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***Physics 100***  
***Lecture 16***

The US Fossil Fuel  
Energy Mix

**March 19, 2018**

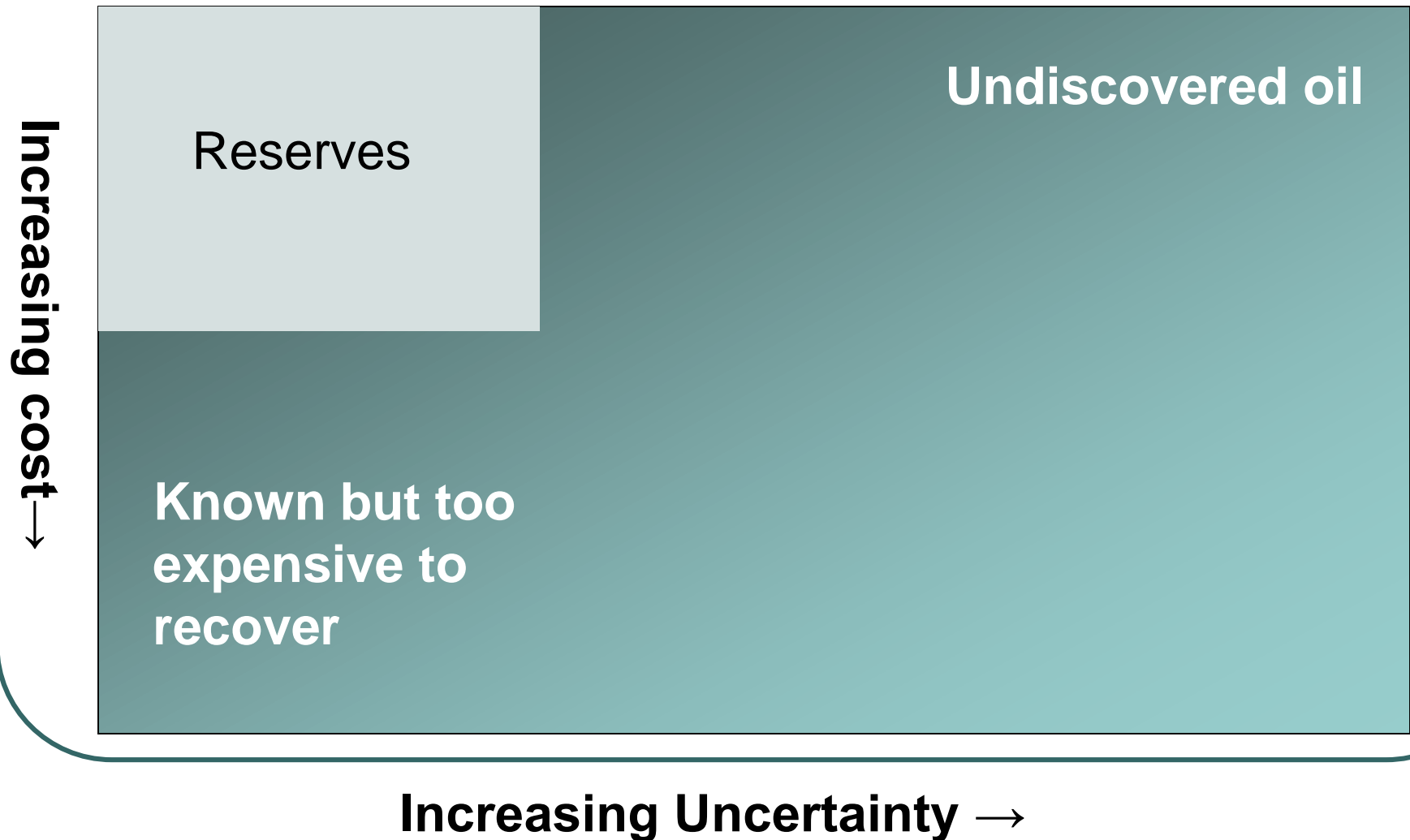
## Oil terminology

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- **Reserves** are those resources that are well known and recoverable with current technology and at current prices
- **Resources** are the total amount of oil that exists, whether known or unknown, accessible or inaccessible.

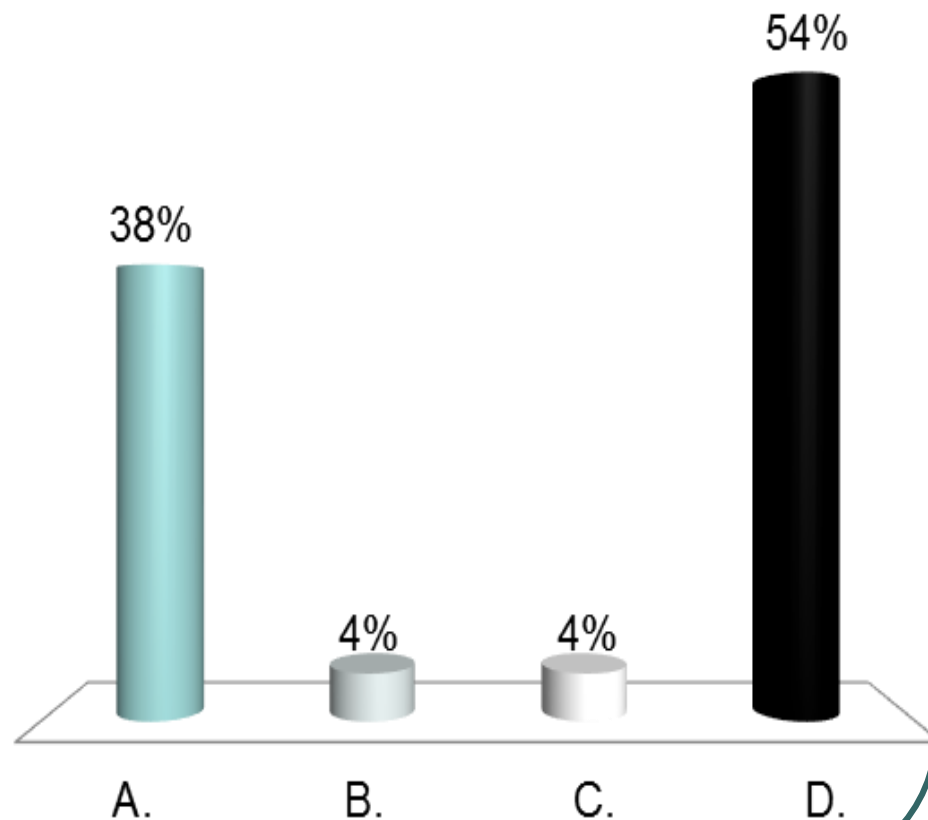
# Reserves and Resources

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**The US uses about 19 MBPD of oil. At that rate, how long would the 5000 MB of oil in the ANWR last?**

- A. 263 y
- B. 95 y
- C. 31 y
- D. 0.72 y



**The US uses about 19 MBPD of oil. At that rate, how long would the 5000 MB of oil in the ANWR last?**

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A. 263 y

B. 95 y

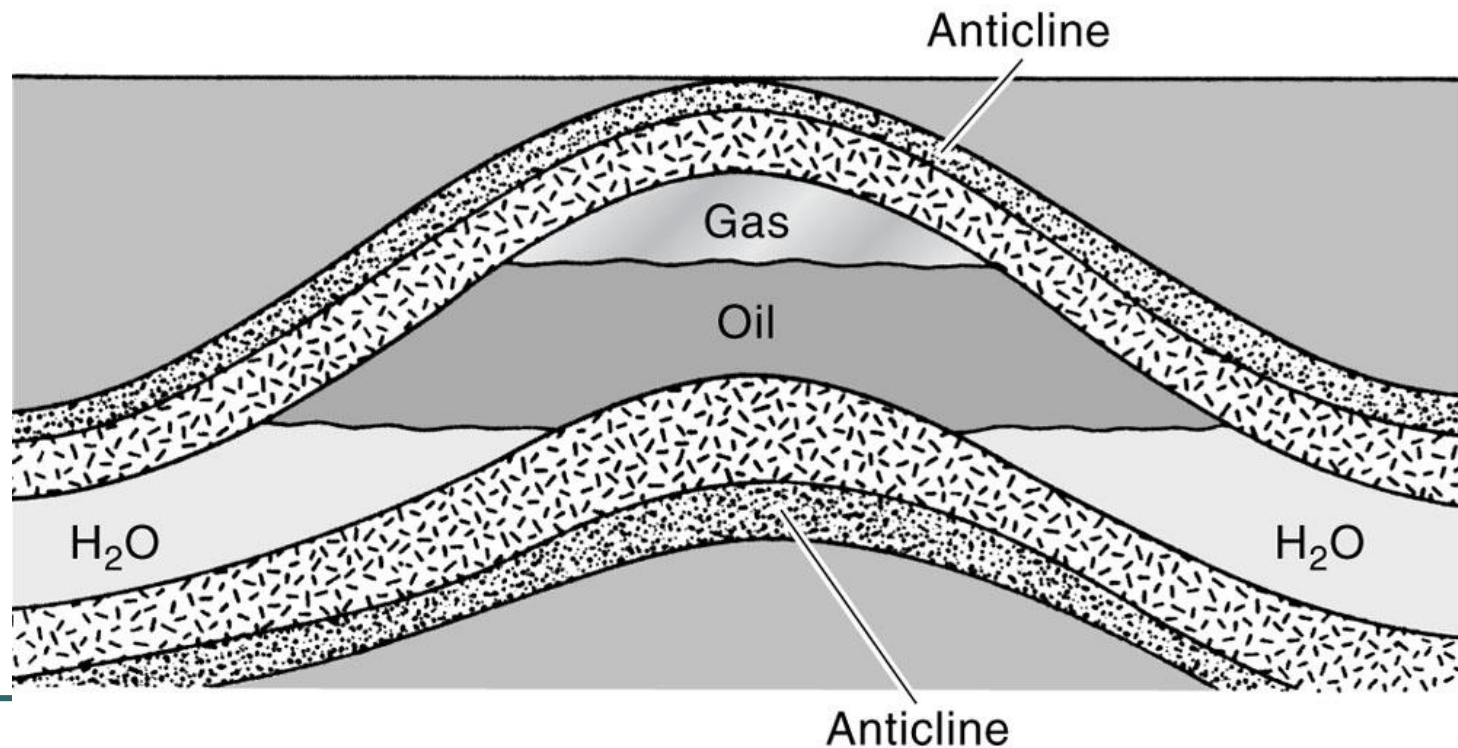
C. 31 y

**D. 0.72 y**

$$\frac{5000 \text{ MB}}{19 \text{ MB/d}} = 263 \text{ d} \times \frac{1 \text{ y}}{365 \text{ d}}$$
$$= \boxed{0.72 \text{ y}} = 8.6 \text{ mo}$$

