Gas Compressor Association

Galveston, Texas April, 2013

State of Tomorrow

Energy, Economy and the Environment

Scott W. Tinker

Bureau of Economic Geology

Jackson School of Geosciences, The University of Texas at Austin

Outline

- Energy, Economy, Environment
- Electricity
- Transportation
- Efficiency
- A Look at the Future

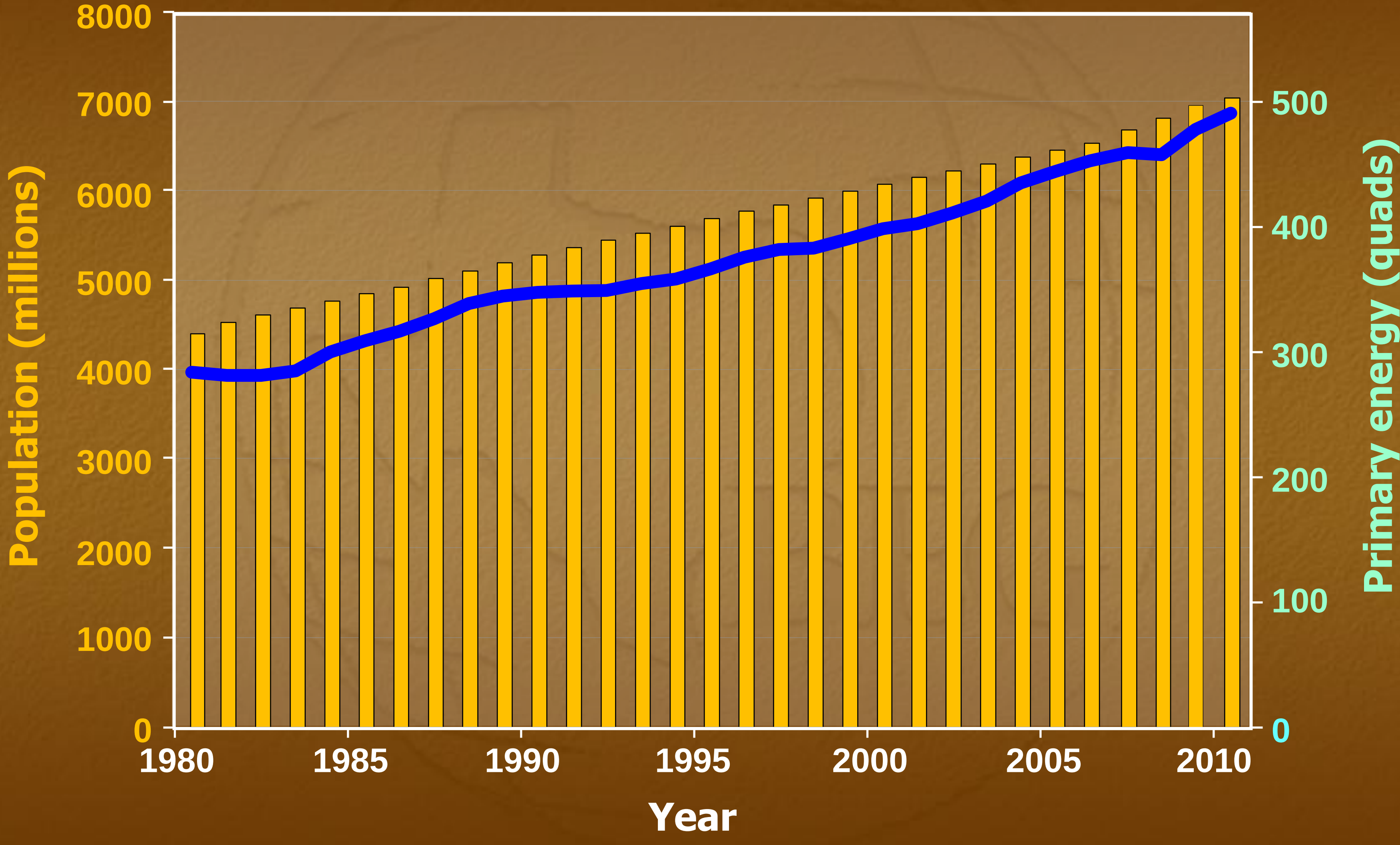
Overarching Themes

Have a bit of fun along the way!

- **Energy transitions take time**
- **Efficiency requires a change in thinking**
- **No form of energy is perfect**
- **Energy, economy and environment linked**
- **Energy demand is about people**

Tinker, 2012

Global Population and Energy



Source: BP Statistical Review of World Energy, 2012

http://www.eia.gov/iea/wecbtu.html

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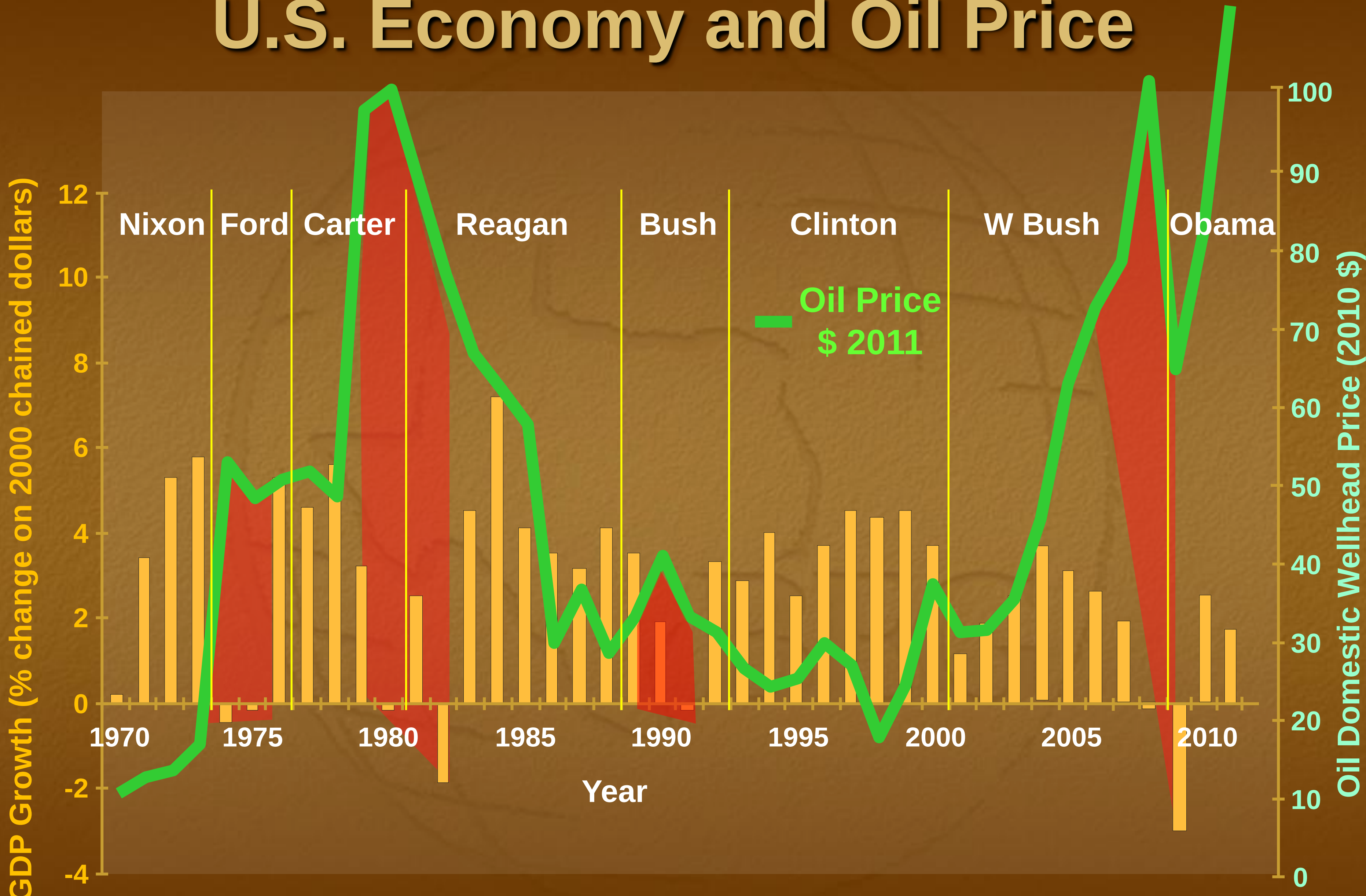
Tinker, 2012

U.S. Economy and Oil Price



Data: EIA and BP Statistical Analysis; US Department of Commerce

http://www.bp.com/sectiongenericarticle800.do?categoryId=9037172&contentId=7068612

1970-1983 Arabian Light 1984-2010 Brent dated

QAe876

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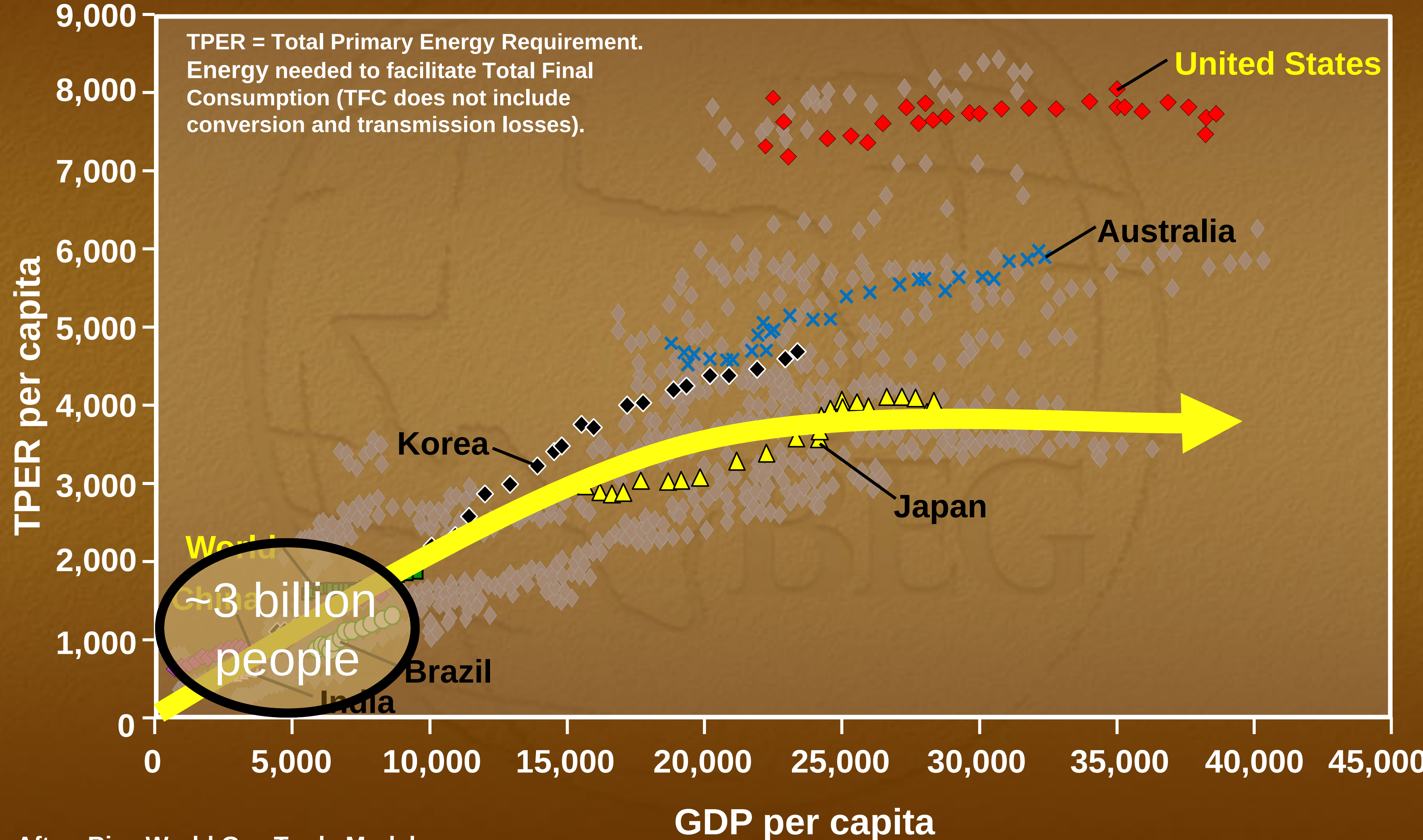
Energy and GDP



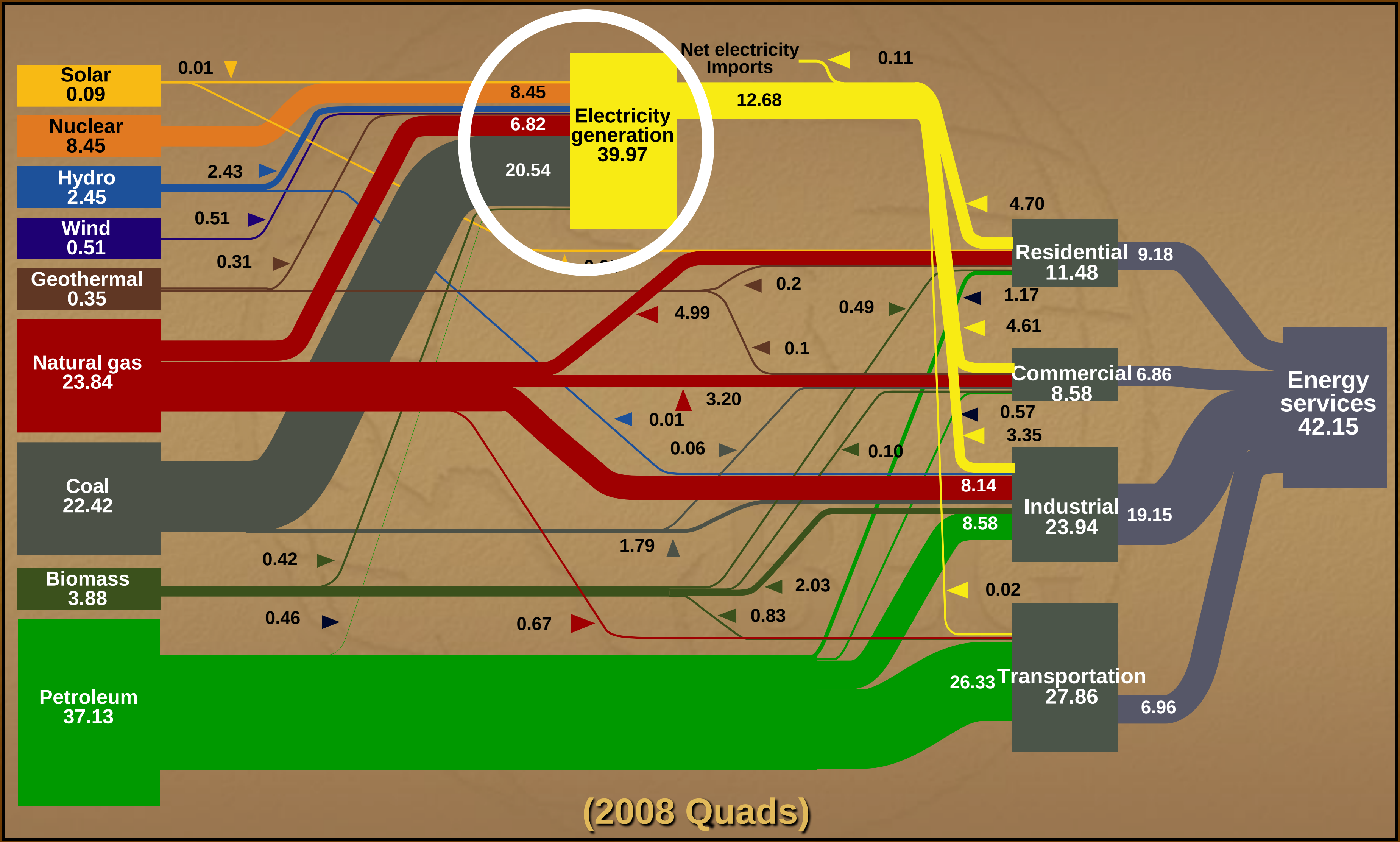
After: Rice World Gas Trade Model
Medlock, 2012

Outline

- Energy, Economy, Environment
- **Electricity**
- Transportation
- Efficiency
- A Look at the Future

Tinker, 2012

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

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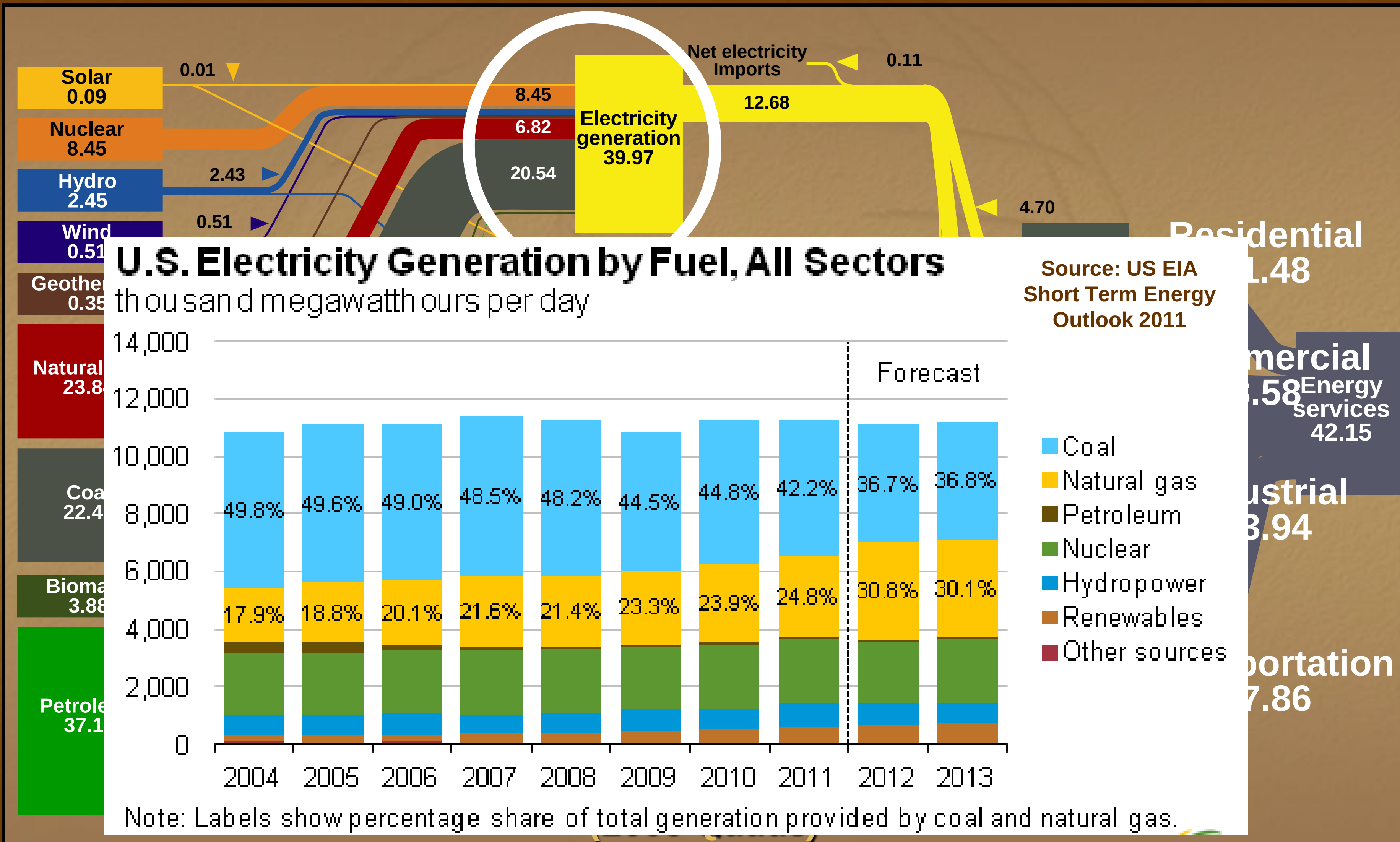
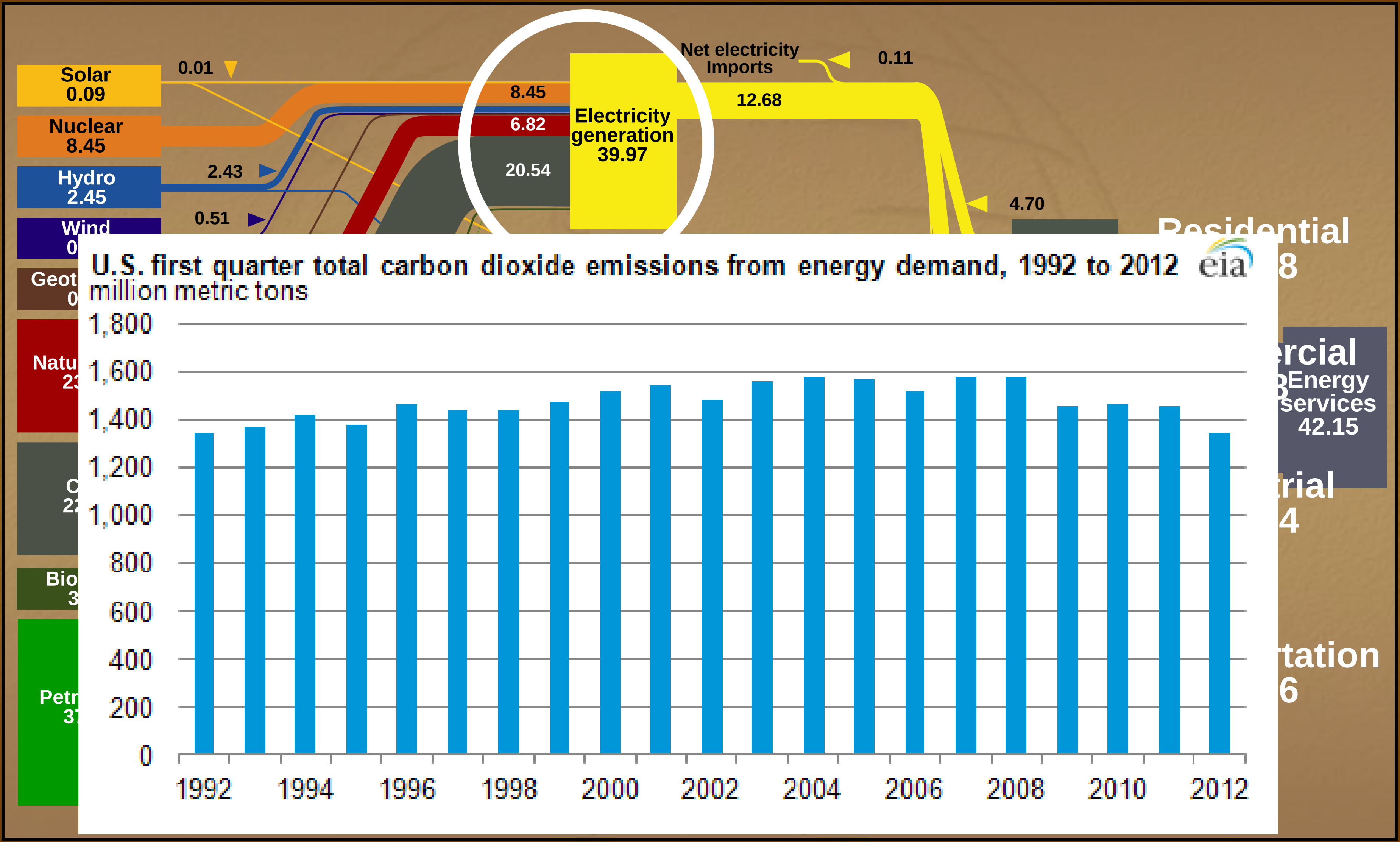
U. S. Energy Flows



