High Energy Society

Why do we care about energy?

Original slides provided by Dr. Daniel Holland.

What is Energy

- We will look at the "Physics" definition in a bit, but essentially, it is the ability to make something move.
- Experiment: Stand up and start doing deep knee bends at a rate of about 1 per 2 seconds.
- You are working (using energy) at a rate of approximately 100W. (We'll come back to this later.)

Audio Link

Energy and Power

- A joule is a measure of the amount of energy.
- A watt (1 J/s) is a measure of the *rate* of energy use.
- It would take the same amount of energy to do 10 deep knee bends in 20 min as it would in 20 sec, but by doing it in 20 sec, you use energy at a faster rate.

- The rate of using energy is called POWER. Something that is powerful uses a lot of energy quickly.

  Power = Energy/Time

- This is a Rate Equation (More soon.)
- Common Unit of Power is a Kilowatt =kW = 1000 W.

Energy = (Power)x(Time)

Common Unit of Energy= kWh (Kilowatt-hour)

1 kWh is the amount of energy you would use if you consume energy at the rate of 1 kW for 1 hr. (10 people doing deep knee bend for an hour.)

Other Units of Energy and Power

- 1 kWh = 3,600,000 Joule
- 1 Btu = 1055 Joule
- 1 Calorie = 4186 Joule
- 1 Calorie = 1000 calorie

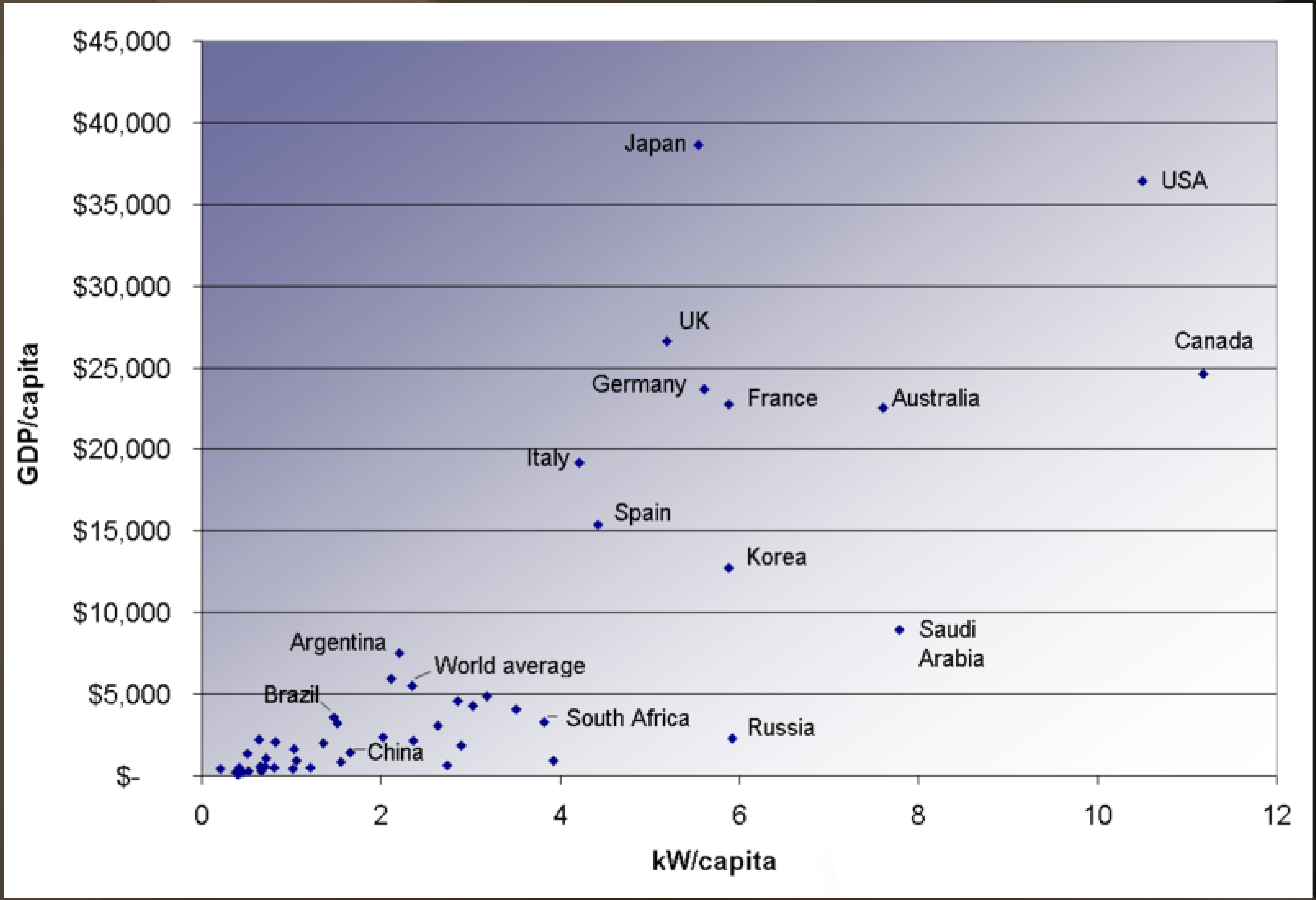
- 1hp=746 Watts

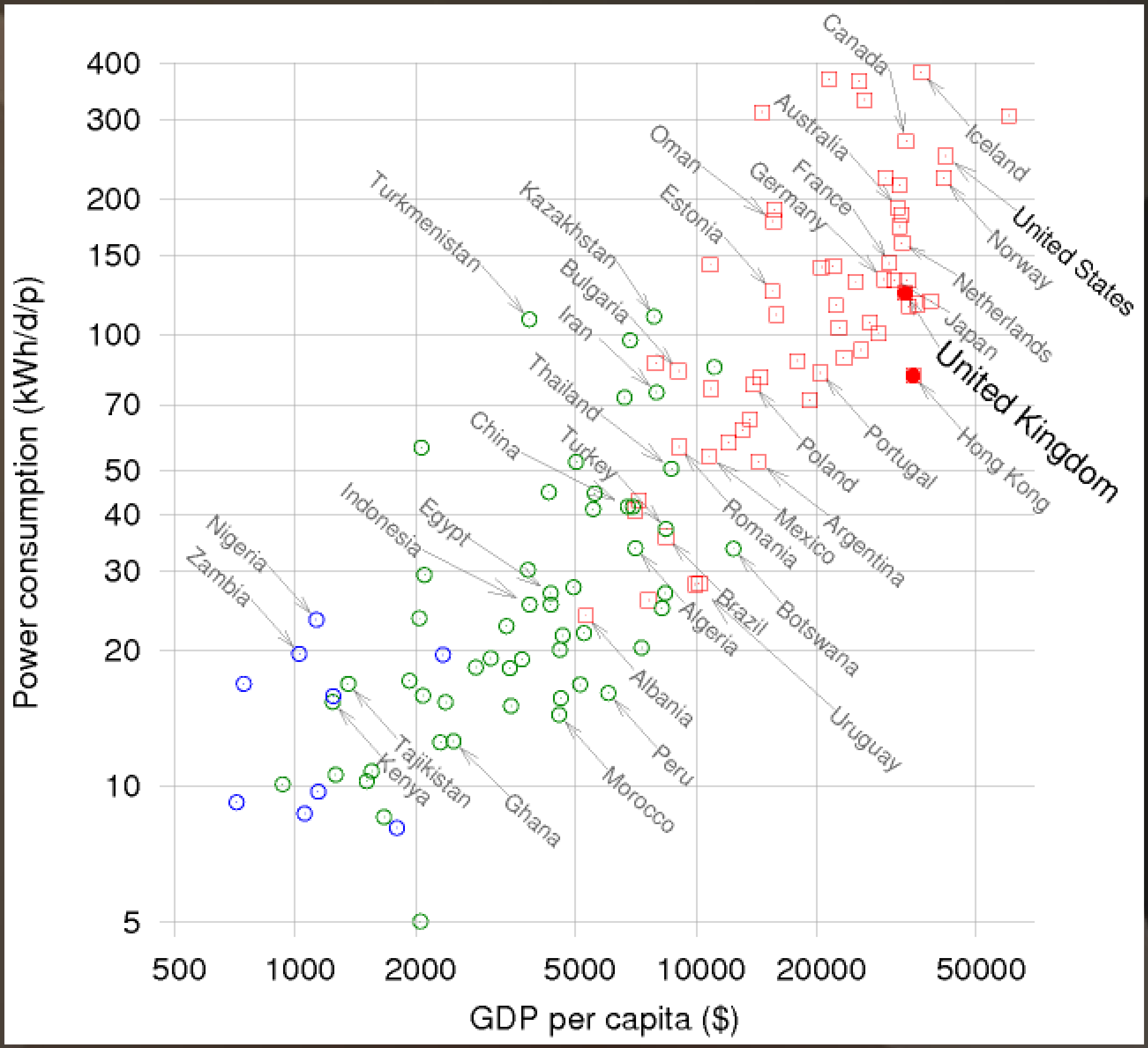
Why do we care about energy?

- The bottom line is that using energy is strongly correlated to standard of living (as measured by GDP per capita.)
- For most of history we could rely on our own body or animals to do work. This is a few hundred watts of power at most.

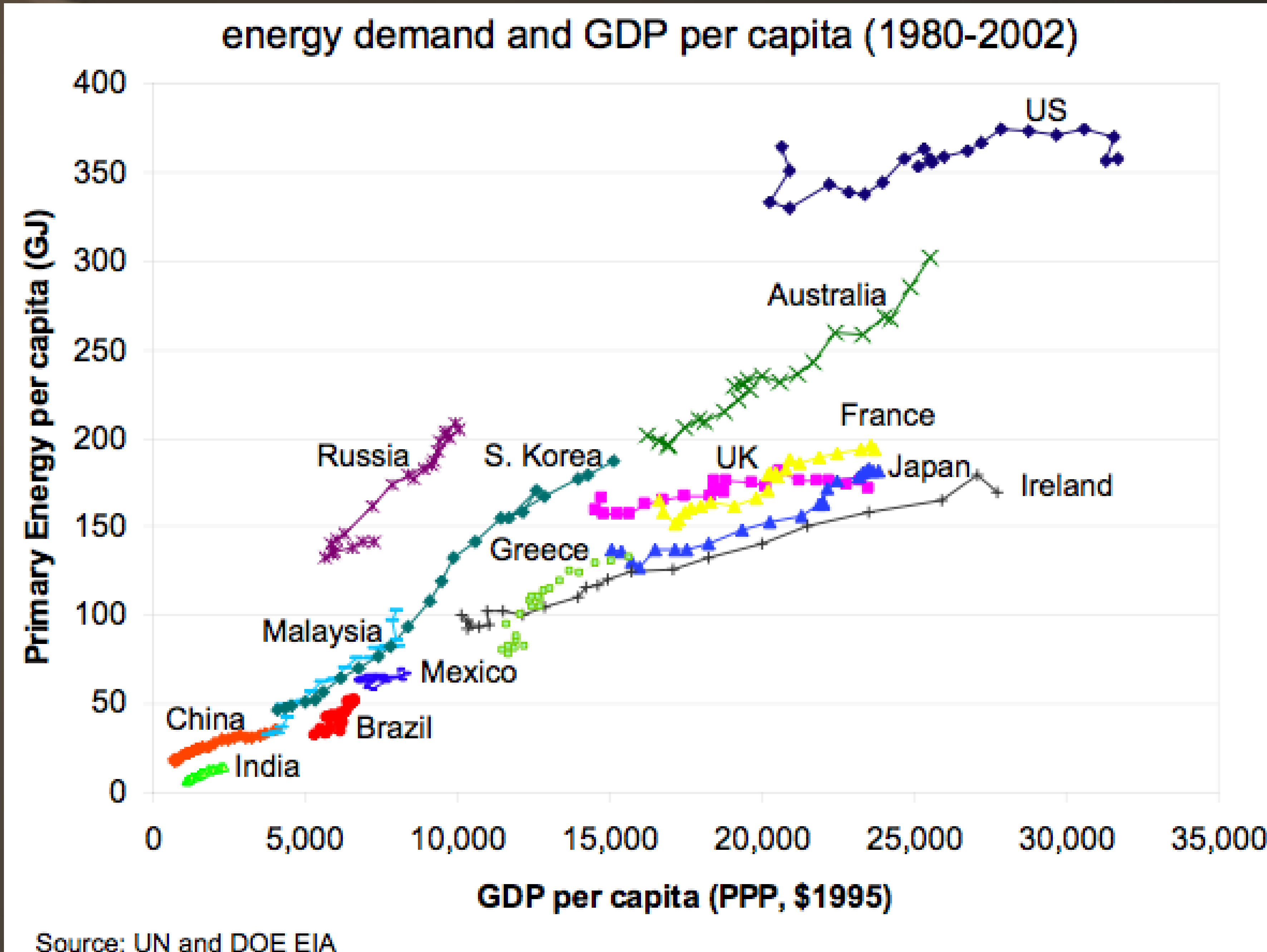
- Today in the US we consume energy at a rate of 11kW per person.
- You may think of this as having 110 “energy servants” doing work for you 24/7.
- Typically less wealthy nations have a lot fewer “servants”

