Lecture 3
April 6, 2012

So far we discussed various types of energy, now we take a simple illustrative calculation.

Problem:

Calculate the mass energy available in a single hydrogen atom expressed in Joules and MeV

- Solution.
- Idea: calculate the mass in kG of the Hydrogen atom and use Einstein;s eqn $E = MC^2$
- Mass= 1proton + 1 electron ≈ 1 proton (electron is lighter by factor of 1000) ≈ 1.67×10^{-27} kG
- $C = 3 \times 10^8$ meters per second
- $E = 1.503 \times 10^{-6}$ Joule ≈ 939 MeV

Similarly a single electron has mass energy ≈.5 MeV

	J	kWh	Btu
Energy equivalents			
Conversion table			
1 Joule	1	2.78×10^{-7}	9.49×10^{-4}
1 kWh Kilowatt Hour	3.60×10^{6}	1	3413
1 calorie	4.184	1.16×10^{-6}	3.97×10^{-3}
1 British Thermal Unit BTU	1055	2.93×10^{-4}	1
1 ft pound (ft-lb)	1.36	3.78×10^{-7}	1.29×10^{-3}
1 electron volt (eV)	1.60×10^{-19}	4.45×10^{-26}	1.52×10^{-22}
1 Barrel petroleum	6.12×10^{9}	1700	5.8×10^{6}
(42 US Gallon)			

In this way we can find the energy equivalent of any mass. In using this formula, we will usually first have to find the mass defect in some reaction, i.e. the difference in mass between LHS and RHS and then multiply by C^2 to get the energy.

Quick review of energy/power

Some real life example

Work= Force x Length

Energy= Power x time

	Force	Energy=Work done	Power= Rate of doing work
MKS	Newton e.g. 1 KG weight suspeded in gravity by a string exerts a force 9.8 Newtons	Joule = Newton Meter e.g. 20 KG suitcase pulled up by 10 meters costs ~1960 Joules	Watt= Joule/sec e.g. if the suitcase is hauled up in 3.25 mins (~190 sec) power used in 10 Watts!
FPS	Pound (lb)	Foot pound (ft lb) 1Joule = 1.32 ft lb The FPS system can be very confusing since pound is used in many contexts: Our strategy is to convert ft-lb to Joule as fast as we can!! In above example the work done is ~2500 J = 2.5 KJ	Horse power = 550 ft lb/sec Convert to Watts using 1 HP= 746 Watts In above problem the "puny human" uses a horse power ~.013

Start thinking of energy content

Table 1.3: Energy Content of Fuels

Type of Fuel	Energy in joules/kg	Type of Fuel	Energy in joules/kg
Coal	2.9×10^7	Garbage and Trash	1.2×10^7
Crude Oil	4.3×10^7	Bread	1.0×10^7
Gasoline	4.4×10^7	Butter	3.3×10^7
Natural Gas	5.5×10^7	Nuclear fission with Uranium 235	$8.0 \times 10^{13} = 8{,}000{,}000 \times 10^7$
Wood	1.4×10^7		

From this table we see that Uranium has huge amount of energy: as compared to converting garbage and trash.
1kg Uranium is appxly 6.7 Million kg of trash!!!

Most materials give us ~10^7 J/kg, not Uranium

In practice the energy contained in nuclear reactions far exceeds any other source. However the risks involved are high, as seen in recent Fukushima incident and before that inChernobyl and the Three mile island.
We will discuss this aspect later.

Stepping up to bigger scales

	Numbers useful on a bigger scale			
	Total energy consumption in USA			
	(1 QBtu ~ referred to as a Quad)		1 Quad=172.4	Million Barrels
	1 Quad = 293 TWh	1000TWh=3.41 Quad		
2003	98.3 Quad	2.88×10^{16}	watt hours	28800 TWh
2007	101.6 Quad	2.97×10^{16} watt hours		29700 TWh
	Annual electricity production in USA in 2010			
	3992 TWh	(China 3715 TWh)		
	Energy Consumption per capita in US = 101.6x 172.4 Mill/290 Mill = 60.4 barrels per person			