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

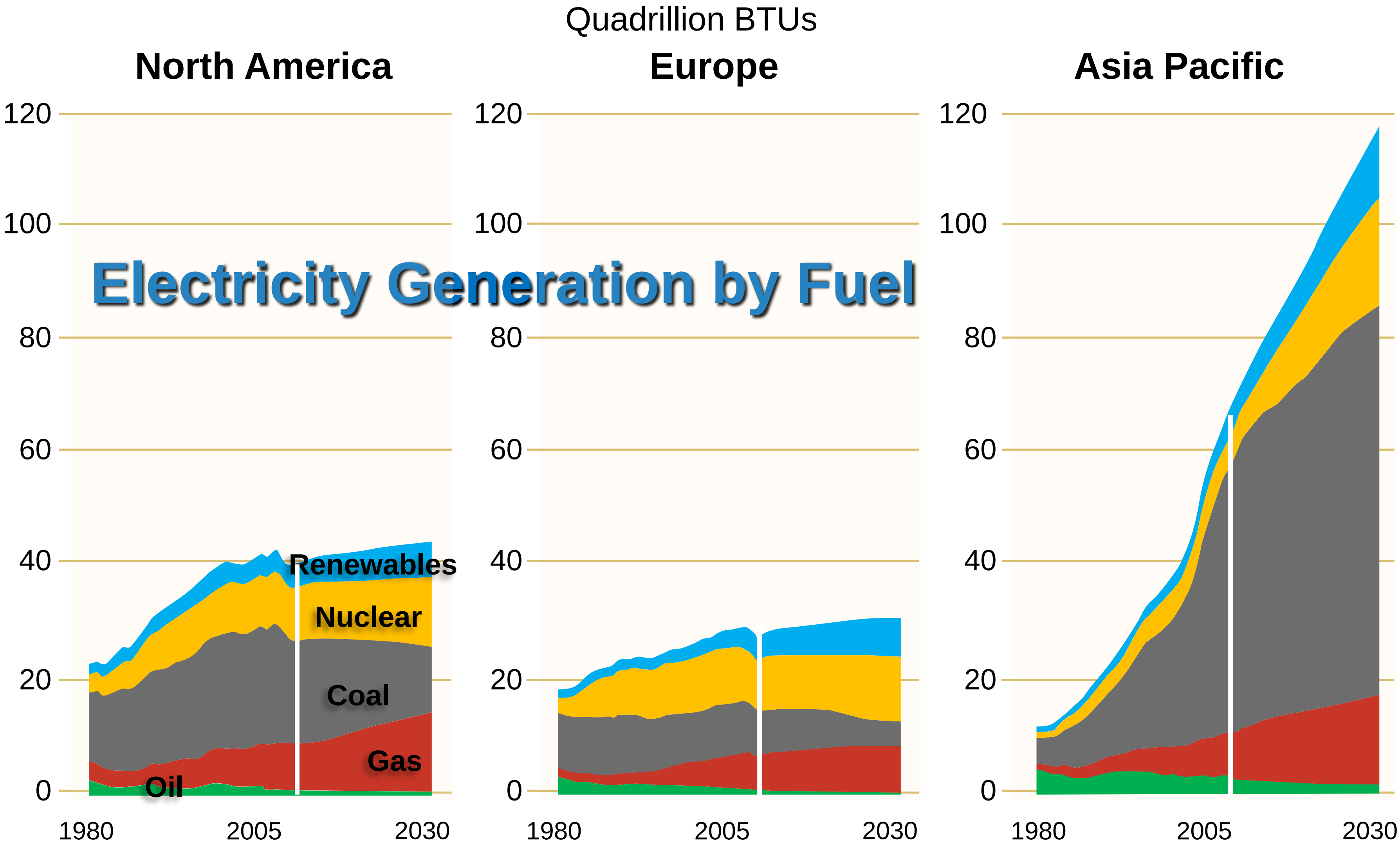
U. S. Energy Flows



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

Tinker, 2012

U. S. Energy Flows



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

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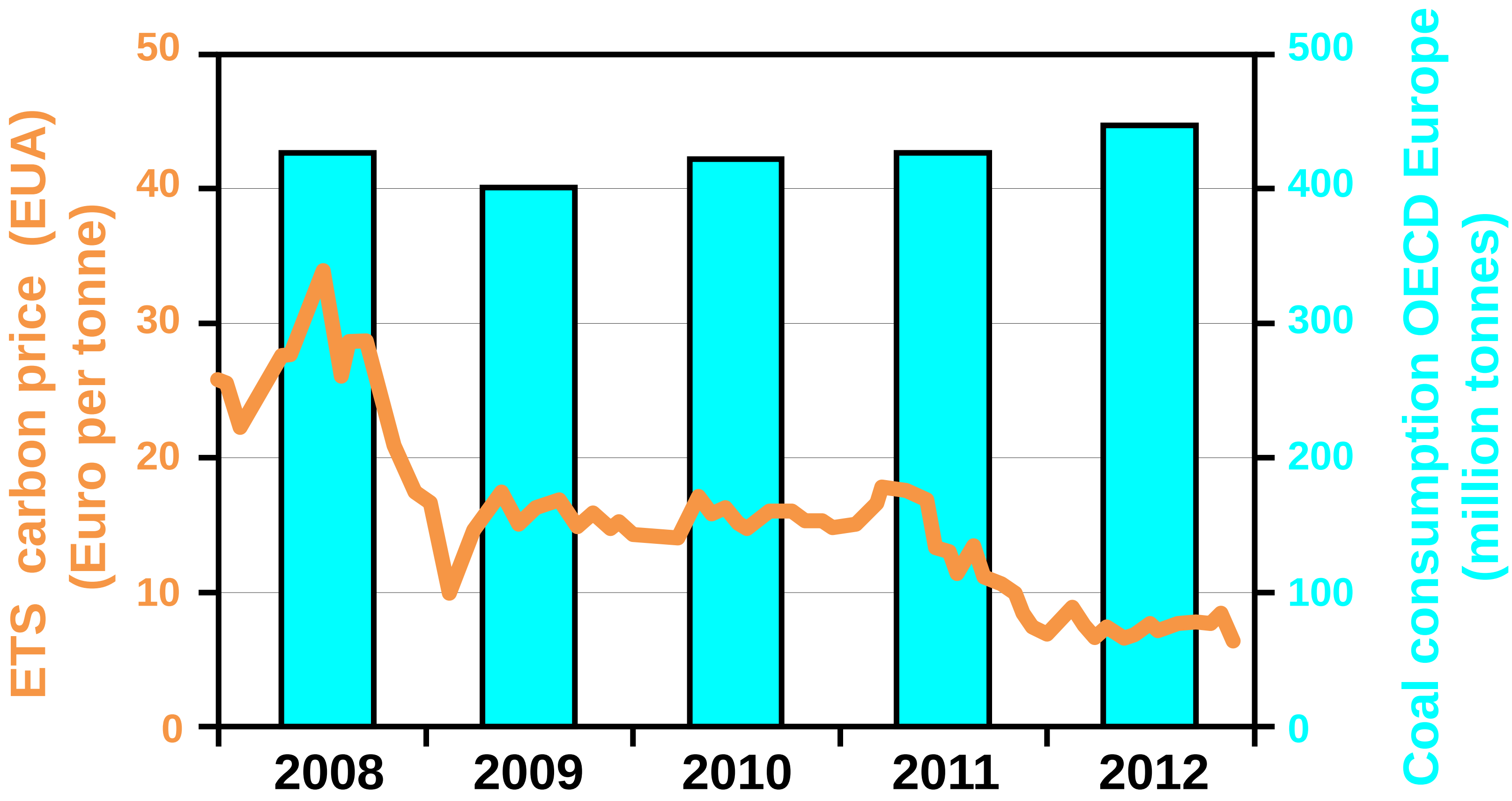
U. S. Energy Flows



1980 2005 2030 1980 2005 2030 1980 2005 2030

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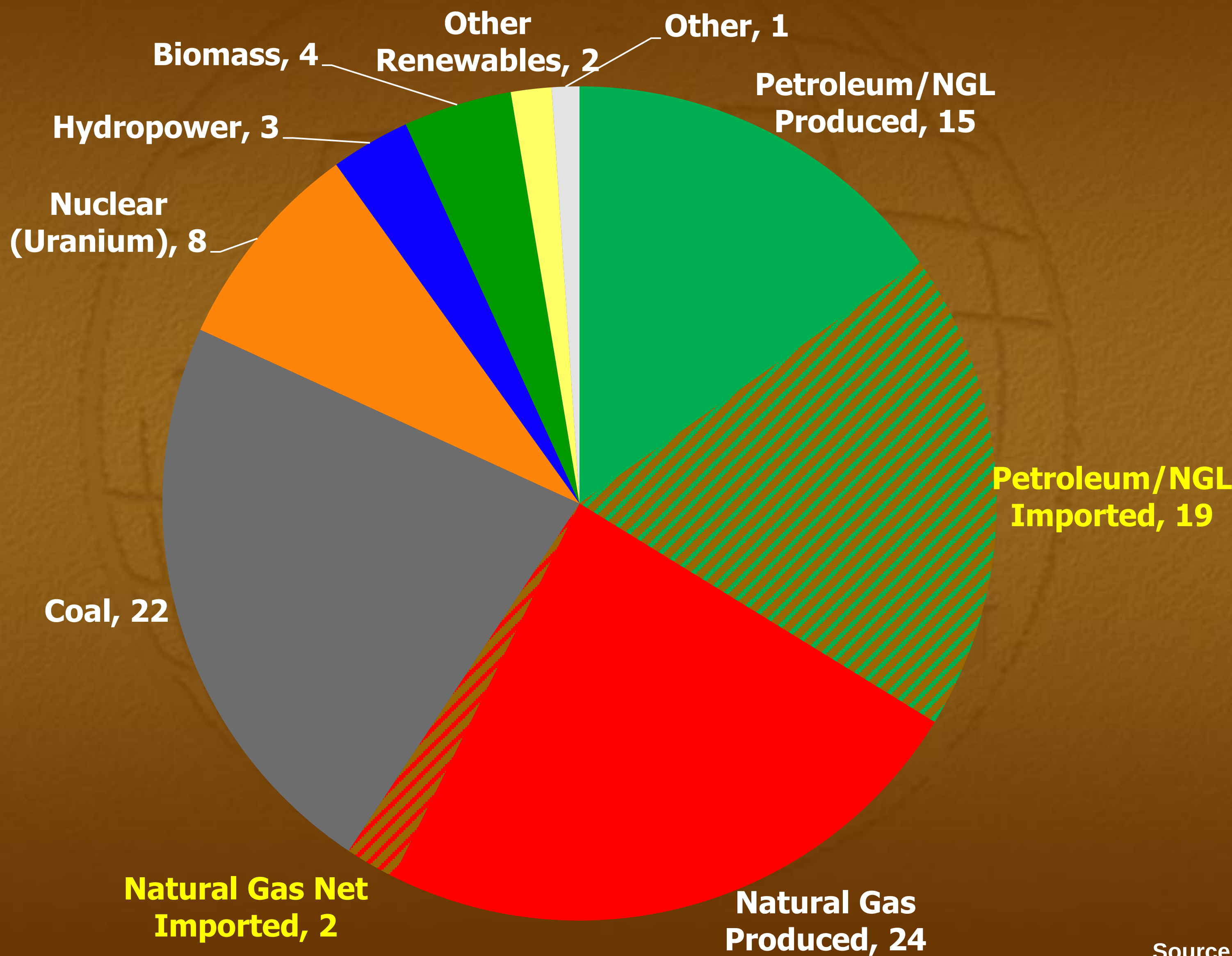
U.S. Energy Mix (%)



Source: EIA, 2012

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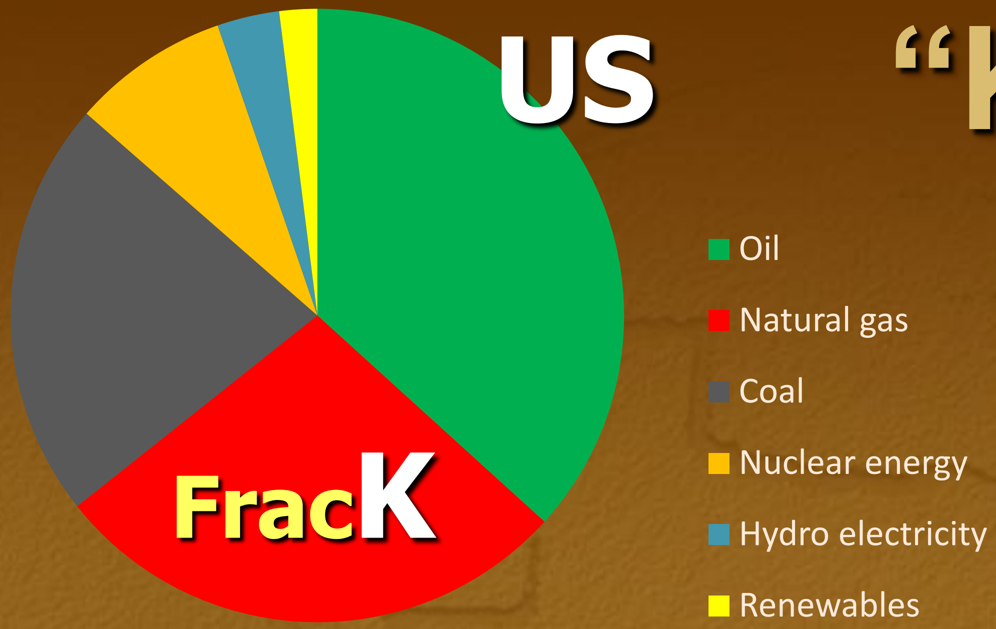
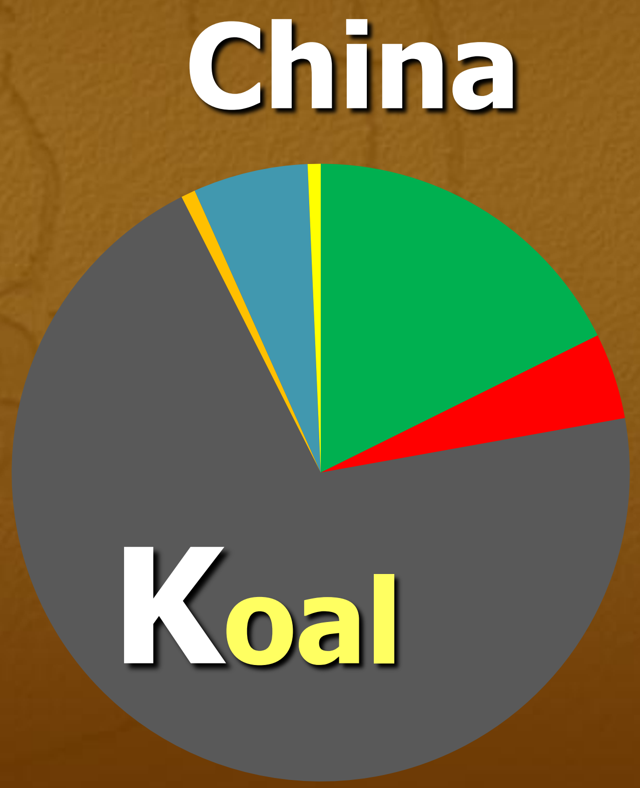
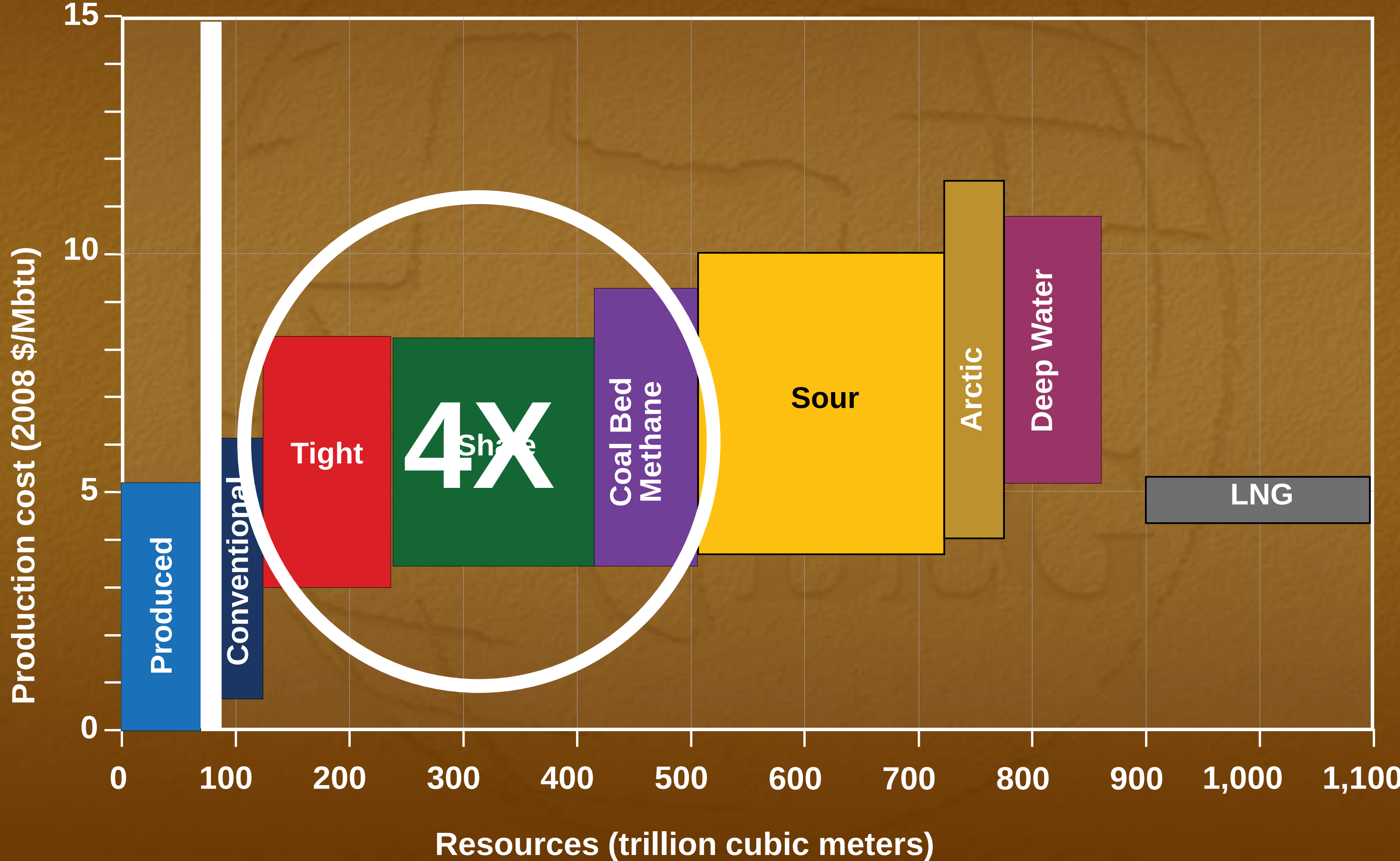
“K” is for…