# Recovering oil

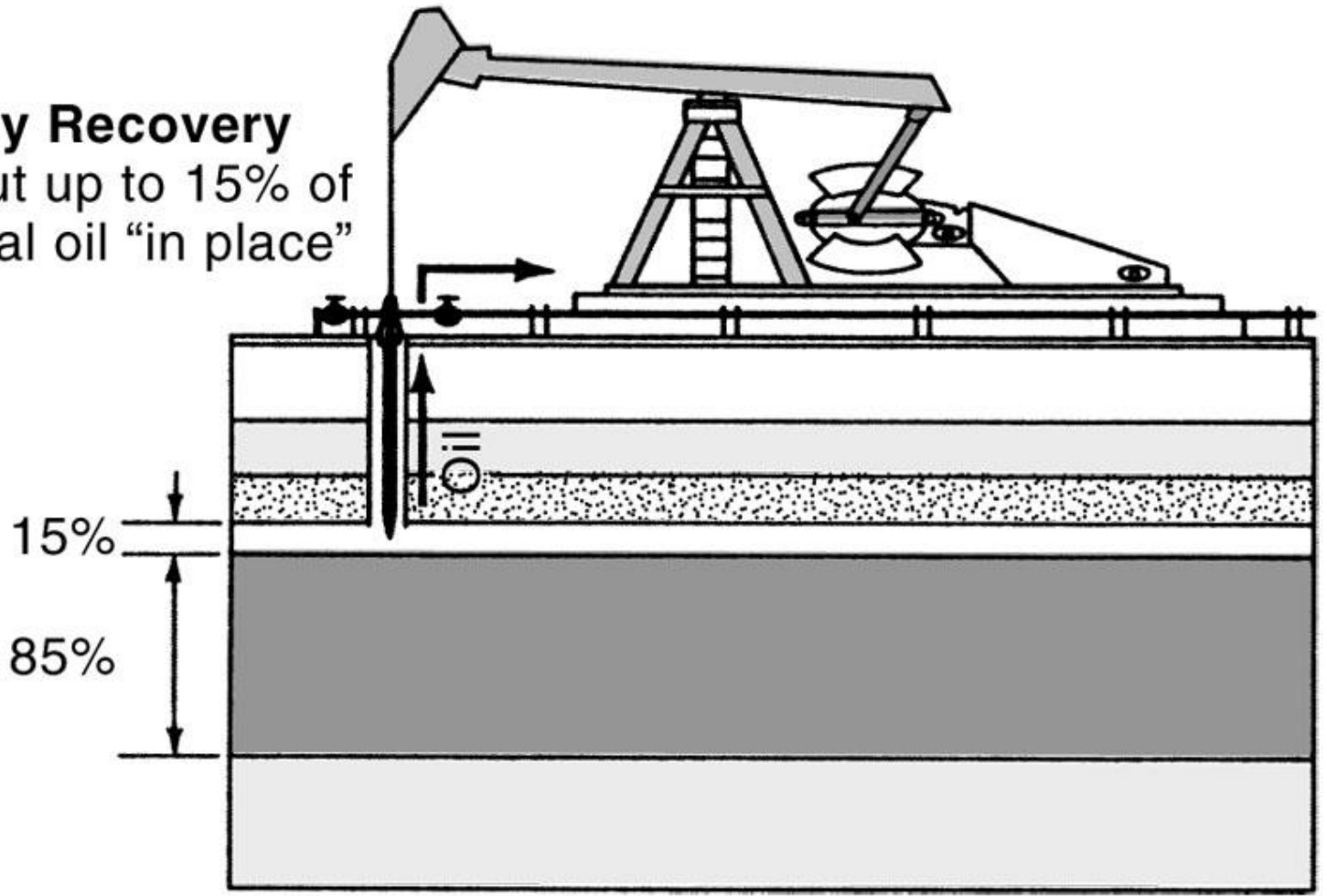
- Petroleum is trapped in deposits deep below the surface

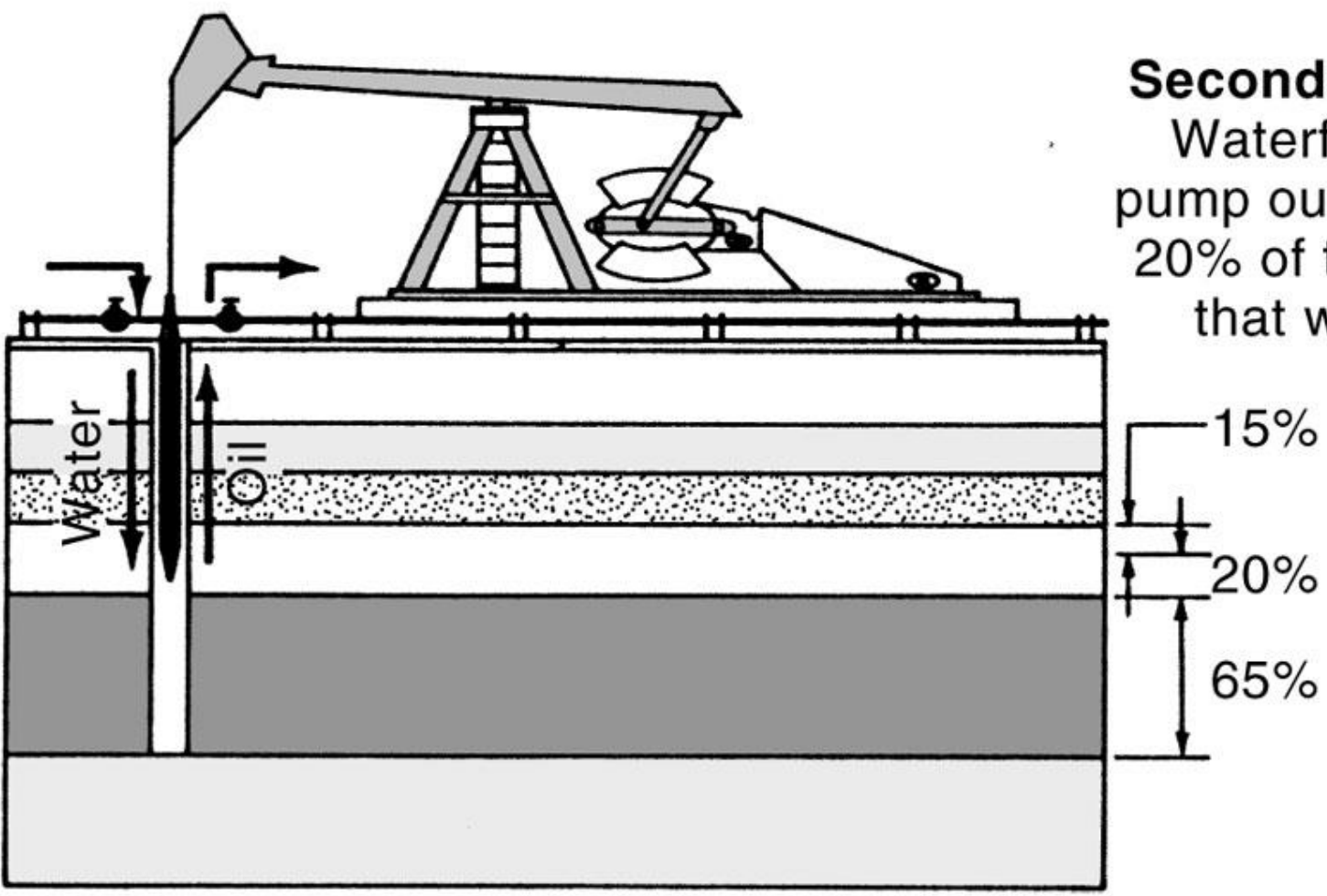


# OIL RECOVERY

(How to pump more from the ground)