1 Tera Watt Hour = 10^{15} Watt Hour = Billion KWH

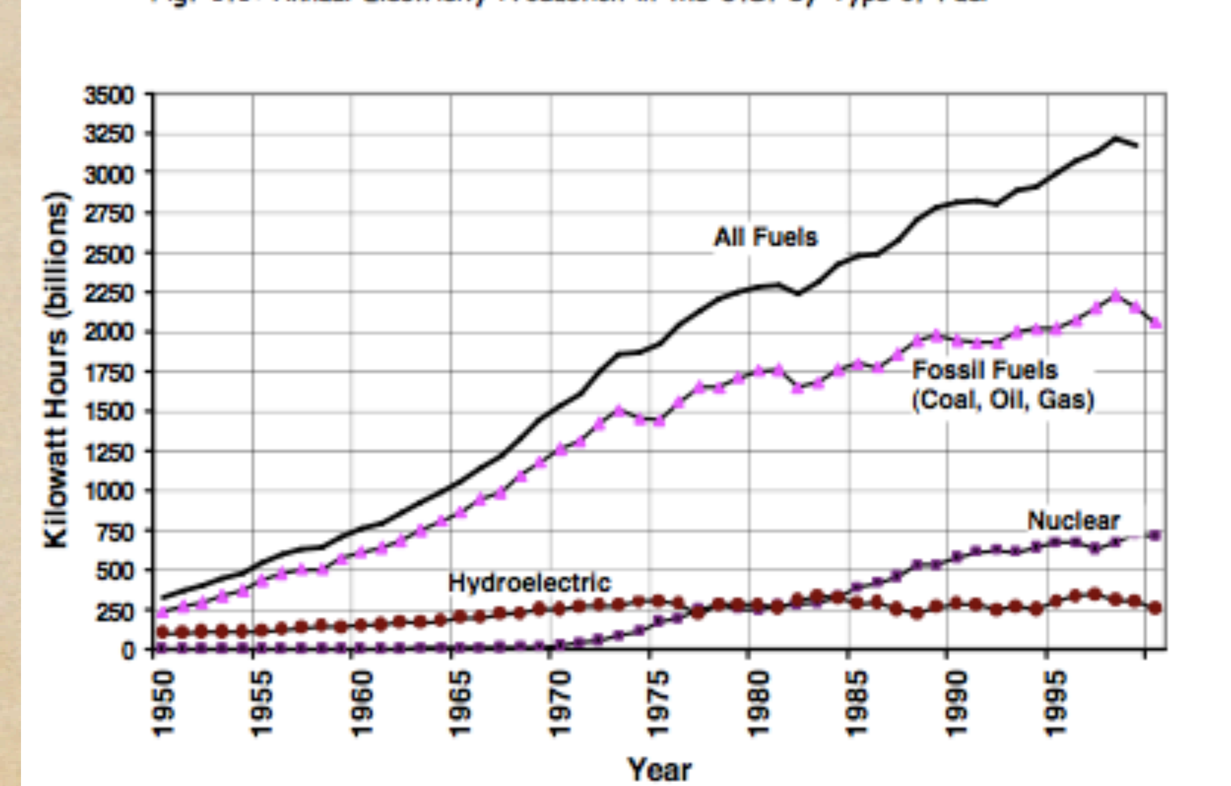
(since Billion = 10^9)