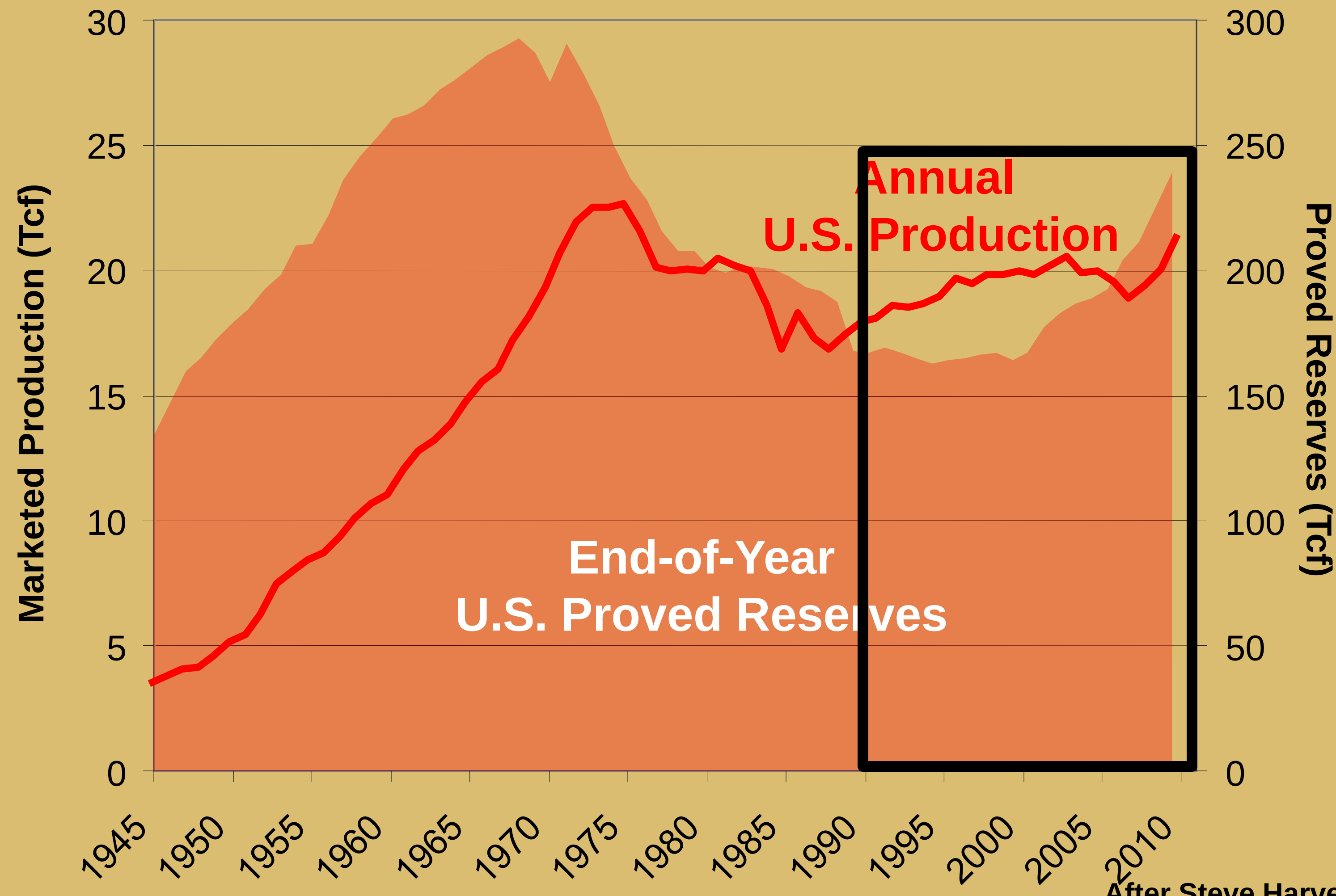
Natural Gas Supply - *Resources and Production*



Source: IEA World Energy Outlook (2009)

Tinker, 2012

U.S. Natural Gas
Production and Reserves



After Steve Harvey, EIA

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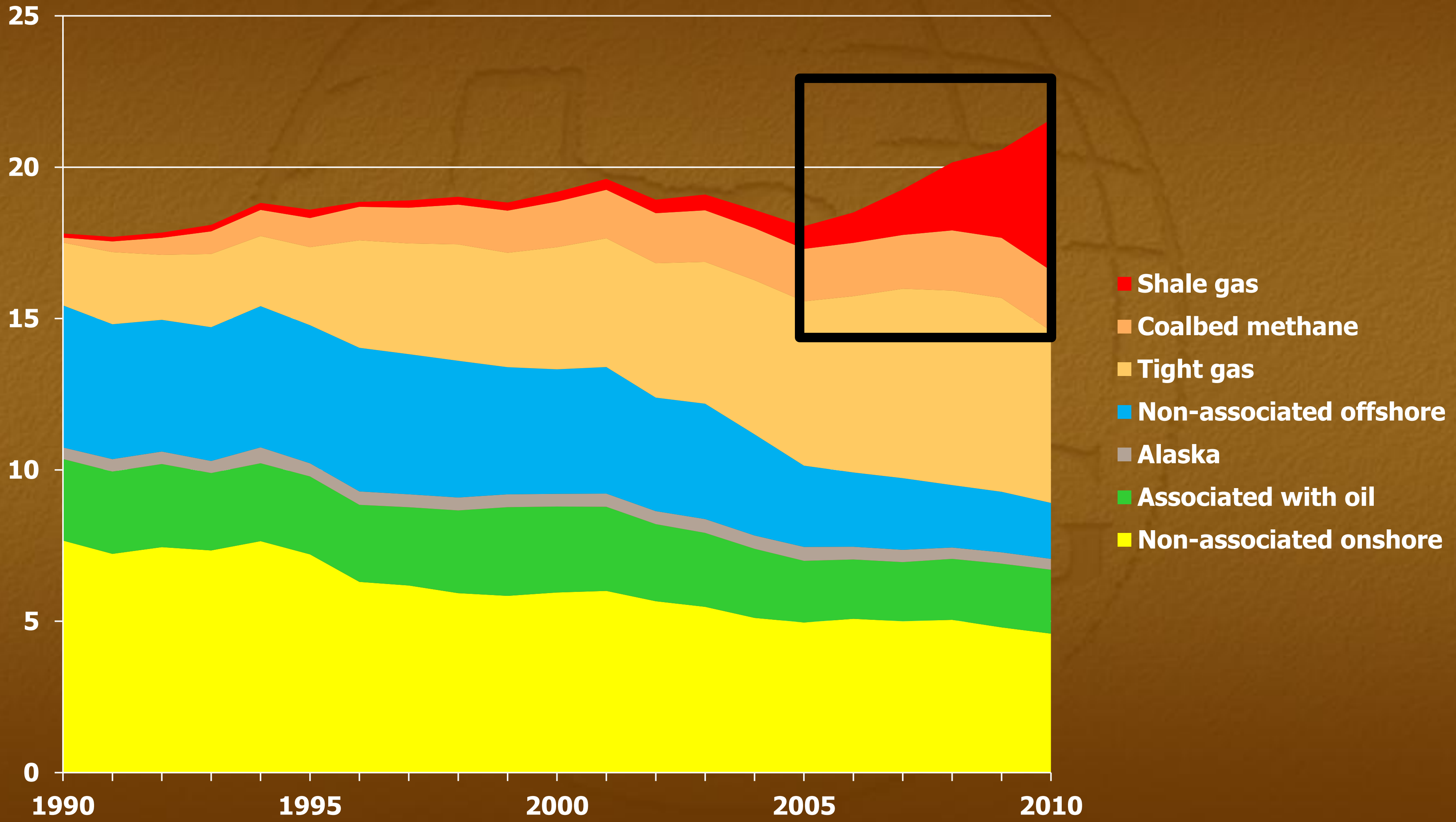
U.S. Natural Gas
Production (TcF)



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

Tinker, 2012

Hydraulic Fracturing
"Fracking"

Water

Proppant

Friction Reducers: always (polyacrylamide)

Biocides: often (glutaraldehyde, chlorine)

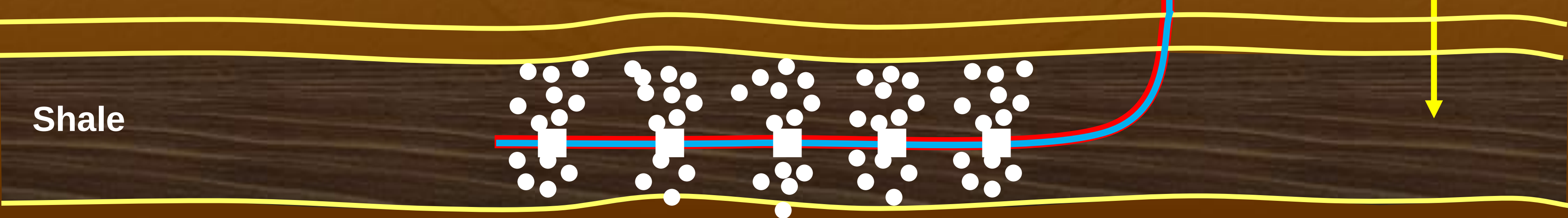
Scale Inhibitors: sometimes (phosphonate)

Surfactants: sometimes (soaps and cleaners)

3,000 to 10,000+ feet

3,000 – 10,000 feet

3 – 6 million gallons



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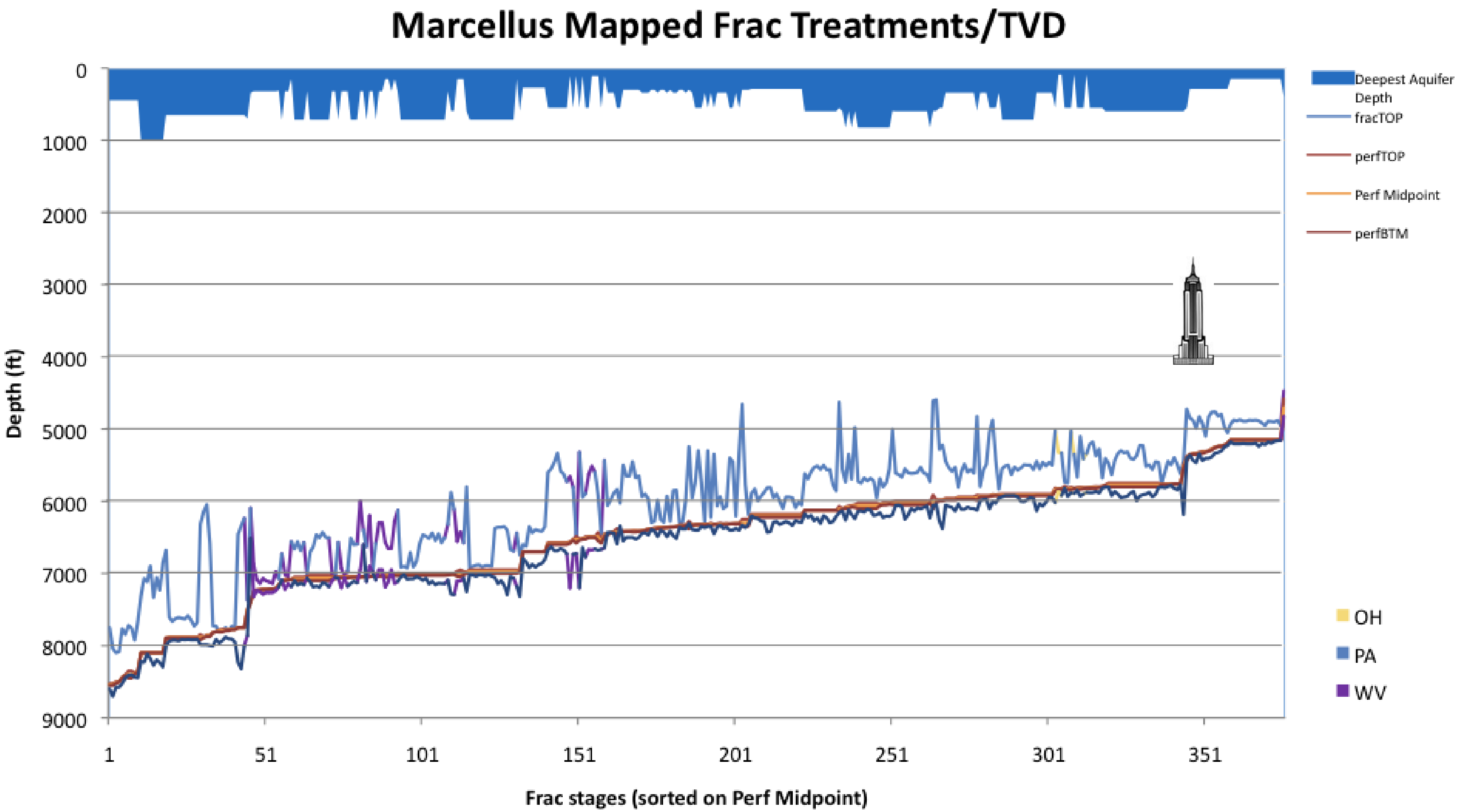
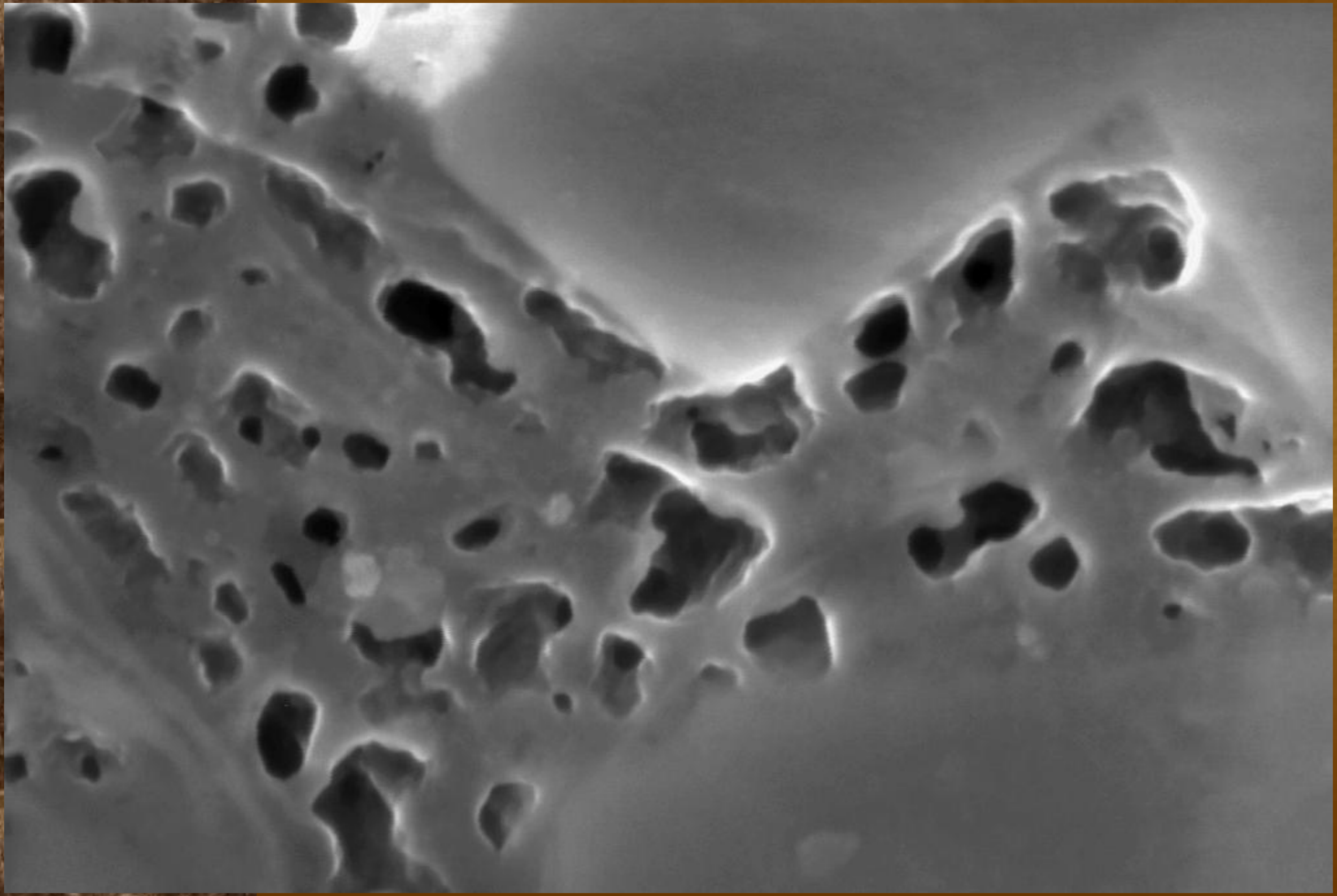
Depth of Operations



Pinnacle
A HALLIBURTON SERVICE

Barnett Shale

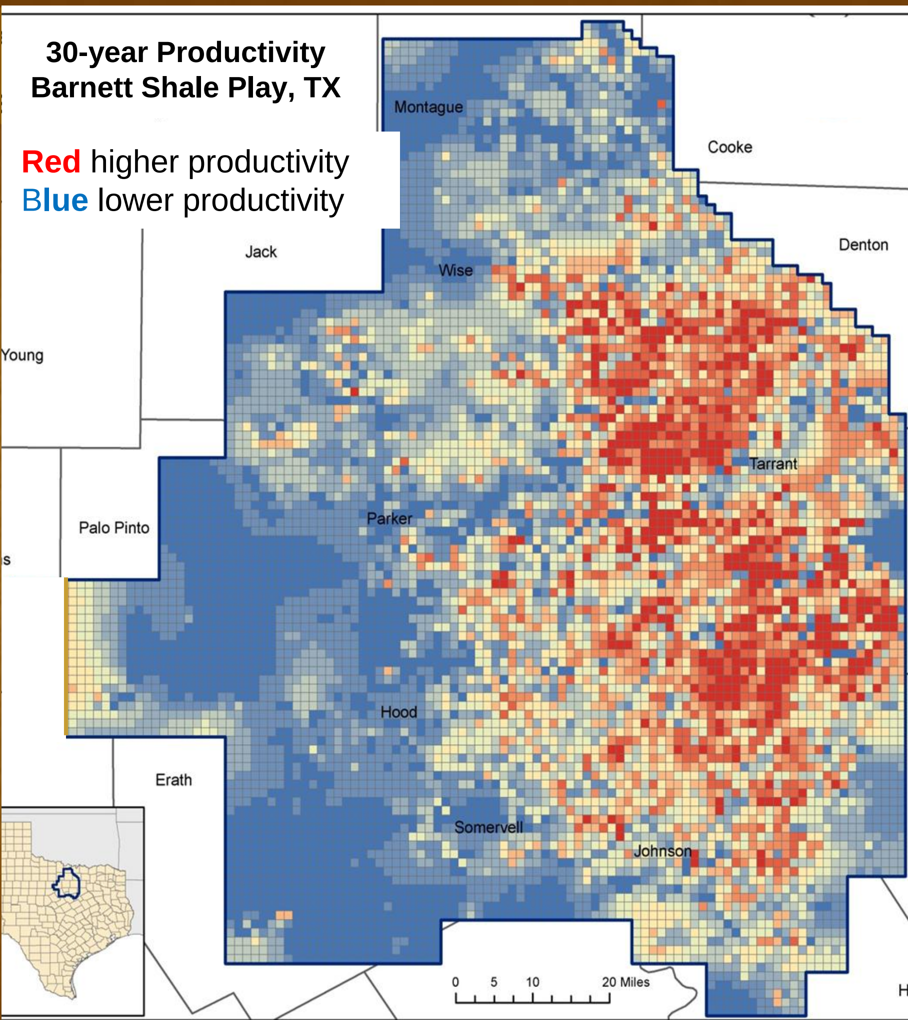
Nanopores in Organics

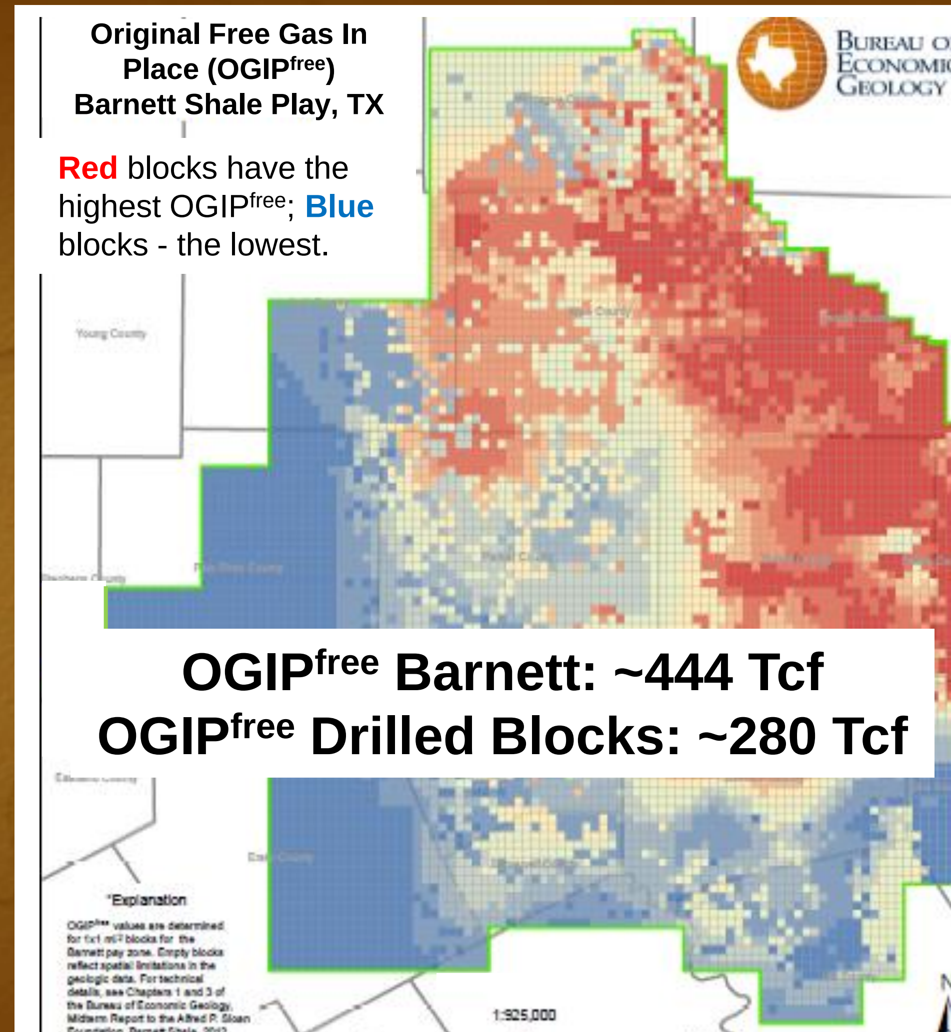


After Reed, BEG

Tinker, 2012

Geologic Analysis





- We estimate the content of natural gas in the formation for each 1 mi^2 of the Barnett Shale.

