers to produce less
- Expensive to install
- Requires a ***cultural change***

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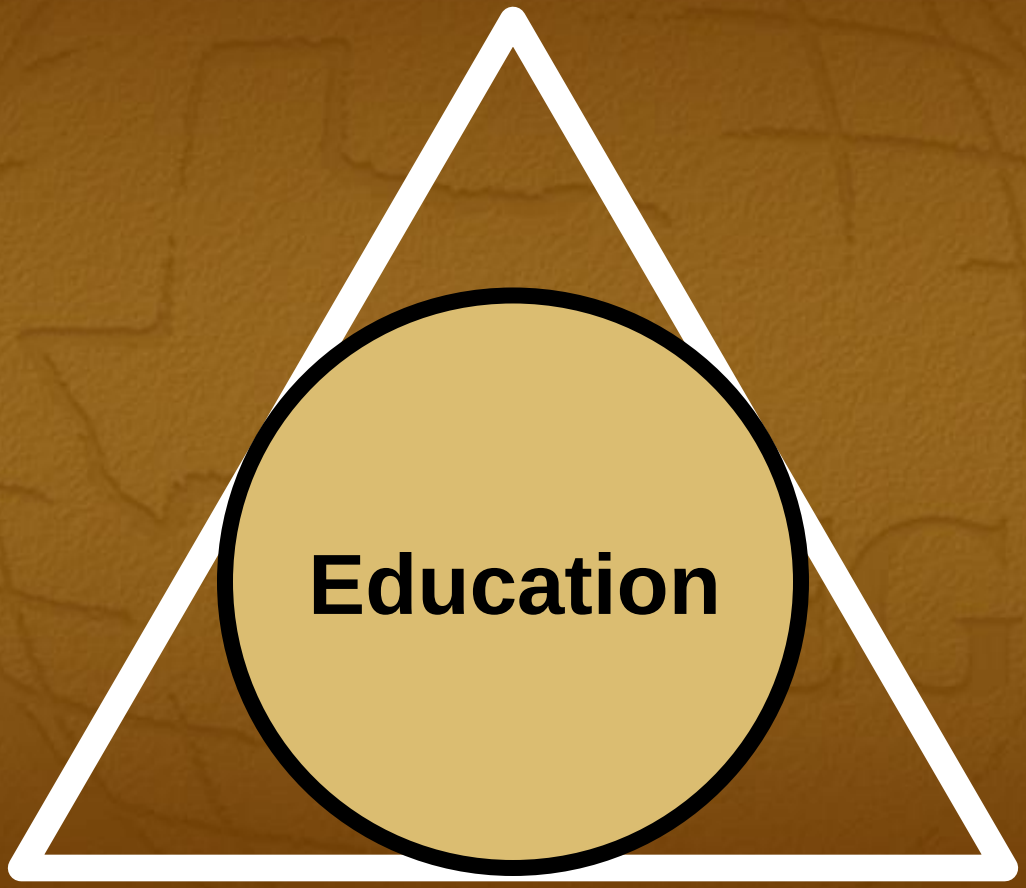
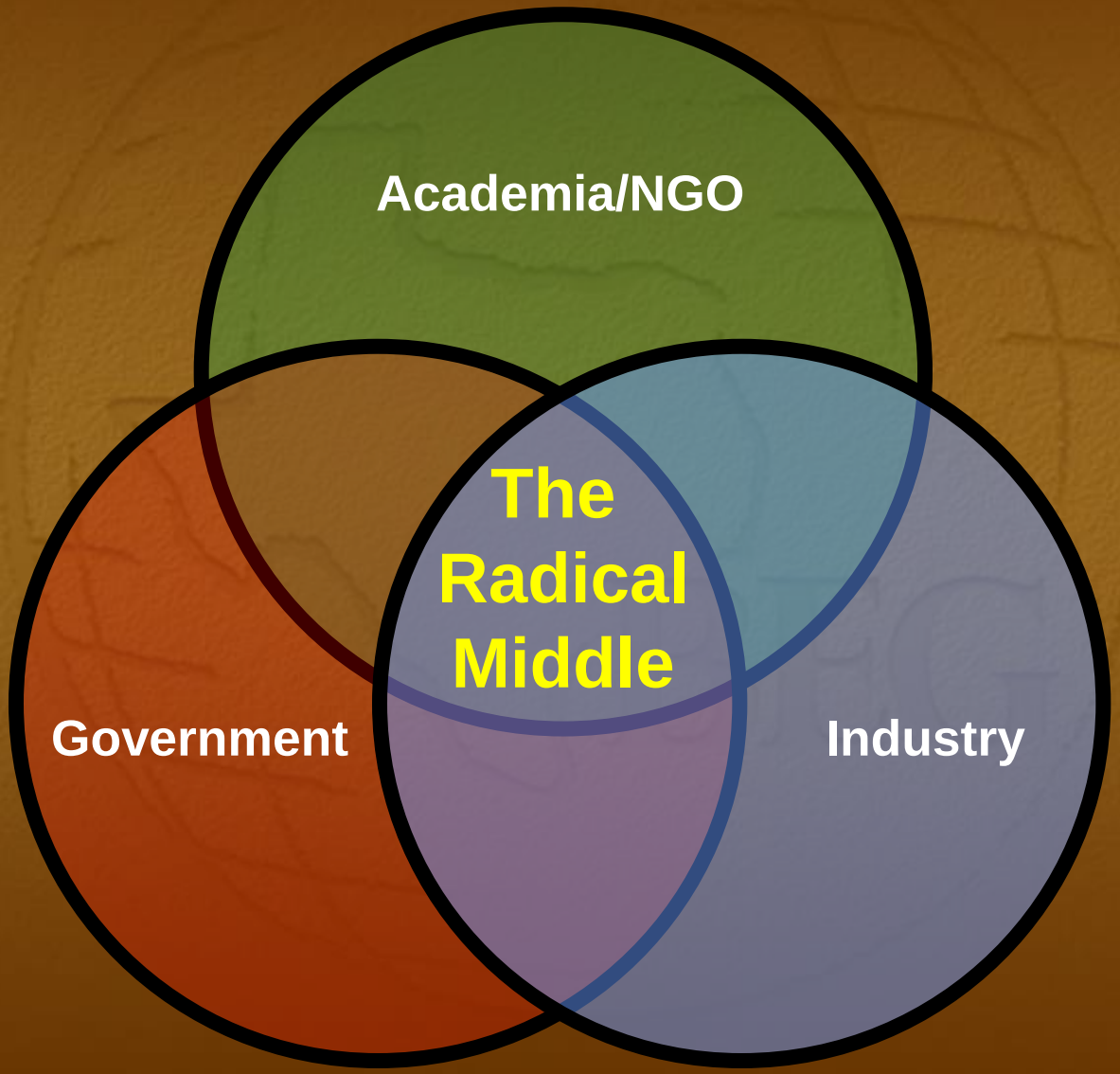
The 5E Waltz

