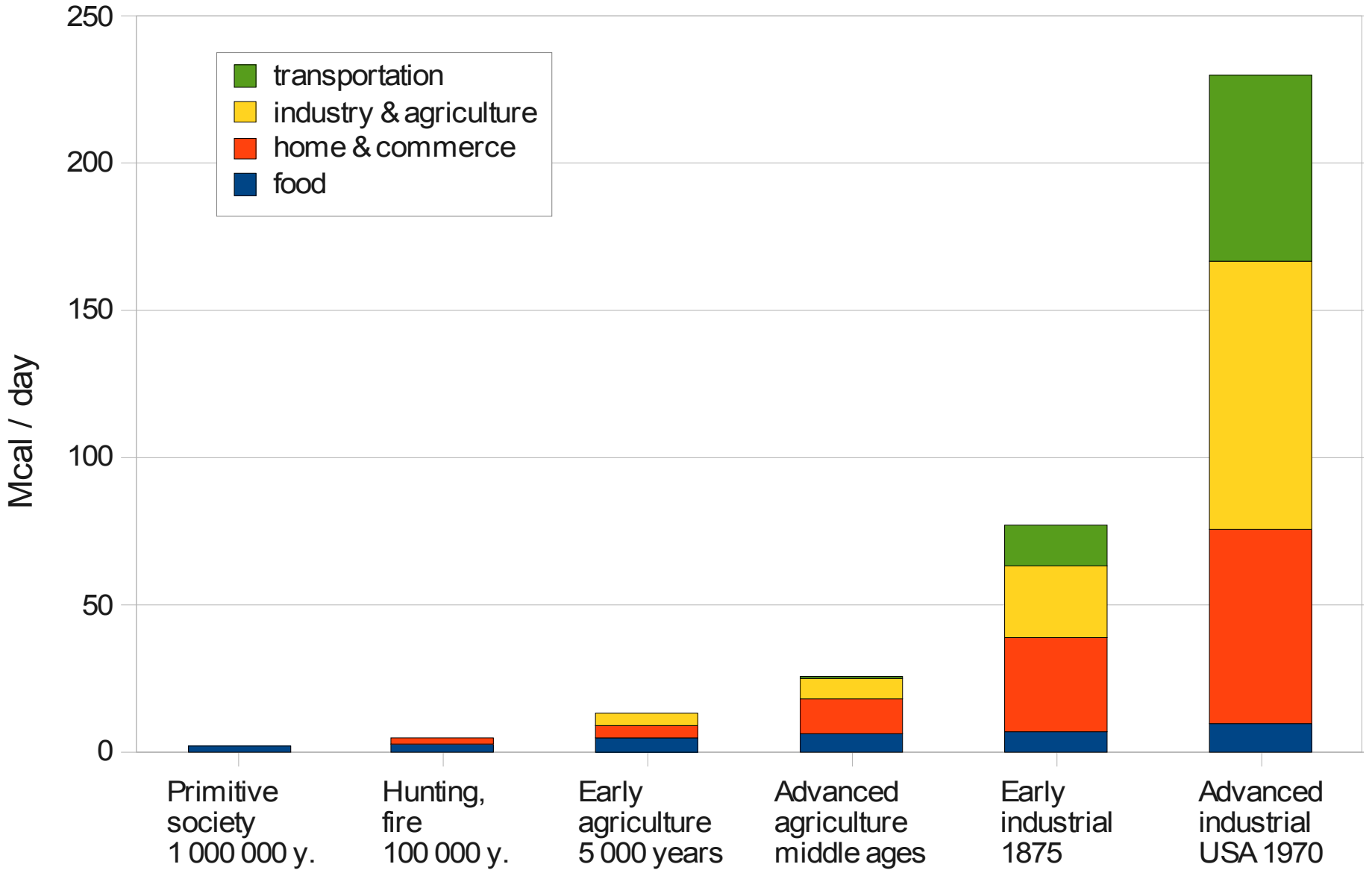
Electric Propulsion in Perspective

- Historical perspective of energy consumption
- Contemporary questions of future energy supply
  - Problem with combustion waste products of carbon fuels (oxides, particulates, poisons), question of future availability of the fuels (price, strategic dependence, limited resources).
  - Most of the combustion sources can be replaced by nuclear and other emission-free alternatives via electrification
- Individual transportation is still a challenge
  - Electric propulsion = clean transportation
- Can we meet this challenge, what time scale?