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Barnett Shale: *Base Case*

Assumption	*Base case*
- Henry Hub price for natural gas	**$4.00/MMBtu**
- Partly drained acreage developable ceiling	**80%**
- Undrilled acreage developable ceiling	**15%**
- WTI price	**$80/bbl**
- GPL/WTI price ratio	**45%**
- Annual technology improvement	**0.39%**
- Annual well-cost improvement	**0.24%**
- Economic limit for shutting-in a well (dry)	**0.05 MMcf/d**
- Economic limit for shutting-in a well (high Btu)	**0.029 MMcf/d**
- Minimum completions in a year (dry)	**20 (Tiers 1–4) 2 (Tiers 5–10)**
- Minimum completions in a year (high Btu)	**25 (Tiers 2–5) 10 (Tiers 1, 6–10)**

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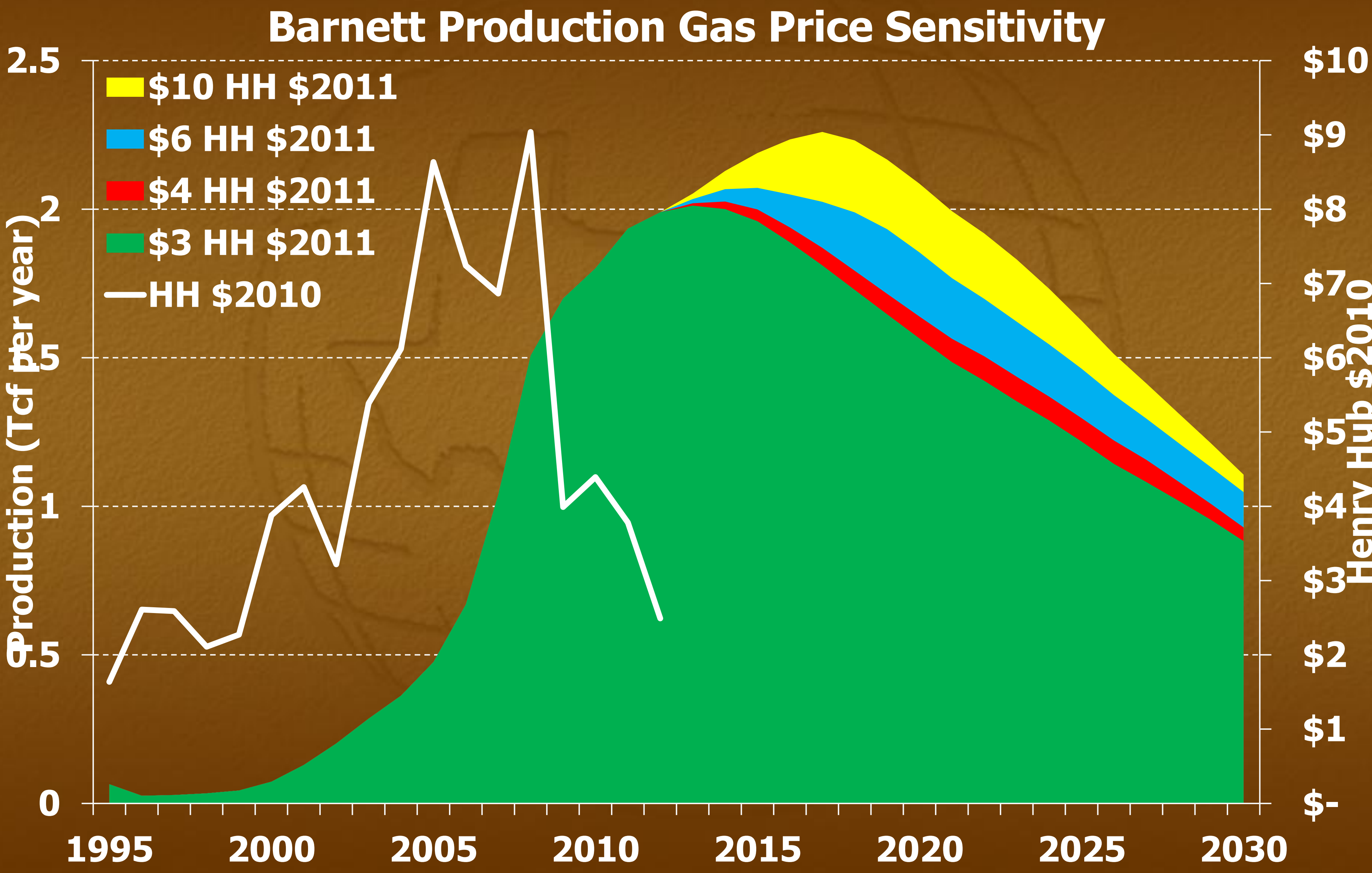
Barnett Shale: *Base Case*



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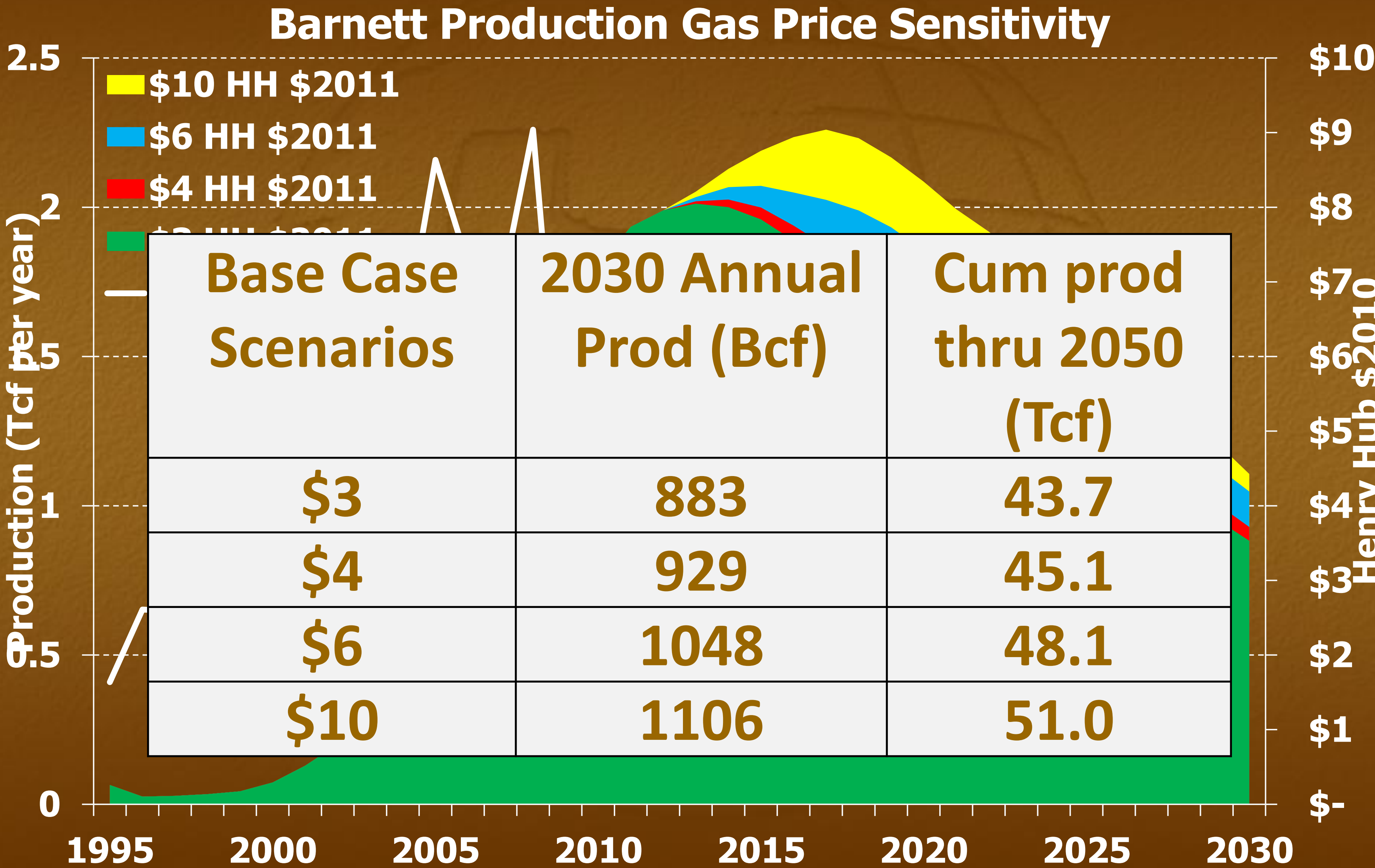
Barnett Shale: *Base Case*



Base Case Scenarios	2030 Annual Prod (Bcf)	Cum prod thru 2050 (Tcf)
$3	883	43.7
$4	929	45.1
$6	1048	48.1
$10	1106	51.0

Press

UT Press Release

http://www.utexas.edu/news/2013/02/28/new-rigorous-assessment-of-shale-gas-reserves-forecasts-reliable-supply-from-barnett-shale-through-2030/

http://www.jsg.utexas.edu/news/2013/02/frequently-asked-questions-faq-beg-barnett-shale-assessment-study/

Gas Boom Projected to Grow for Decades

Russell Gold, Wall Street Journal Front Page, Feb. 28

http://online.wsj.com/article/SB10001424127887323293704578330700203397128.html

Texas Study Points To A Longer Natural Gas Boom

Wade Goodwynm, NPR All Things Considered

http://www.npr.org/2013/02/28/173173548/texas-study-points-to-a-longer-natural-gas-boom

U.S. Barnett shale to pump natural gas to 2050

Reuters, Feb. 28

http://uk.reuters.com/article/2013/02/28/usa-natgas-barnett-idUKL1N0BSDKC20130228

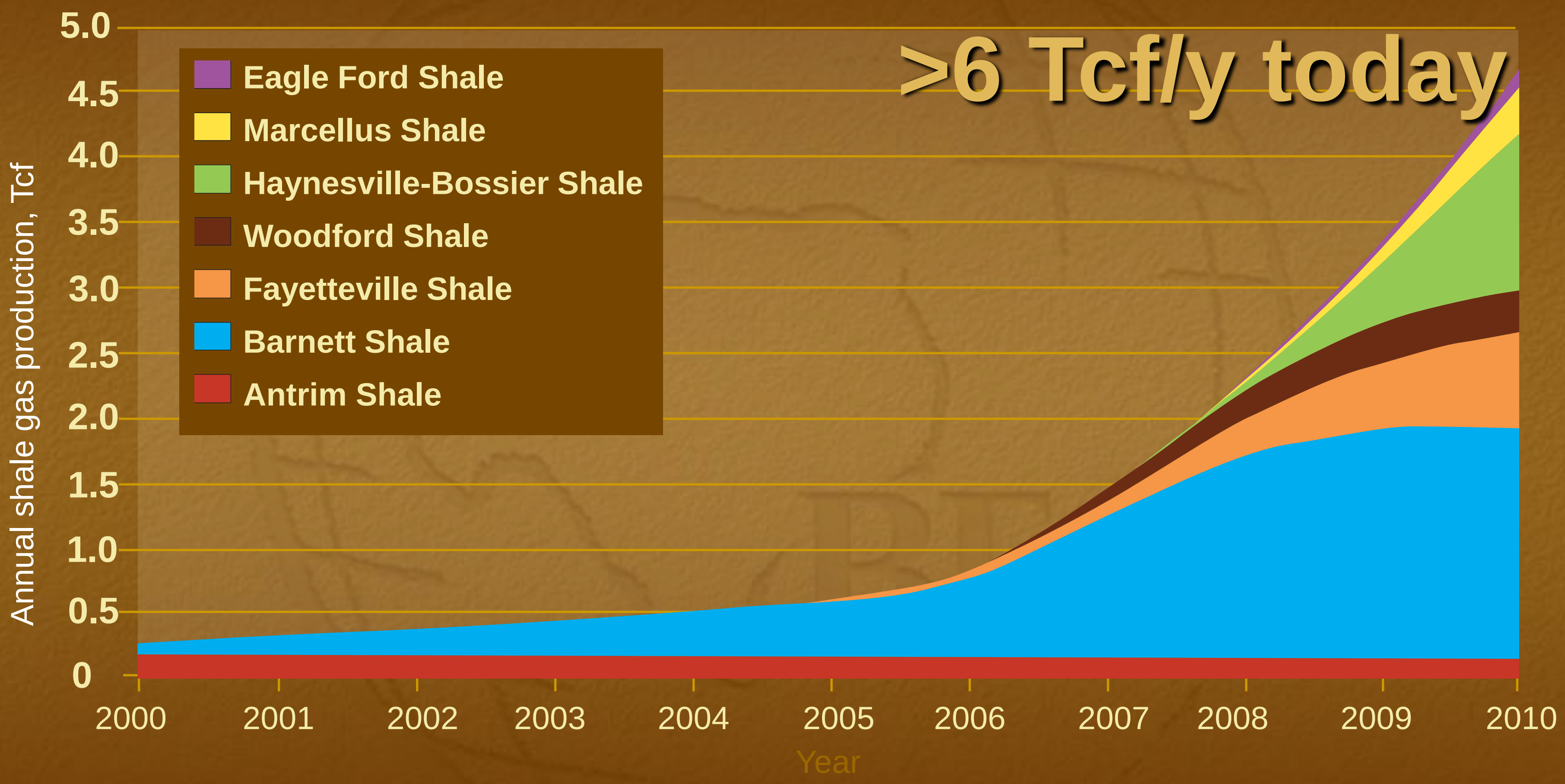
Barnett Shale Output to Tumble Through 2030, Study Says

Bloomberg, Joe Carroll, Feb. 28

http://www.bloomberg.com/news/2013-02-28/barnett-shale-output-to-tumble-through-2030-study-says.html

Tinker, 2012

U.S. Gas Shale Production



Boyer, C., Clark, B., Jochen, V., Lewis, R., and Miller, C. K., 2011, Shale gas: a global resource: Oilfield Review, Autumn, p. 30 [adapted from U.S. DOE and NETL, 2011, "Shale Gas: Applying Technology to solve America's Energy Challenges," Washington, D.C.: http://www.netl.doe.gov/technologies/oil-gas/publications/brochures/Shale_Gas_March_2011.pdf (accessed 8-22-11)].

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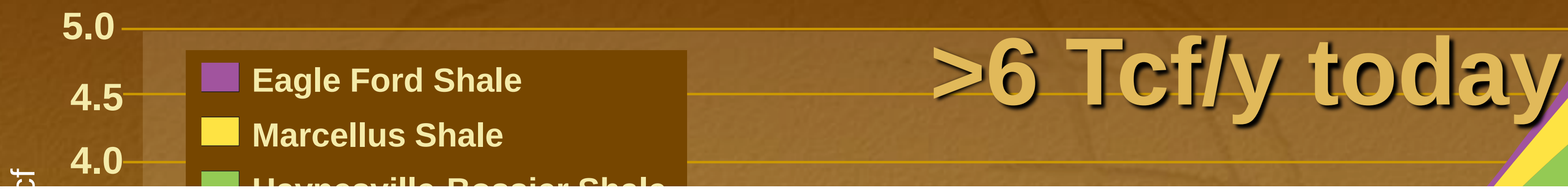
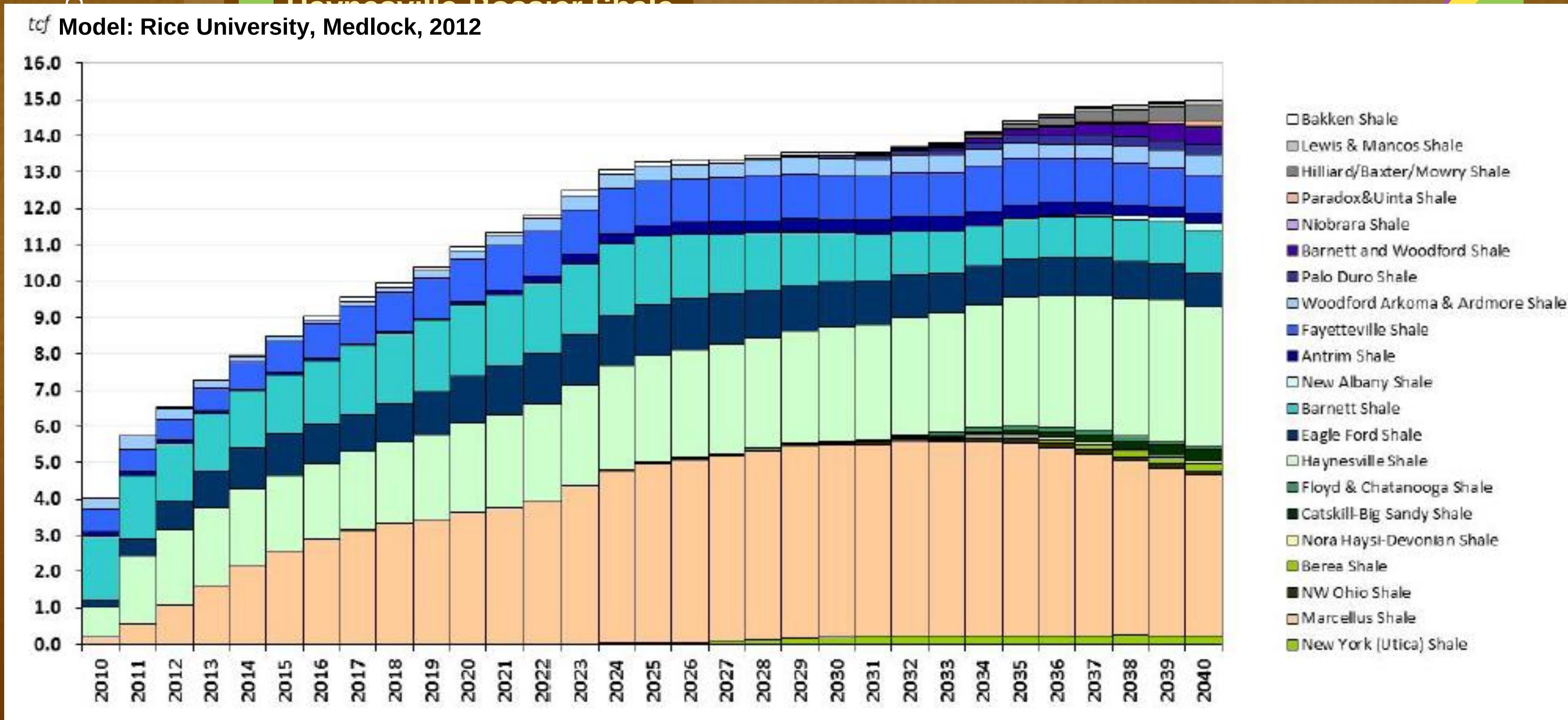
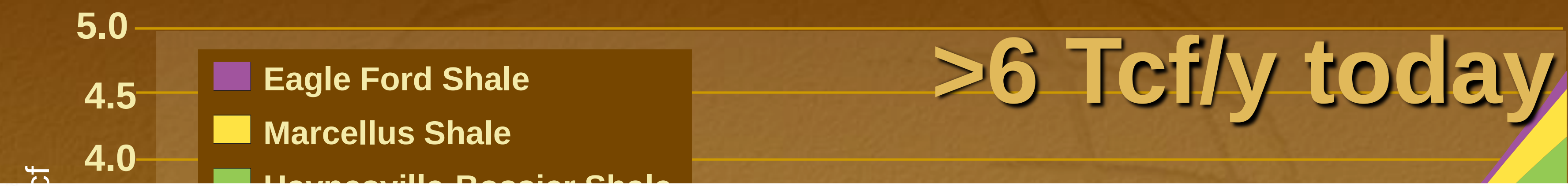
U.S. Gas Shale Production