Watt Hour = 3600 Joules

Therefore TWh= 3.6×10^{18} Joules

US production ~ 1.4×10^{23} Joules

Fig. 1.1: Annual Electricity Production in the U.S. by Type of Fuel



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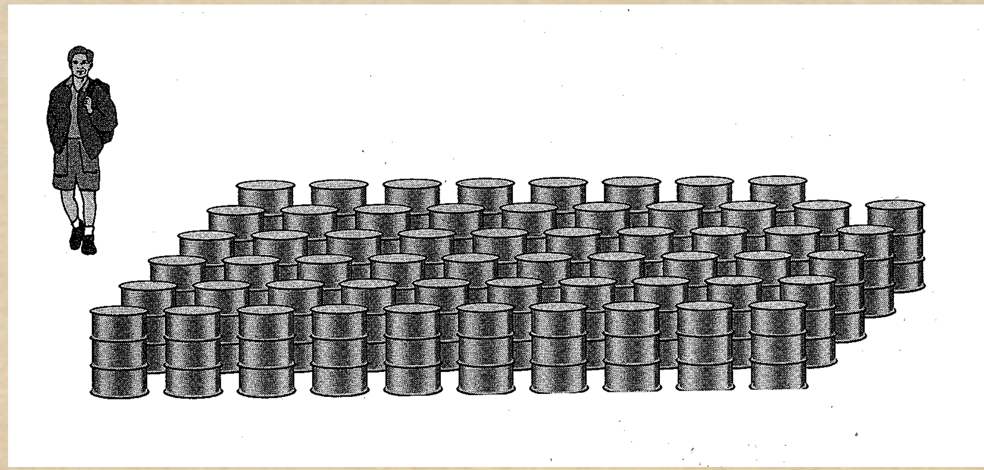
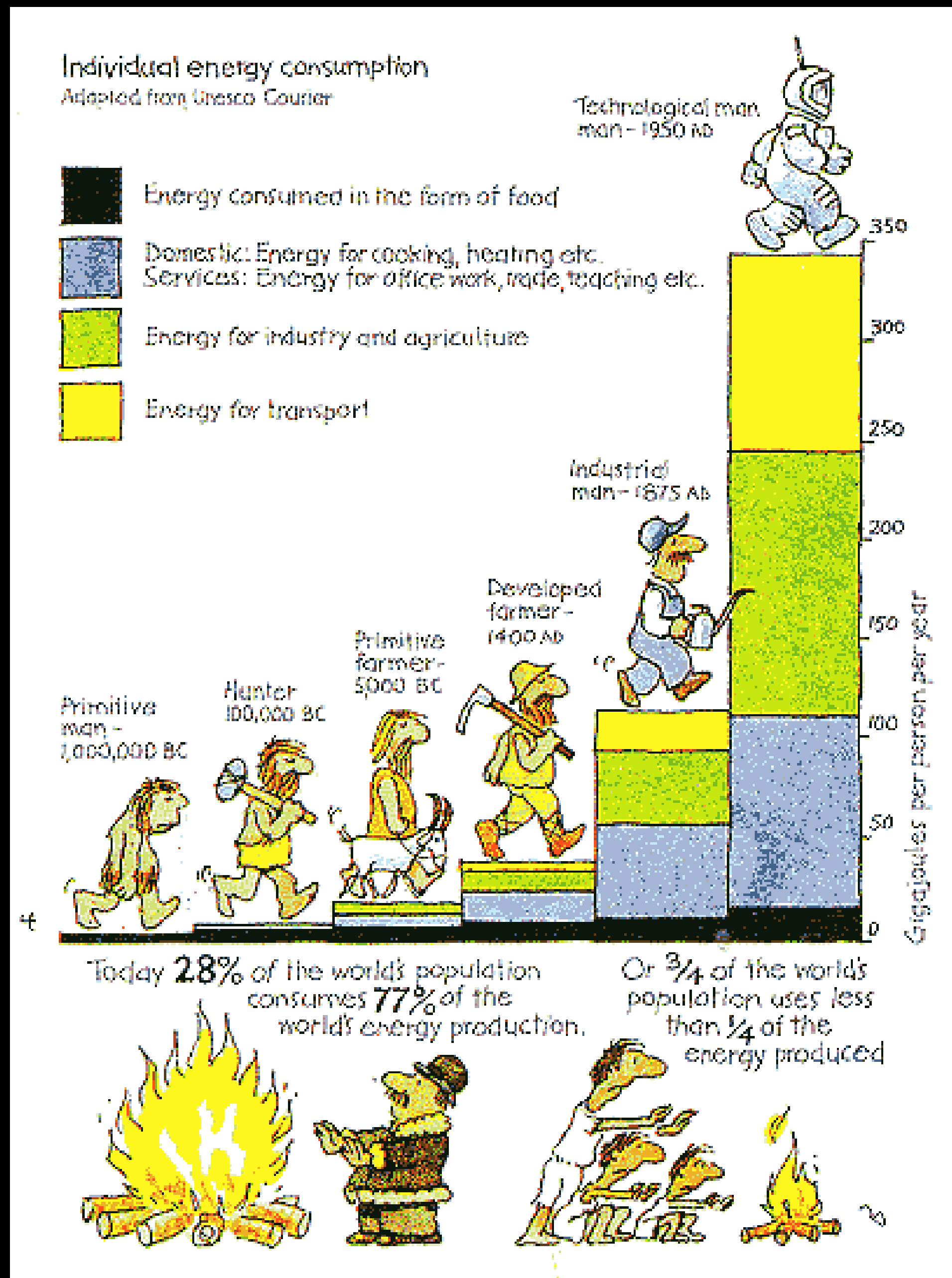
300 Giga Joule/ person /year