**Primary Recovery**  
Pumps out up to 15% of the original oil "in place"

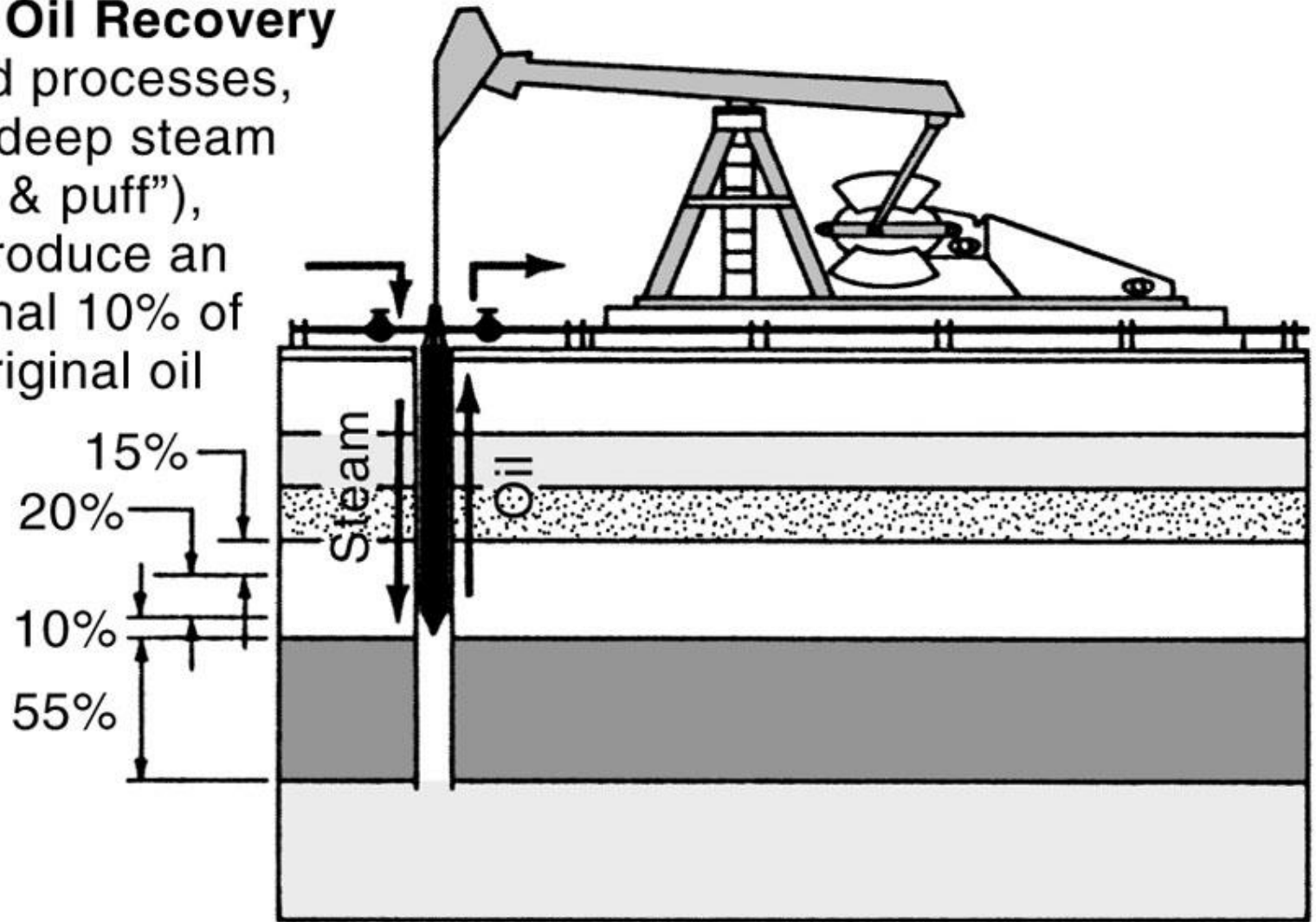




**Secondary Recovery**  
Waterflooding may pump out up to another 20% of the original oil that was in place

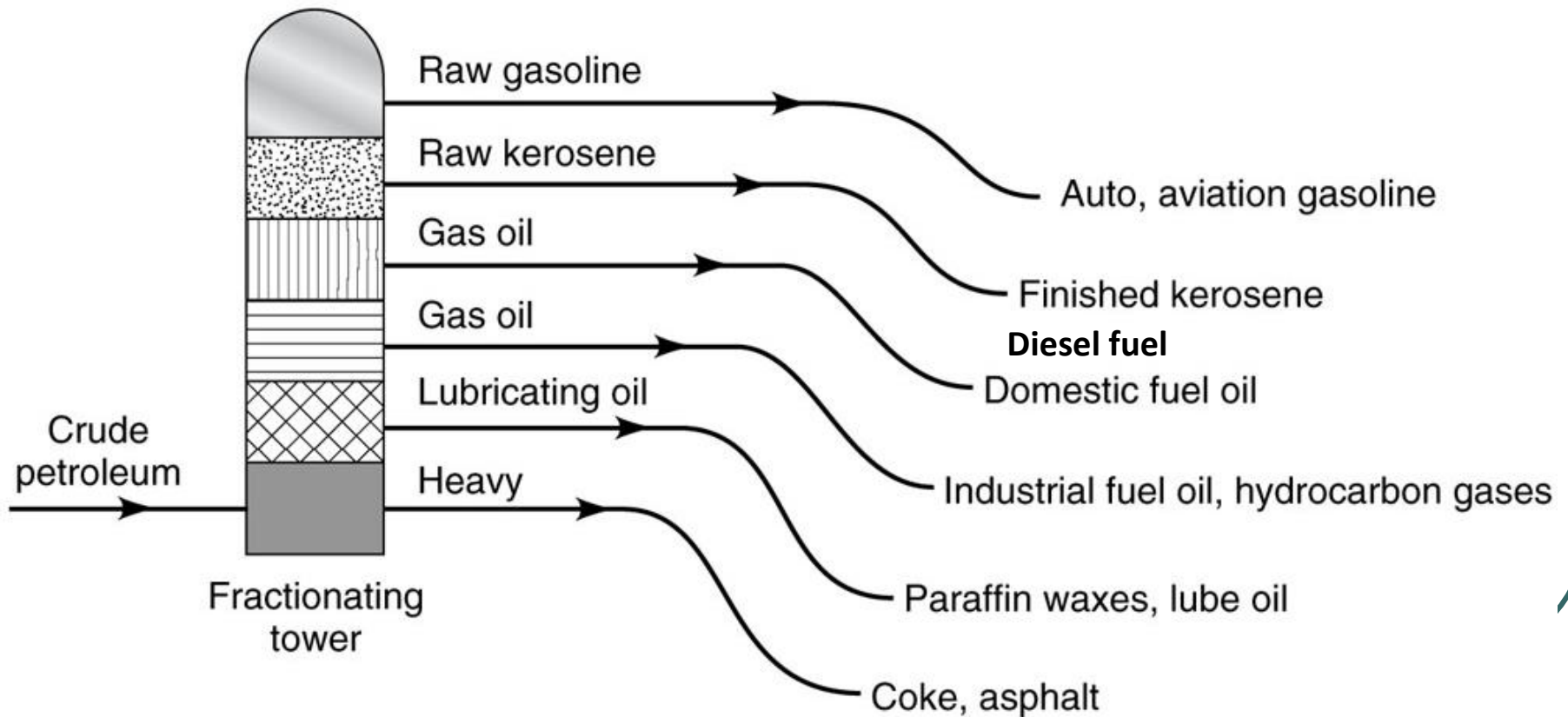
## Enhanced Oil Recovery

Advanced processes, such as deep steam ("huff & puff"), may produce an additional 10% of the original oil



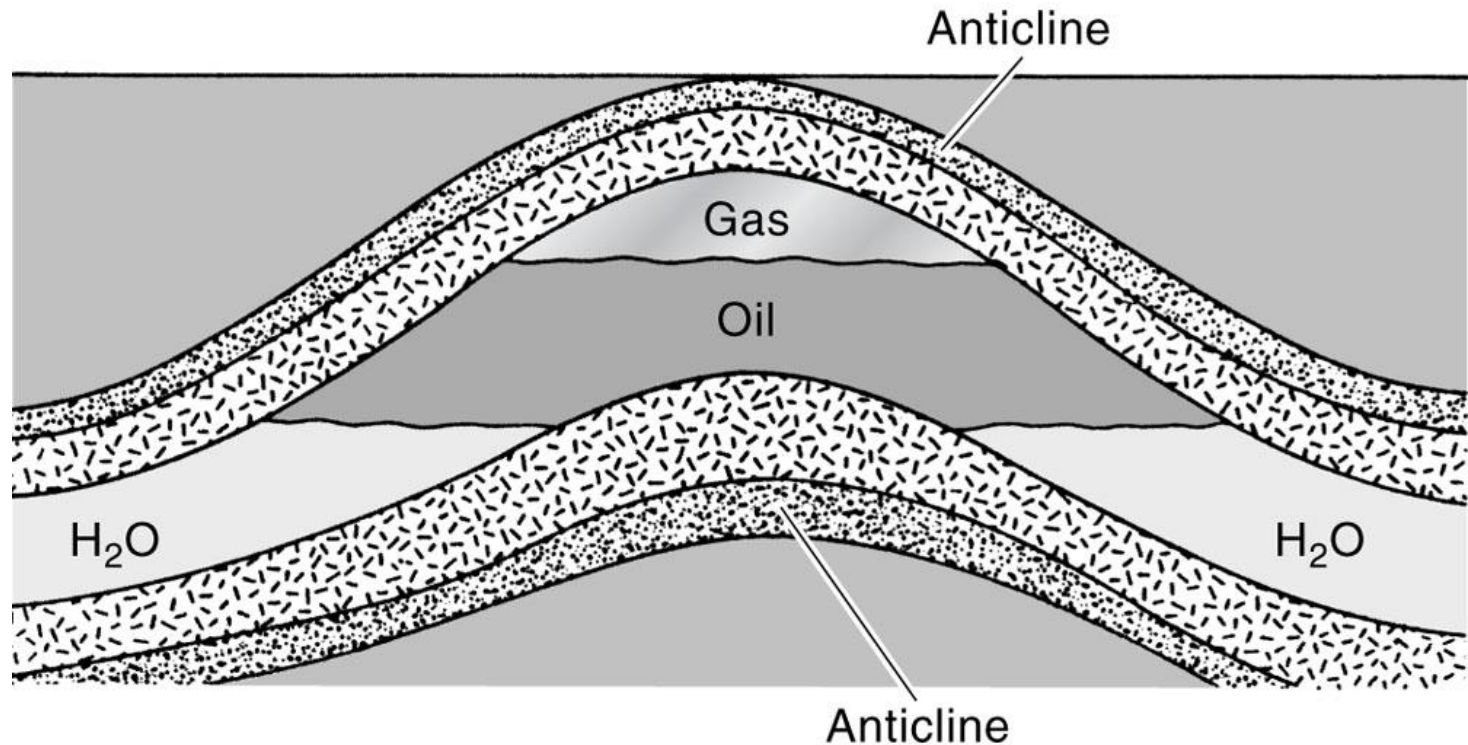
# The Refinery

- The crude oil is *distilled* to separate its different parts according to boiling temperature



# Recovering gas

- Natural gas is trapped together with the oil.



# Natural Gas

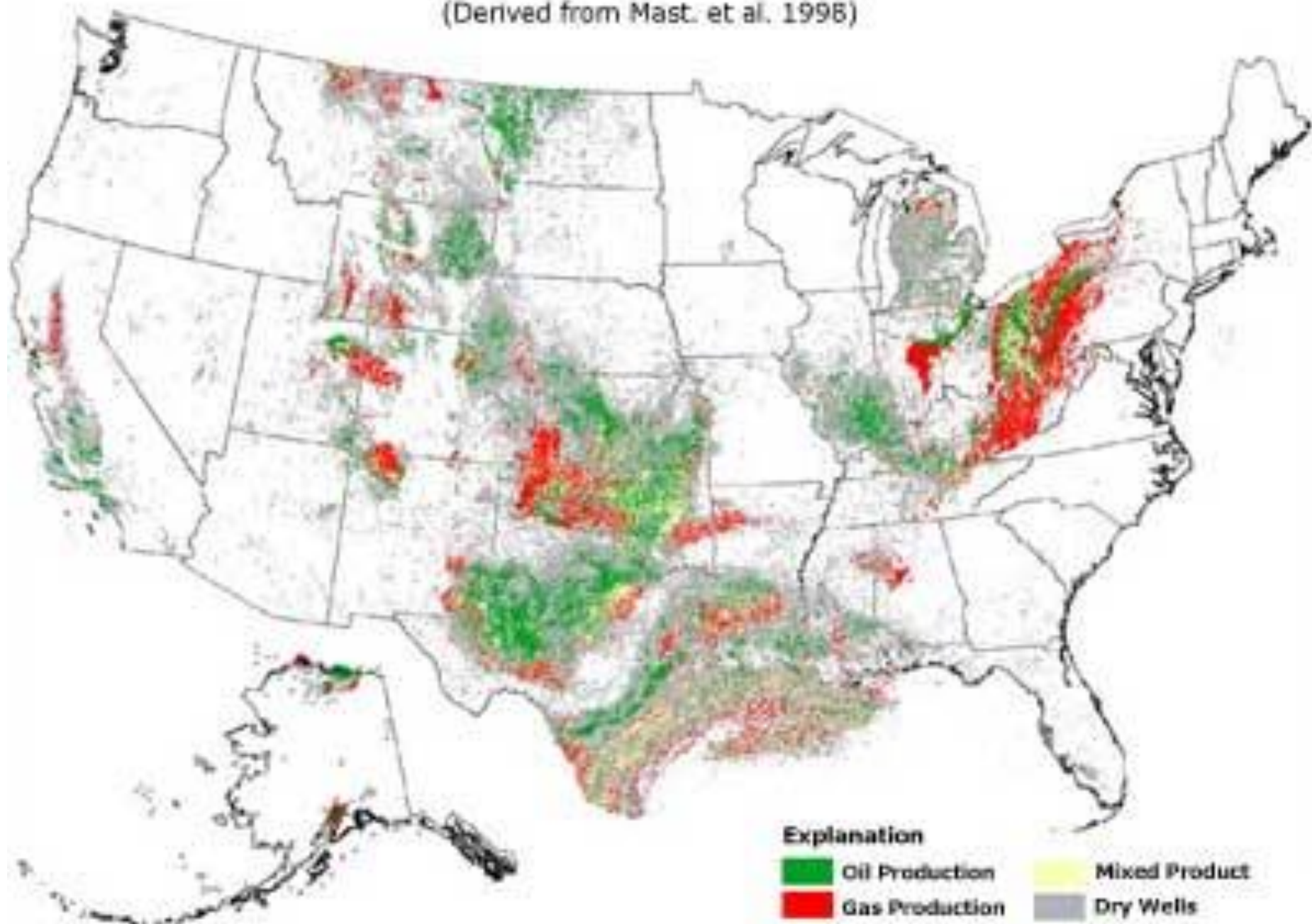
- Inexpensive, clean burning (no  $\text{SO}_2$ , one third the  $\text{CO}_2$  of coal)
- Space heating, water heating, cooking, transportation, chemical processing, production of electricity
- Many NG plants are co-generating plants where the exhaust thermal energy is utilized



Natural gas-fired, steam co-generation plant in Whitewater, WI

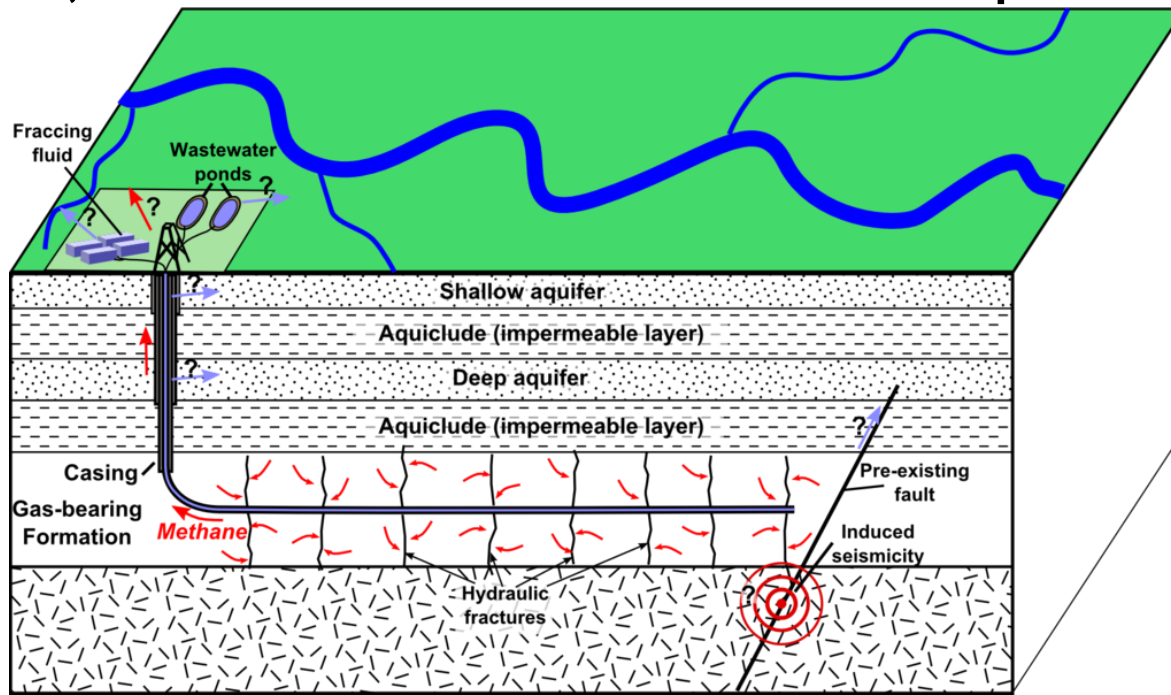
# Oil and Natural Gas Production in the United States