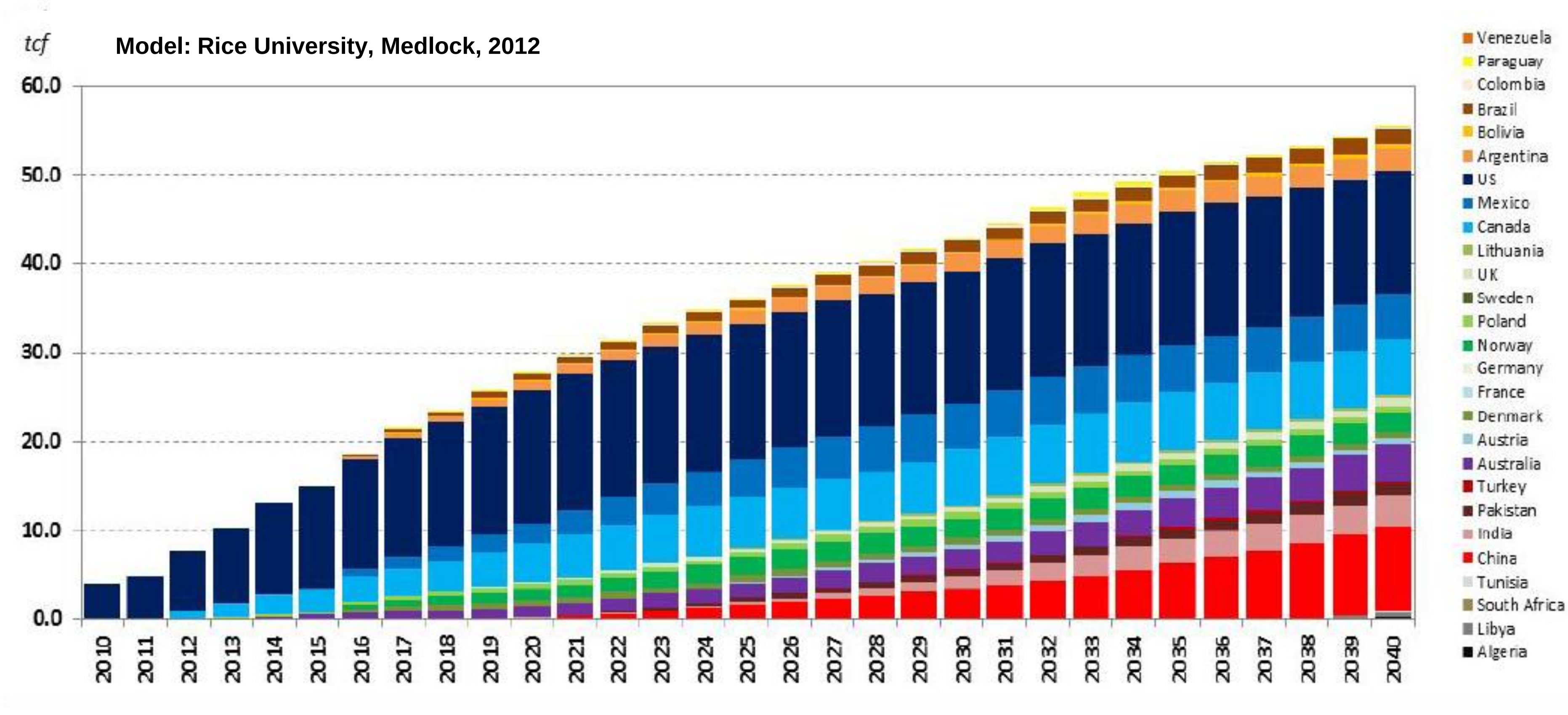




Tinker, 2012

U.S. Gas Shale Production





Unconventional Reservoirs

Implications

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

Not mutually exclusive…

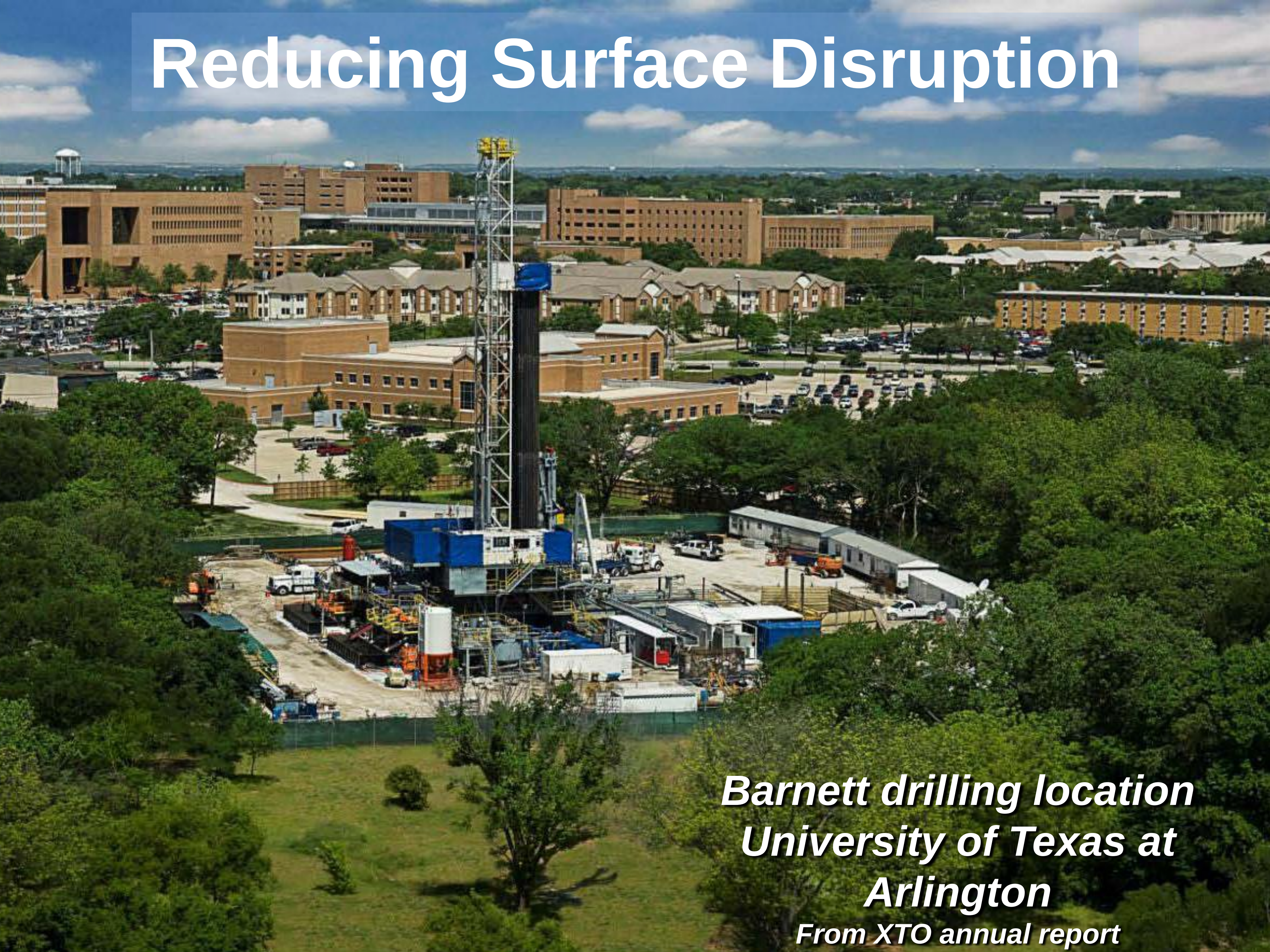
Tinker, 2012

Handling Environmental Issues

I. Mandatory baseline data
II. Cement all gas producing zones
III. Minimize fresh water use
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

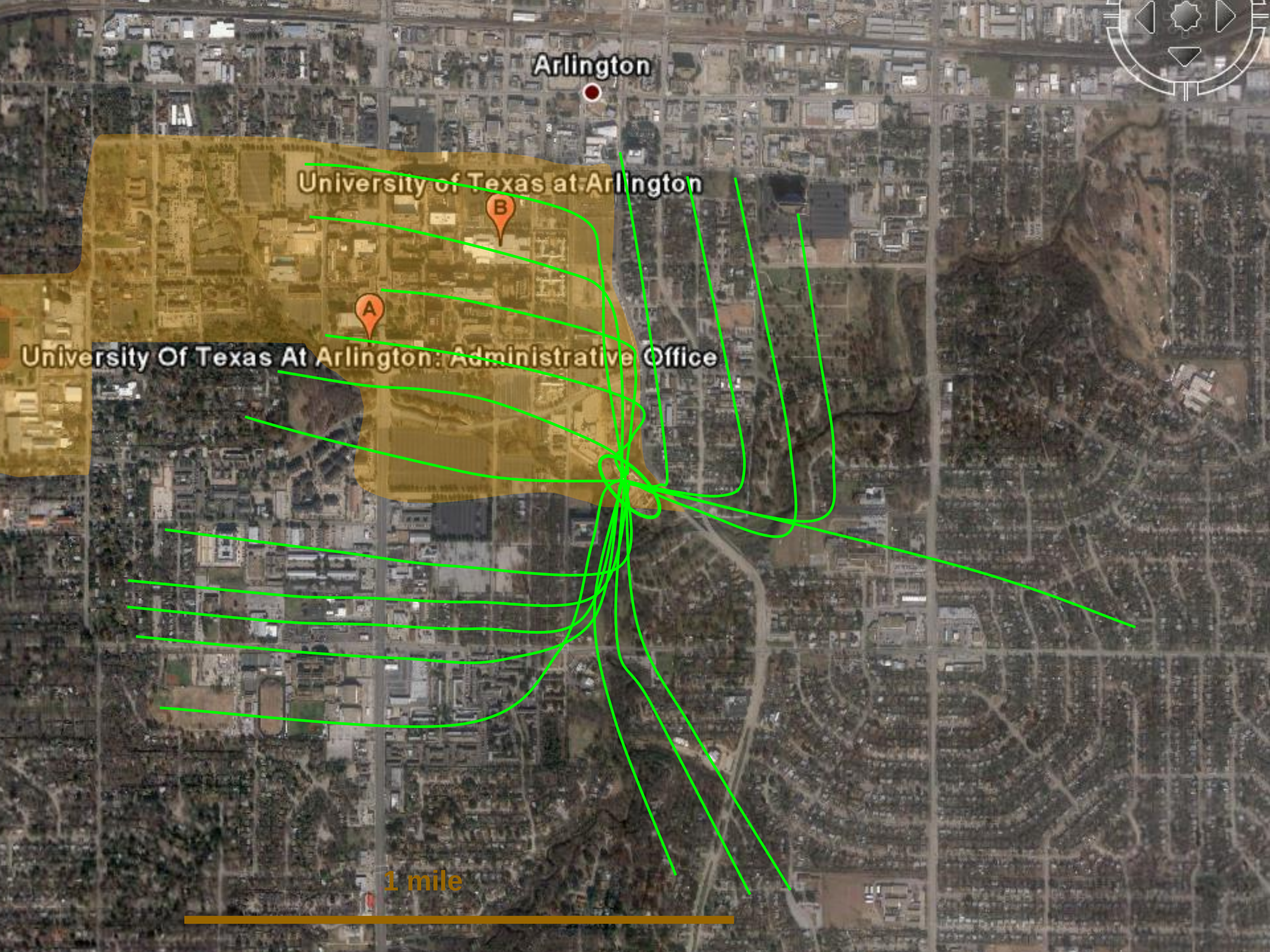
after Rao, 2012

Reducing Surface Disruption



Barnett drilling location University of Texas at Arlington

From XTO annual report

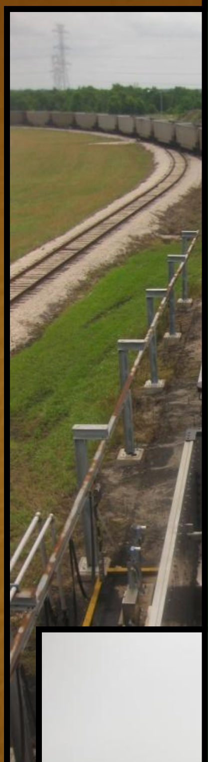

Arlington
University of Texas at Arlington
B
A
University Of Texas At Arlington: Administrative Office
1 mile

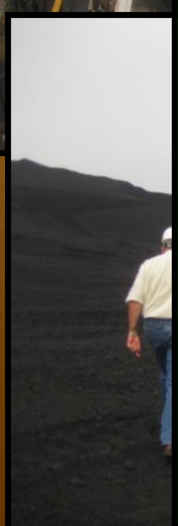
Source: U.S. Energy Information Administration based on data from various published studies. Canada and Mexico plays from ARI.

Coal

Powder River Basin, WY

Coal





Coal Challenges

- Mining Impacts
- CO_2
- Air Quality
- Mercury
- Fresh Water

Parish Plant, TX

Nuclear

Le Hague Waste Recycling

Normandy, France

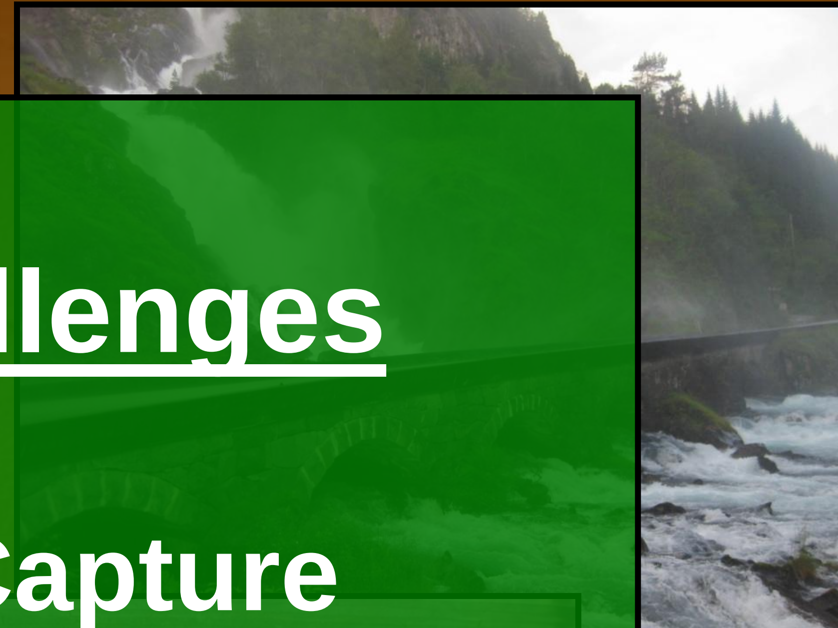
Nuclear Challenges

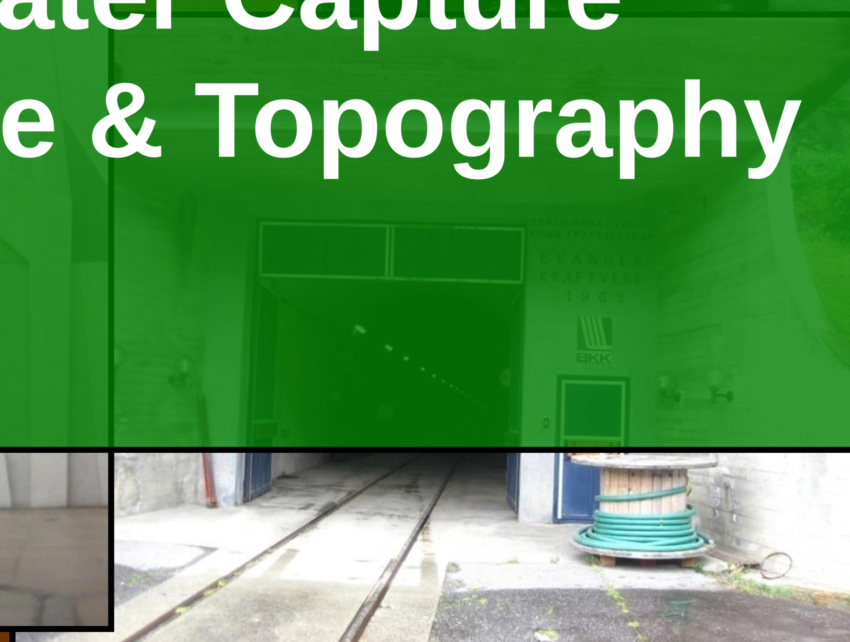
- Natural and Human Disasters
- Front End Cost
    - ❖Permitting and Regulatory
- Waste Protection
- Proliferation