1 GigaJoule= 10^9 J

6.12 GigaJoule= 1 Barrel

350 GigaJoule =57 Barrels

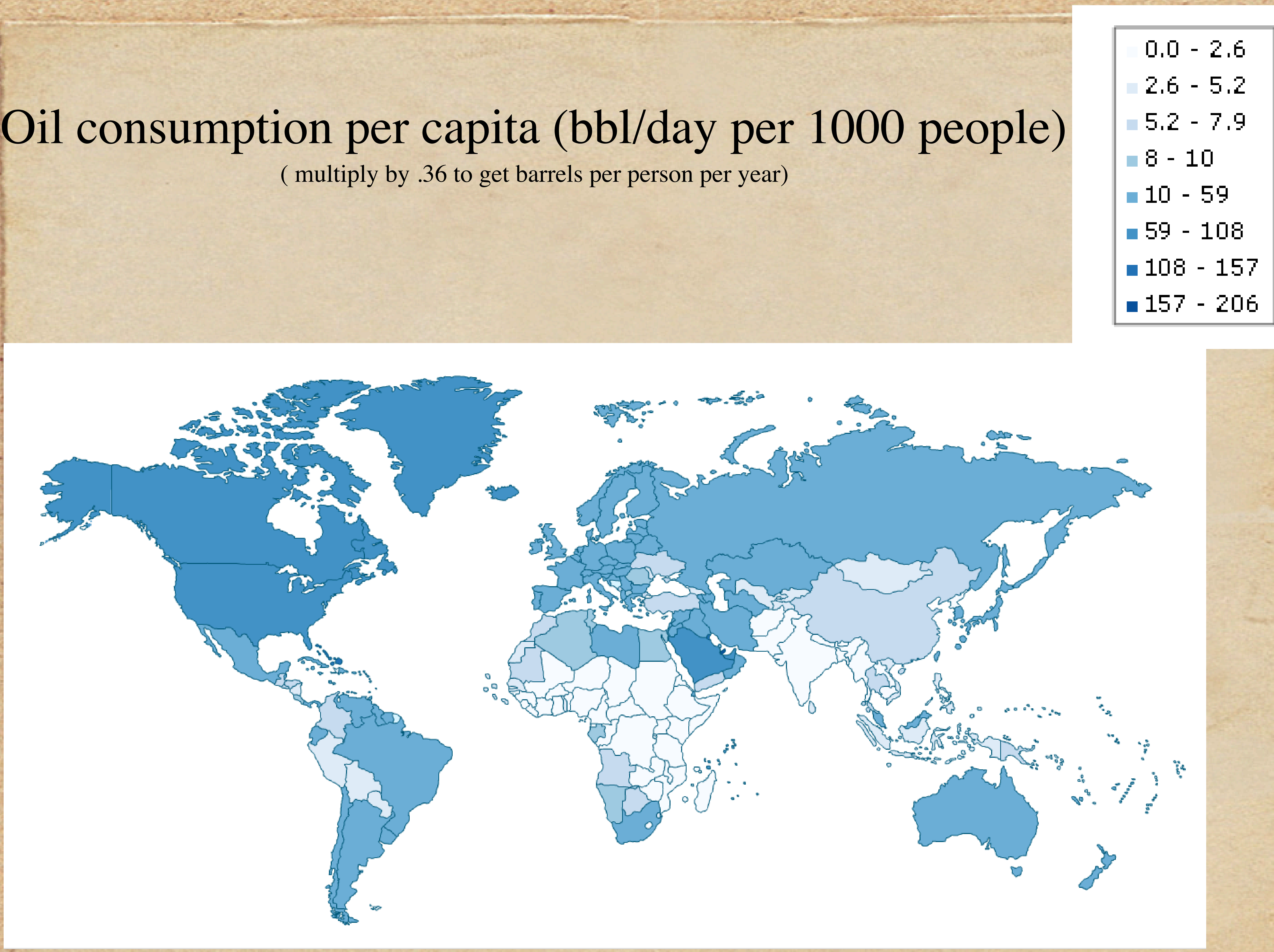


Individual Energy Consumption across the Ages

Today, a man uses **100 times** the Energy his primitive ancestors used to consume!

Oil consumption per capita (bbl/day per 1000 people)

(multiply by .36 to get barrels per person per year)