(Derived from Mast. et al. 1996)



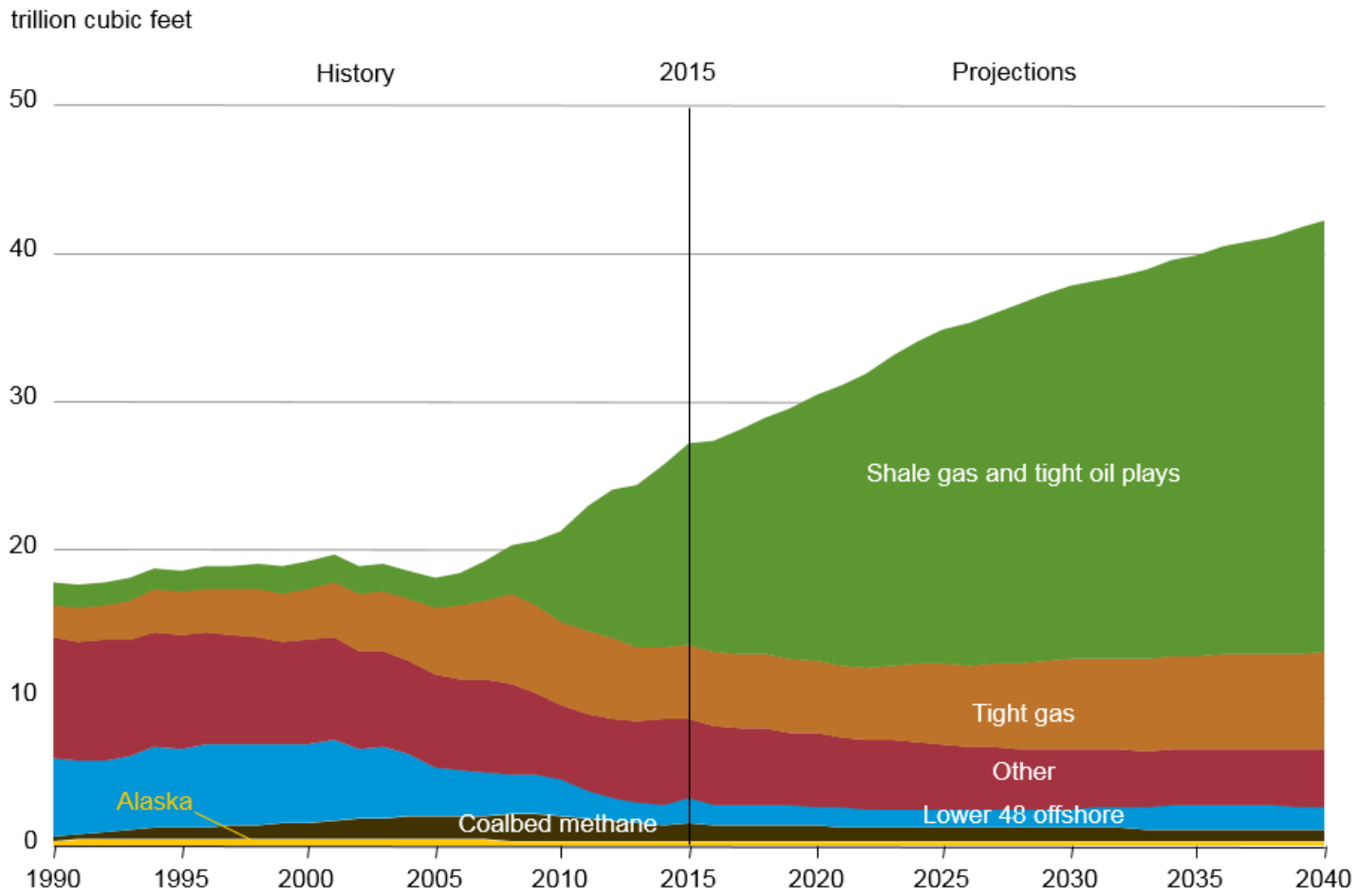
# Hydraulic Fracturing (fracking)

- Breaking certain impermeable rock layers releases natural gas and oil
- Inject high pressure water together with sand, which holds the fractures open



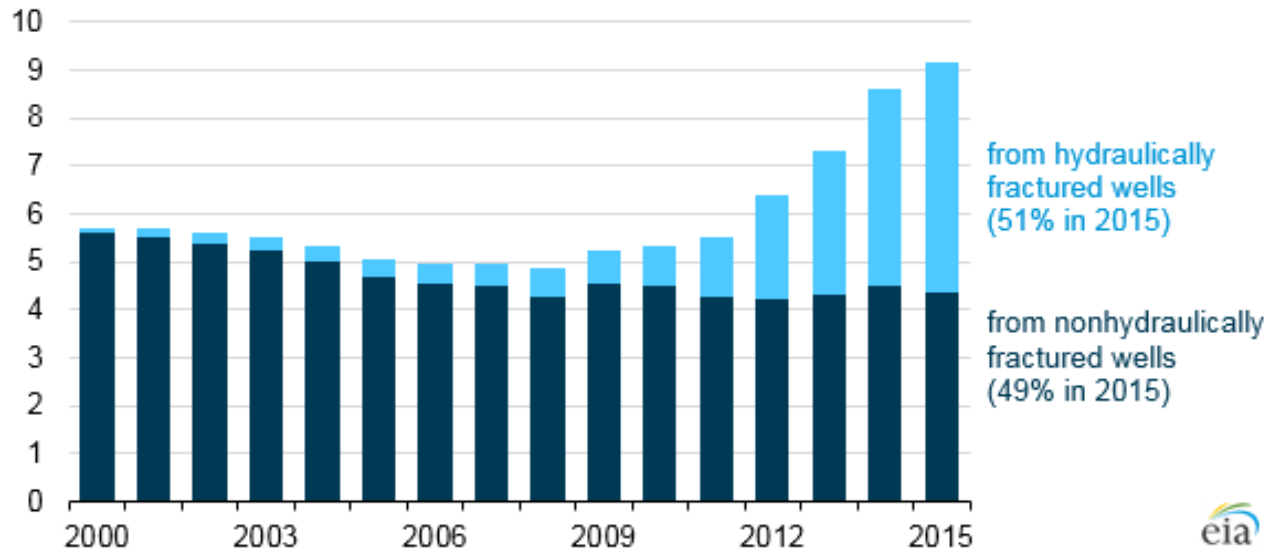
# Fracking has led to a large increase in US natural gas production

Figure MT-46. U.S. dry natural gas production by source in the Reference case, 1990–2040



# Most US oil and gas now comes from fracking

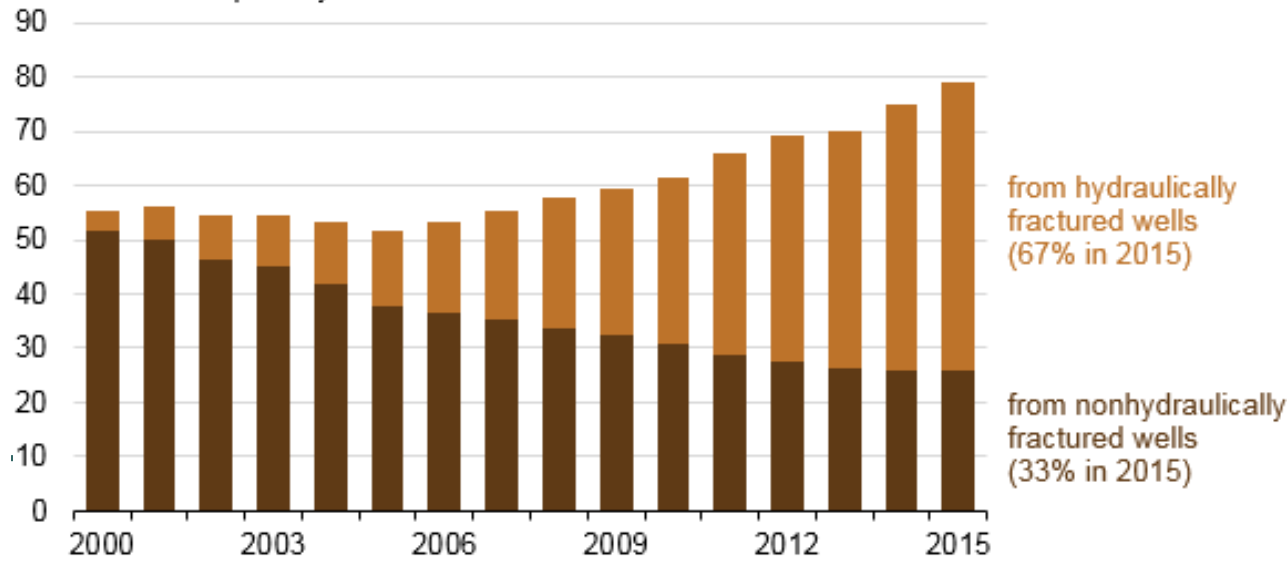
Oil production in the United States (2000-2015)  
million barrels per day



Source: US EIA  
[Today in Energy](#)  
[March 15, 2016](#)



Marketed natural gas production in the United States (2000-2015)  
billion cubic feet per day



Source: US EIA  
[Today in Energy](#)  
[May 5, 2016](#)