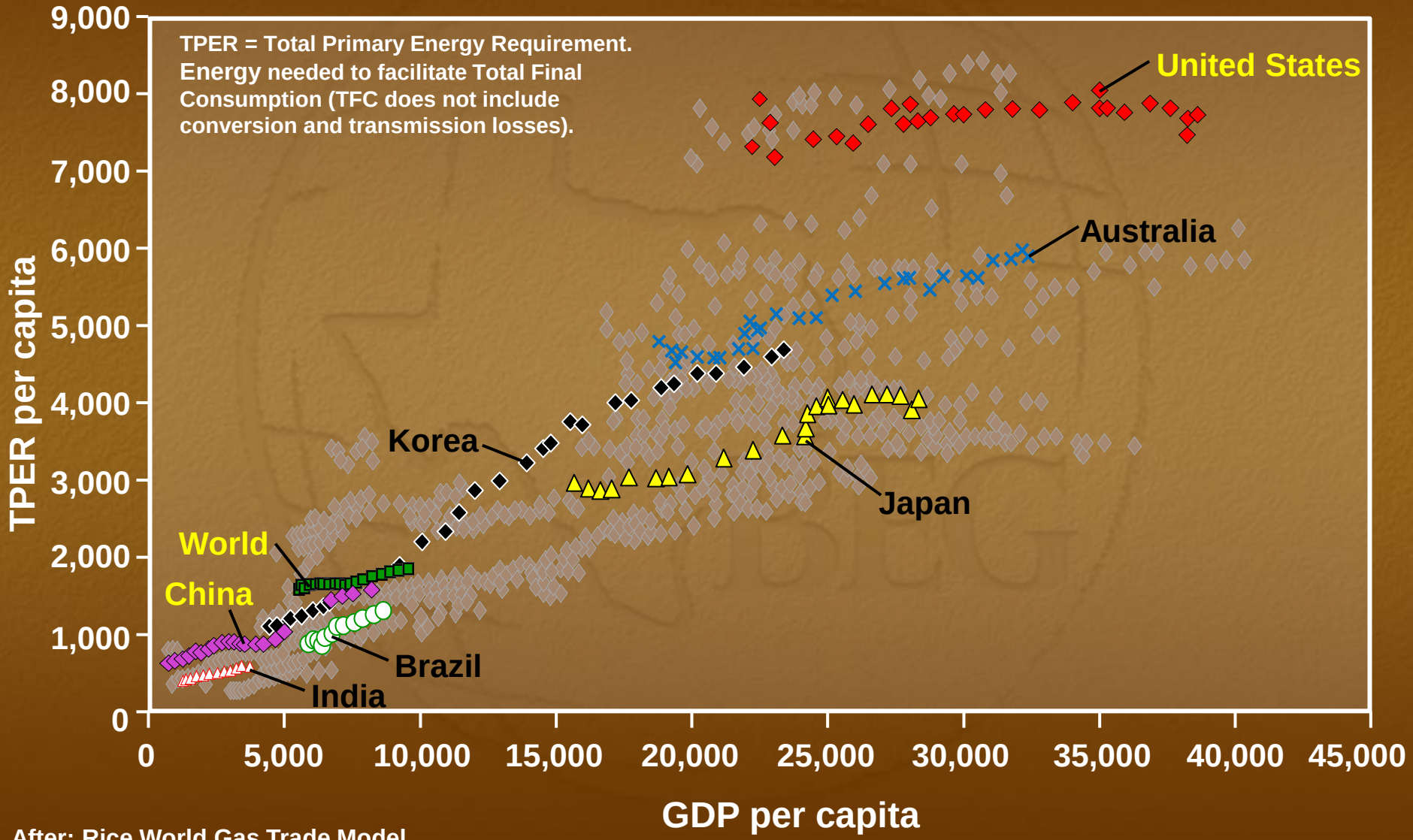


The Radical Middle

Tinker, 2014

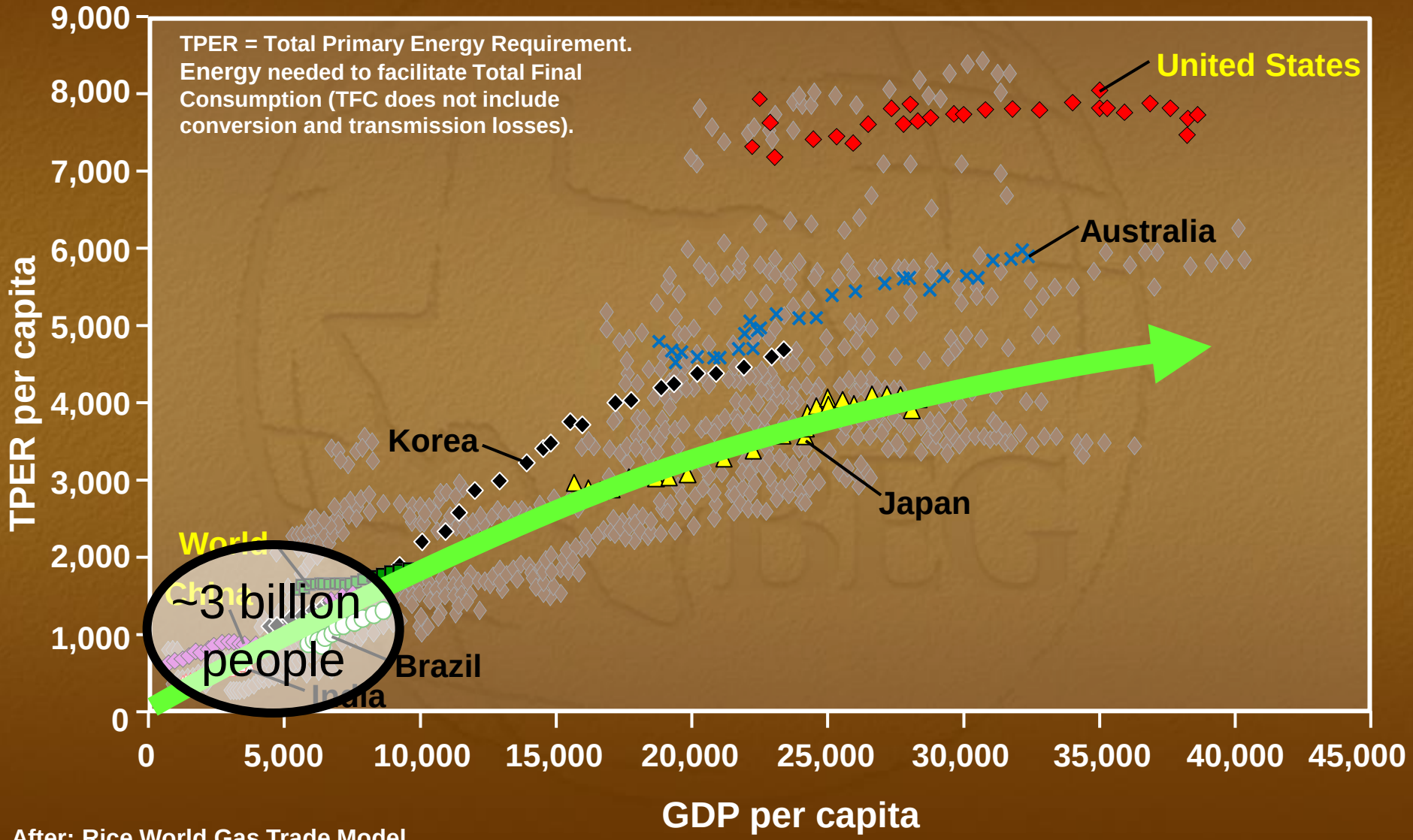


Energy and the Economy



After: Rice World Gas Trade Model