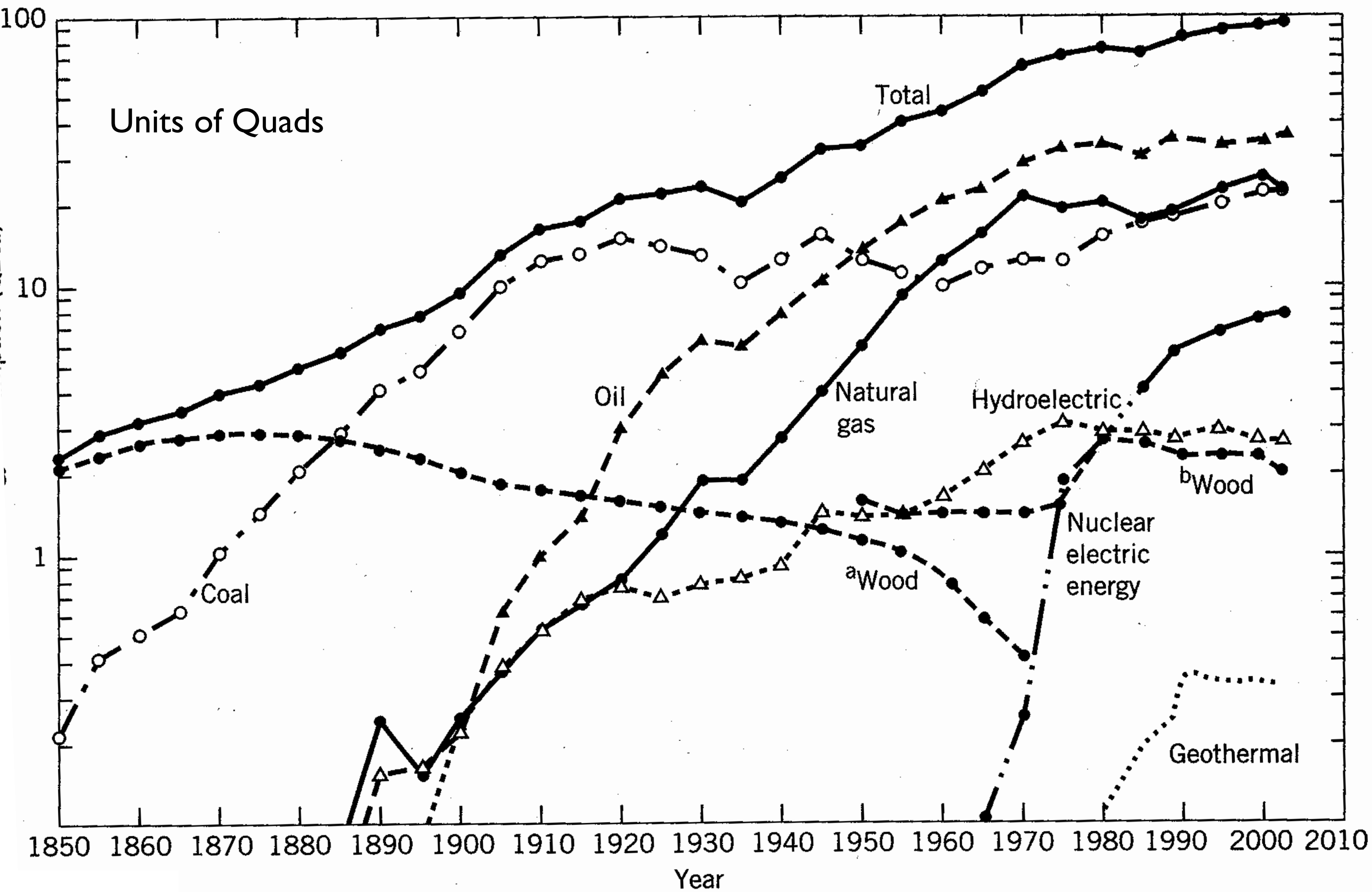
Big question and thoughts

- Why do we use so much energy?
- Poor efficiency in part
- "Unconscious" Habits of affluent civilizations
- Poor or exuberantly optimistic planning
- Will we have to change our energy usage patterns?

Fossil fuel is a single time usage affair
and is far from being inexhaustible.
M King Hubbert's realization.

Today we distinguish between
Renewable and non renewable fuel.
Renewable implies that nature replenishes the resource over time.
Non renewable is clearly everything else.

Different forms of energy in the US



Various forms of energy consumed in the United States since 1850. This

Current table on web in resources folder

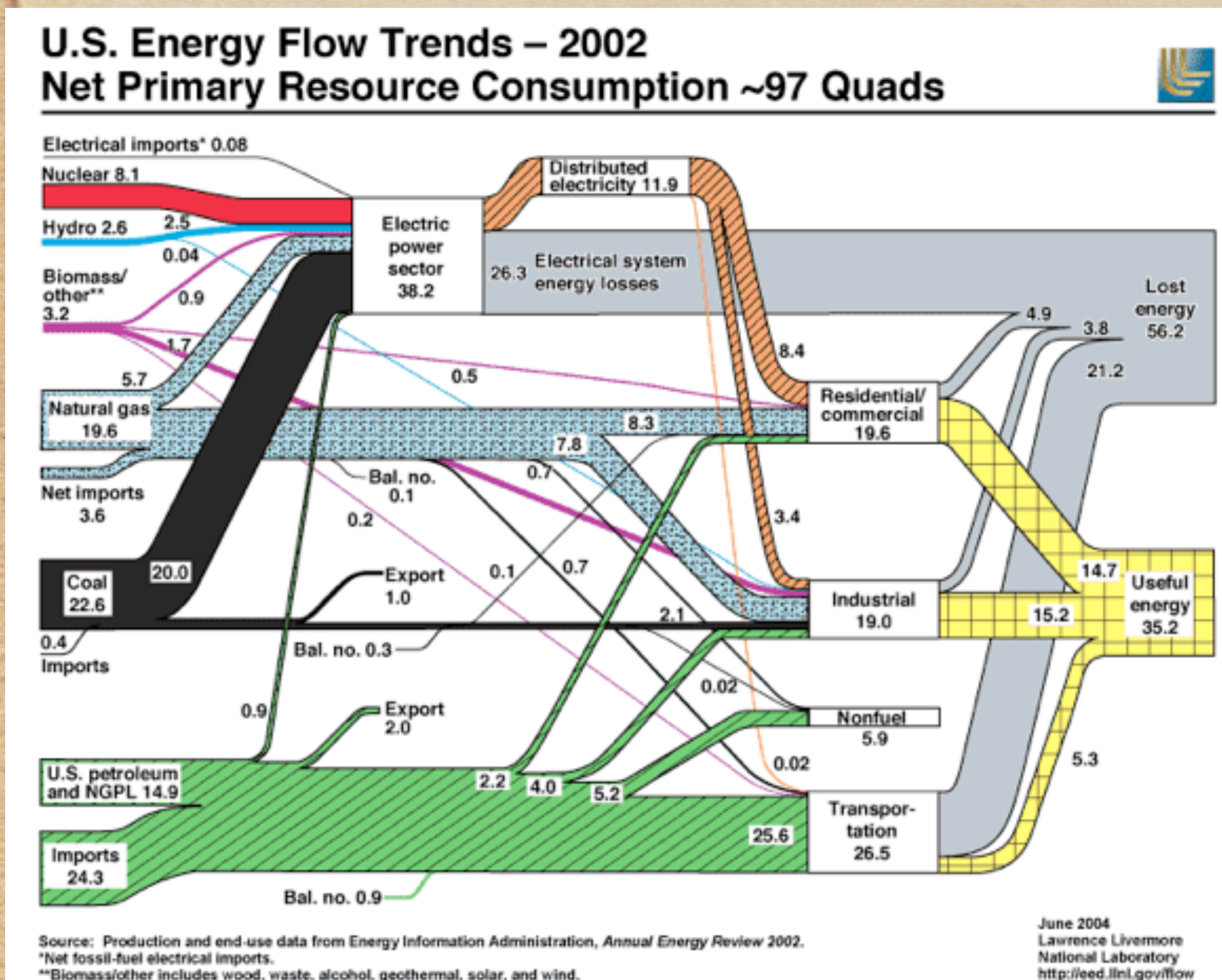
- **Renewable energy**
  - ✦Biofuel
  - ✦**Biomass**
  - ✦Hydroelectricity
  - ✦Solar energy
  - ✦Tidal power
  - ✦Wave power
  - ✦Wind power