# Lower 48 states shale plays



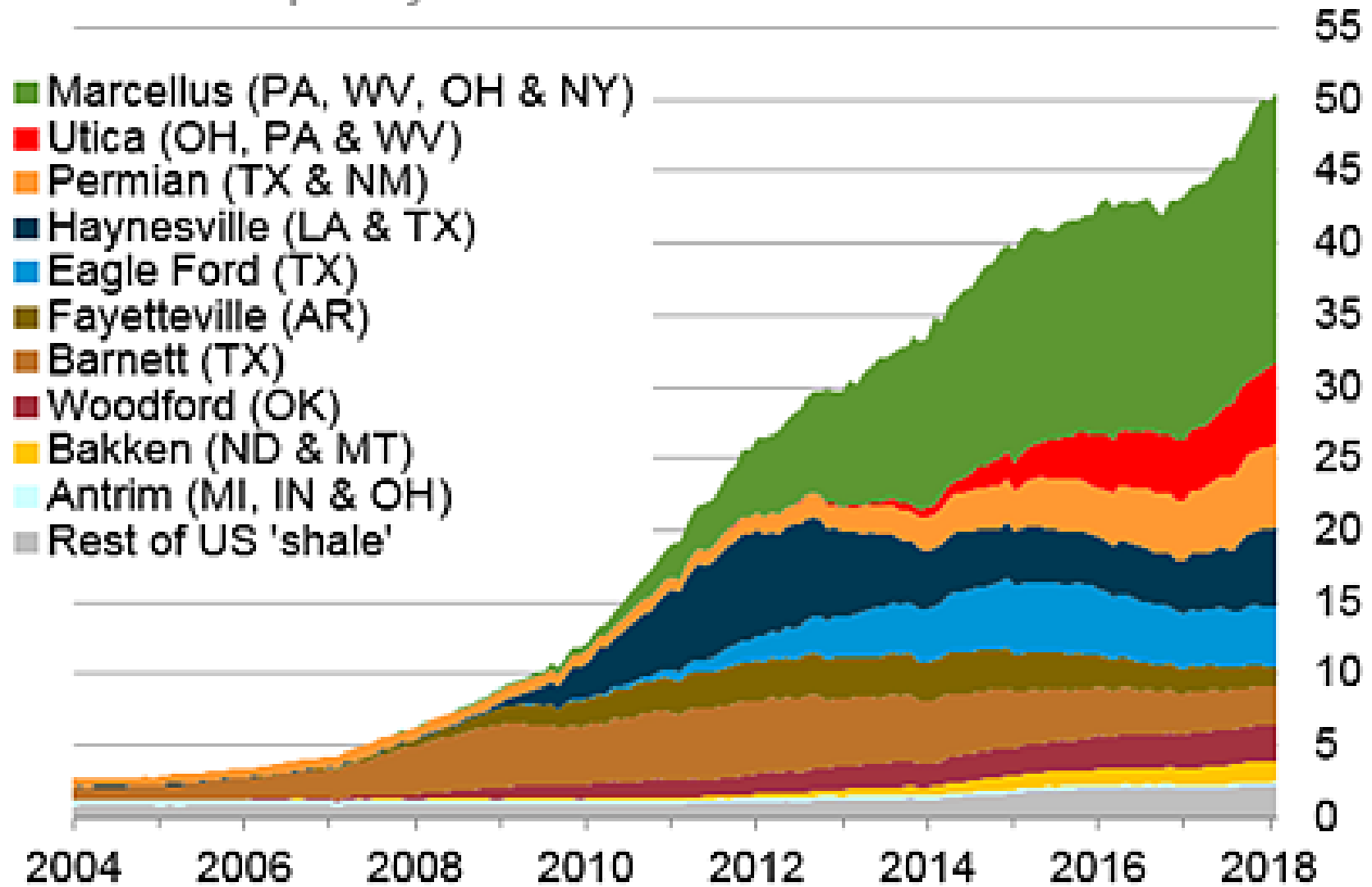
\* Mixed shale & chalk play  
 \*\* Mixed shale & limestone play  
 \*\*\* Mixed shale & dolostone-siltstone-sandstone play  
 \*\*\*\* Mixed shale & limestone-siltstone-sandstone play

Source: U.S. Energy Information Administration based on data from various published studies.  
 Updated: June 2016.



# Monthly dry shale gas production

billion cubic feet per day



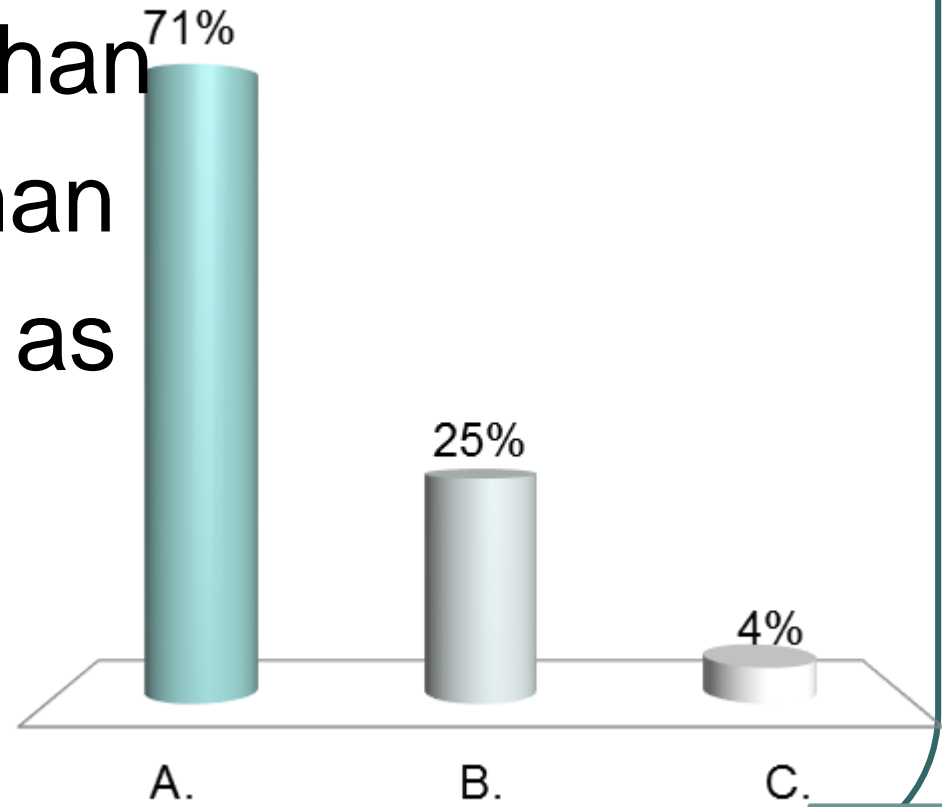
Sources: EIA derived from state administrative data collected by DrillingInfo Inc. Data are through February 2018 and represent EIA's official shale gas estimates, but are not survey data. State abbreviations indicate primary state(s).



**Kerosene is lighter than heating oil. It is extracted from the distillation tower at \_\_\_\_\_ the heating oil.**

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- ✓ A. a higher level than
- B. a lower level than
- C. the same level as



# Coal

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- Ancient, compressed plant material
- The US has more recoverable reserves of coal than any other country. See [www.eia.gov/coal](http://www.eia.gov/coal)
- In 2015, 92.5% of coal mined in the US was [burned by utilities to produce electricity](#)
- In 2015, 33% of [US-produced electricity came from coal](#), down from 50% in 2007 as many power plants switch to natural gas.
- Plentiful and inexpensive but associated with a number of environmental hazards