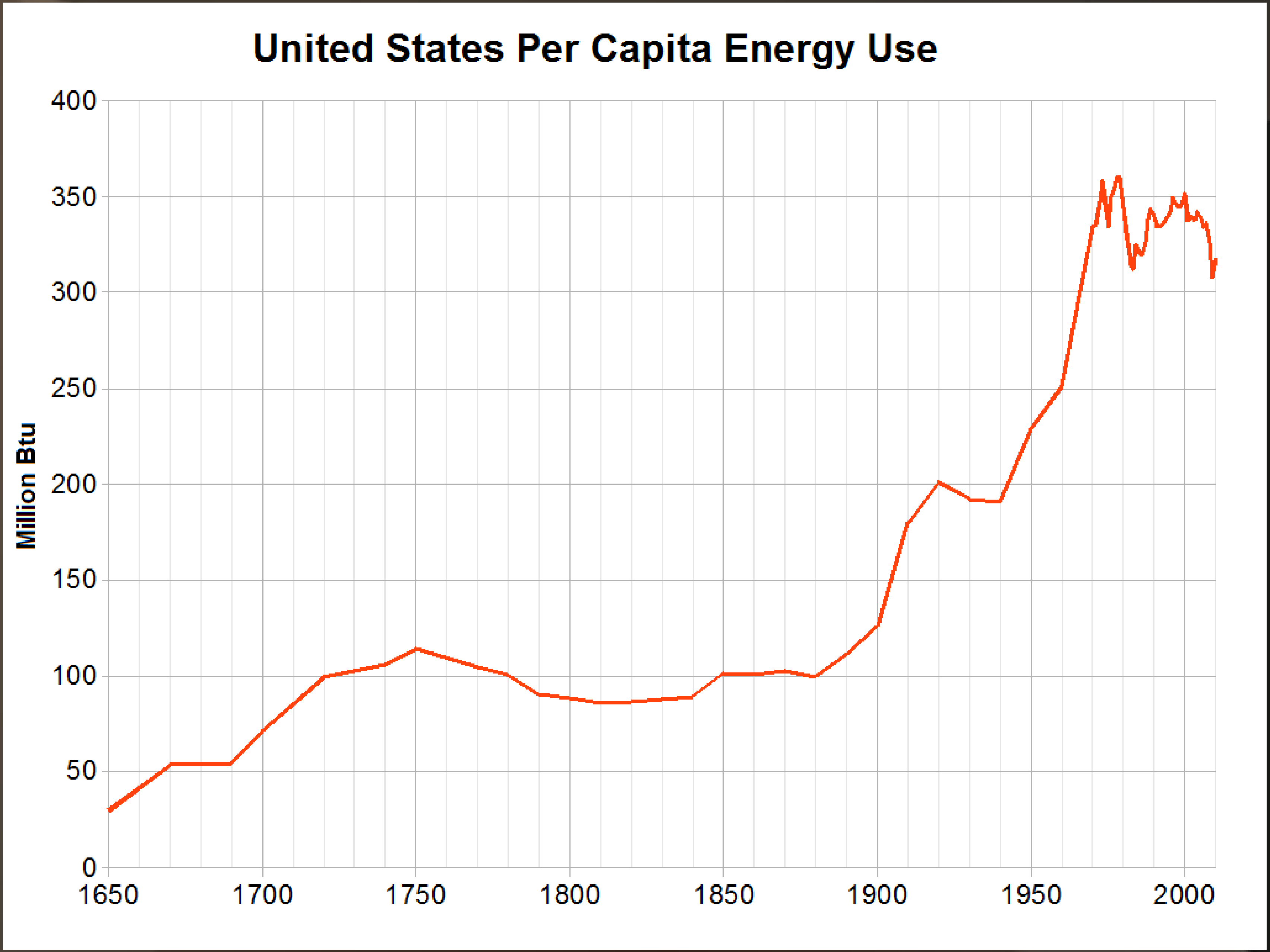
Energy use is directly tied to GDP (2006)



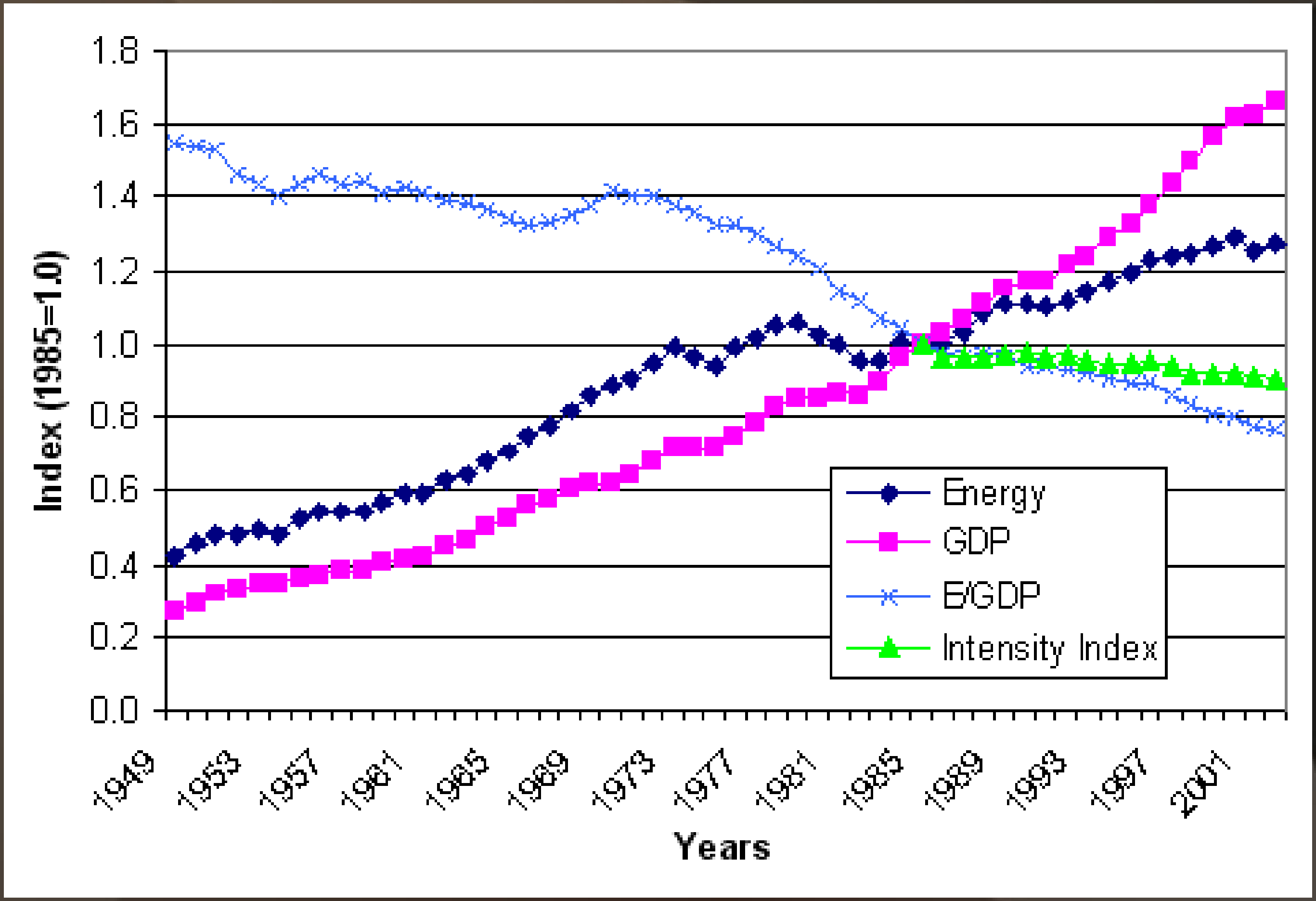


Power consumption (kWh/d/p)
GDP per capita ($)
400
300
200
150
100
70
50
40
30
20
10
5
500
1000
2000
5000
10000
20000
50000
Canada
Iceland
Australia
Oman
France
Germany
Estonia
United States
Norway
Netherlands
Japan
United Kingdom
Hong Kong
Portugal
Poland
Argentina
Mexico
Romania
Botswana
Uruguay
Brazil
Algeria
Albania
Peru
Morocco
Ghana
Tajikistan
Kenya
Zambia
Nigeria
Indonesia
Egypt
China
Turkey
Thailand
Iran
Bulgaria
Kazakhstan
Turkmenistan


energy demand and GDP per capita (1980-2002)
Primary Energy per capita (GJ)
400
350
300
250
200
150
100
50
0
GDP per capita (PPP, $1995)
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
US
Australia
France
UK
Japan
Ireland
Russia
S. Korea
Greece
Malaysia
Mexico
China
Brazil
India
Source: UN and DOE EIA

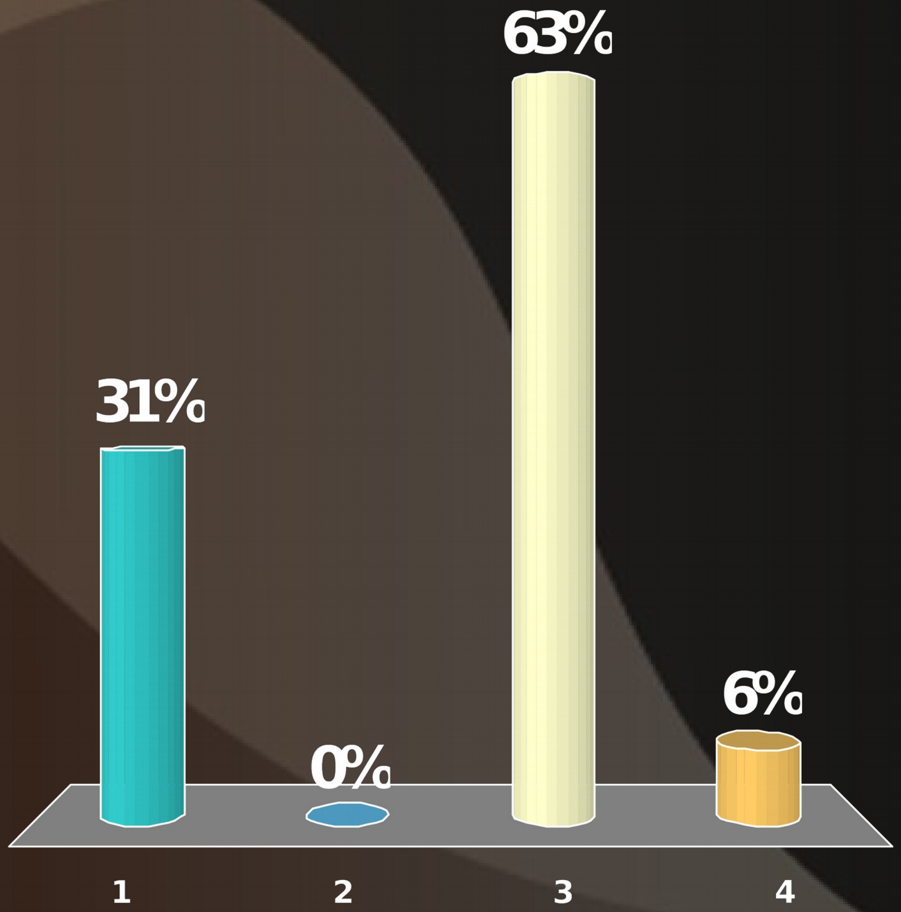

United States Per Capita Energy Use
Million Btu
400
350
300
250
200
150
100
50
0
1650
1700
1750
1800
1850
1900
1950
2000

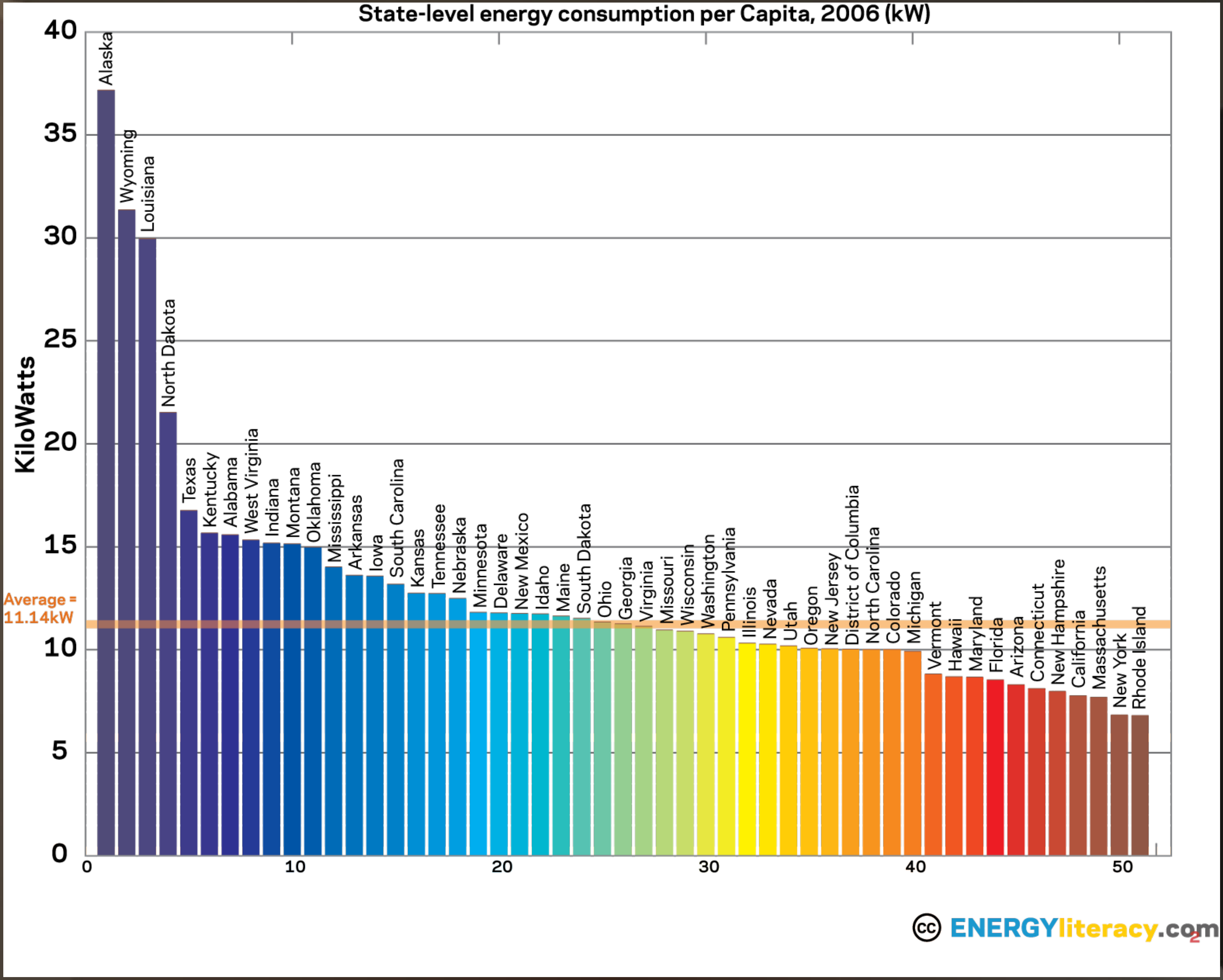
We are doing better on a GDP per kWh basis.