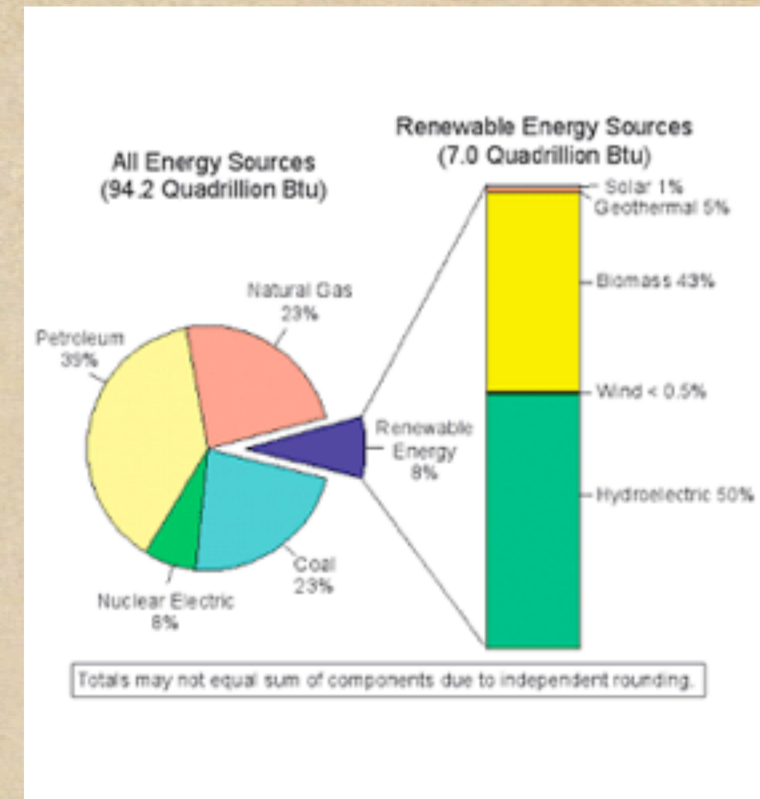
Energy equation

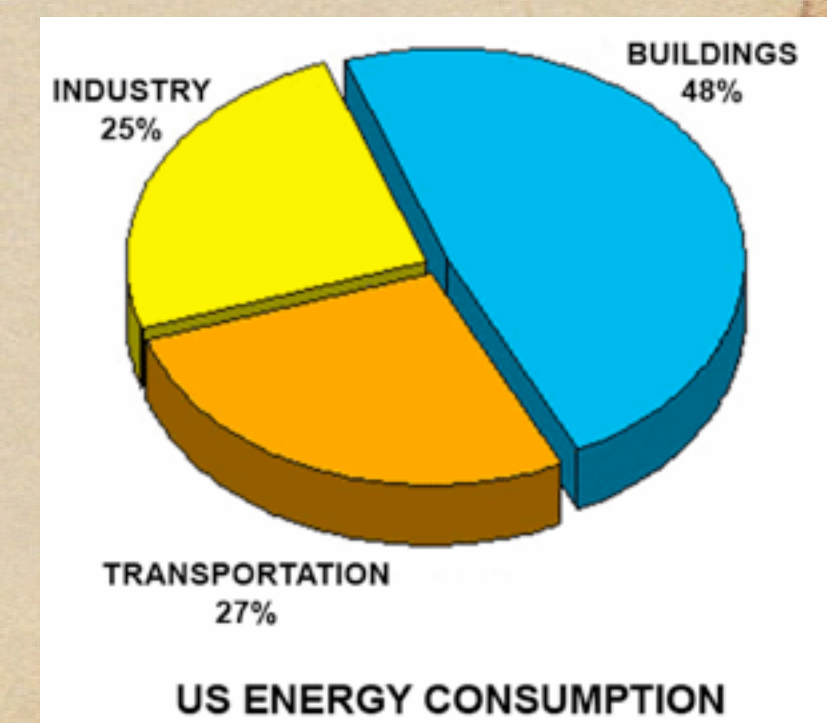
Expense vs.