Tinker, 2012

Hydro

Norway





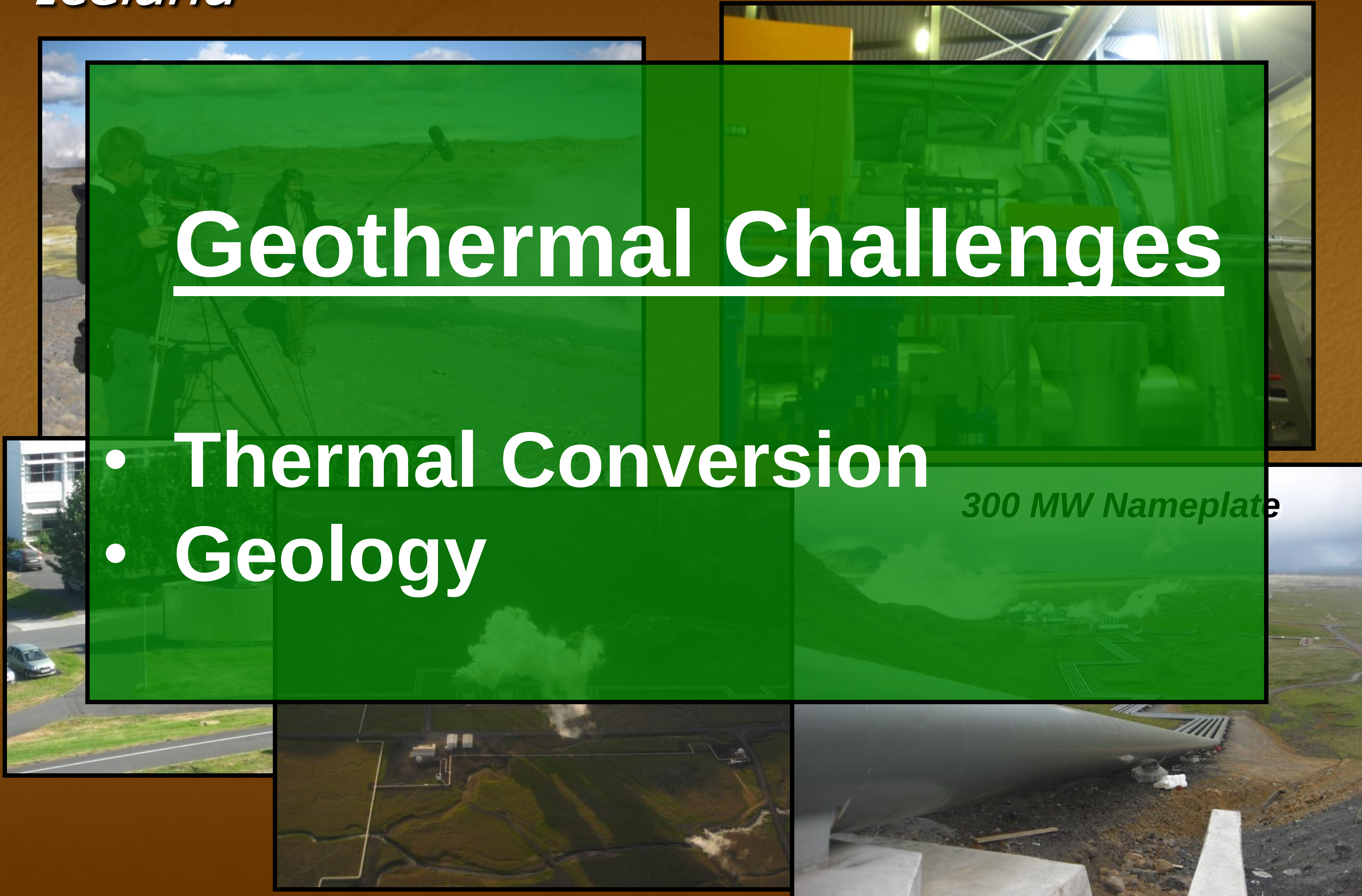
300 MW Nameplate

Hydro Challenges

- Fresh Water Capture
- Land Use & Topography
- Drought

Geothermal

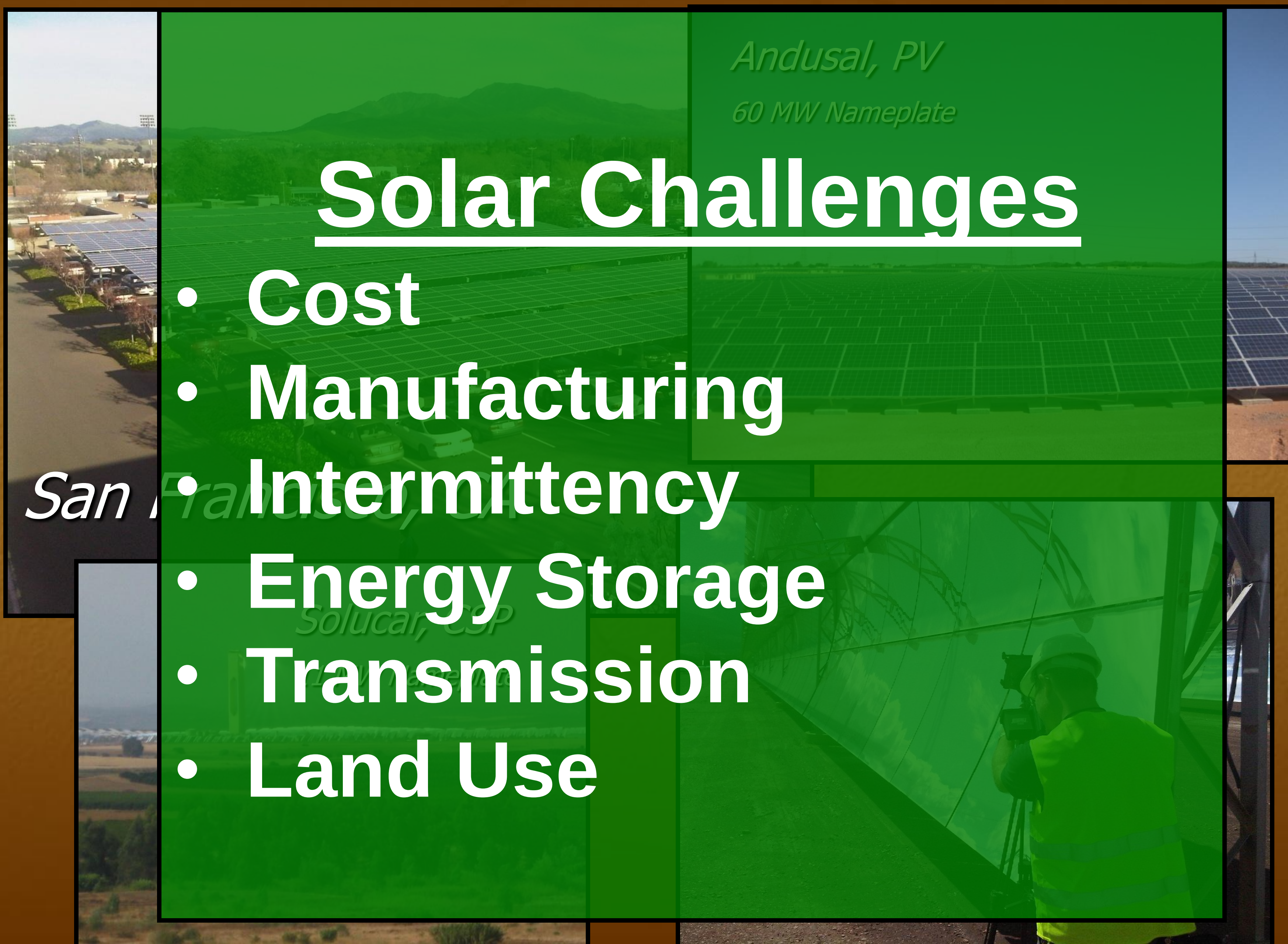
Iceland



Geothermal Challenges

- Thermal Conversion
- Geology

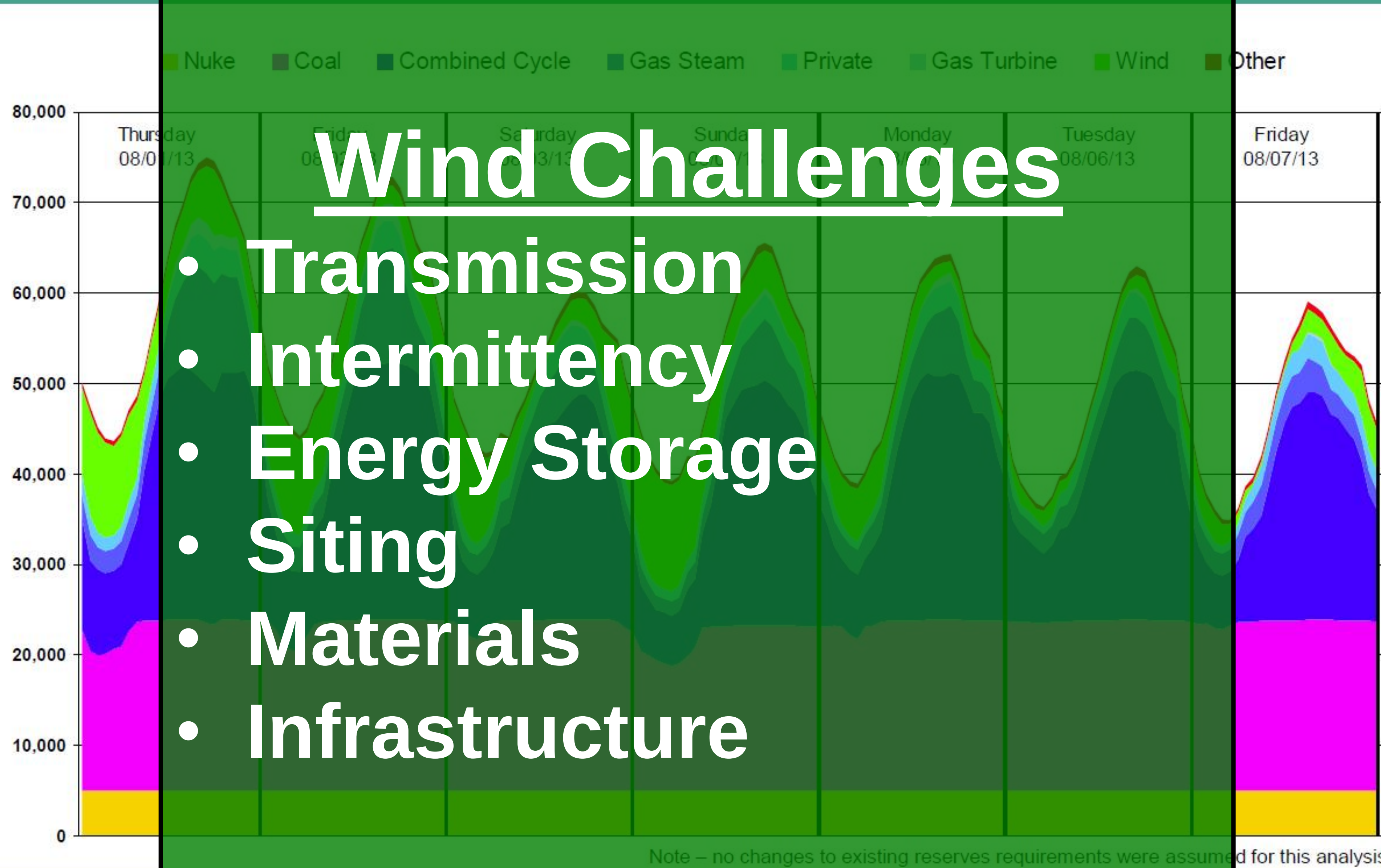
Solar



Solar Challenges

- Cost
- Manufacturing
- Intermittency
- Energy Storage
- Transmission
- Land Use

2013 Peak Load Week - Generation by Fuel Type

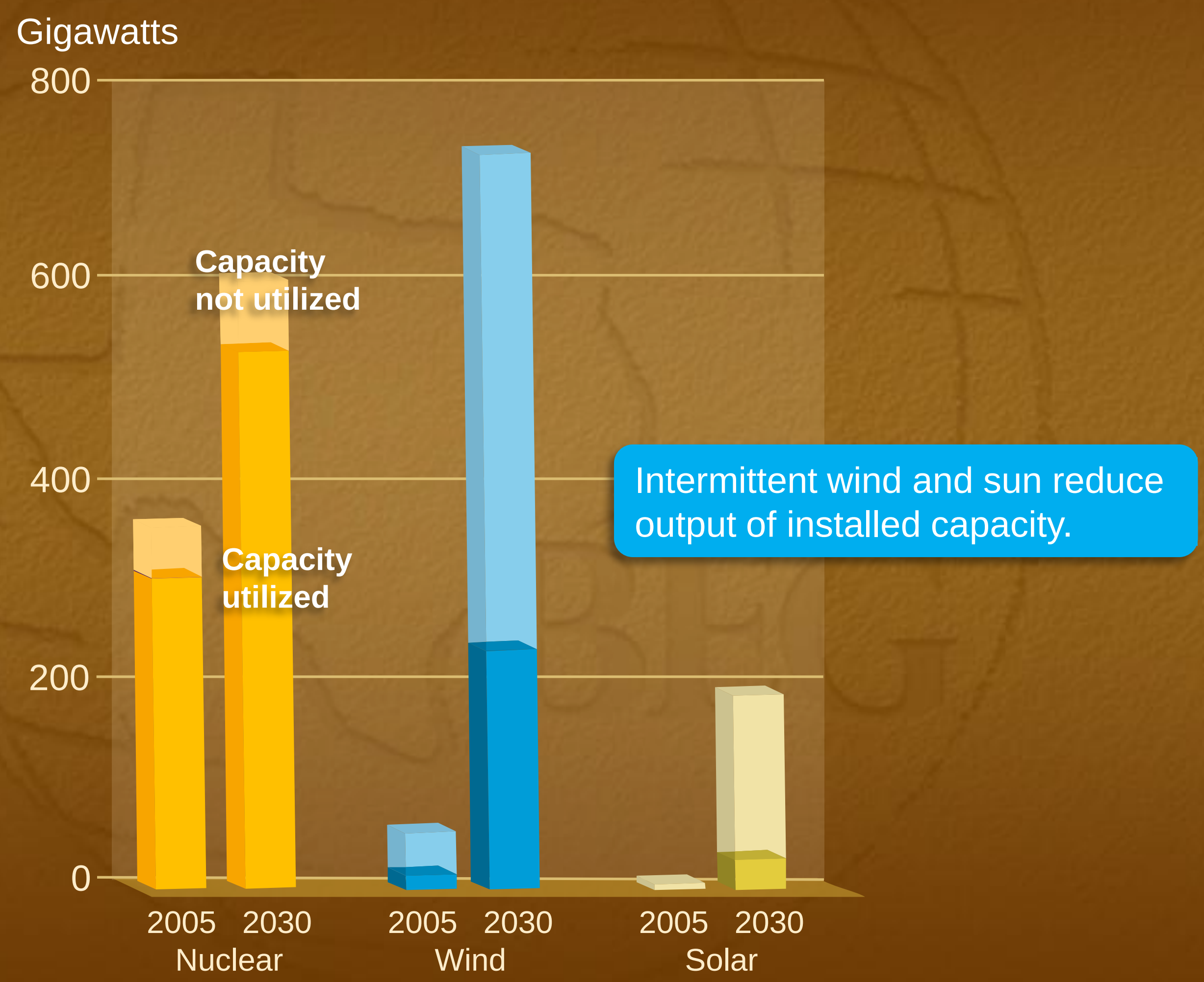


Wind Challenges

- Transmission
- Intermittency
- Energy Storage
- Siting
- Materials
- Infrastructure

Global Power-Generation Capacity

The Impact of Intermittency



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

Tinker, 2012

Options to Natural Gas for Power

I. Coal
   - Available, affordable to generate, reliable
   - Dirty, expensive to build
II. Nuclear
   - Powerful, efficient, no emissions, affordable to generate
   - 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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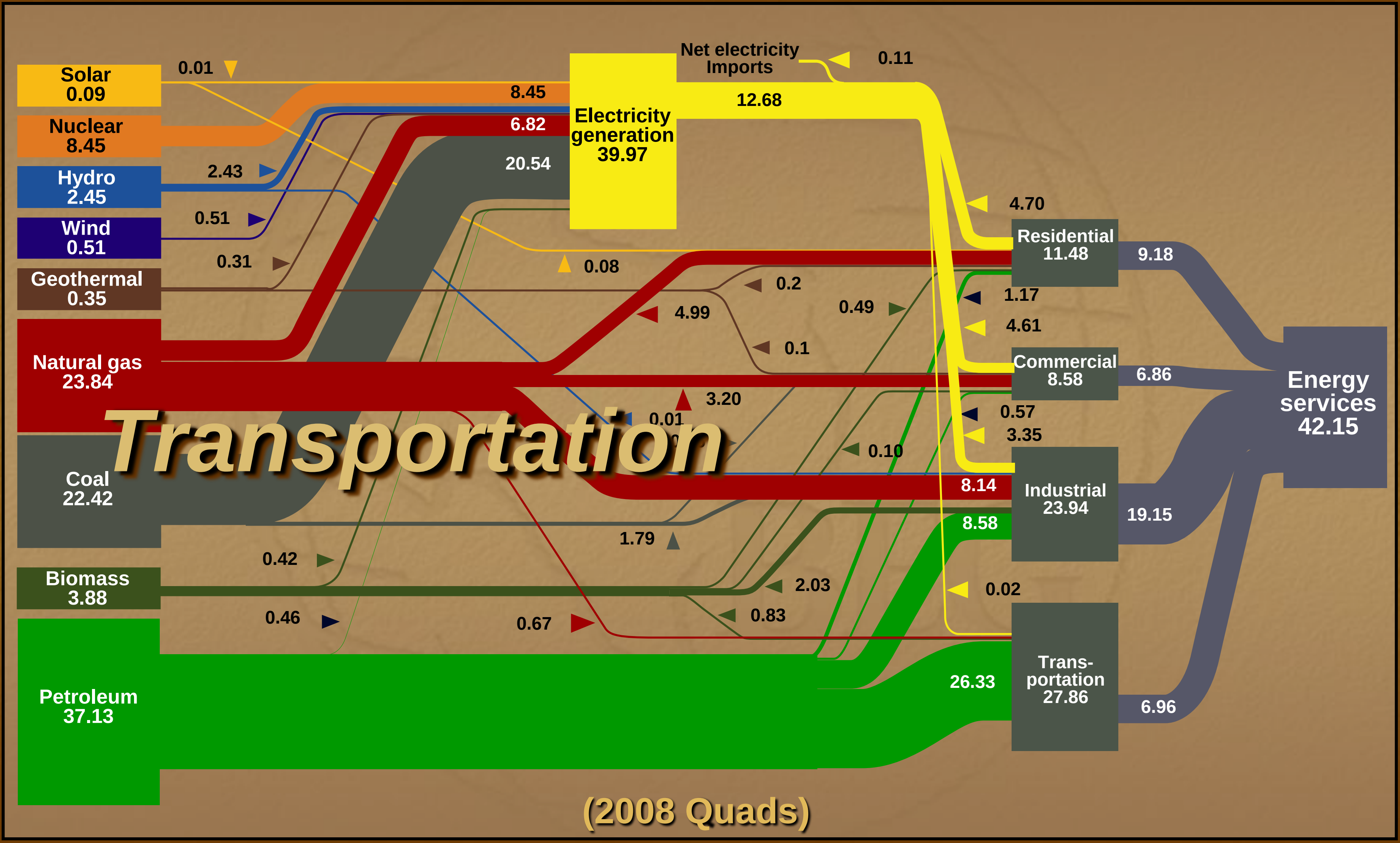
Tinker, 2012

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

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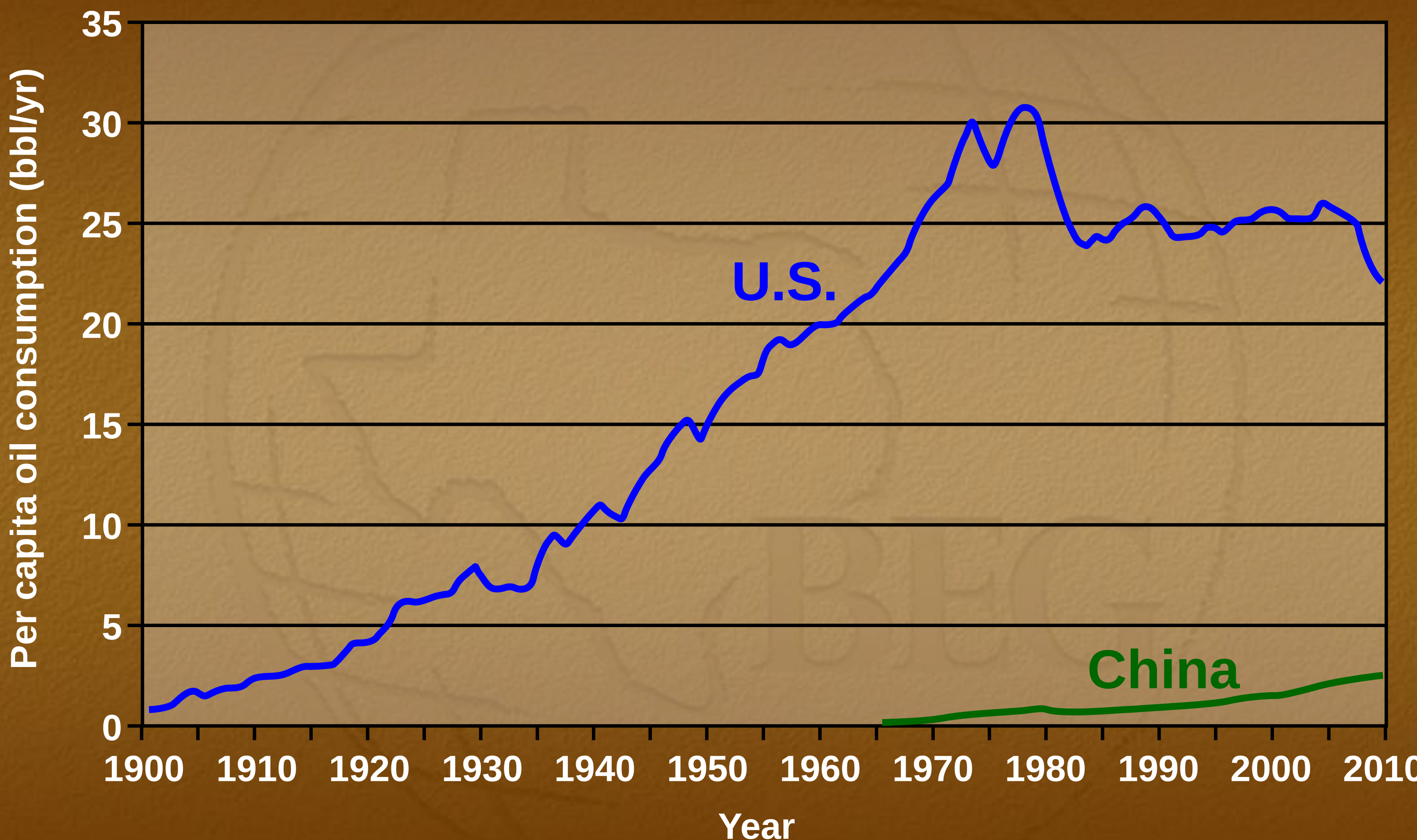
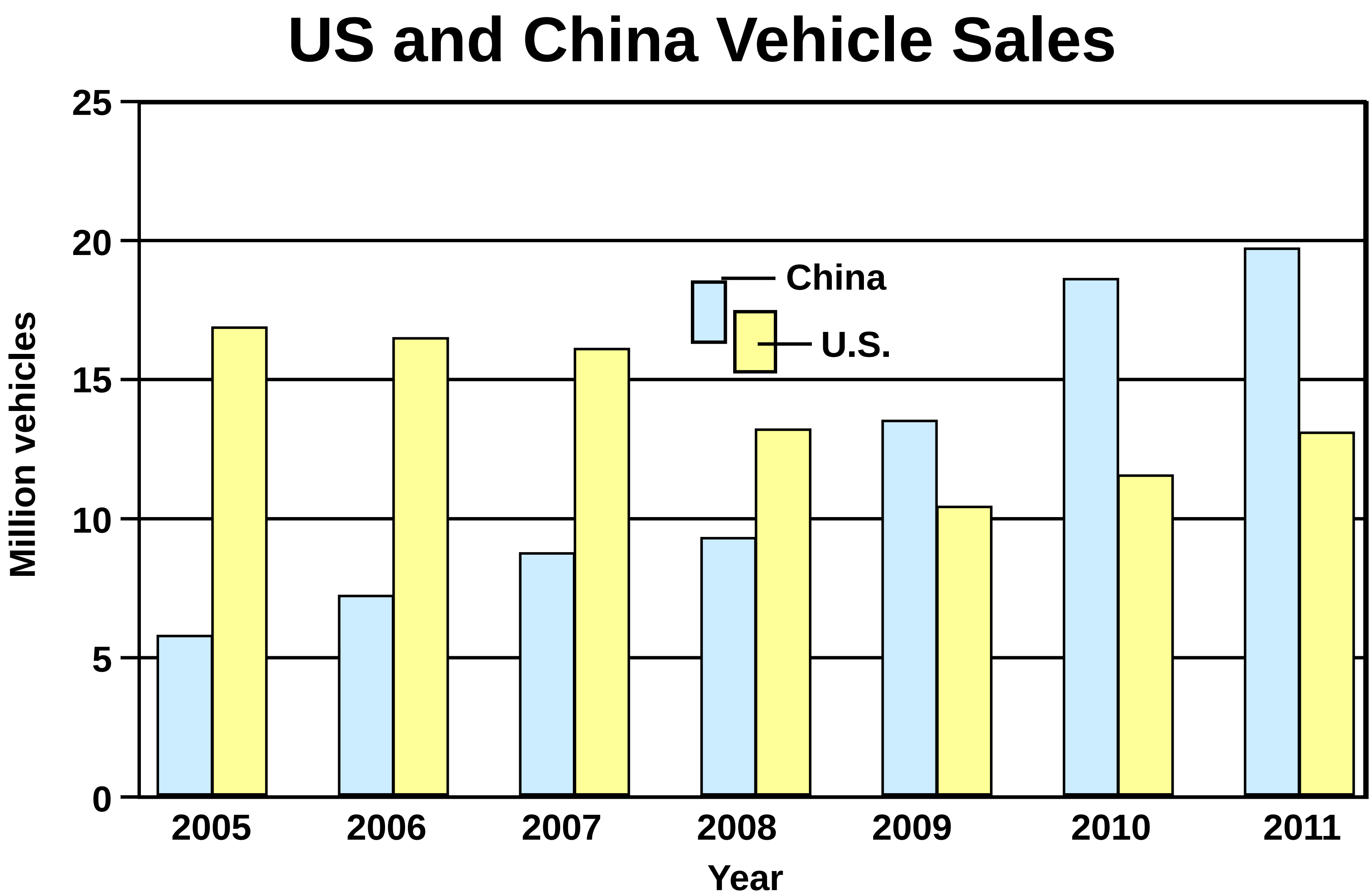
Oil Consumption