Which state would you guess has the highest per capita energy use?

1. Alaska
2. Louisiana
3. California
4. Illinois



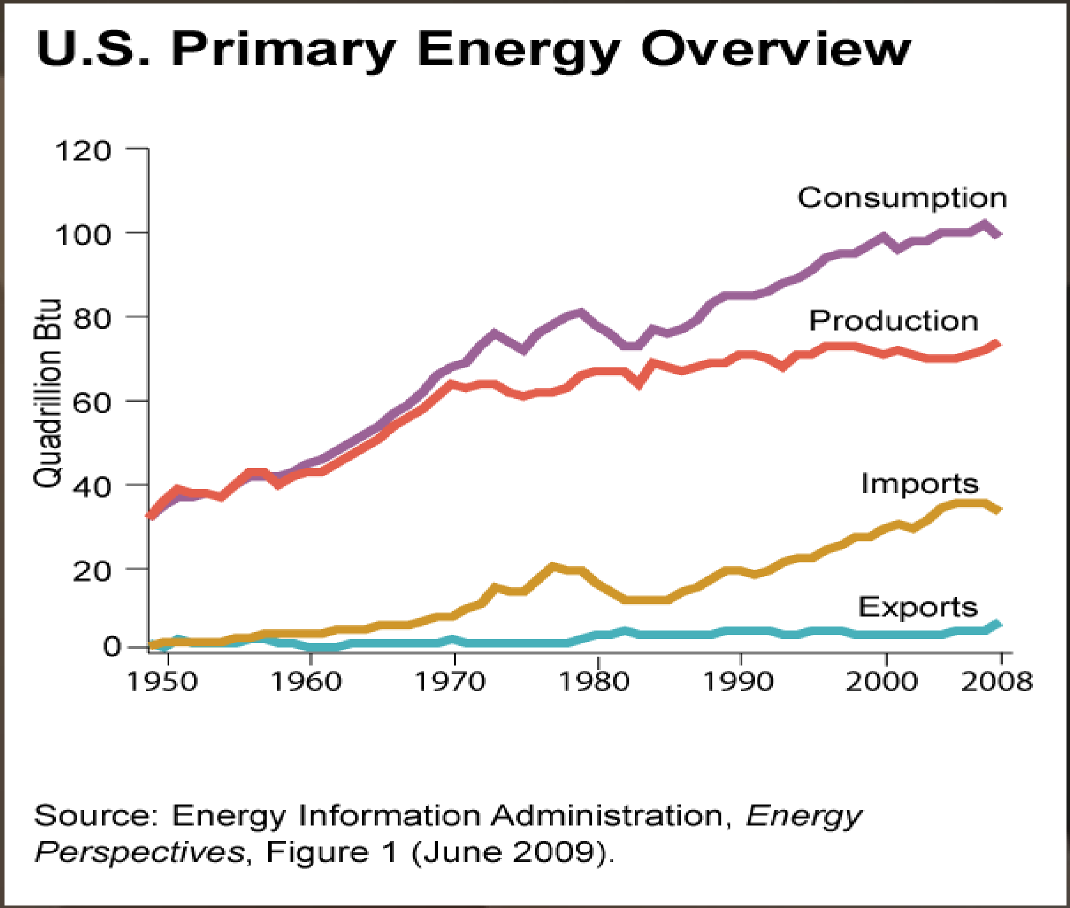


State-level energy consumption per Capita, 2006 (kW)
KiloWatts
Average = 11.14kW
Alaska
Wyoming
Louisiana
North Dakota
Texas
Kentucky
Alabama
West Virginia
Indiana
Montana
Oklahoma
Mississippi
Arkansas
Iowa
South Carolina
Kansas
Tennessee
Nebraska
Minnesota
Delaware
New Mexico
Idaho
Maine
South Dakota
Ohio
Georgia
Virginia
Missouri
Wisconsin
Washington
Pennsylvania
Illinois
Nevada
Utah
Oregon
New Jersey
District of Columbia
North Carolina
Colorado
Michigan
Vermont
Hawaii
Maryland
Florida
Arizona
Connecticut
New Hampshire
California
Massachusetts
New York
Rhode Island
ENERGYliteracy.com

Videos

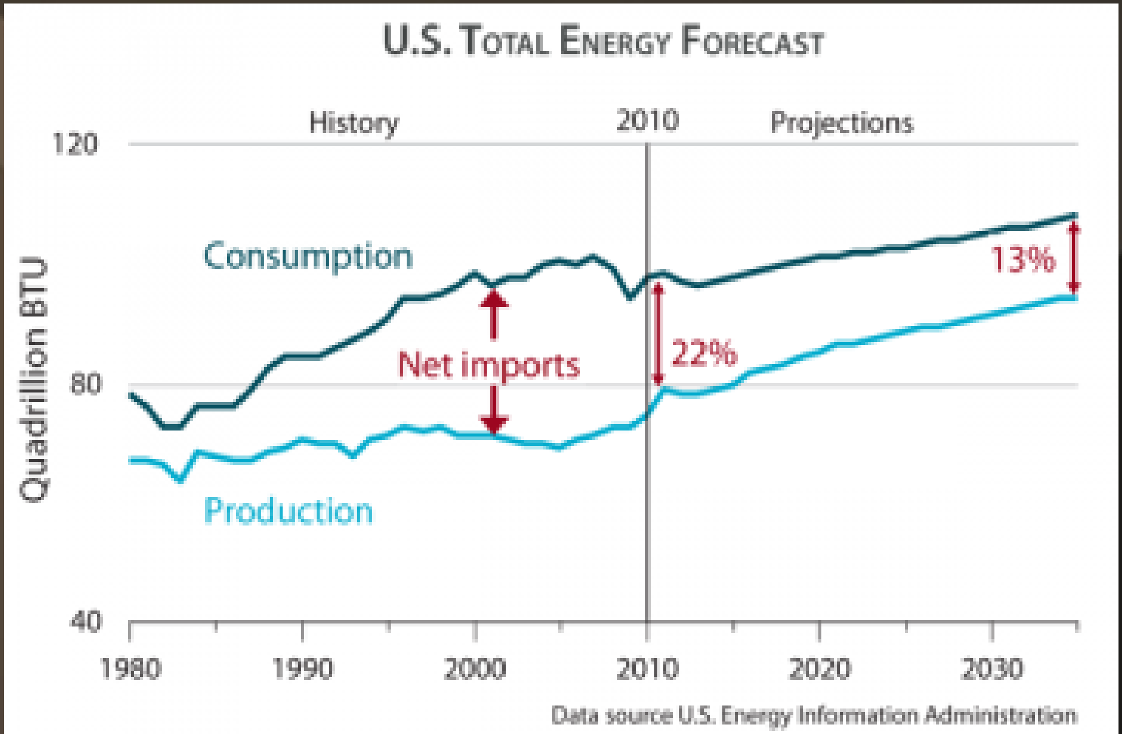
This one may be defective
http://news.bbc.co.uk/2/hi/science/nature/8392451.stm

This one worked last time I checked
https://www.youtube.com/watch?v=C93cL_zDVIM



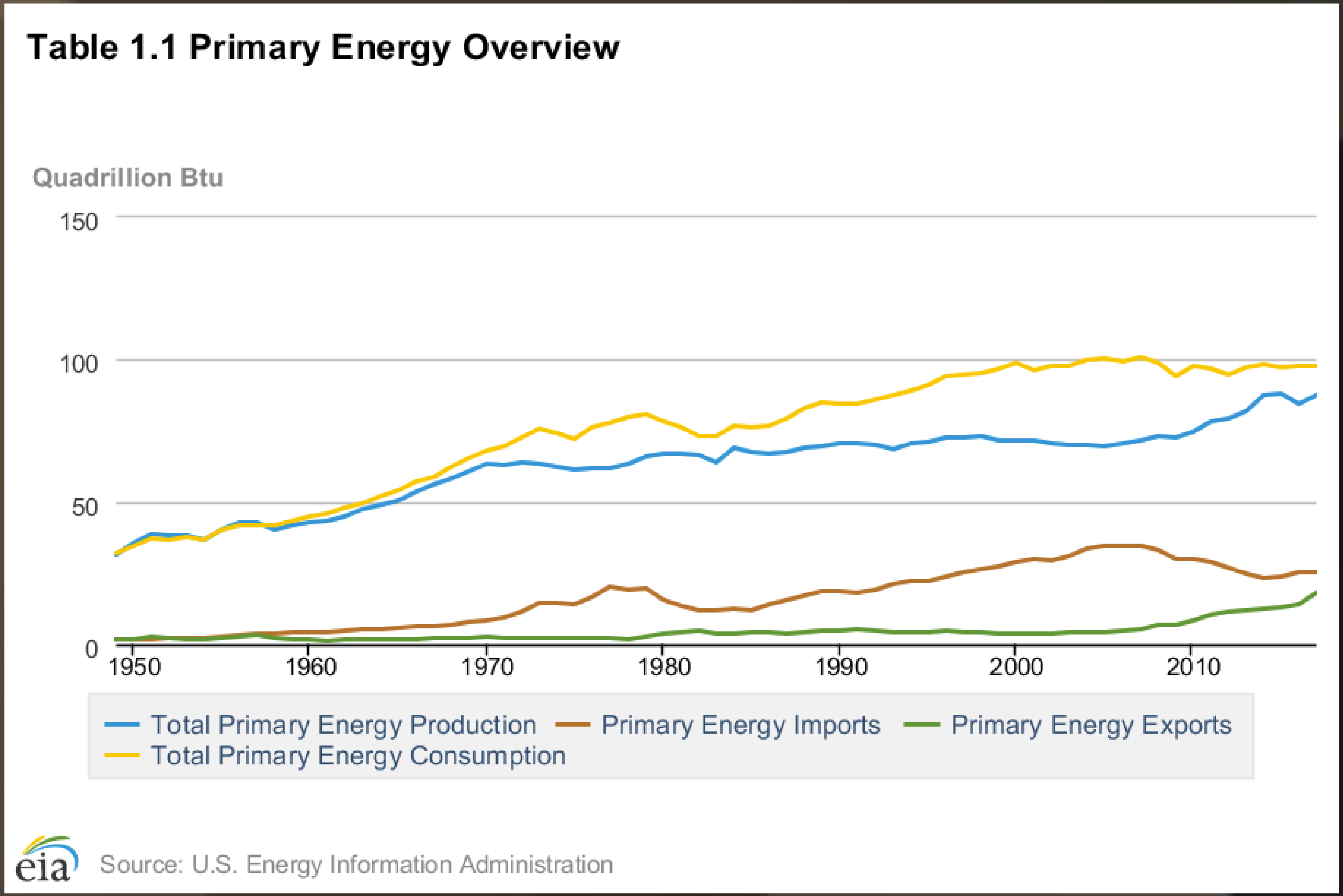
A number of figures are taken from the U.S. Energy Information Administration (EIA). All of them should report the EIA as the source.

Audio Link

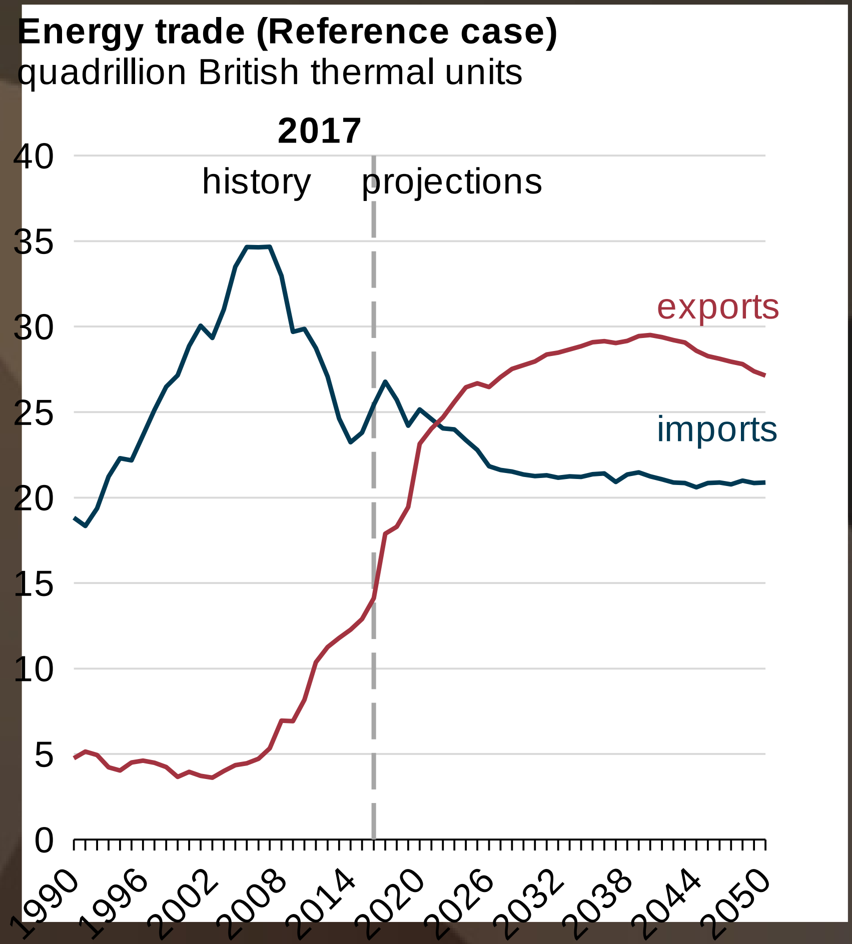


Forecast of U.S. total energy production and consumption over the next couple of decades (in quadrillion BTU). The data for this plot is dated, so it lets us look at how good the prediction was. How good was it? Check the previous slide.

http://www.earthmagazine.org/article/why-us-so-insecure-about-its-energy-security-measures-energy-independence-show-it-increasing