Sources of energy

Flow chart of energy eqn







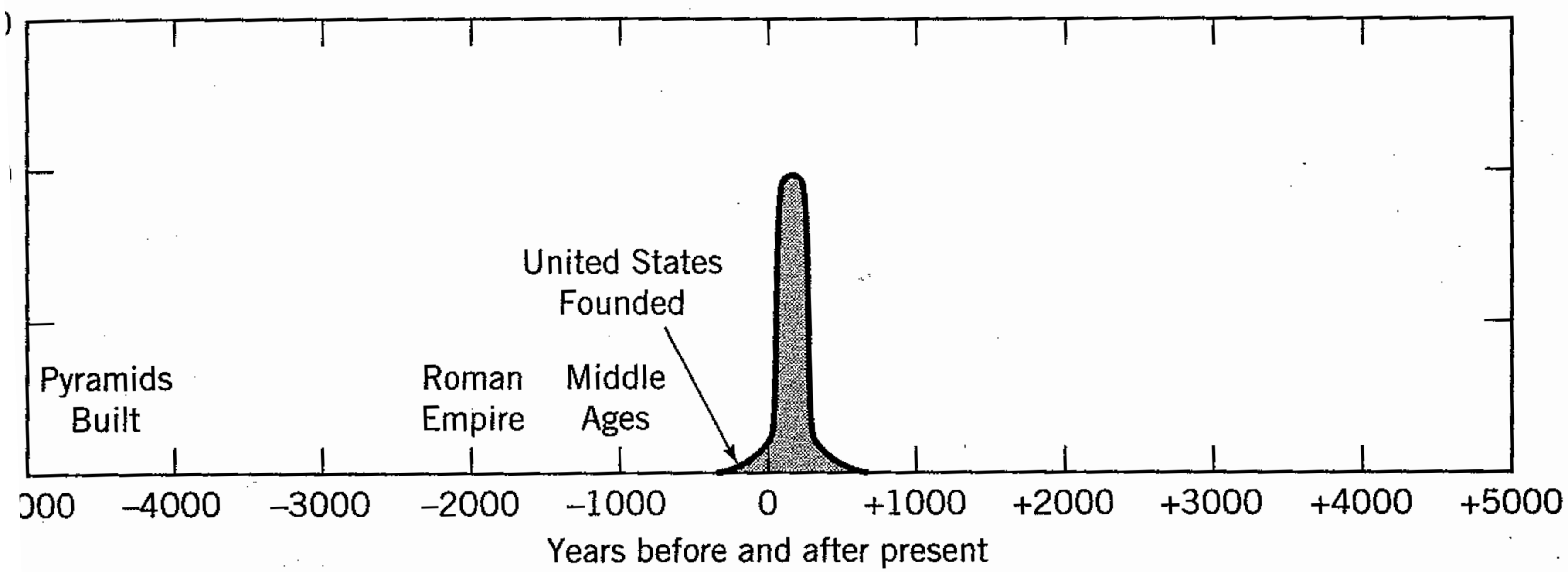
Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). In 2008, about 19% of global final energy consumption came from renewables,

The share of renewables in electricity generation is around 18%, with 15% of global electricity coming from hydroelectricity and 3% from new renewables.

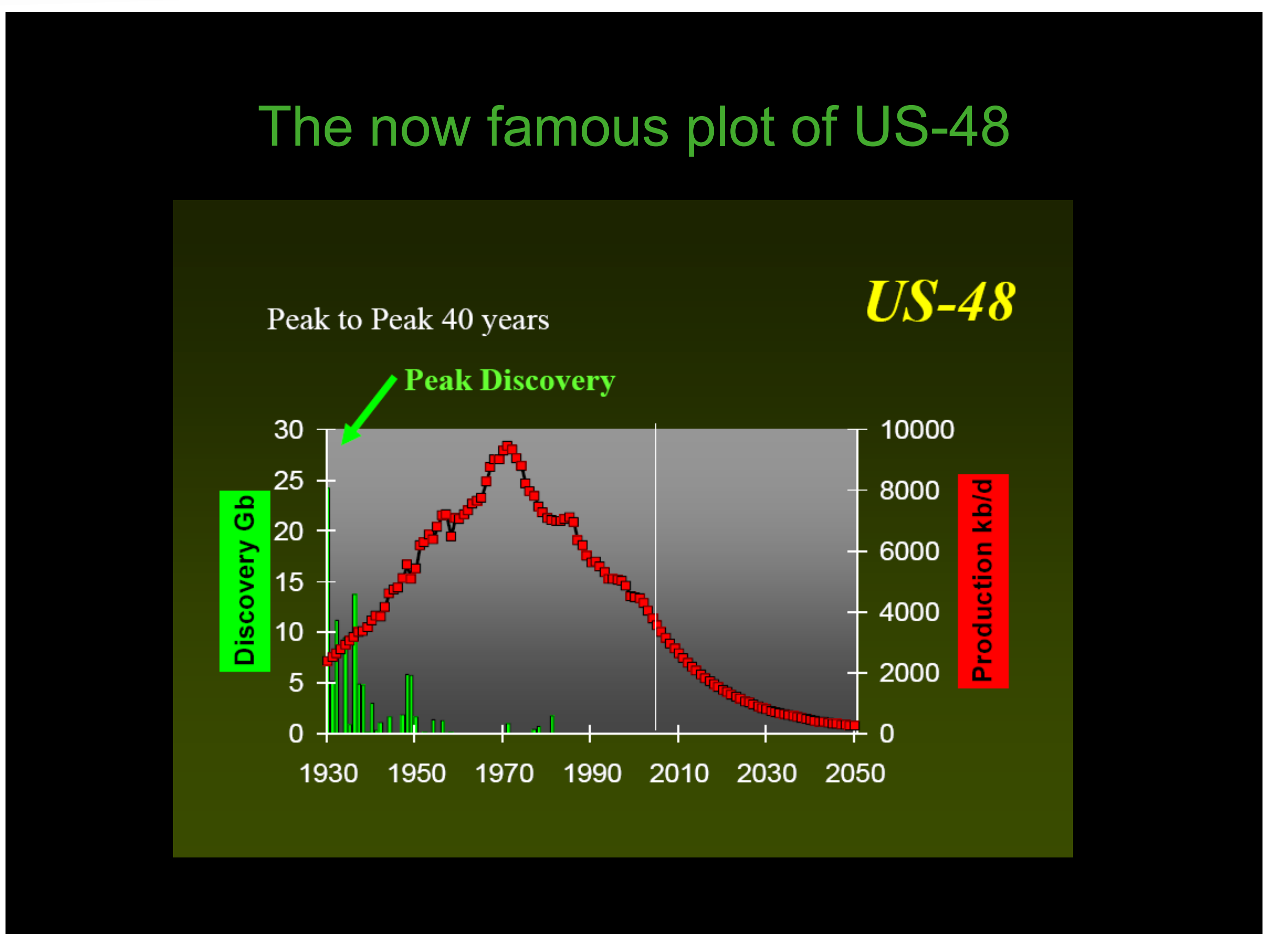
Wind power is growing at the rate of 30% annually, with a worldwide installed capacity of 158 gigawatts (GW) in 2009, and is widely used in Europe, Asia, and the United States. At the end of 2009, cumulative global photovoltaic (PV) installations surpassed 21 GW and PV power stations are popular in Germany and Spain. Solar thermal power stations operate in the USA and Spain, and the largest of these is the 354 megawatt (MW) SEGS power plant in the Mojave Desert. The world's largest geothermal power installation is The Geysers in California, with a rated capacity of 750 MW. Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugar cane, and ethanol now provides 18% of the country's automotive fuel. Ethanol fuel is also widely available in the USA.