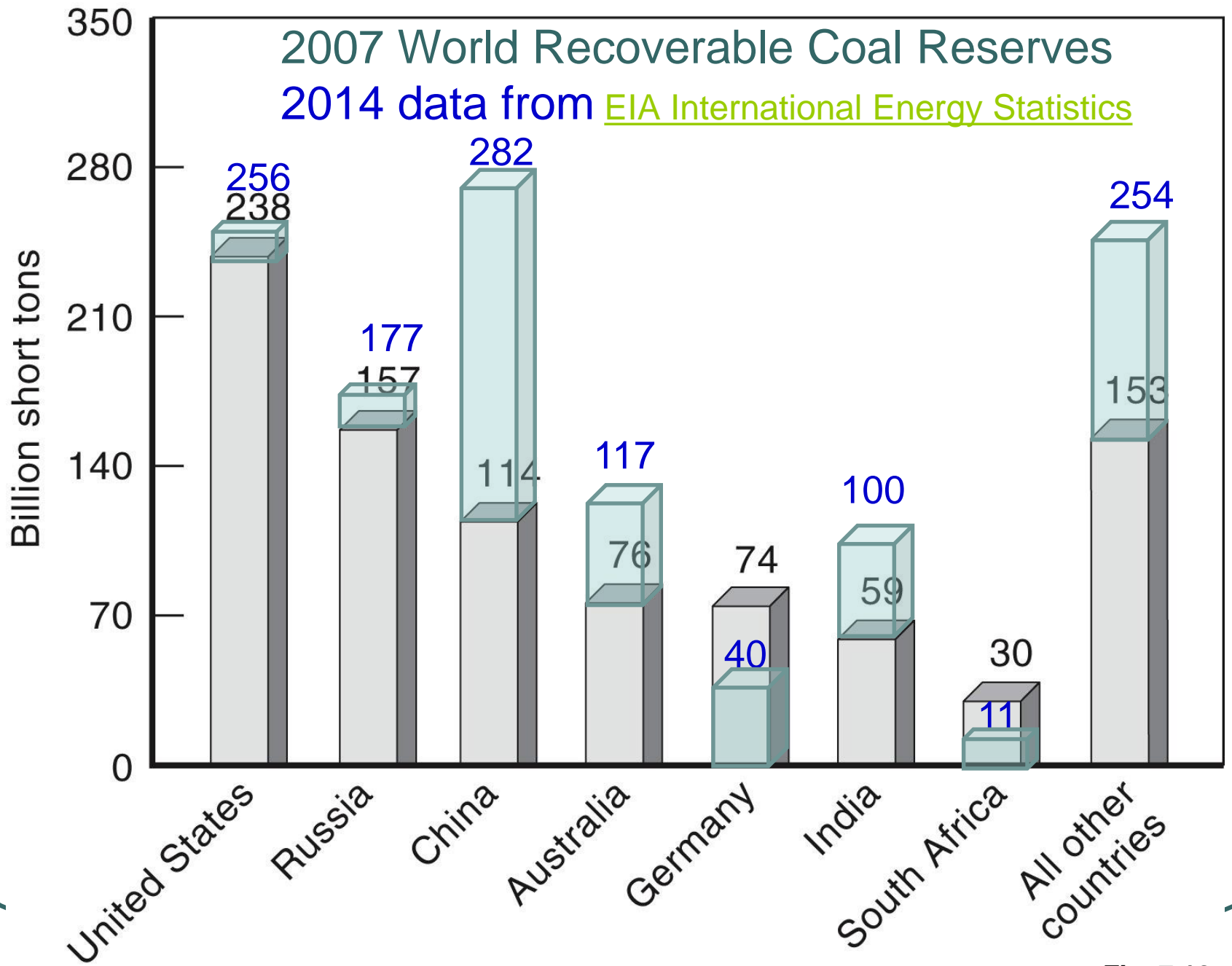


Fig. 7.18, p. 215

## Ranks of Coal

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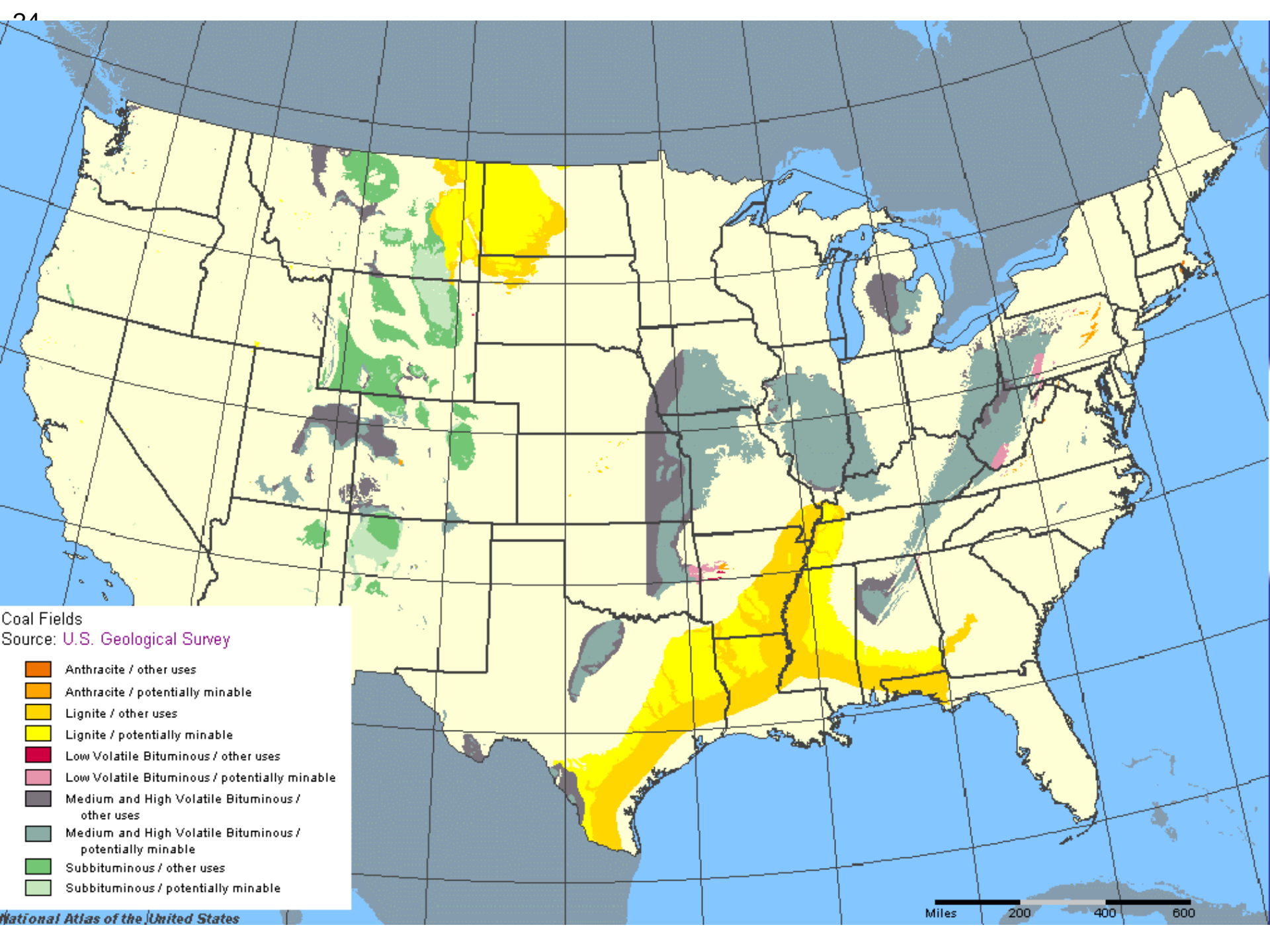
- **Lignite** – youngest, high water content, low energy content
- **Subbituminous** – low sulfur, high water, medium energy content. Great plains surface mines, inexpensive to harvest
- **Bituminous** – high sulfur, high energy content. Most plentiful supply
- **Anthracite** – very hard, very high energy content, low dust. Limited supply.

Table 7.3 RANKS OF COAL

Rank	Carbon (%)	Energy Content (Btu/lb)
Lignite	30	5000–7000
Subbituminous	40	8000–10,000
Bituminous	50–70	11,000–15,000
Anthracite	90	14,000

Source: P. Averitt, *U.S. Geological Survey Bulletin*, 1412 (1975).

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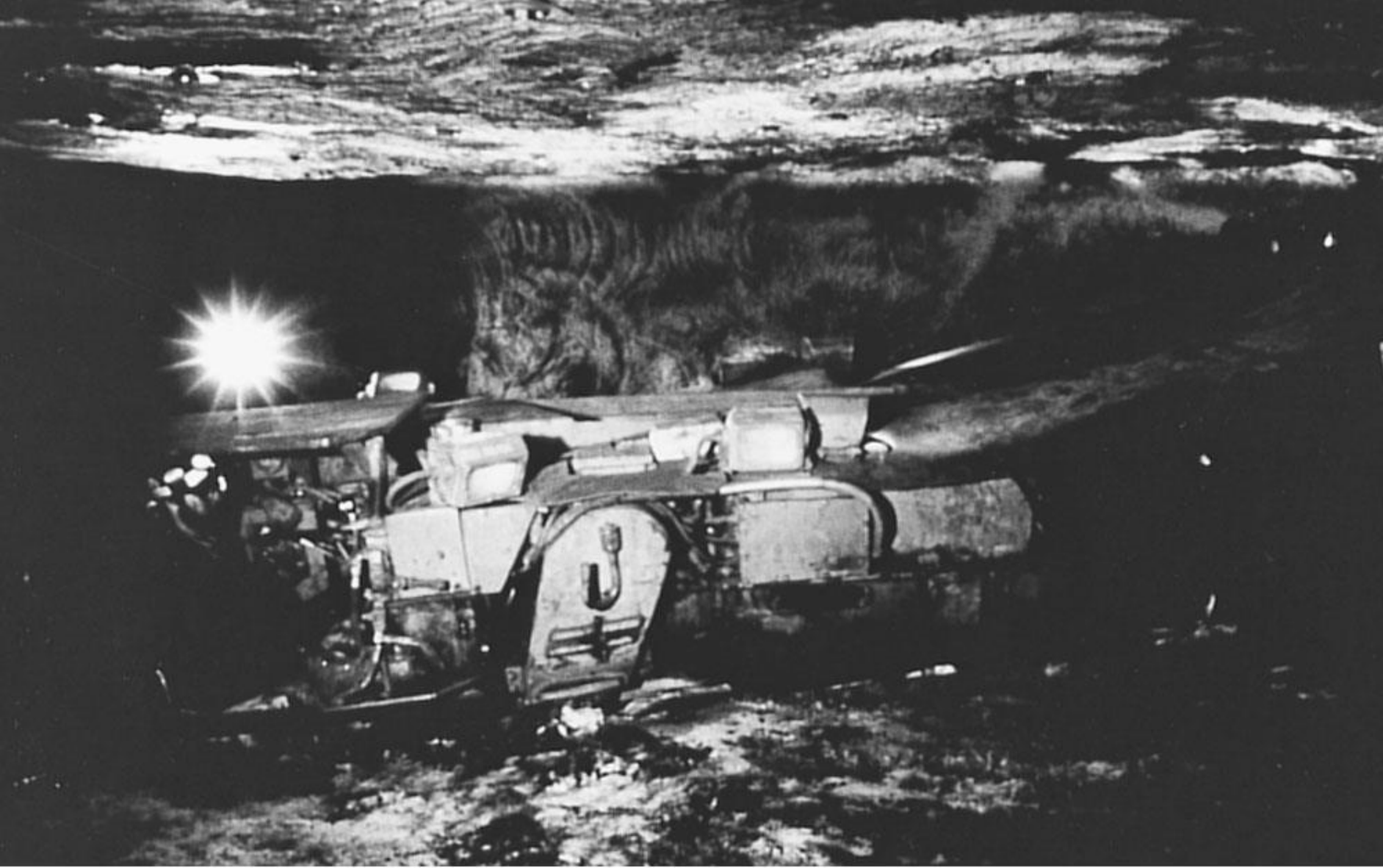
**Coal Fields**  
Source: U.S. Geological Survey

- Anthracite / other uses
- Anthracite / potentially minable
- Lignite / other uses
- Lignite / potentially minable
- Low Volatile Bituminous / other uses
- Low Volatile Bituminous / potentially minable
- Medium and High Volatile Bituminous / other uses
- Medium and High Volatile Bituminous / potentially minable
- Subbituminous / other uses
- Subbituminous / potentially minable

# Environmental Hazards

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- Burning coal releases large amounts of  $\text{CO}_2$ , a greenhouse gas
- Burning high-sulfur coal produces a large amount of  $\text{SO}_2$ , linked to acid rain (environmental effects of acid rain are debatable – see pp. 252-256)
- Ash and dust in the air cause breathing difficulties
- Strip mining can produce a damaged landscape incapable of supporting vegetation



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World's largest excavator:  
The Bagger 288 (Germany)  
265,000 tons of lignite per day  
<http://www.popsci.com/bagger-288-facts>

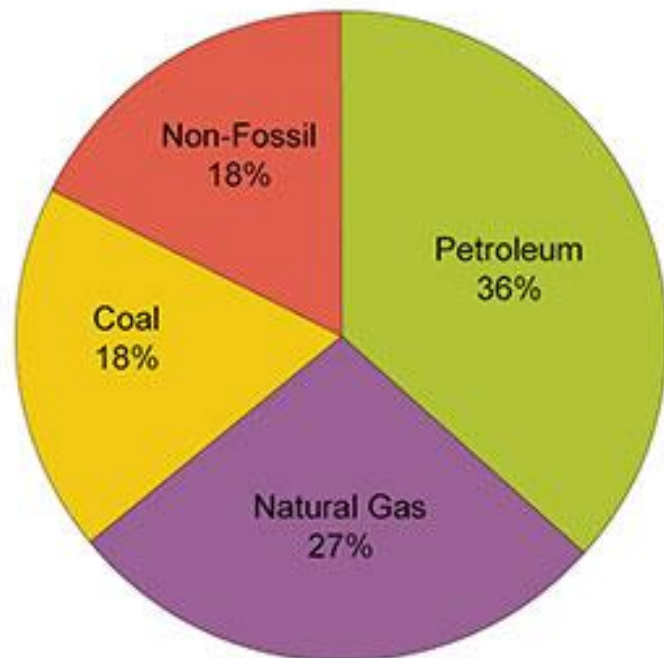


On 3/29/16 I couldn't find an equivalent pie chart, but I found a different chart (next slide) for 2014. The percentages didn't change much in the two year span...

## The US Energy Mix 2012

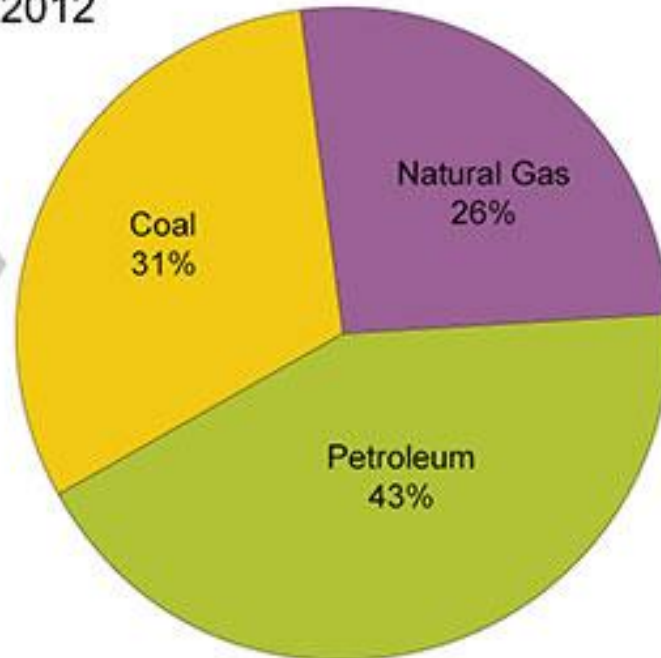


U.S. energy consumption by major fuel type, 2012



Totals may not equal 100 due to independent rounding.  
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 (May 2013), preliminary 2012 data.