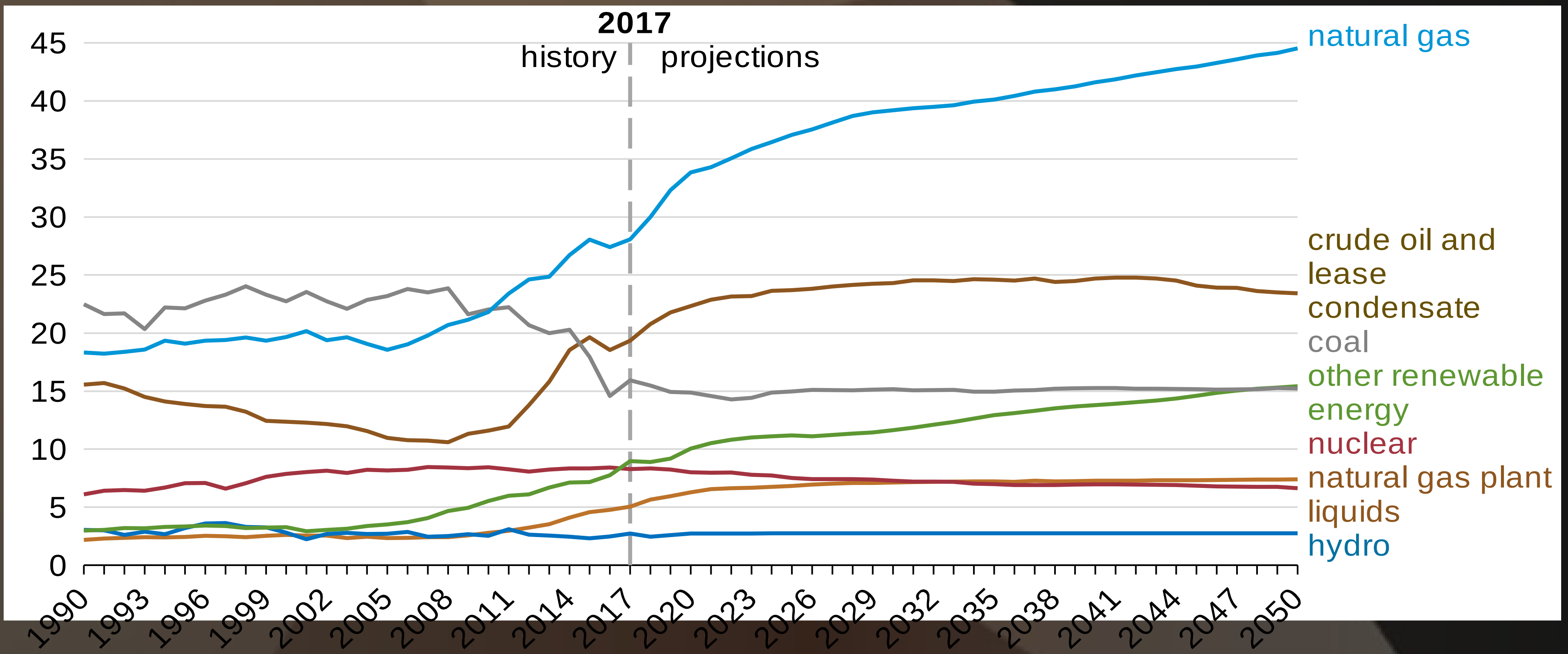


… and an updated version (2018). What is the most important change?

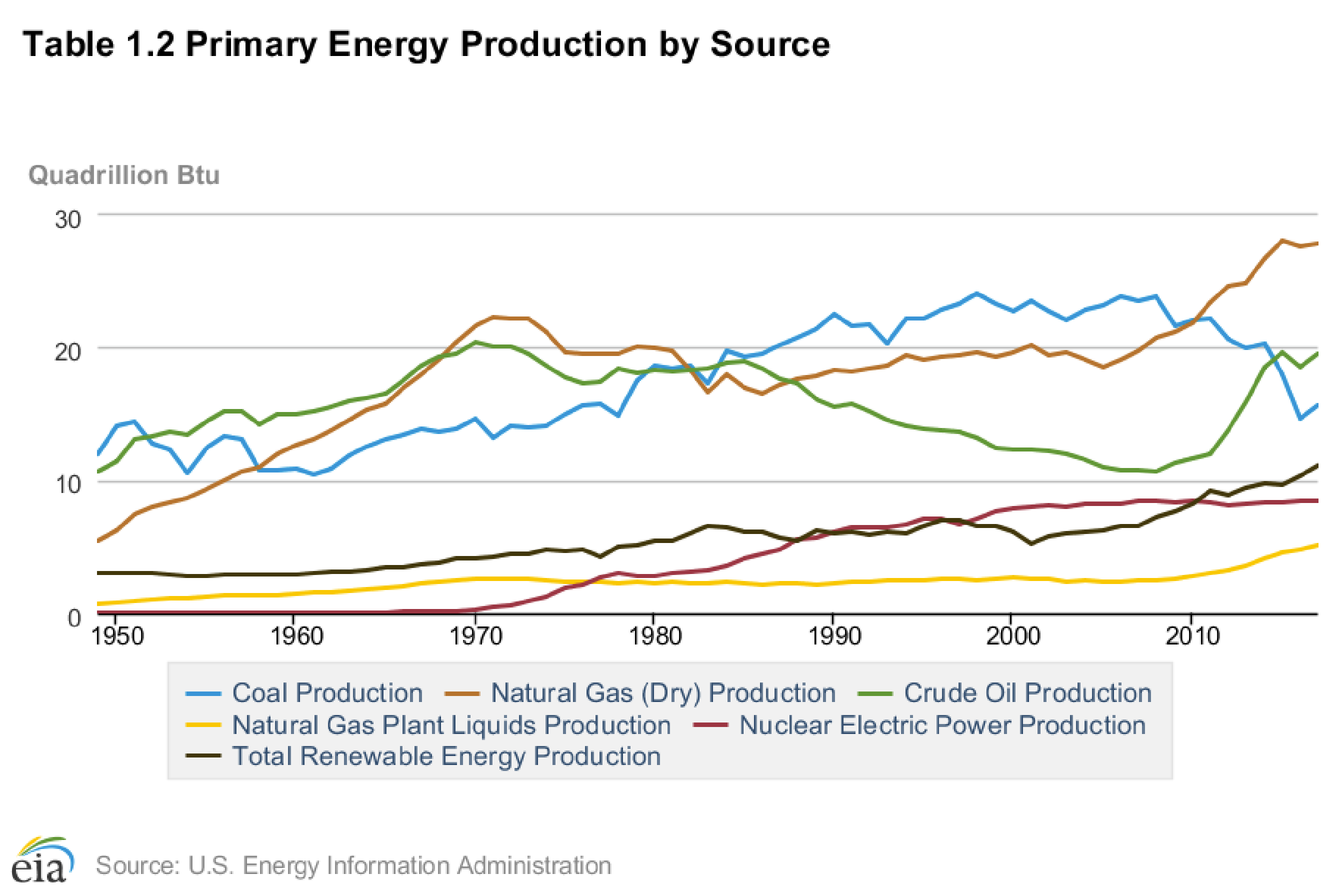


So the forecast was off just a bit. Now the gap is expected to close by about 2025.

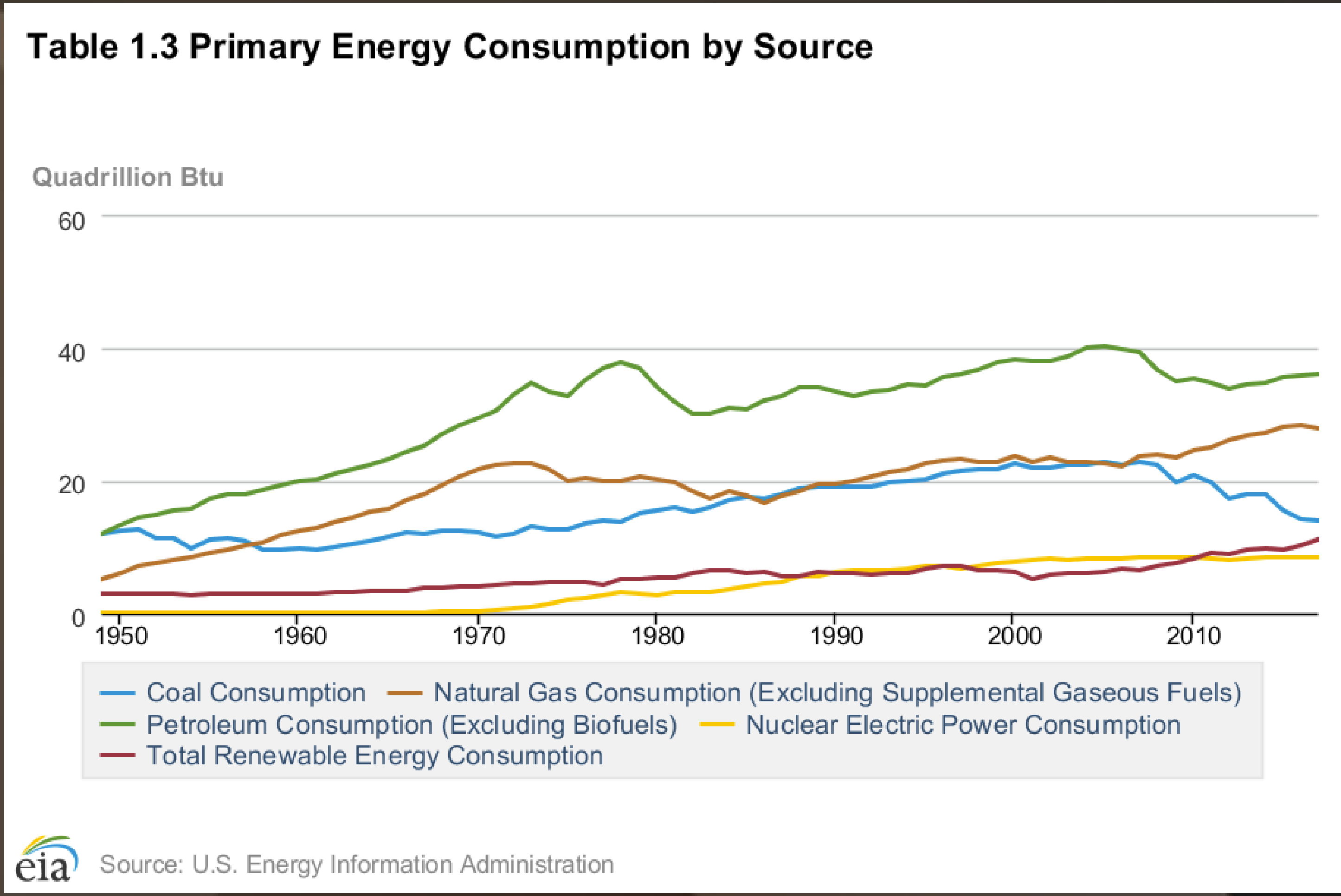
Energy production (Reference case)
quadrillion British thermal units



U.S. Energy Information Administration (2018)



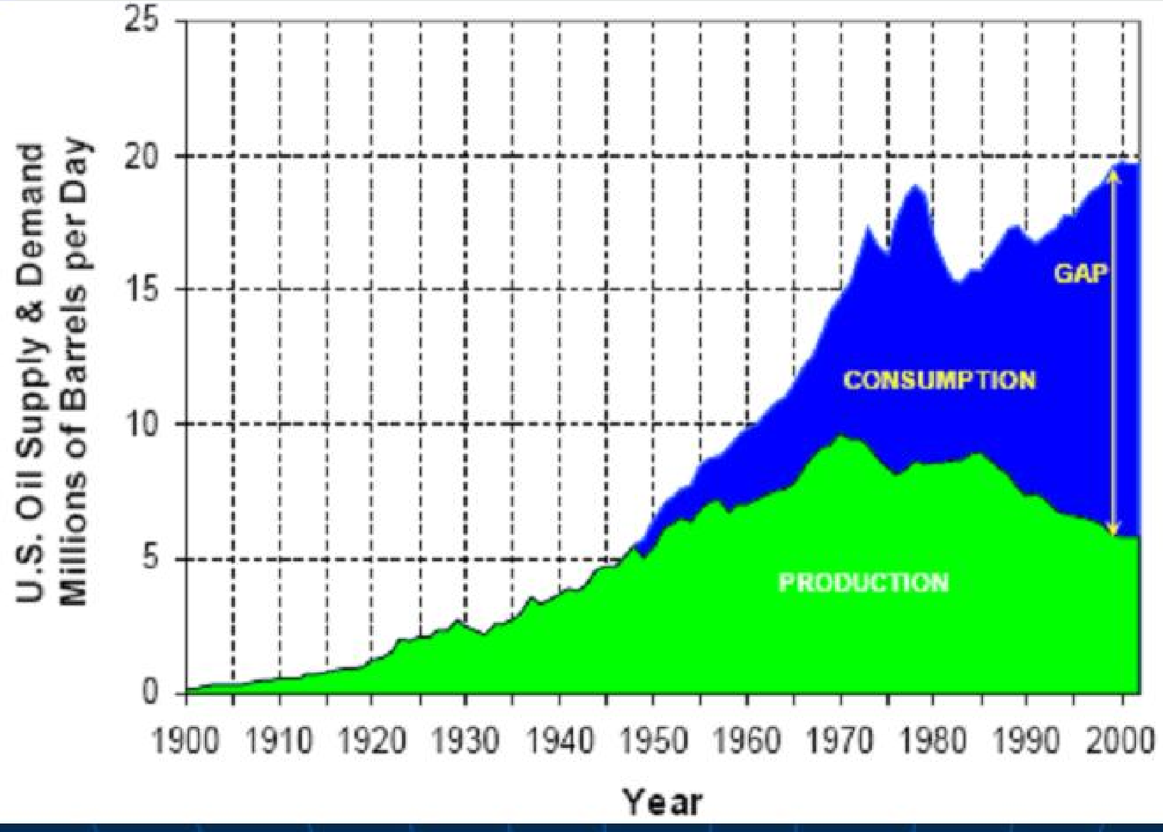
What are the big changes since 2008?