The **DeSoto Next Generation Solar Energy Center** is a photovoltaic solar power facility in Arcadia, DeSoto County, Florida owned by Florida Power & Light (FPL)

Goodbye Fossil Fuels!



1.2 The complete exploitation of the world's fossil fuels will span only a rela-
›rief time in the 10,000 year period shown centered around the present. (*Source*:
ted with permission from M. K. Hubbert, *Resources and Man*, Washington,
ational Academy of Sciences, 1969. Historical events added.)



M King Hubbert predicted in a famous report written in 1956 (available on the resource page) that the peak of discovery of oil fields in 1932 followed by a drop off, would be mirrored in the oil production curve with a time lag caused by the development activity.

Some problems relating to conversions
with useful hints

1. If you push a cart along a horizontal surface with a force of 10 pounds, and the cart moves 10 feet, how much work have you done in ft·lbs? In joules?

Hint: (1) Identify the formula needed (2) Plug in the numbers.

$W = F \times L$ $10 \times 10 = 100\ FootPounds\ = 136\ Joules$

2. How many tons of coal would be needed each year to provide for the entire energy needs for the average person in the United States?

Hint: This problem requires us to find out the energy content in coal by looking up a table, finding out how much energy is needed per person in USA from another table and combining the two.

60 barrels per person = $60 \times 6.12/42 \times 10^9 = 8.7 \times 10^9$ Joules

1 Ton coal = 2.8×10^{10} Joules

Answer 0.31 Tons coal per person per year!!

3. Solar energy is incident on a black parking lot with an intensity of 1000 Watts/m^2 and 90% of it is absorbed. What is this in Btu/hr per square meter? What happens to the other 10%?

Hint: This problem is much simpler than it looks at first sight. We can take 1 square meter as the relevant area, and then we just need to convert from watts to BTU/hour

Table tells us that 1 Kilowatt hour = 3413 Btu
Hence answer = .9 x 3413 = 3071 Btu/hr

4. Palo Verde Power Plant, is a nuclear power plant located in Wintersburg, Arizona, about 45 miles west of central Phoenix. It is currently the largest nuclear generation facility in the United States, averaging over 3.2 Gigawatts (GW) of electrical power production in 2003.

Power plants reckon production by GigaWatt

1 year has 3.15×10^7 secs
or
8760 hours.

Note the units:
1gigawatt= 10^9 watts

Tera= 10^{12}

Total power calculation:
This figure gives us the power available on average through 2003.
If we want the total power during the year 2003, we multiply by
3.15×10^7 secs (the number of seconds per year)
to get 1.008×10^{17} Joule
This is better expressed in terms of Watt hours:
(1kW Hour= 3.6×10^6 J) as
2.8×10^{13} WattHours= 28 TWH

Recall that the total electrical power generation in the US in 2010 is 3992 TWh