Resulting U.S. energy-related carbon dioxide emissions by major fuel type, 2012

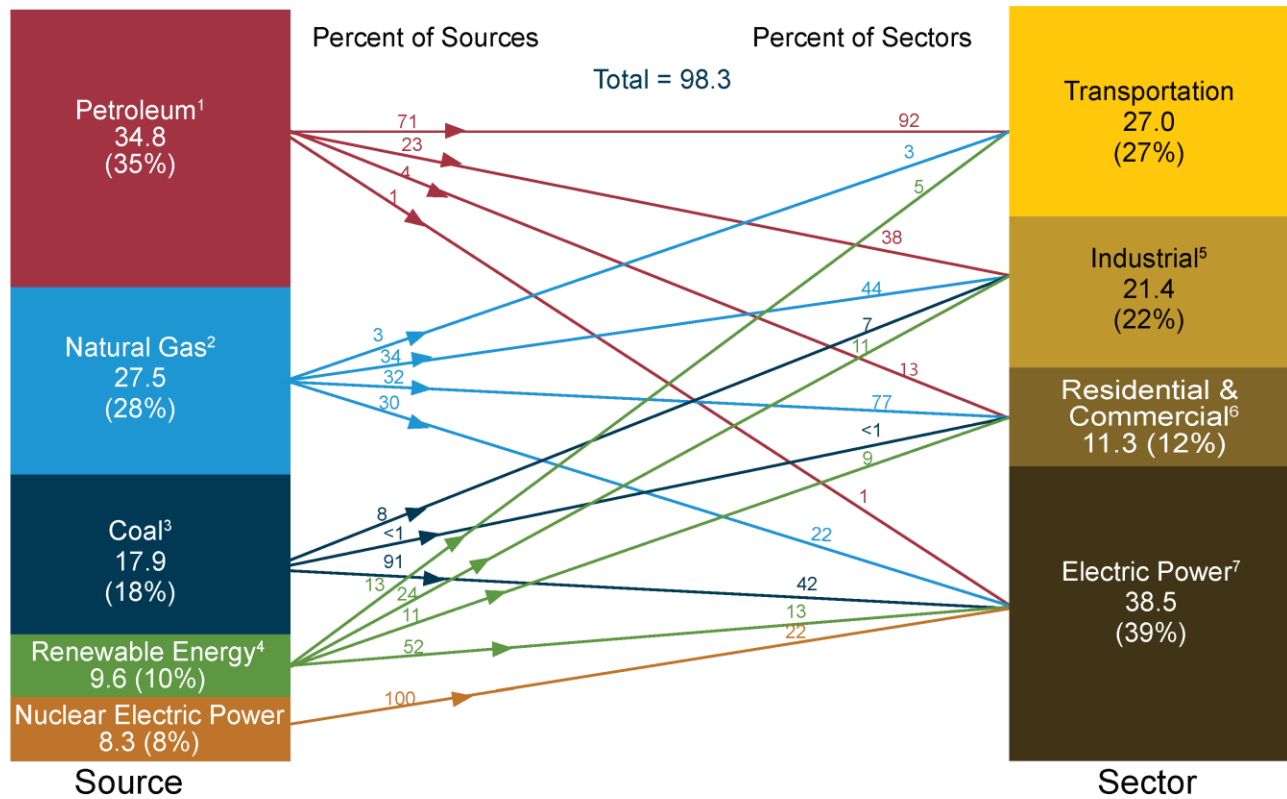


Totals may not equal 100 due to independent rounding.  
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 12.1 (May 2013), preliminary 2012 data.

# The US Energy Mix 2014

[http://www.eia.gov/totalenergy/data/monthly/pdf/flow/css\\_2014\\_energy.pdf](http://www.eia.gov/totalenergy/data/monthly/pdf/flow/css_2014_energy.pdf)

### Primary Energy Consumption by Source and Sector, 2014 (Quadrillion Btu)



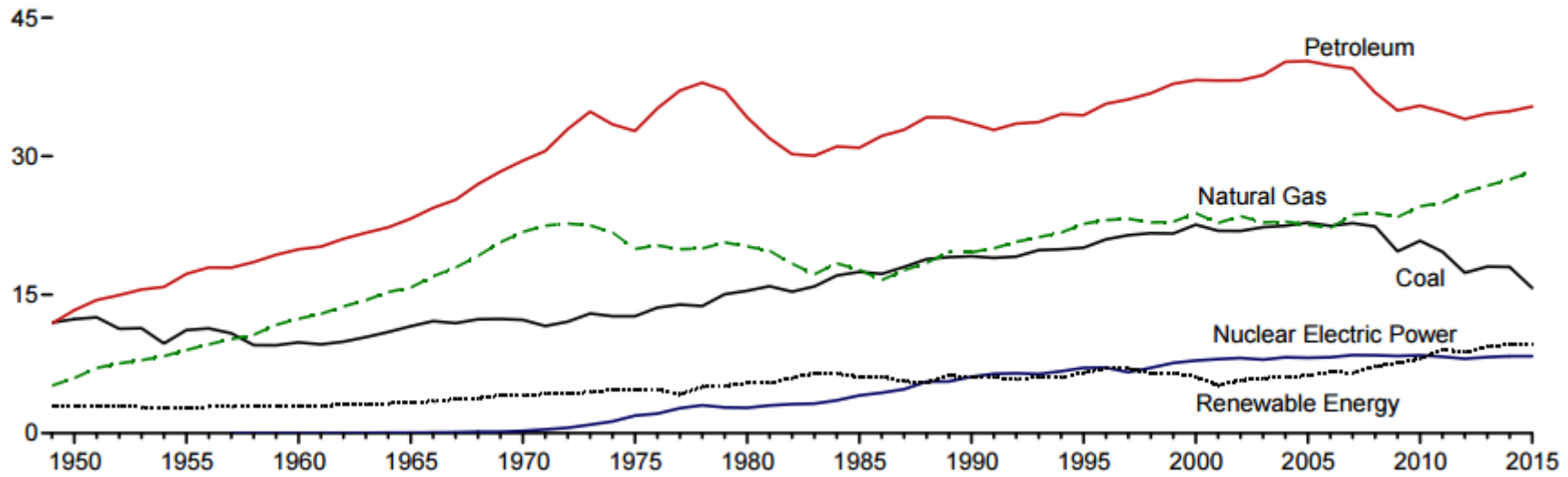
<sup>1</sup> Does not include biofuels that have been blended with petroleum—biofuels are included in "Renewable Energy."  
<sup>2</sup> Excludes supplemental gaseous fuels.  
<sup>3</sup> Includes less than -0.1 quadrillion Btu of coal coke net imports.  
<sup>4</sup> Conventional hydroelectric power, geothermal, solar/photovoltaic, wind, and biomass.  
<sup>5</sup> Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.  
<sup>6</sup> Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.

<sup>7</sup> Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes 0.2 quadrillion Btu of electricity net imports not shown under "Source."  
 Notes: Primary energy in the form that it is first accounted for in a statistical energy balance, before any transformation to secondary or tertiary forms of energy (for example, coal is used to generate electricity). • Sum of components may not equal total due to independent rounding.  
 Sources: U.S. Energy Information Administration, Monthly Energy Review (March 2015), Tables 1.3, 2.1-2.6.

# Energy Consumption history

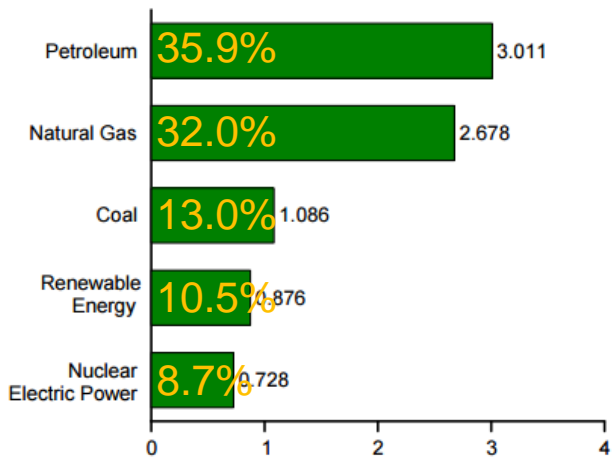
**Figure 1.3 Primary Energy Consumption**  
(Quadrillion Btu)

By Source,<sup>a</sup> 1949–2015



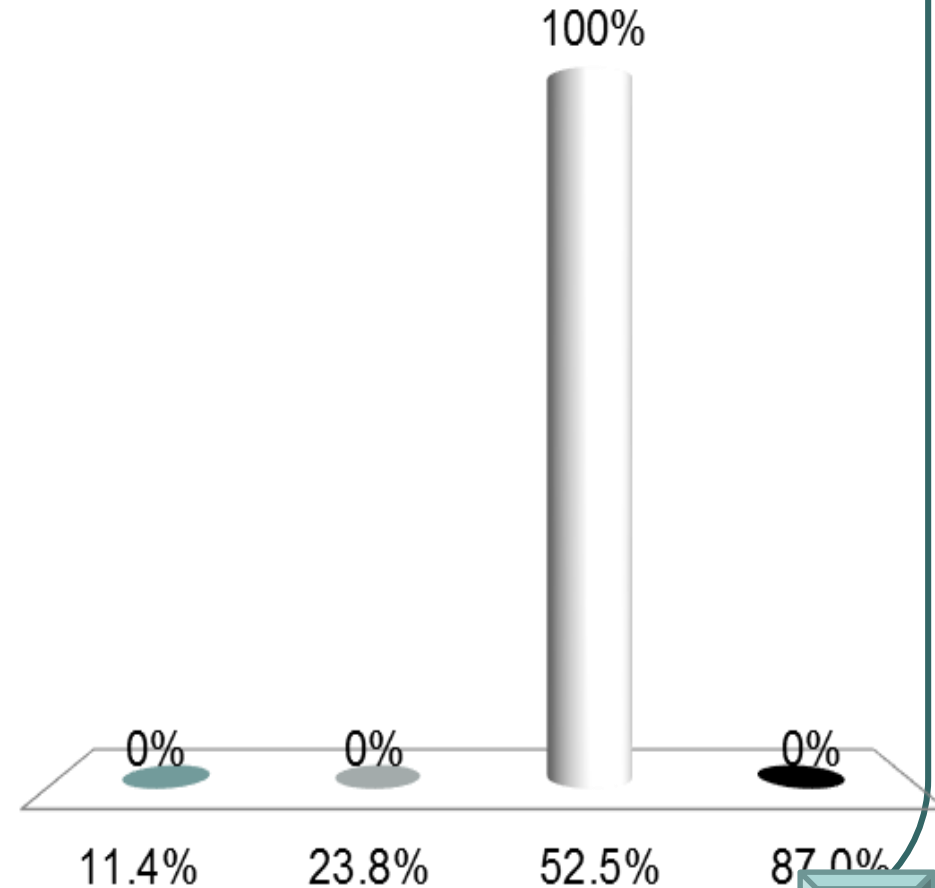
By Source,<sup>a</sup> December 2015

By Source,<sup>a</sup> Monthly



**A gasification plant converts 26,000 tons of coal (8700 BTU/lb) per day to produce  $2.5 \times 10^8$  ft<sup>3</sup>/day of natural gas (950 BTU/ft<sup>3</sup>). What is its efficiency?**

- A. 11.4%
- B. 23.8%
- C. 52.5%
- D. 87.0%



**A gasification plant converts 26,000 tons of coal (8700 BTU/lb) per day to produce  $2.5 \times 10^8$  ft<sup>3</sup>/day of natural gas (950 BTU/ft<sup>3</sup>). What is its efficiency?**

A. 11.4%

$$e = \frac{E_{\text{natural gas}}}{E_{\text{coal}}}$$

B. 23.8%

$$E_{\text{natural gas}} = 2.5 \times 10^8 \text{ ft}^3 \times 950 \text{ BTU/ft}^3$$

C. **52.5%**

$$= 2.38 \times 10^{11} \text{ BTU}$$

D. 87.0%

$$E_{\text{coal}} = 26,000 \text{ ton} \times 2000 \text{ lb/ton} \times 8700 \text{ BTU/lb}$$