About 84% of our energy was from fossil fuels in 2000. Now it looks like it is about 78%. See the EIA website or this document (https://www.eia.gov/totalenergy/data/browser/?tbl=T01.03#/?f=A) for details.

U.S. Oil Supply & Demand

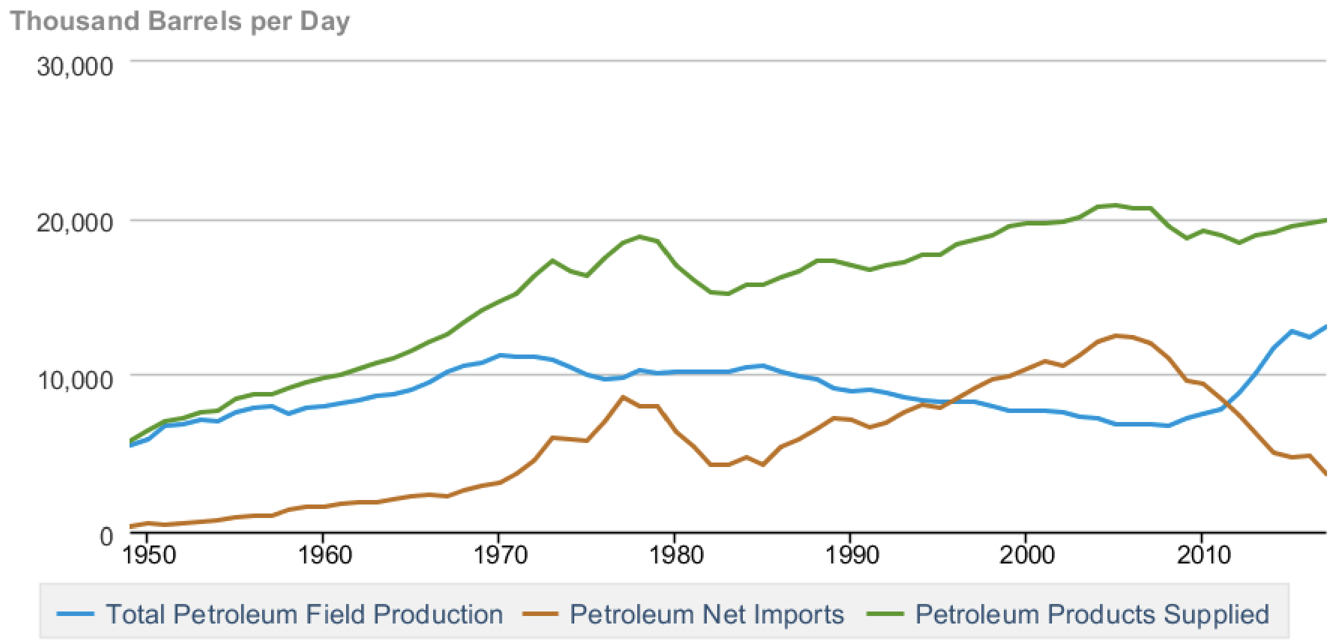
Georgia Tech



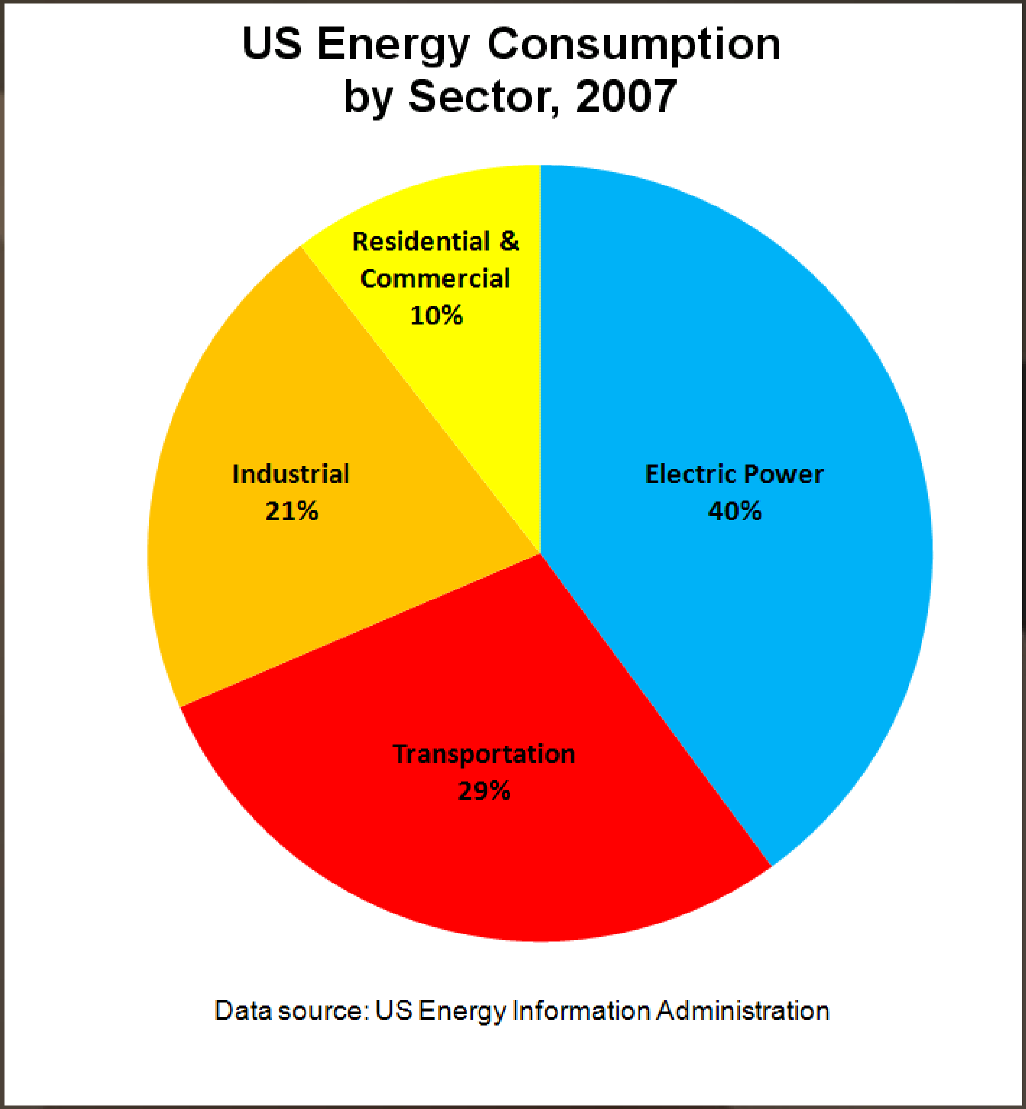
Production Data:
1900-1937:
World Energy Council
1938-1953:
C.J. Campbell, "The Coming Oil Crisis"
1954-2002:
EIA: Annual Energy Review, Table 1.2, Crude Oil Production and Oil Well Productivity

Consumption Data:
1900-1949:
Est. Production = Consumption
1949-2002:
EIA: Annual Energy Review Table 5.1, Petroleum Overview

Table 3.1 Petroleum Overview



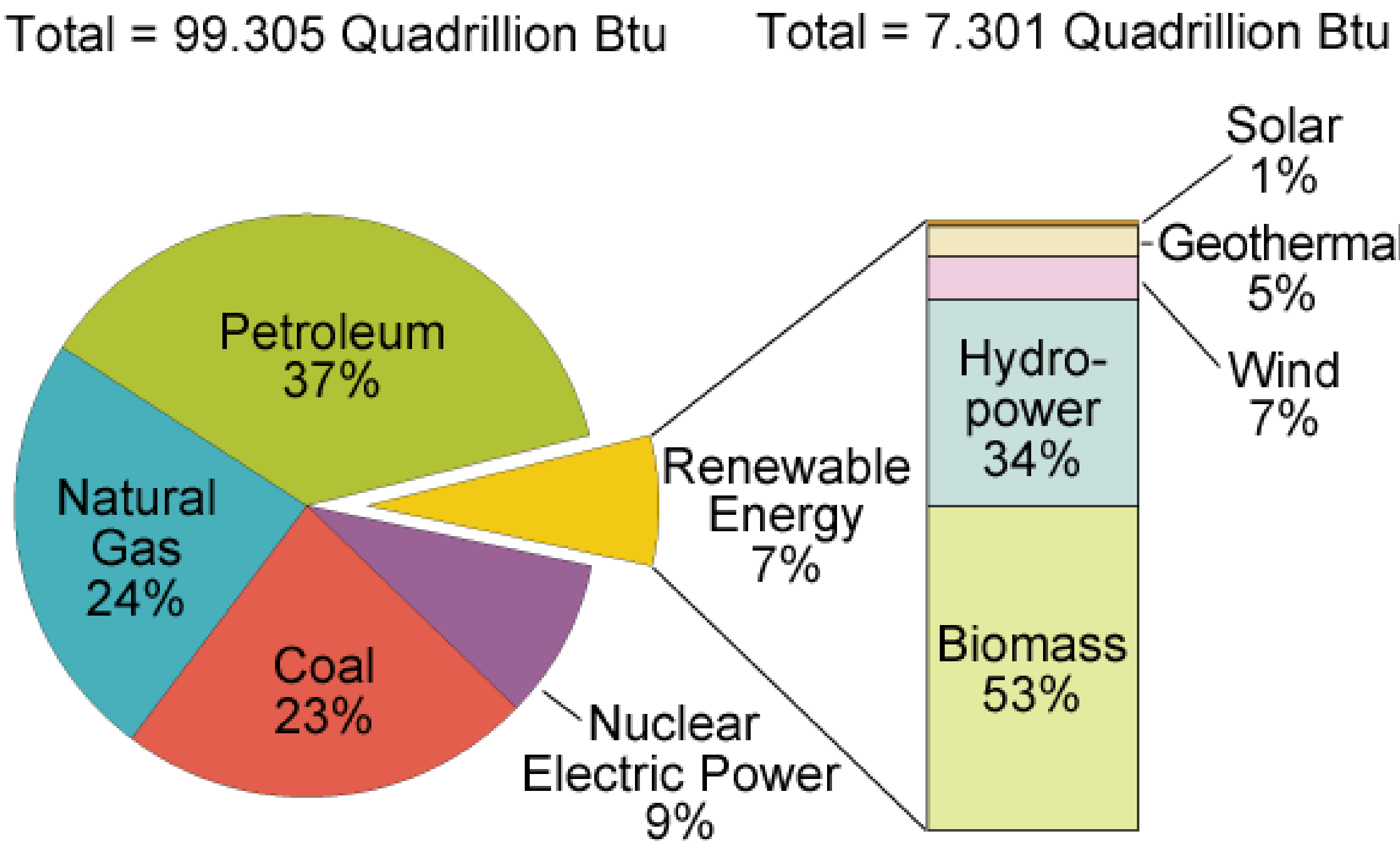
Source: U.S. Energy Information Administration



http://en.wikipedia.org/wiki/Energy_in_the_United_States

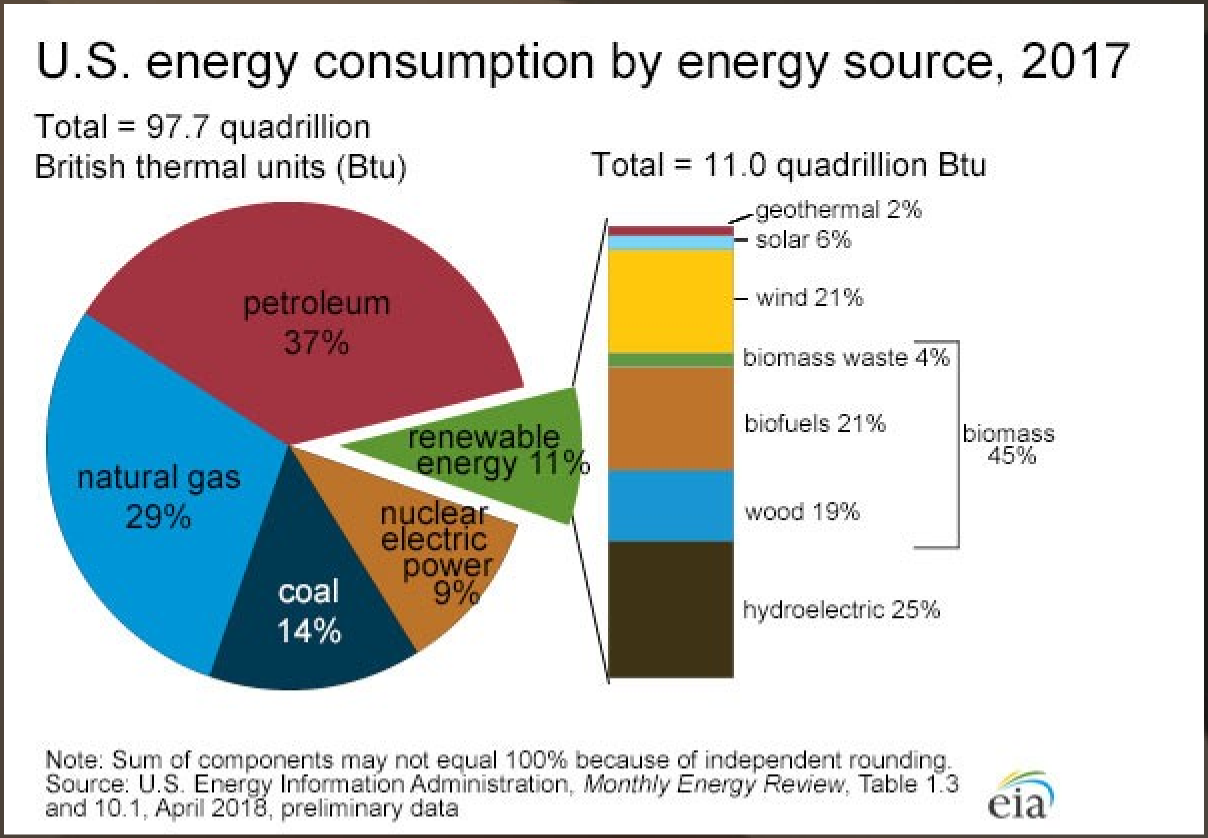
The next few charts are dated but present the data in a very nice way.