Energy consumption per capita in history



(*) http://www.wou.edu/las/physci/GS361/electricity%20generation/HistoricalPerspectives.htm

Development of human civilization is closely connected to energy consumption

Energy consumption per capita in several stages of development

Mcal / day	Primitive society 1 000 000 y.	Hunting, fire 100 000 y.	Early agriculture 5 000 years	Advanced agriculture middle ages	Early industrial 1875	Advanced industrial USA 1970
food	2	3	5	6	7	10
home & commerce	0	2	4	12	32	66
industry & agriculture	0	0	4	7	24	91
transportation	0	0	0	1	14	63
total Mcal / day / person	**2**	**5**	**13**	**26**	**77**	**230**
total Gcal / year / person	0.7	1.8	4.7	9.5	28.1	84.0
total GJ / year / person	3.1	7.6	19.9	39.7	117.7	351.5
total average kW / person	**0.1**	**0.2**	**0.6**	**1.3**	**3.7**	**11.1**

* http://www.wou.edu/las/physci/GS361/electricity%20generation/HistoricalPerspectives.htm

- Now we use 2.5 x more energy for transportation only than the total per capita energy use before industrialization => No way to save enough energy to replace fossil fuels

- Total per capita use in technological age is ~ 100x that of primitive society
  - Everyone has about **100 "energy slaves"** which heat our homes, water, carry us around, provide energy for machines in factories etc.

Development of human civilization is closely connected to available energy resources

Long history of "limits of growth" - <u>deforestation</u>

- 6000 BC – communities around Jordan collapse
- 2700 BC – King Gilgamesh chopped down cedars in southern Iraq, civilization moved north to Babylon, Assyria
- Mediterranean civilization from Minoan via Greek to Roman wrestle with limited timber resources

Fossil sources

Coal – wood substitute

- Sporadic utilization since the stone age
- Growth since 1750 due to Industrial revolution – steel production, steam engines
- Today – electricity generation, chemistry and other industry uses

Oil – steam engine substitute

- Used for asphalt in Babylon, oil wells in China since ~ 300 AC
- Since 1857 refined to kerosene to replace whale (and other renewable) oil in lamps etc.
- Today – 90% of transportation, electricity generation, chemistry and other industry uses

Natural gas – another carbon fuel

- Religious uses in Delphi (500 BC), old China
- 1785 – public lights in U.K.
- Today – oil substitute

Development of human civilization is closely connected to available energy resources, II

Renewables - substitutes of animal and human muscles

Wind – water pumping, grain mills

- 500 BC – oldest windmills in Persia (Iran)
- 13th century – China, western Europe
- Stable utilization since middle ages until the industrial revolution

Water – mills, saws

- 80 BC – grain mills in Greece
- 8th century - Britain
- Since 19th century - electricity generation

Nuclear energy – a new 10^8 x more copious fire

- 1936 – nuclear reactor patent (Leo Szilard)
- 1938 – nuclear fission confirmed (Otto Hahn, Lise Meitner)
- 1942 – controlled chain reaction (Enrico Fermi)
- 1951 – Experimental Breeder Reactor 1 (Arco, Idaho)
  - First usable electricity from nuclear fission ---------->

Quality of life and energy consumption

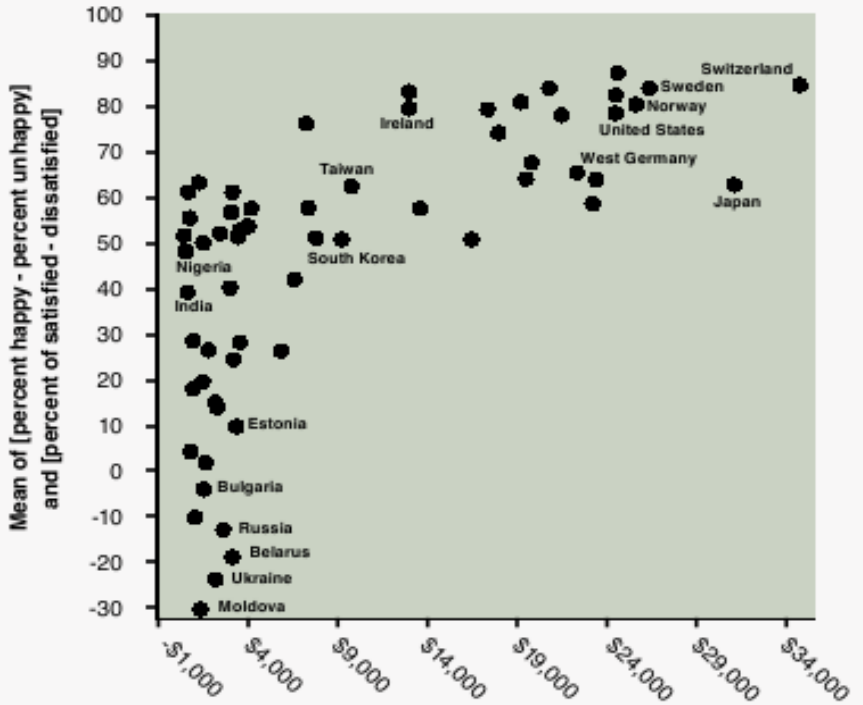
Quality of life and energy consumption are closely correlated:

In countries with energy cons. **~190 GJ/**capita the GDP/capita is **~$20 000**, child mortality **<1 %,** and life expectancy **>70 years**.