BP Statistical Review of World Energy, CIA World Factbook, Census Bureaus, Marc Faber Limited, RJ Estimates
From Raymond James and Associates, Inc., August 2, 2010

Oil Consumption



U.S. Bureau of Transportation Statistics, RJ Estimates, China Association of Automobile Manufacturers
From Raymond James and Associates, Inc., August 2, 2010

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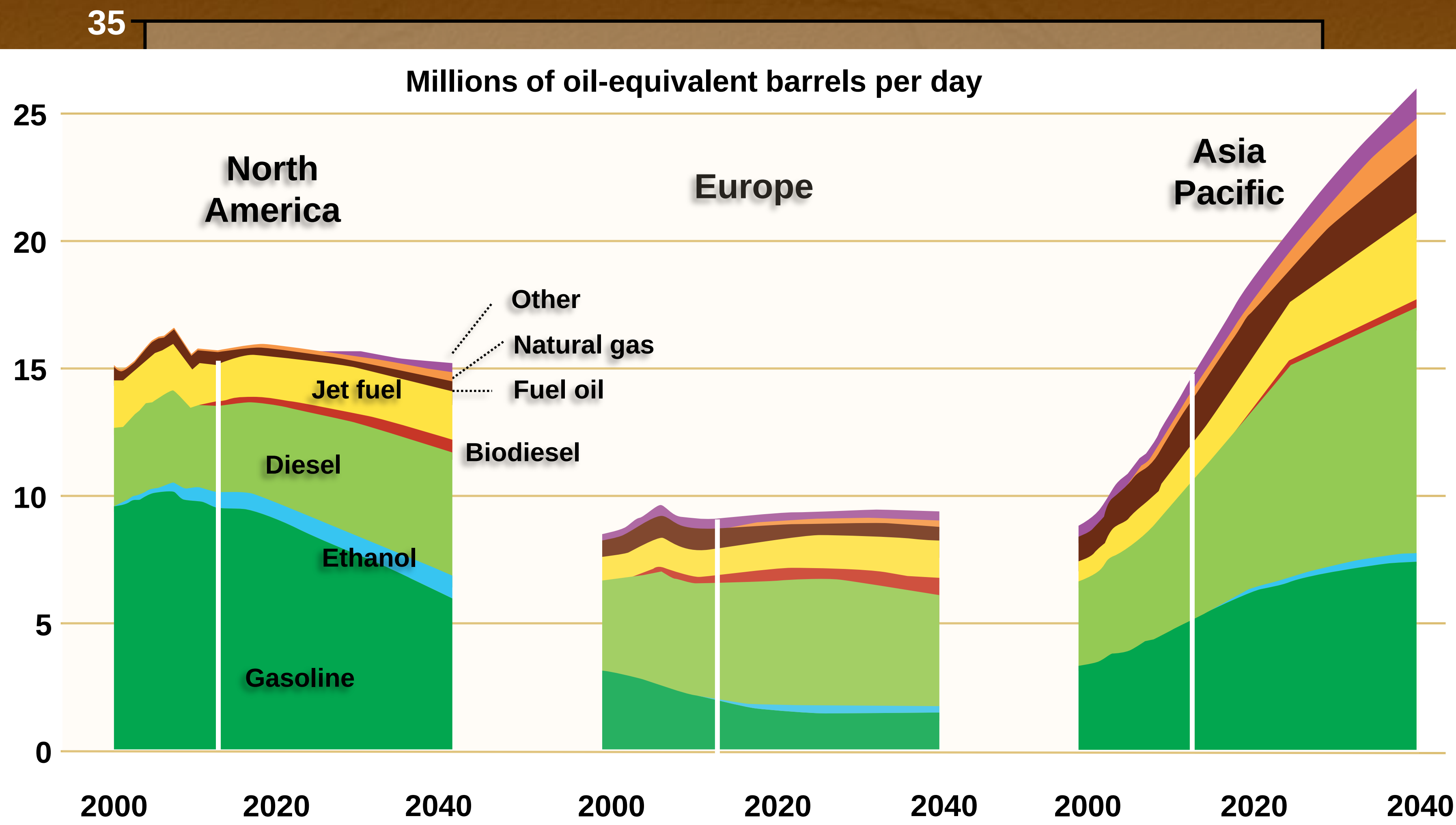
Oil Consumption

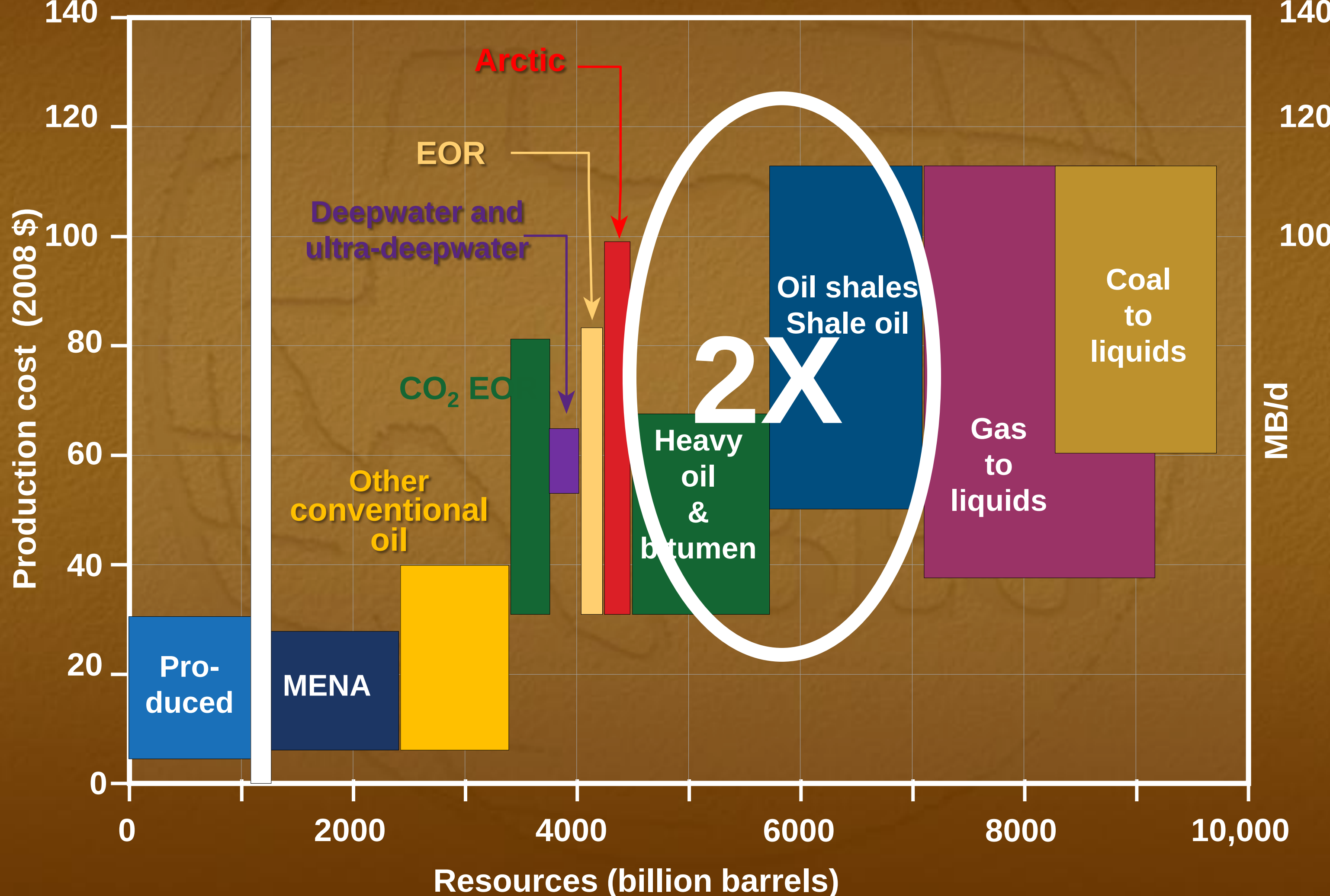


ExxonMobil Corporation, 2013 The Outlook for Energy: A View to 2040, page 20.

Tinker, 2012

Long-Term Oil Supply

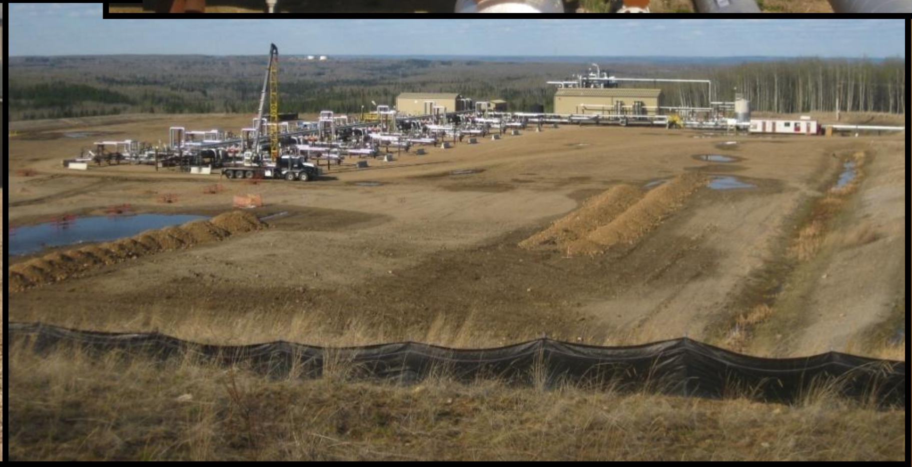
Resources and Production



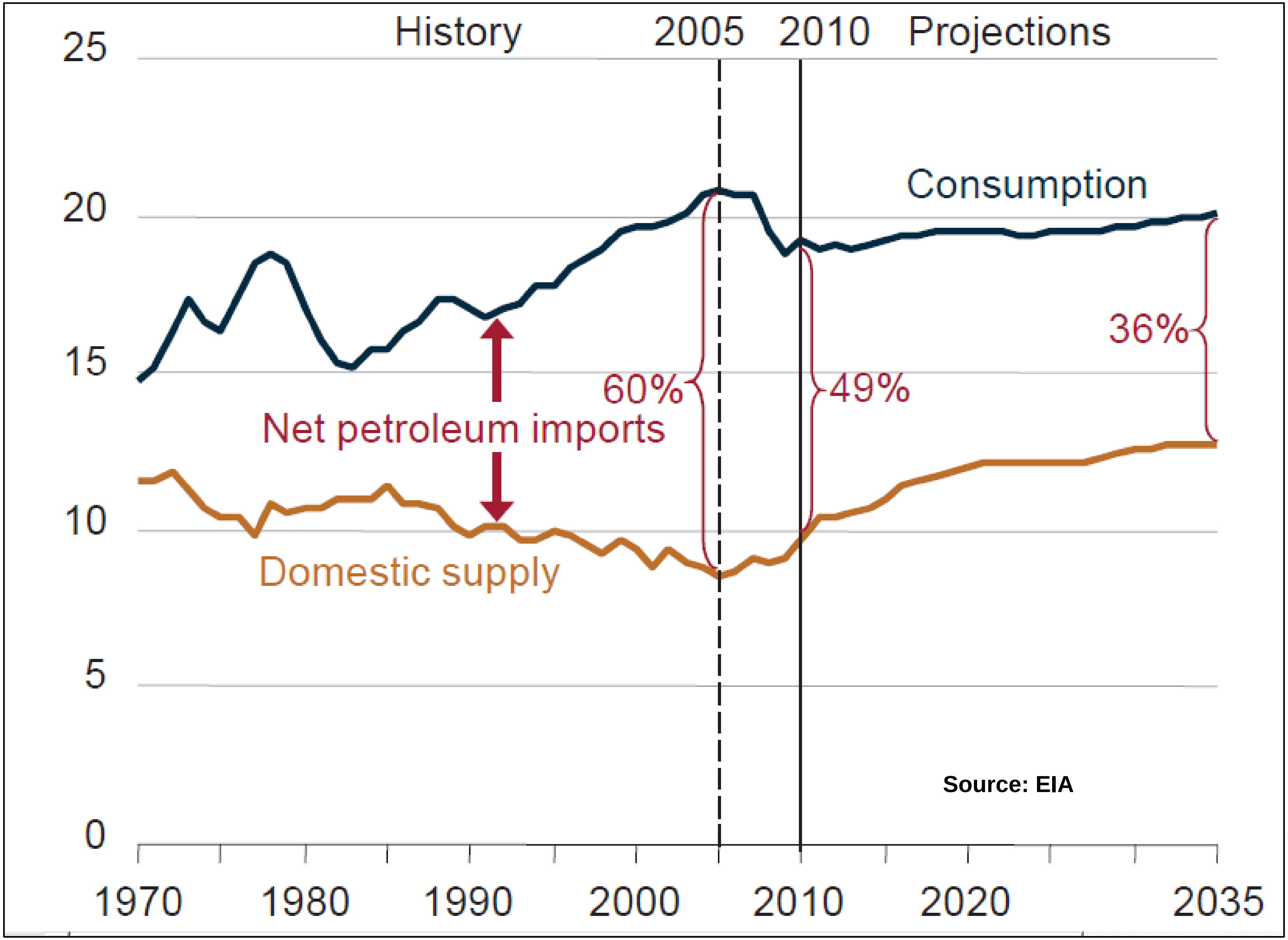
Source: IEA World Energy Outlook (2009)