U.S. Energy Consumption by Energy Source, 2008

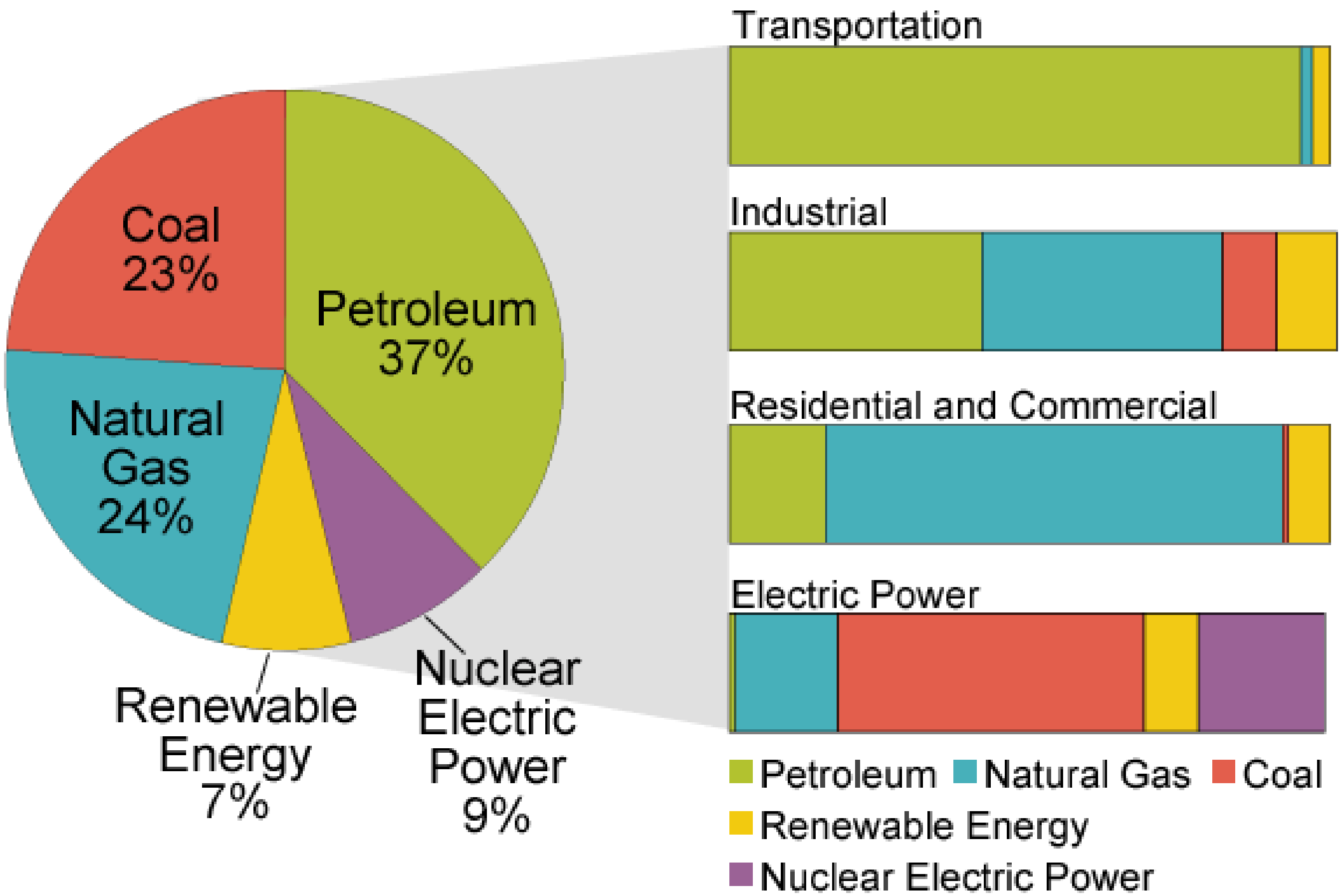


Note: Sum of components may not equal 100% due to independent rounding.

Source: EIA, *Renewable Energy Consumption and Electricity 2008 Statistics*, Table 1: U.S. Energy Consumption by Energy Source, 2004-2008 (July 2009).


U.S. energy consumption by energy source, 2017
Total = 97.7 quadrillion British thermal units (Btu)
Total = 11.0 quadrillion Btu
petroleum 37%
natural gas 29%
coal 14%
nuclear electric power 9%
renewable energy 11%
geothermal 2%
solar 6%
wind 21%
biomass waste 4%
biofuels 21%
wood 19%
hydroelectric 25%
biomass 45%
Note: Sum of components may not equal 100% because of independent rounding.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2018, preliminary data
eia

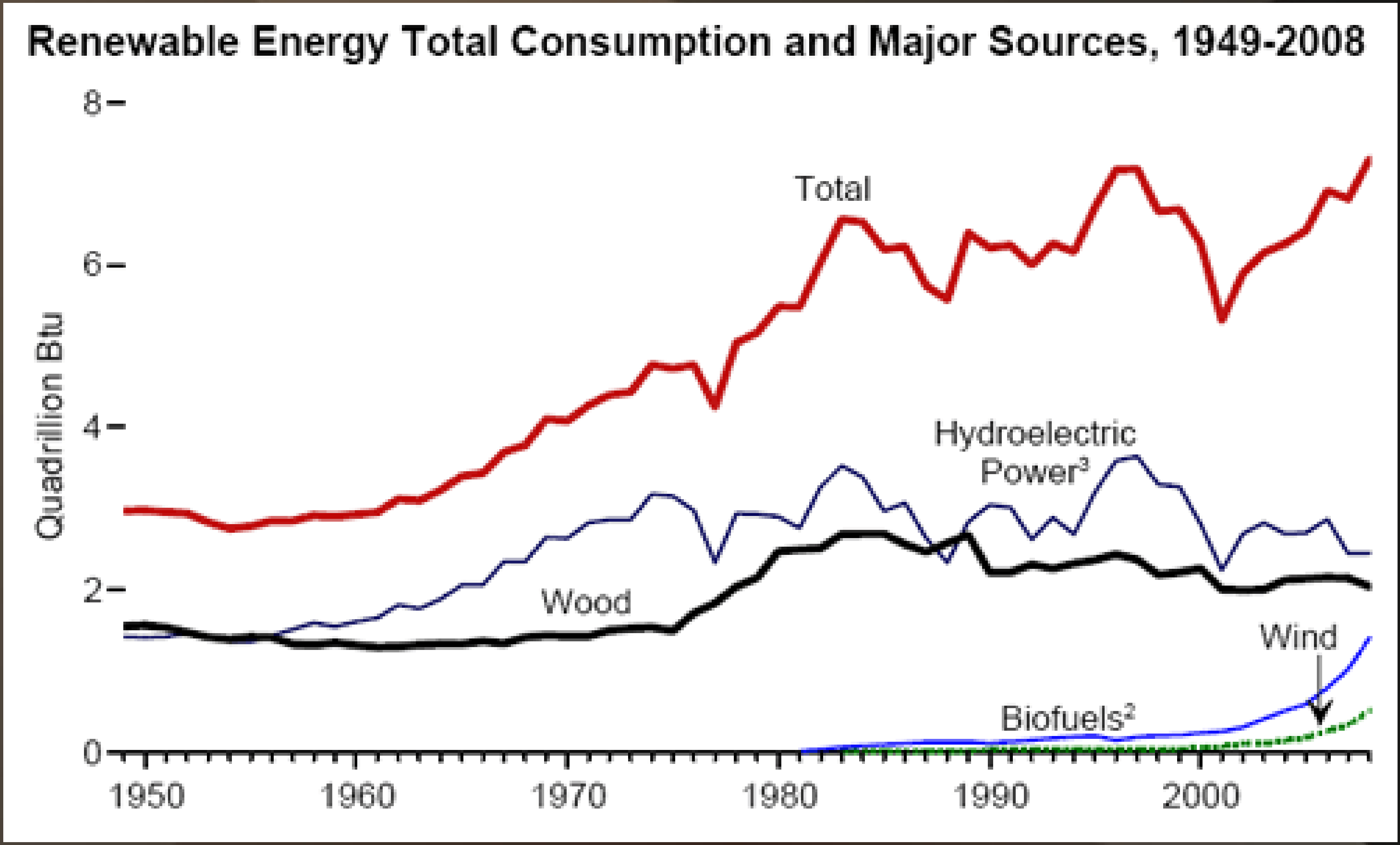
U.S. Primary Energy Consumption by Source and Sector, 2008



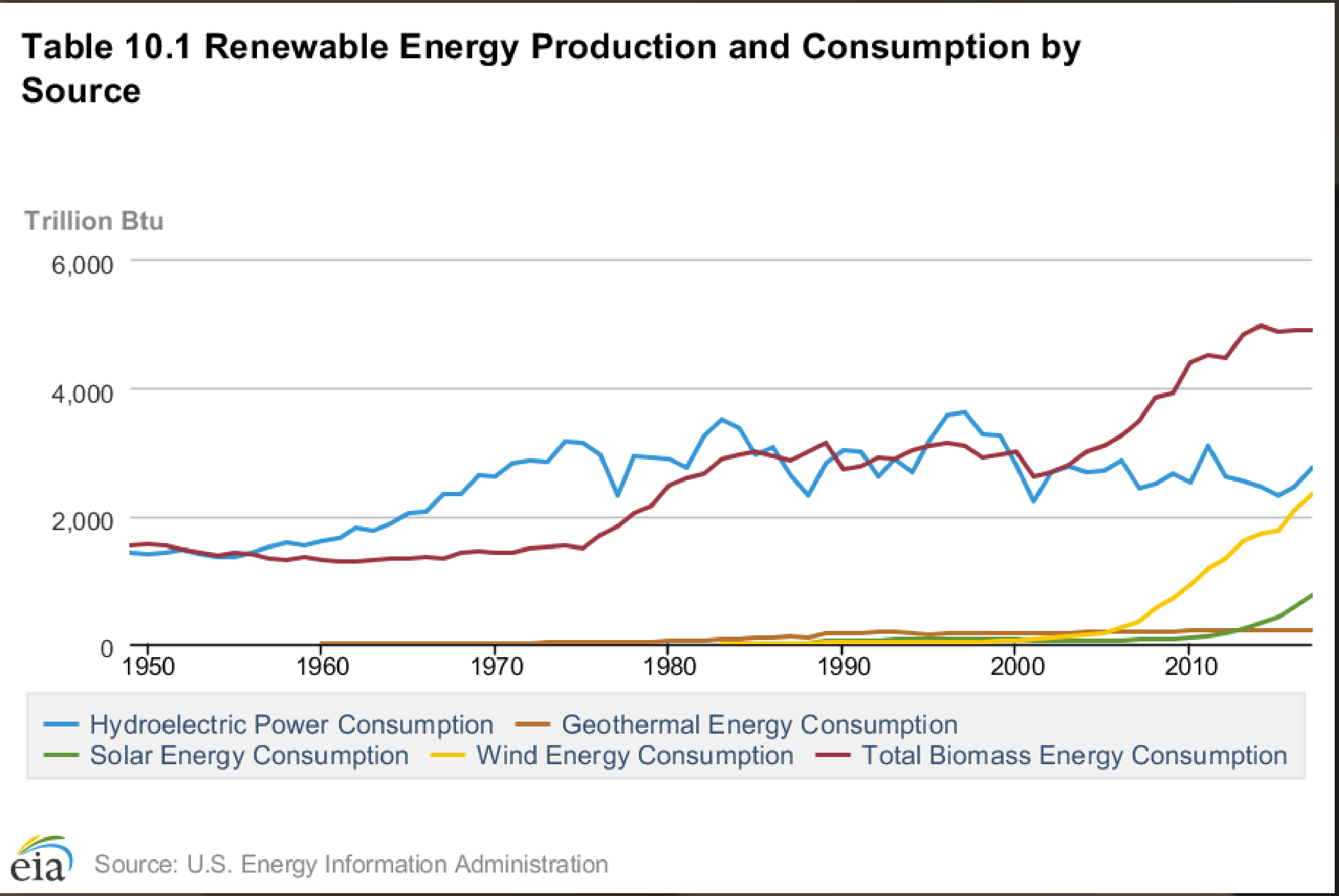
Total U.S. Energy = 99.3 Quadrillion Btu

Source: Energy Information Administration, *Annual Energy Review 2008*, Tables 1.3, 2.1b-2.1f.