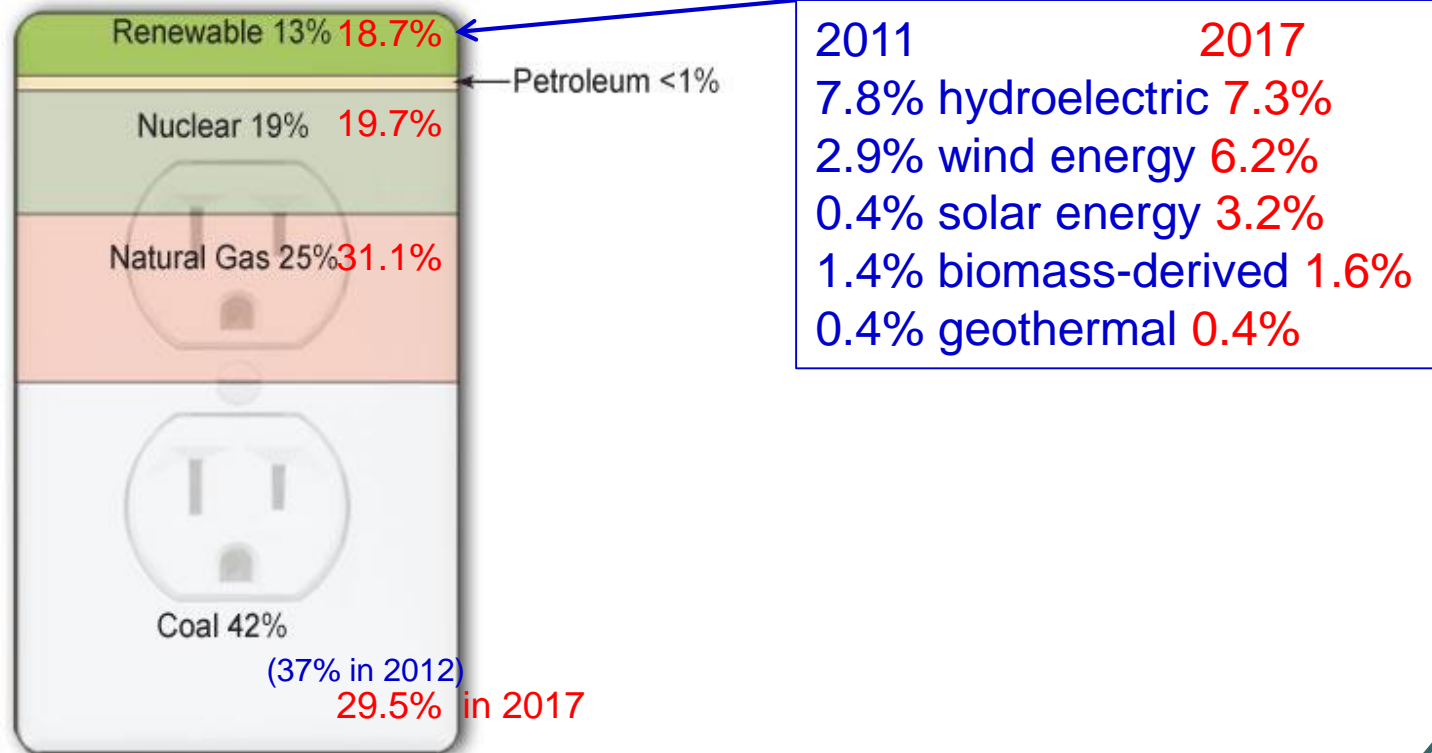
$$= 4.52 \times 10^{11} \text{ BTU}$$

$$e = \frac{2.38 \times 10^{11} \text{ BTU}}{4.52 \times 10^{11} \text{ BTU}} = 0.525 \times 100 = \boxed{52.5\%}$$

# US Generated Electricity

<http://www.eia.gov/electricity/monthly/>

## Sources of U.S. Electricity Generation, 2011 2017

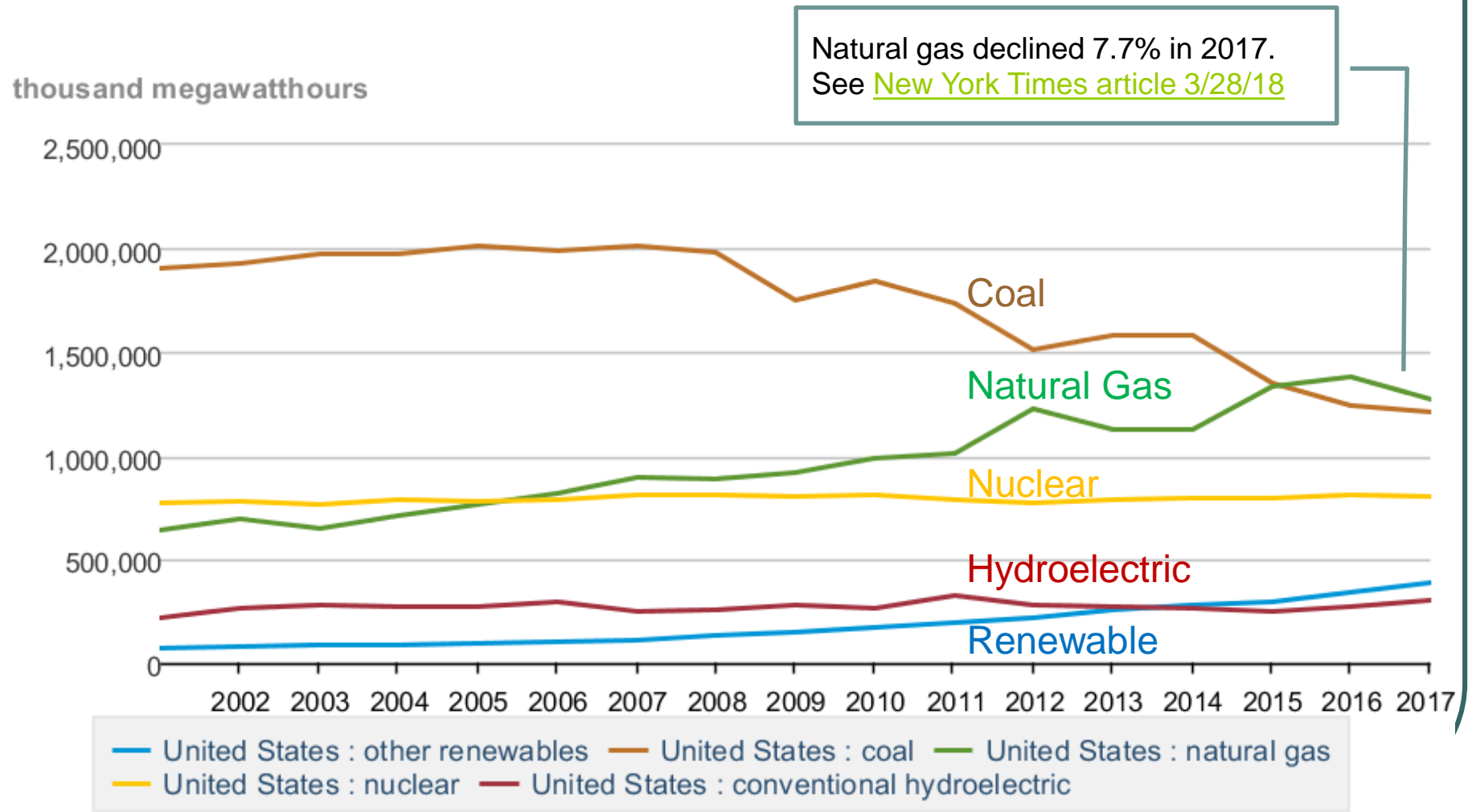


Source: U.S. Energy Information Administration, *Electric Power Monthly* (March 2012). Percentages based on Table 1.1, preliminary 2011 data.

# US Electricity generation history

<http://www.eia.gov/electricity/data/browser/>

## Net generation for all sectors, annual



Data source: U.S. Energy Information Administration

## Some possible solutions

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- Installation of exhaust gas scrubbers at power plants
- Cleaner-burning fluidized bed combustion
- Use of low-sulfur coal
- Coal gasification and liquefaction
- Careful land reclamation after mining

## Right here at UWSP

- Steam for heating is provided by a power plant that can burn various combinations of natural gas, coal, paper pellets, and fuel oil.
- 2008 Usage:
  - 62.4% coal
  - 37.6% gas
- 2017 Usage:
  - 21.6% coal
  - 78.4% gas
- Goal: eliminate coal by March 2020



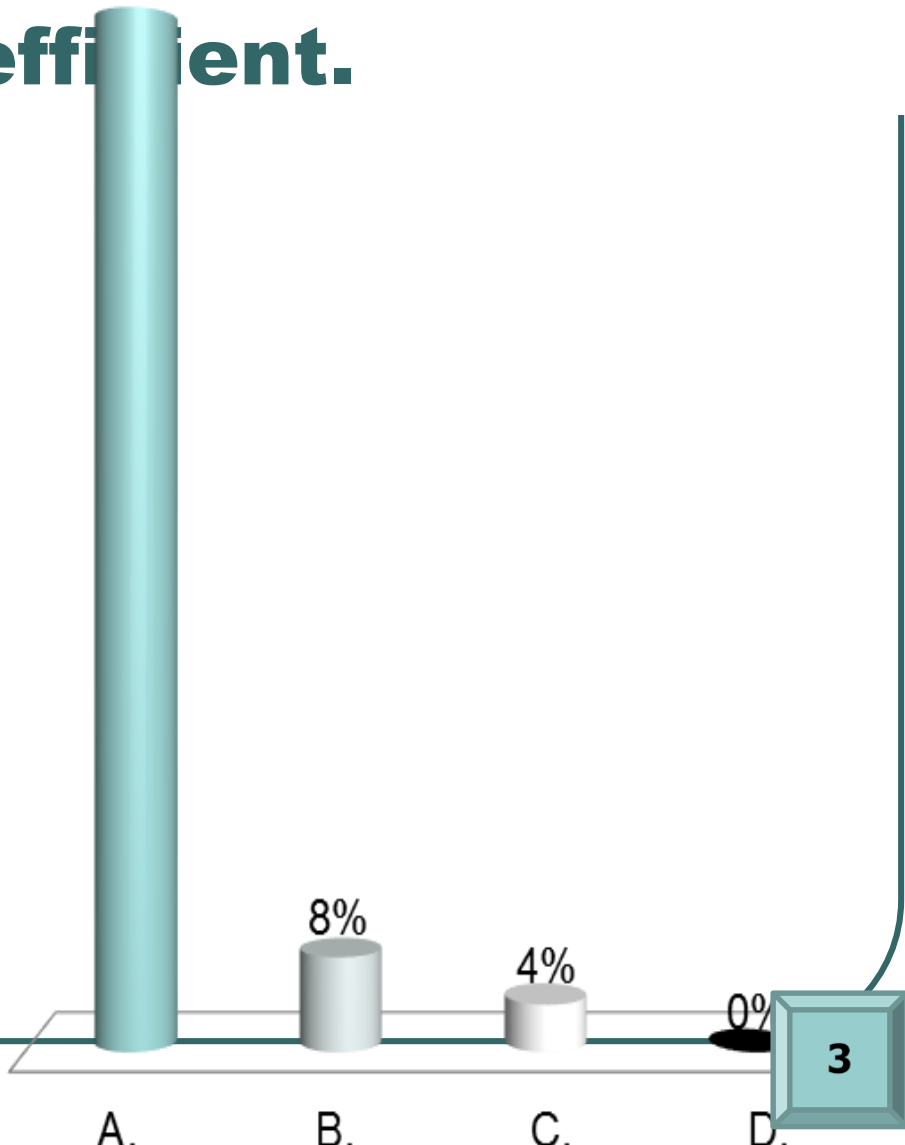
## Right here at UWSP

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- Electricity is purchased from off campus.
- 100% of overall campus electricity consumption is from renewable sources (by purchasing energy credits through Renewable Choice Energy).
- The campus has a Carbon Neutrality Plan
- See the Energy and Carbon page

**How many kWh of electricity can be delivered from 1 ton of coal ( $2.6 \times 10^{10}$  J) fuel? The plant is 35% efficient and the transmission is 90% efficient.**

- A. 2275 kWh
- B. 825 kWh
- C. 35 kWh
- D. 2.9 kWh



**26 of 34**

**3**

**How many kWh of electricity can be delivered from 1 ton of coal ( $2.6 \times 10^{10}$  J) fuel? The plant is 35% efficient and the transmission is 90% efficient.**

$$(2.6 \times 10^{10} \text{ J}) \times 0.35 \times 0.90 = 8.19 \times 10^9 \text{ J}$$

$$(8.19 \times 10^9 \text{ J}) \times \frac{1 \text{ kWh}}{3.6 \times 10^6 \text{ J}} = \boxed{2275 \text{ kWh}}$$

About 2 month's worth for a house