Tinker, 2012

Oil Sands and Shale Oil

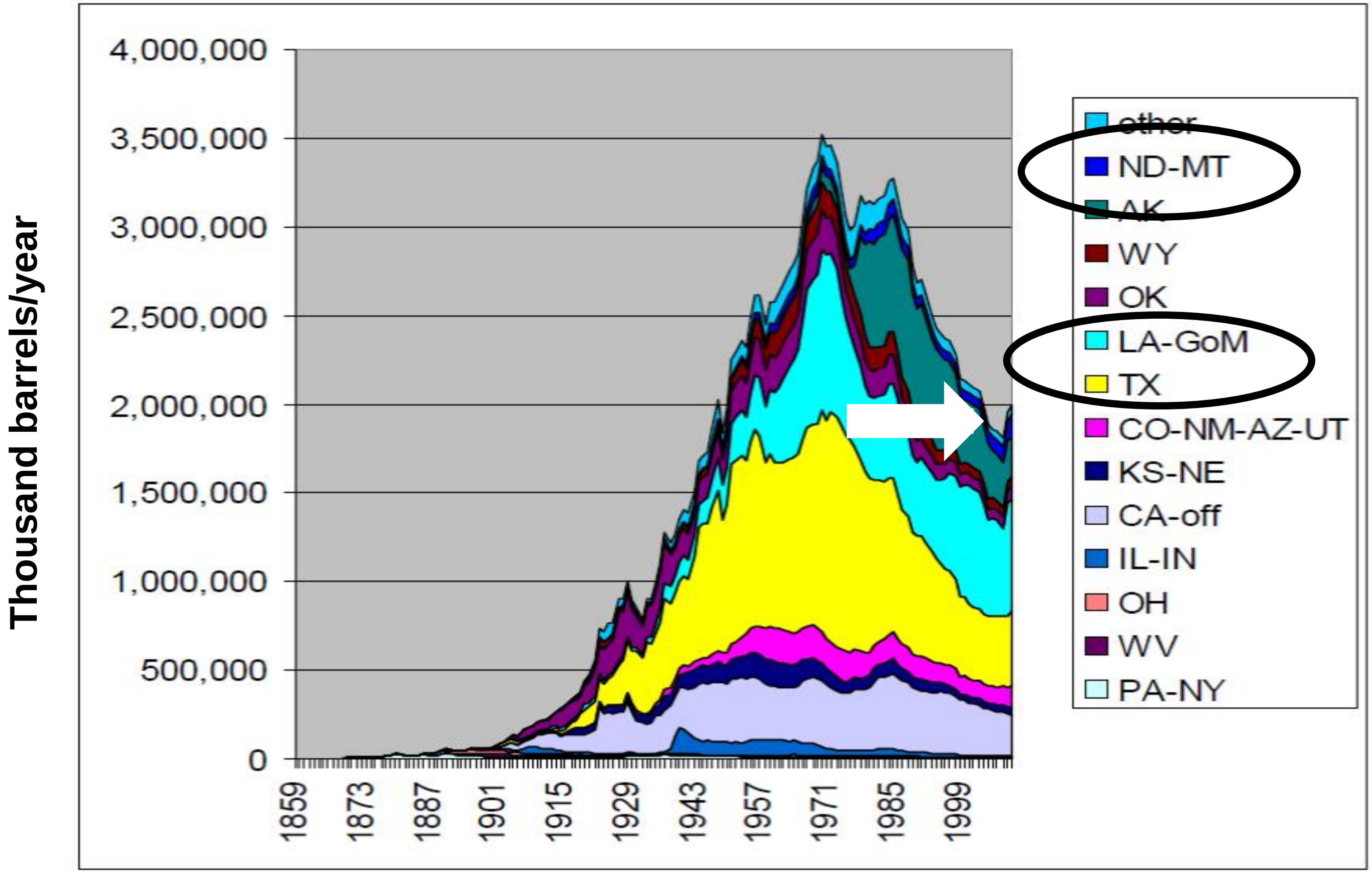


Annual US Oil Production



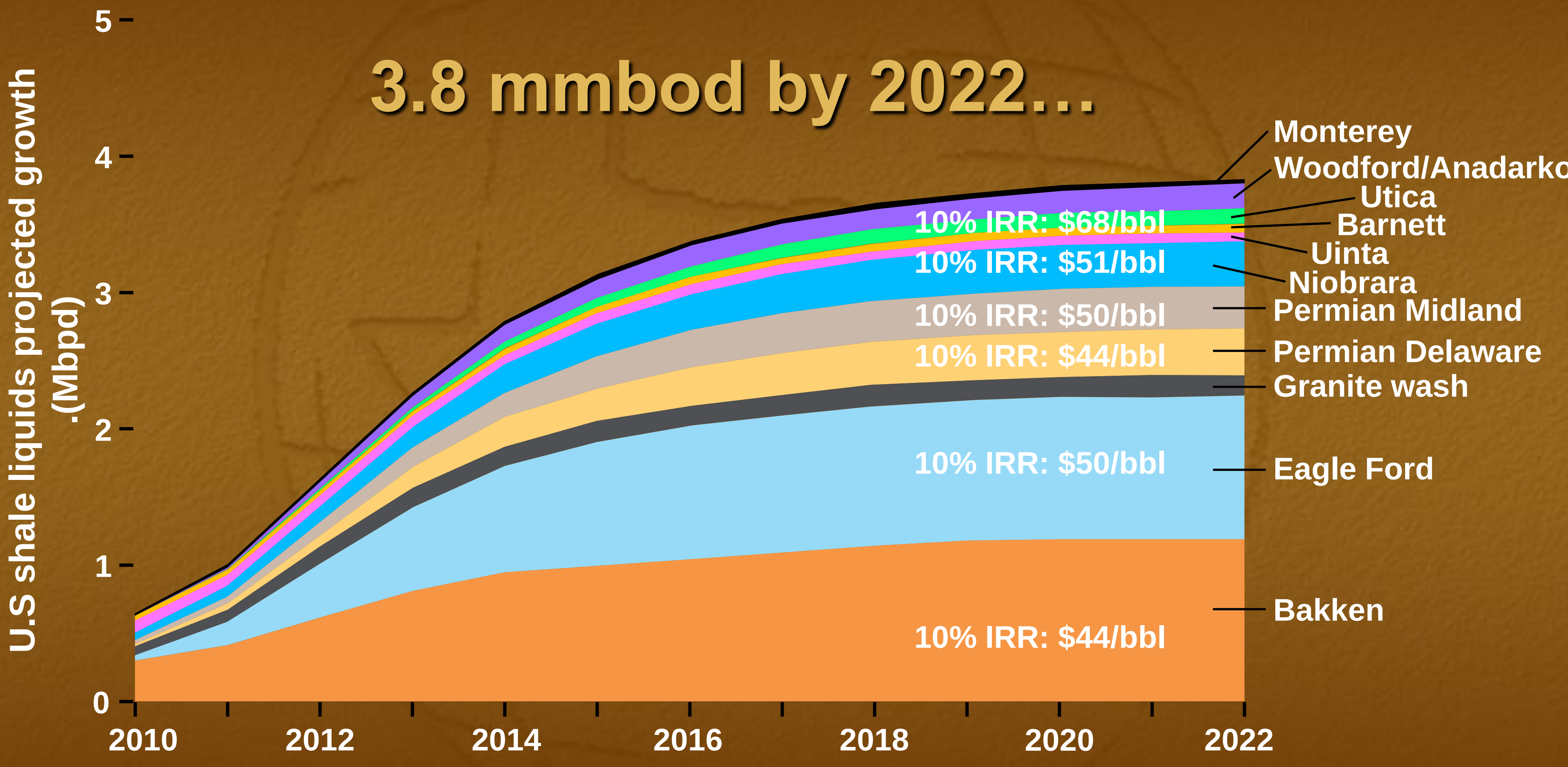
Tinker, 2012

Annual US Oil Production



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

U.S. SHALE LIQUIDS PROJECTIONS

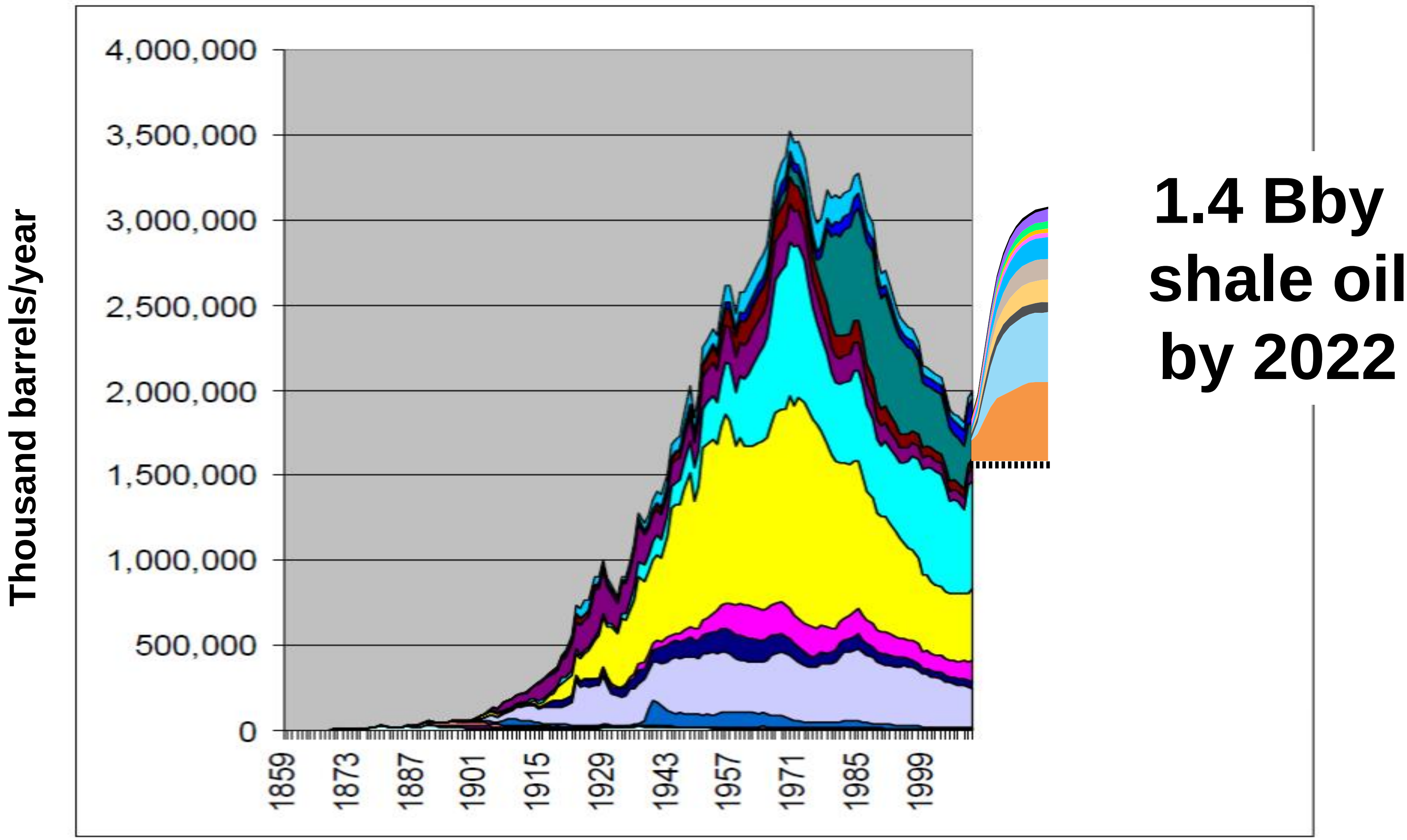


After Morse et. al., 2012, Energy 2020: North America, the new Middle East: Citi GPS: Global Perspectives & Solutions, figure 14, p. 17.

IRR Source: Rystad Energy

Tinker, 2012

Annual US Oil Production



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

Tinker, 2012

Options to Oil for Transport

I. **Biefuels**

- Valuable supplement, lower carbon
- Scale, land use, cost

II. **CNG, LPG, LNG, GTL**

- Cleaner than oil, regionally cheap, available
- Dirtier than others, regionally expensive

III. **Electricity**

- Clean depending on source, efficient engine
- Expensive, chemicals, range

IV. **Hydrogen**

- Ten years away

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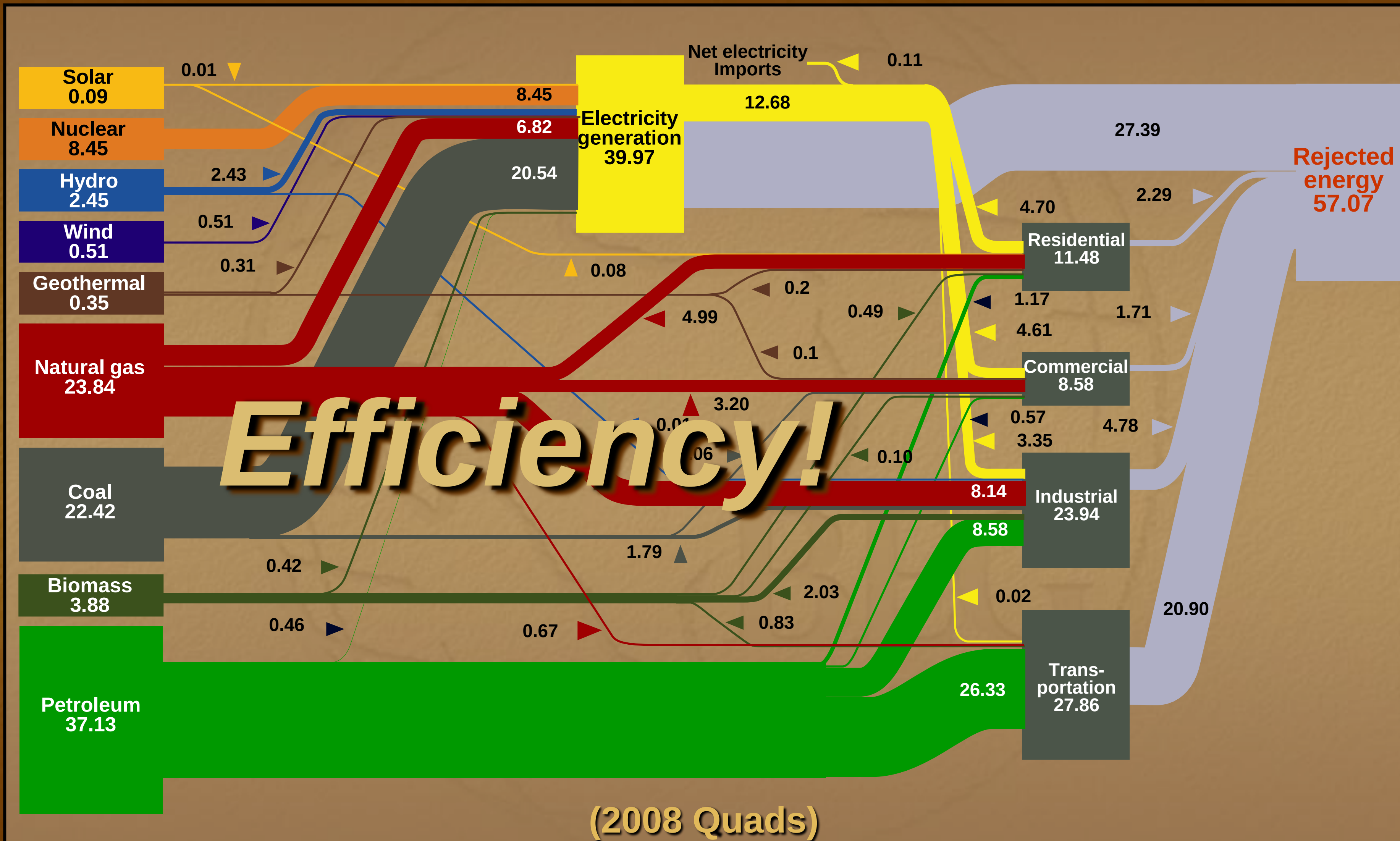
Tinker, 2012

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

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Tinker, 2012

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***

Efficiency

Efficiency requires a change in thinking

- **Fuel**
- **Lighting**
- **Electronics**
- **Insulation**

Energy efficiency can be improved across all consumption sectors.

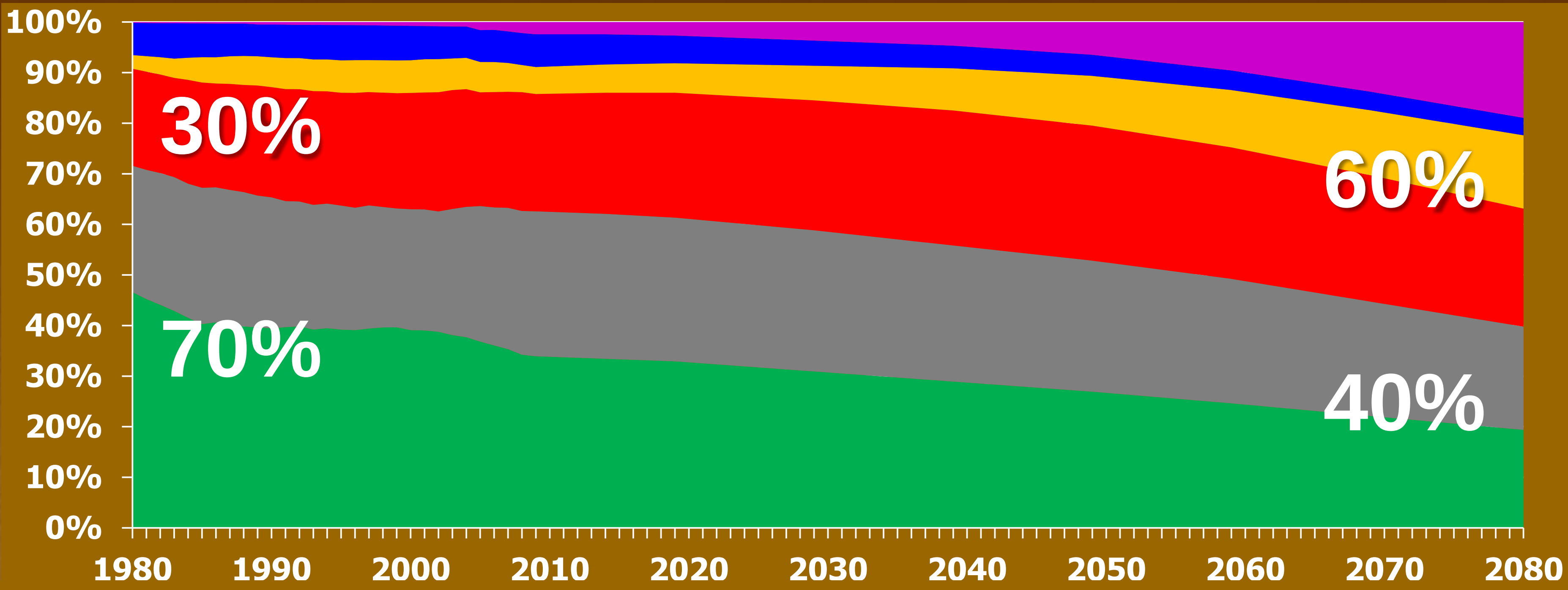
Outline

- Energy, Economy, Environment
- Electricity
- Transportation
- Efficiency
- **A Look at the Future**

Tinker, 2012

Energy Security

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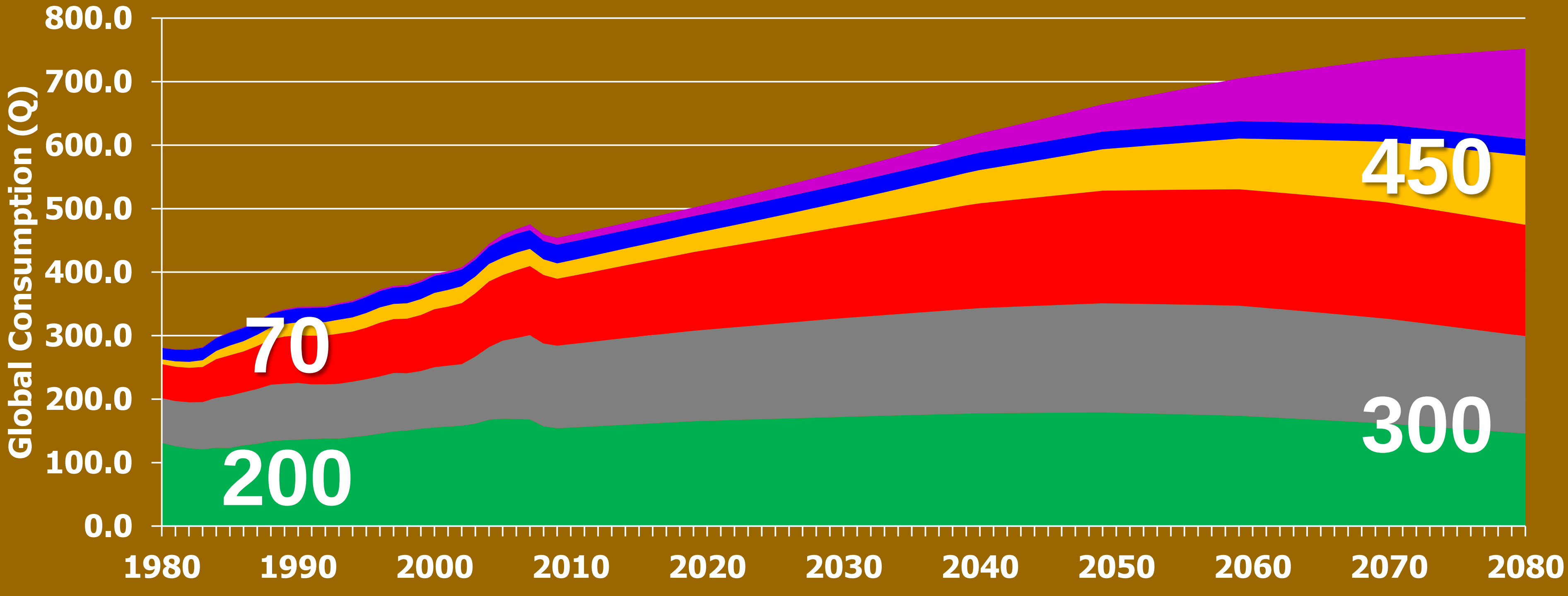
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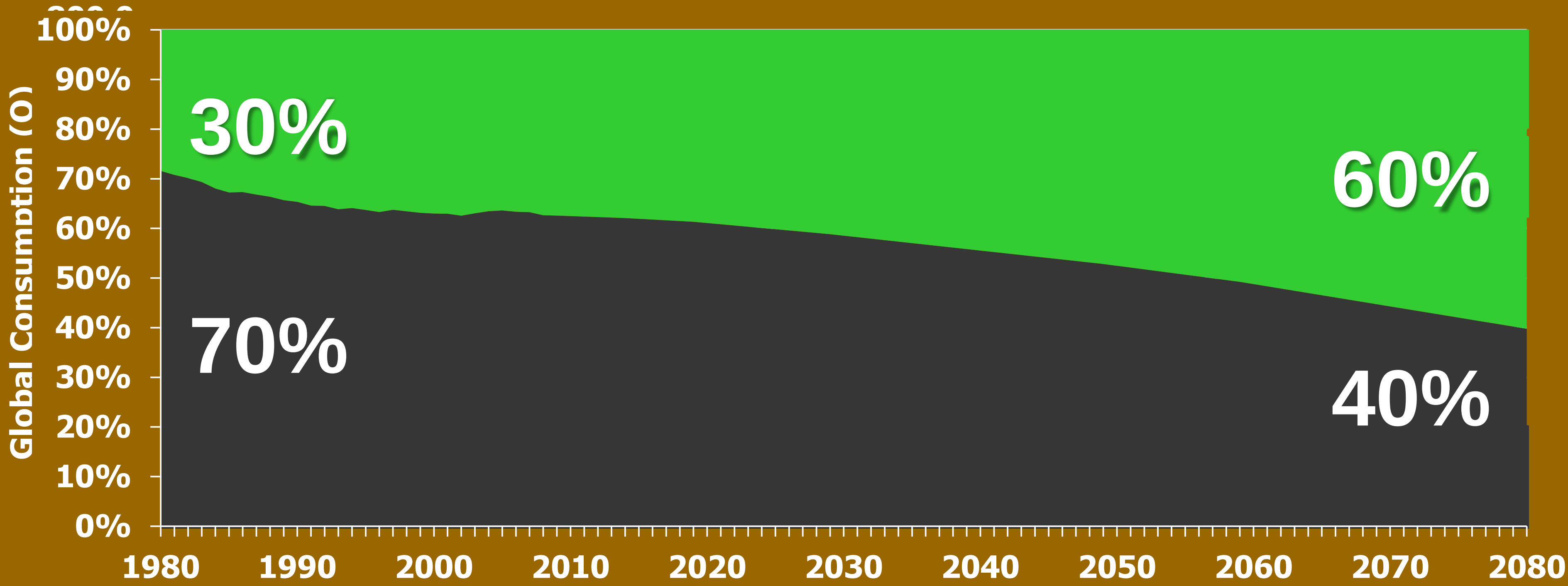
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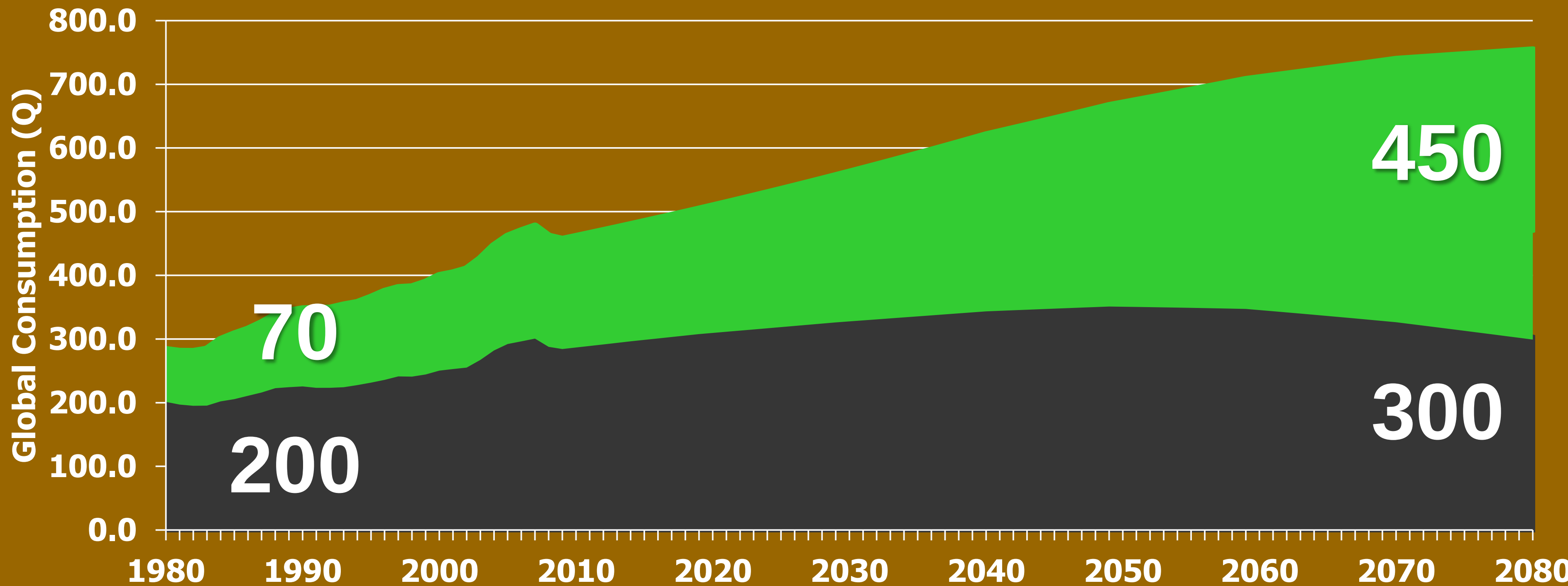
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