Renewables



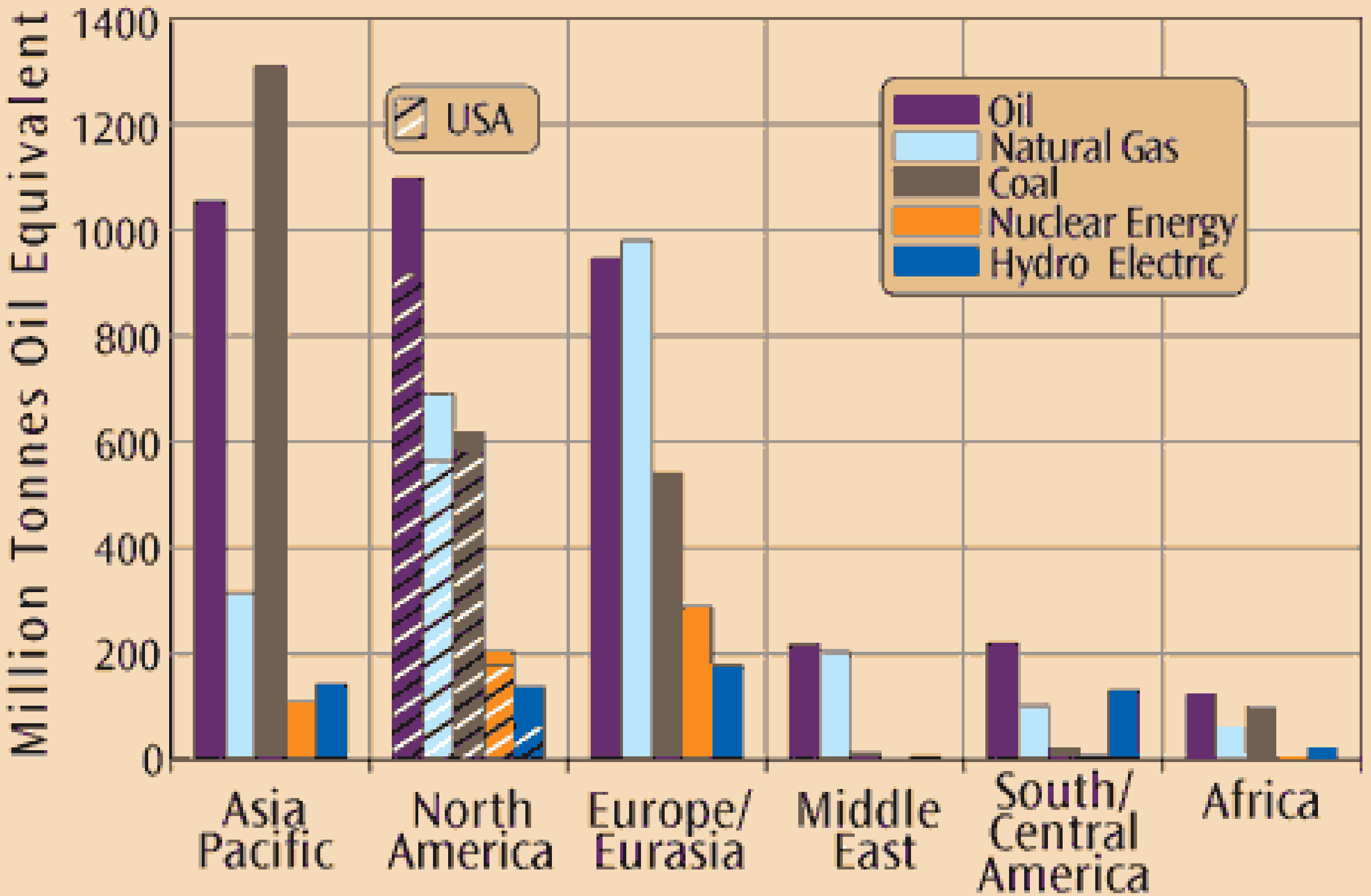
Renewable Energy Total Consumption and Major Sources, 1949-2008
Quadrillion Btu
8
6
4
2
0
Total
Hydroelectric Power³
Wood
Wind
Biofuels²
1950
1960
1970
1980
1990
2000



This is the latest Renewable energy plot from June 2018. What has changed from the previous plot? Notice that wood and biofuels are grouped together in this plot.

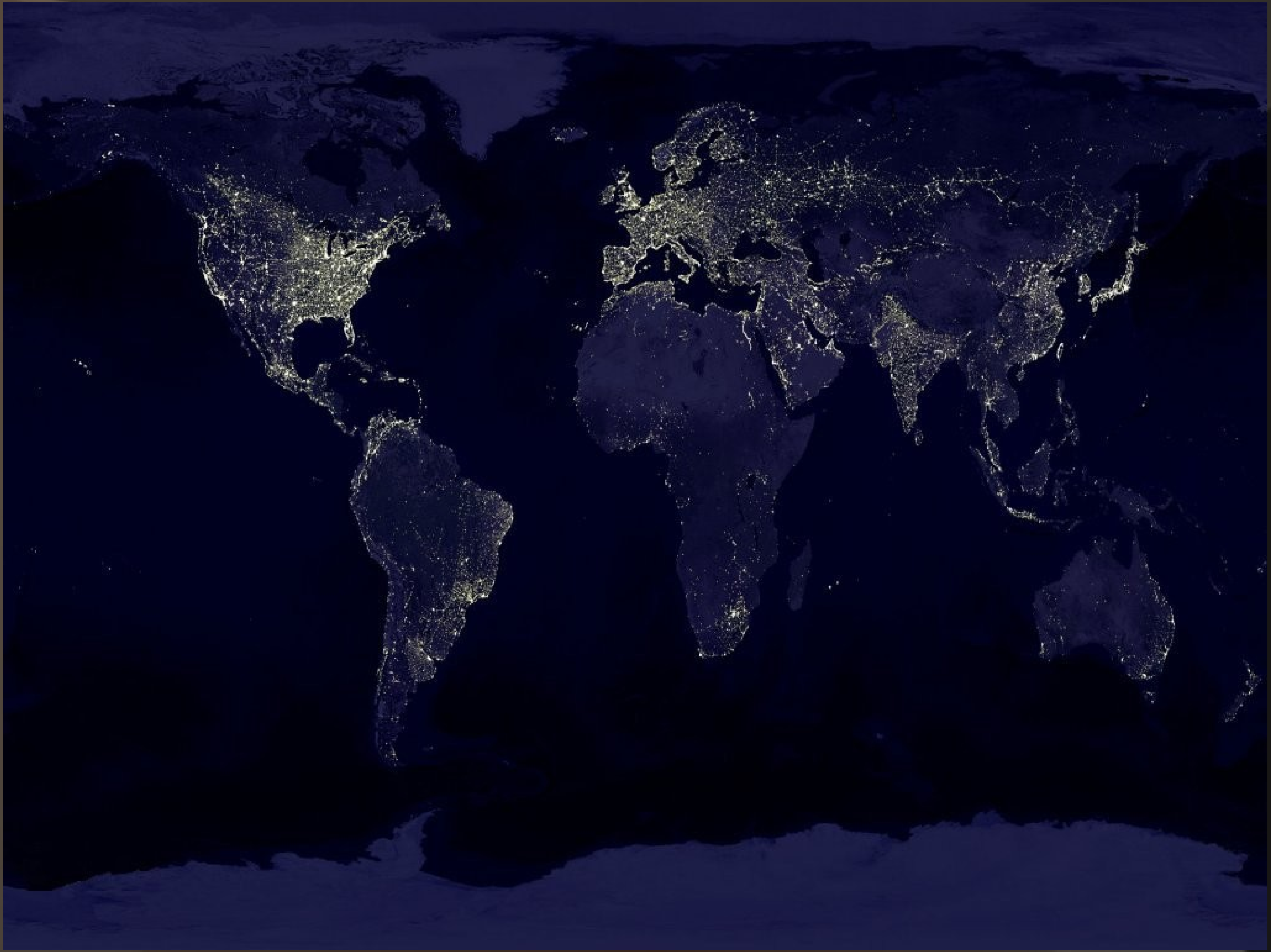
Why am I showing you old plots and new plots?

WORLD ENERGY USE BY FUEL



This chart includes major commercially traded fuels only. Although important in many countries, reliable consumption statistics for fuels such as wood, peat and animal waste are not available.

Source: BP Statistical Review of World Energy 2004, www.bp.com



How Much Is There?

- Proven Reserves: Resource that we know is there AND we can extract it at current prices with current technology.
- We can increase Proven Reserves by

  1) Finding new reserves.

  2) Improvements in technology

  3) Changes in economic conditions

- Note: We never totally extract all of the energy, it just gets too difficult to get after a while.

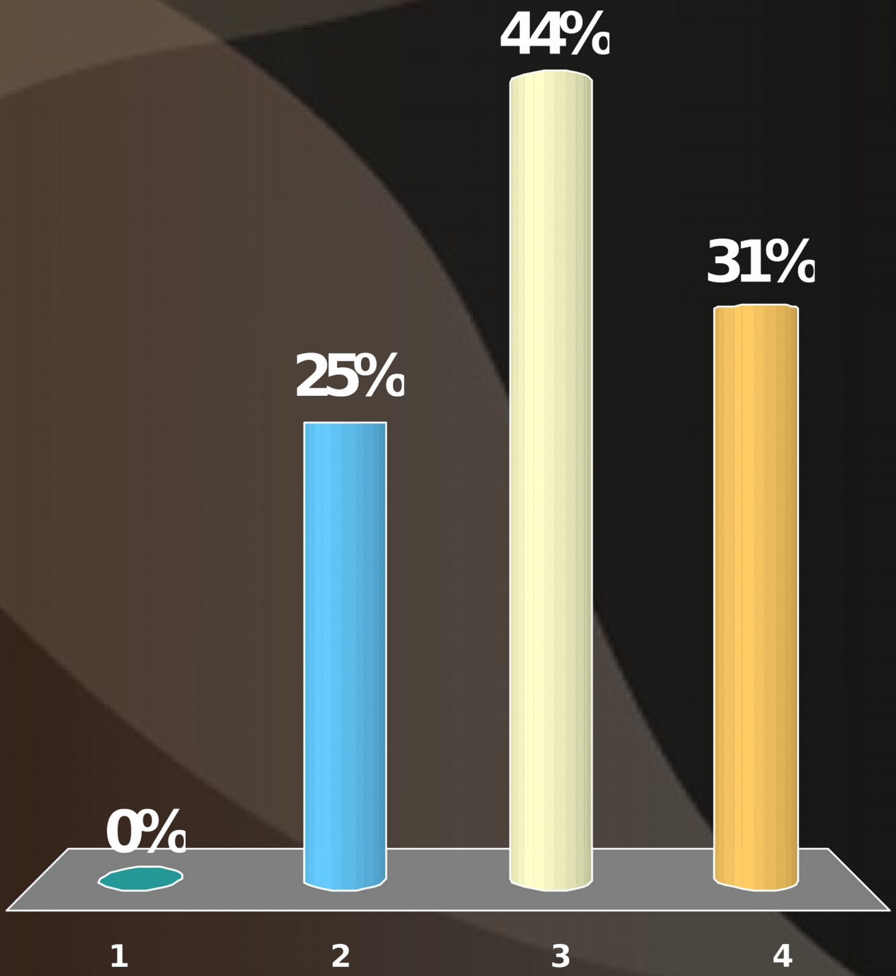
- Unproven Reserves: We think that it is there based on testing/experience

  OR

  We know that it is there but it is too expensive to extract with current technology/economics.

How long do you think that the world's oil supply will last?

1. 10 to 20 years.
2. 20 to 50 years.
3. 50 to 100 years.
4. More than 100 years.



How Long Will Fossil Fuels Last ?

- Simplest analysis (Rate Equation and Linear Picture)
- If we know (or can guess) how much we started with (Q_∞) and we know the rate we are using it (R) and how much we have already used (Q_u)

$$\text{Time} = (Q_\infty - Q_u)/R$$

Audio Link

- The linear picture is a really a bad approximation because it does not take into account changes in rate of use.
- The demand for energy has been constantly increasing so rate equation time is probably too long, but still interesting.
- Remember energy use and GDP are linked.
- Each person tends to use energy at an increasing rate and the population is increasing.

Exponential Growth Model

- Amount of growth depends on current amount, i.e. we have a certain percentage change.
- Examples include: Cost of living (3% / year), Cost of a college education (4% / year), Health care (6.5% / year)
- Financial Example: Start with $1000 and have it gain interest at 10% per year.

Year	Amount	Interest	Total
0	$1000	$100	$1100
1	$1100	$110	$1210
2	$1210	$121	$1331
3	$1331	$133	$1464
4	$1464	$146	$1610
5	$1610	$161	$1771
6	$1771	$177	$1948
7	$1948	$195	$2143
8	$2143		

Note: Money had just about doubled after 7 years. If we had just added $100 per year (constant rate) we would have only had $1700 after 7 years. (really get a big effect for longer times)

Doubling Time

- In general, if our percentage growth per unit time is P (%/unit time) then the time for our initial quantity to double is DT where:

  DT=70%/P

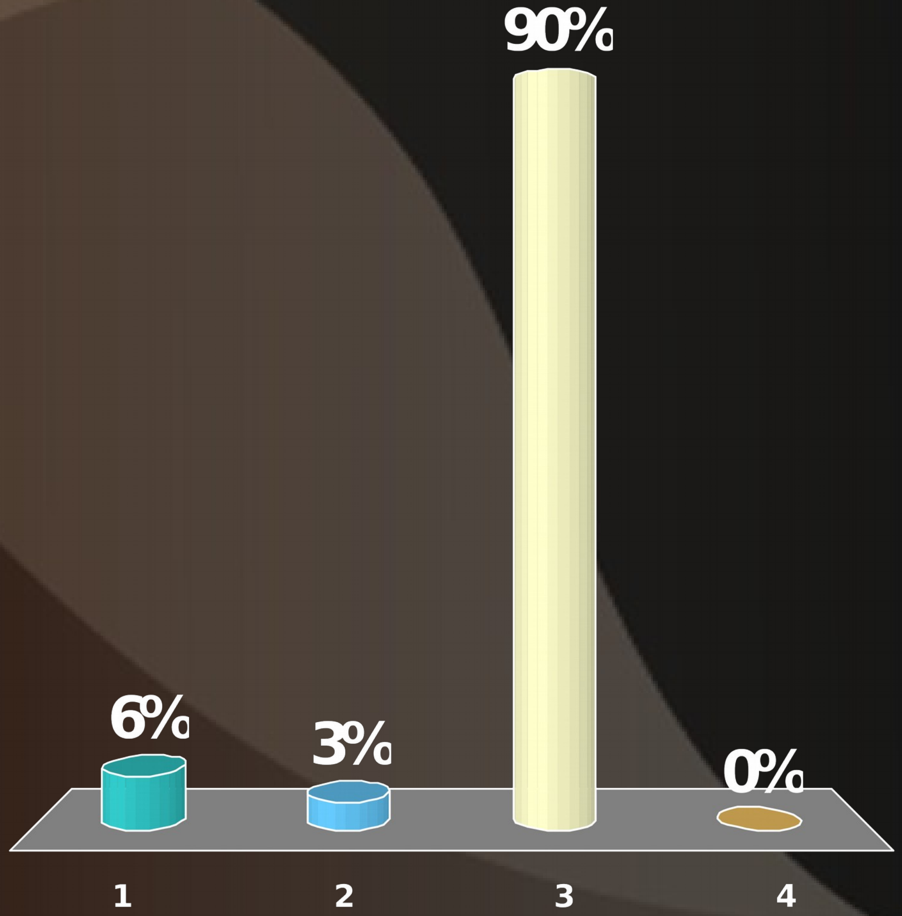
Example: If P=10%/year then

DT = (70/10)years =7 years

(This is a simple to remember estimate)

If we start with $1000, approximately how much money will we have at the end of 21 years if it earns interest at 10% per year?