Medlock, 2012

Energy and the Economy



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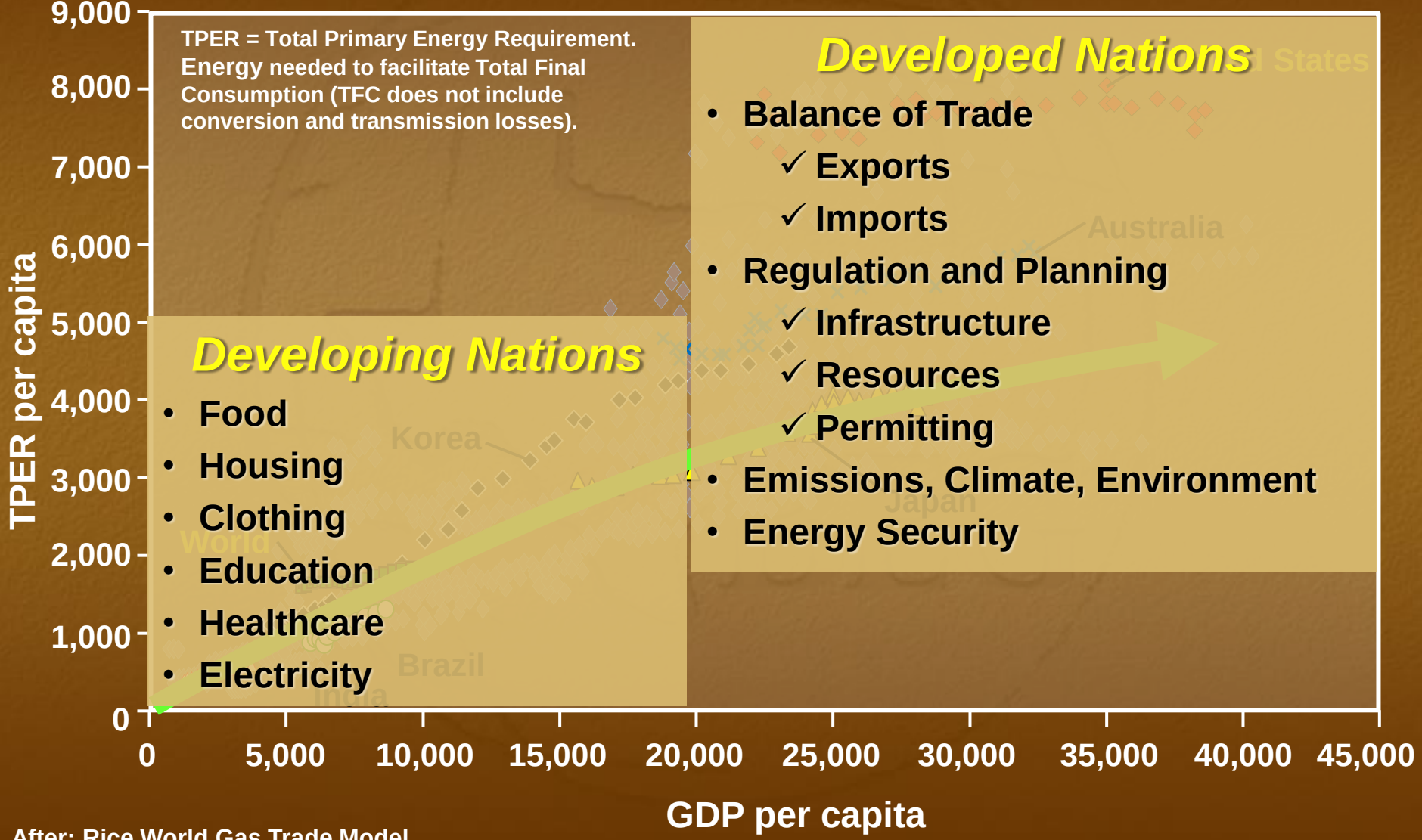
Medlock, 2012

Energy and the Economy
A Global Challenge



After: Rice World Gas Trade Model
Medlock, 2012

Tinker, 2014

Tinker's Top Ten

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.