1. $3100
2. $5300
3. $8000
4. $1600



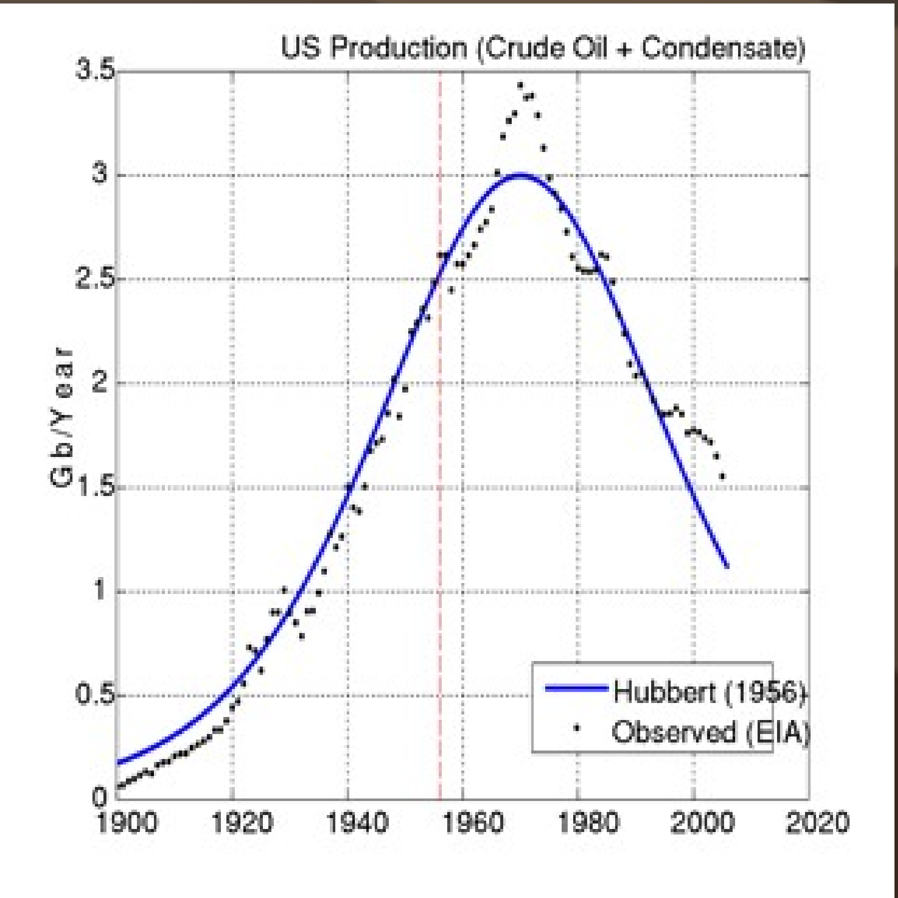
- Between 1960 and 1970, US energy consumption grew by 4.5%/yr. This would mean energy use would double in only 70/4.5 =15.5 years!
- With constant rate if we double our reserves, we double their expected life. With exponential growth, doubling reserves will only add a short amount of time.
- Obviously exponential growth in energy demand CANNOT go on for very long.

- With an energy consumption doubling time of 20 years, we would be using energy at 32 times the current rate in 100 years. Put another way, what amounts to a 320 year supply of energy now will only last for 10 years at the increased rate.

Hubbert Analysis

- Works for just about any natural resource. (Not just fossil fuels)
- Initially a new resource show a period of rapid growth. Easy to find, new markets, etc.
- As high quality, easy to find resources are depleted, production will peak and then decline.

Hubbert (1956)



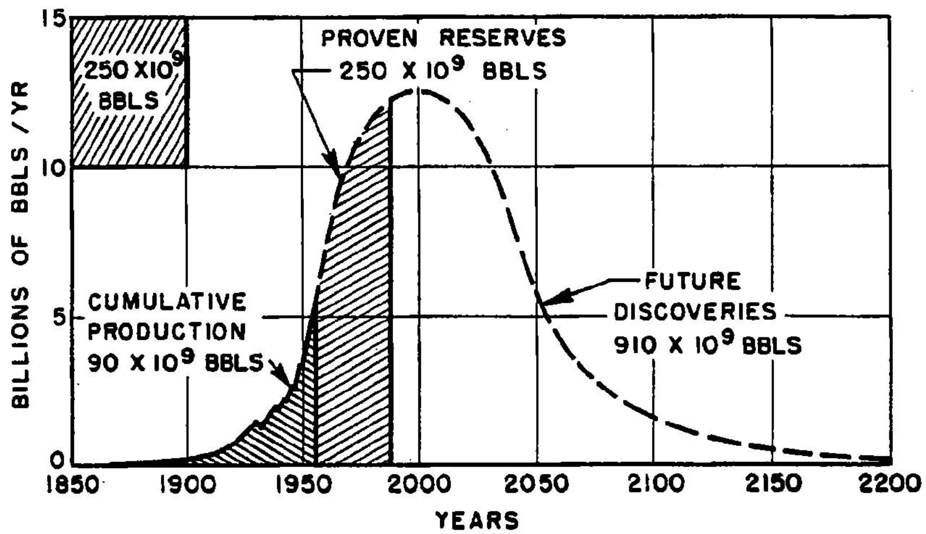
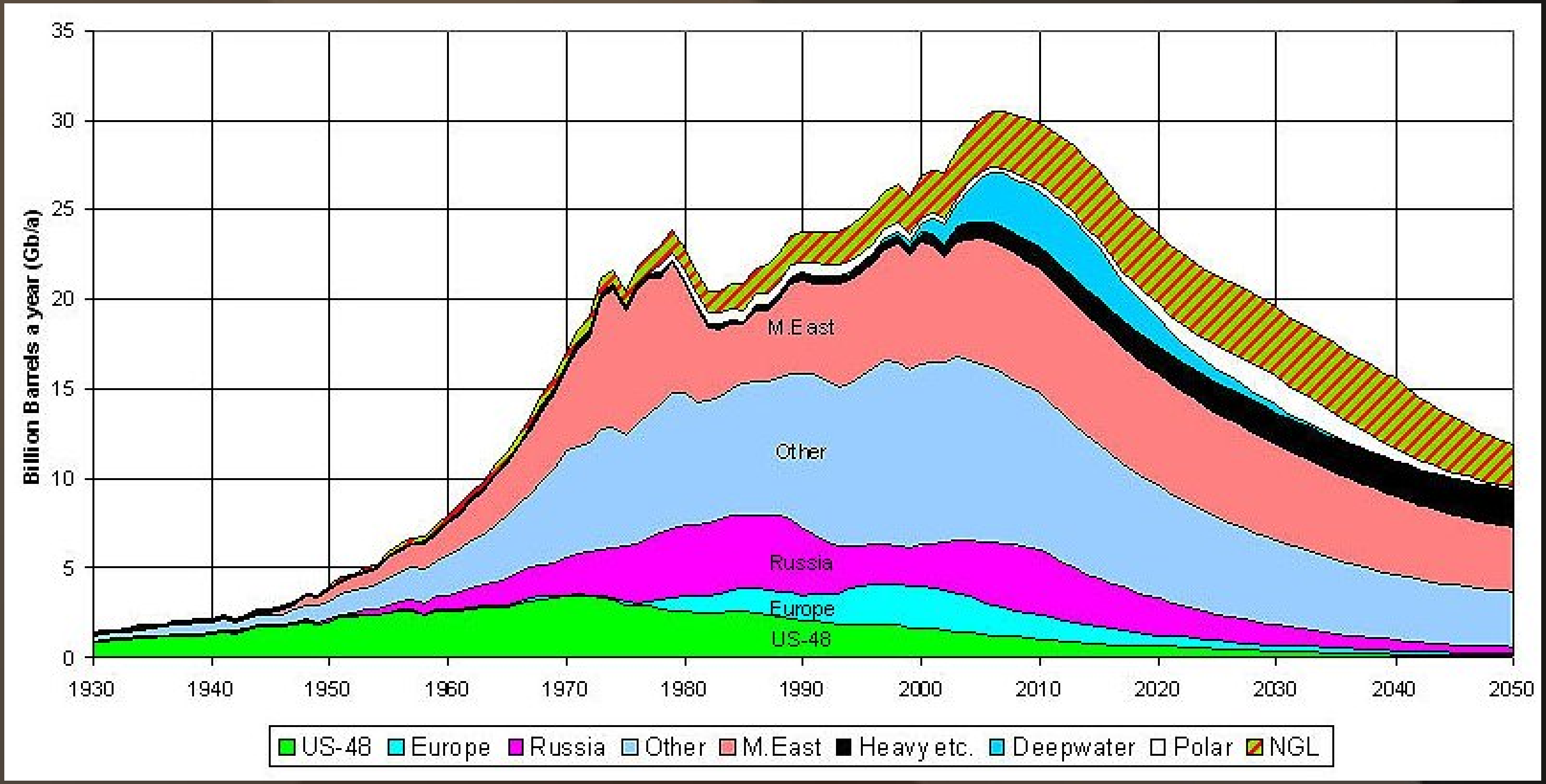
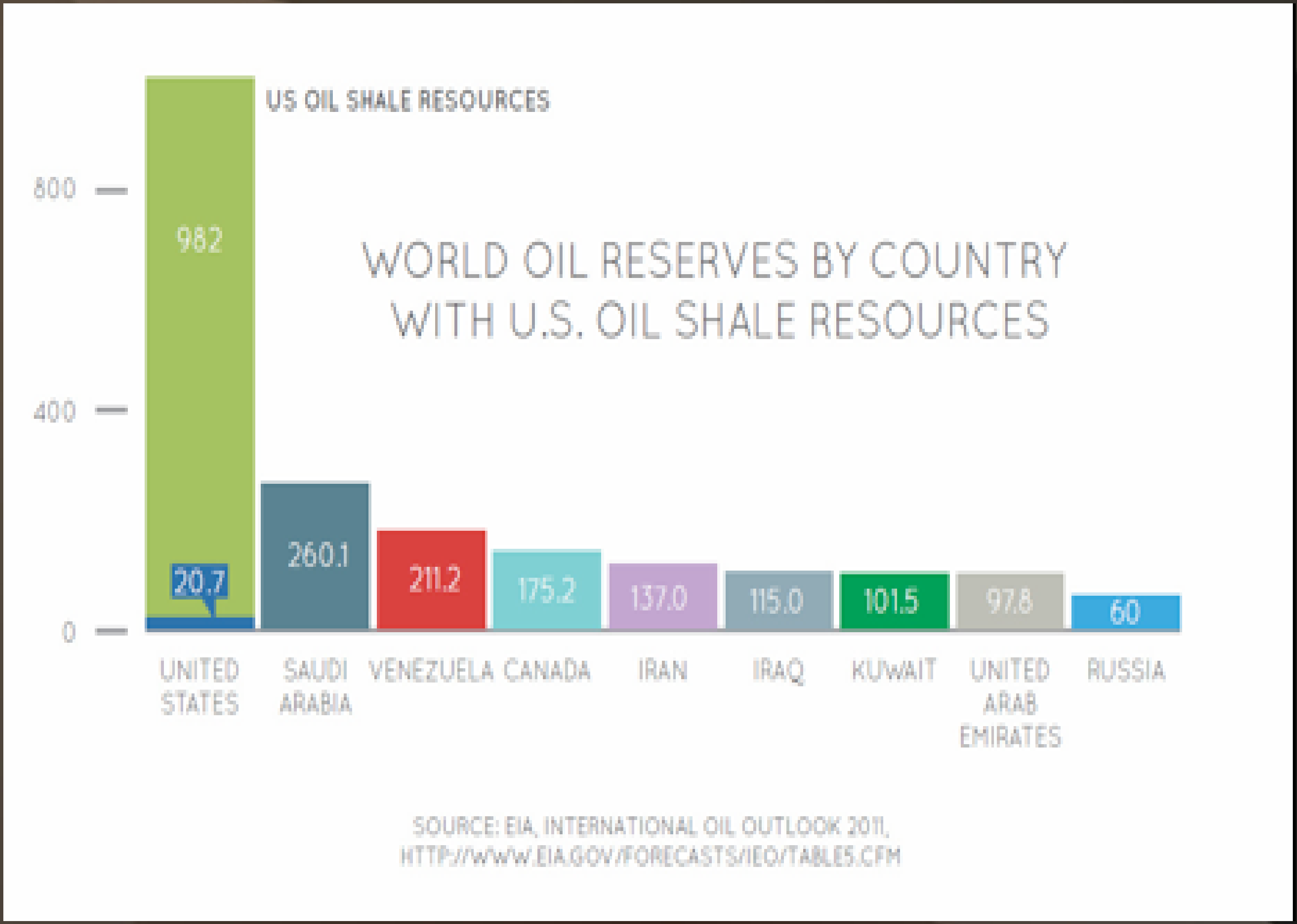


Figure 20 – Ultimate world crude-oil production based upon initial reserves of 1250 billion barrels.

- Production will have a "Bell Shaped" Curve.



- Data up to 2007


US OIL SHALE RESOURCES
800
400
0
982
20.7
WORLD OIL RESERVES BY COUNTRY
WITH U.S. OIL SHALE RESOURCES
260.1
211.2
175.2
137.0
115.0
101.5
97.8
60
UNITED STATES
SAUDI ARABIA
VENEZUELA
CANADA
IRAN
IRAQ
KUWAIT
UNITED ARAB EMIRATES
RUSSIA
SOURCE: EIA, INTERNATIONAL OIL OUTLOOK 2011,
HTTP://WWW.EIA.GOV/FORECASTS/IEO/TABLES.CFM

- In the 1950's, Hubert predicted that the US oil production would peak in the 1970's….It did.
- Current models predict world oil production will peak in 0-20 years…watch out!
- Much more when we get to each fossil fuel source.