Countries with energy cons. **~4 GJ**/cap. produce GDP/cap. **~400$**, child mortality **>12 %,** and life expectancy **<50 years.**

(data from the early 1990s)

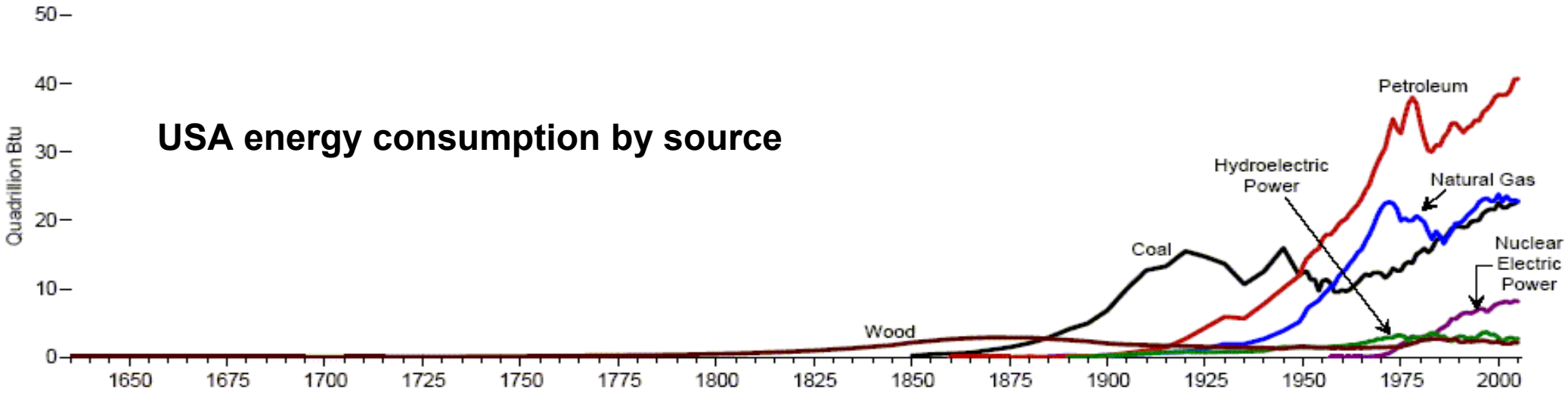
Figure 1. Subjective well-being by level of economic development



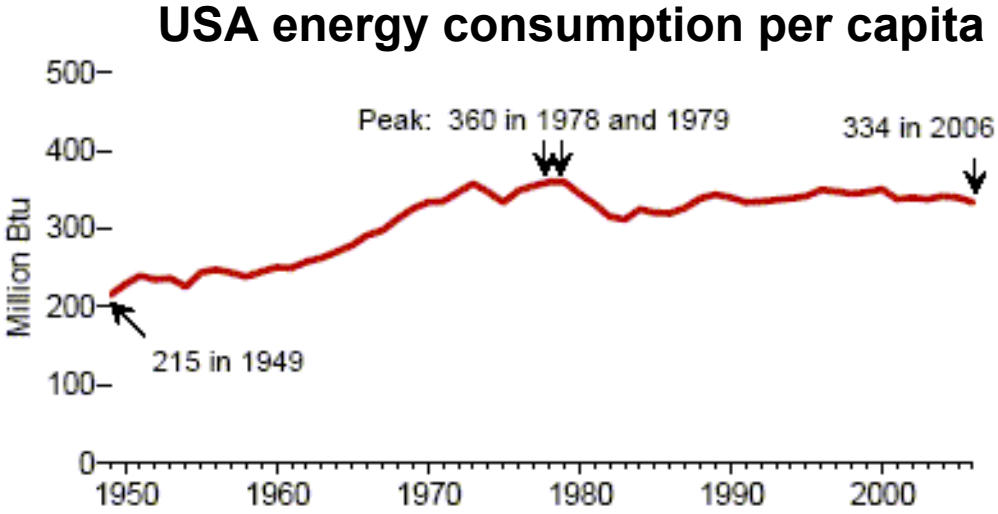
NOTE: The subjective well-being index reflects the average of the percentage in each country who describe themselves as "very happy" or "happy" minus the percentage who describe themselves as "not very happy" or "unhappy"; and the percentage placing themselves in the 7–10 range, minus the percentage placing themselves in the 1–4 range, on a 10-point scale on which 1 indicates that one is strongly dissatisfied with one's life as a whole, and 10 indicates that one is highly satisfied with one's life as a whole.

SOURCE: R. Inglehart, "Globalization and Postmodern Values," Washington Quarterly 23, no. 1 (1999): 215–228. Subjective well-being data from the 1990 and 1996 World Values Surveys. GNP per capita for 1993 data from World Bank, World Development Report, 1995 (New York: Oxford University Press, 1995).

USA – historic perspective of energy uses



- Energy consumption per capita is mostly determined by civilization era.
- In the technological age, energy consumption per capita does not rise any more, however we need to change the energy source away from combustion.
- Total energy consumption by humans will rise as billions living in 3rd world countries transit from agriculture and industrial civilizations to the technological age.

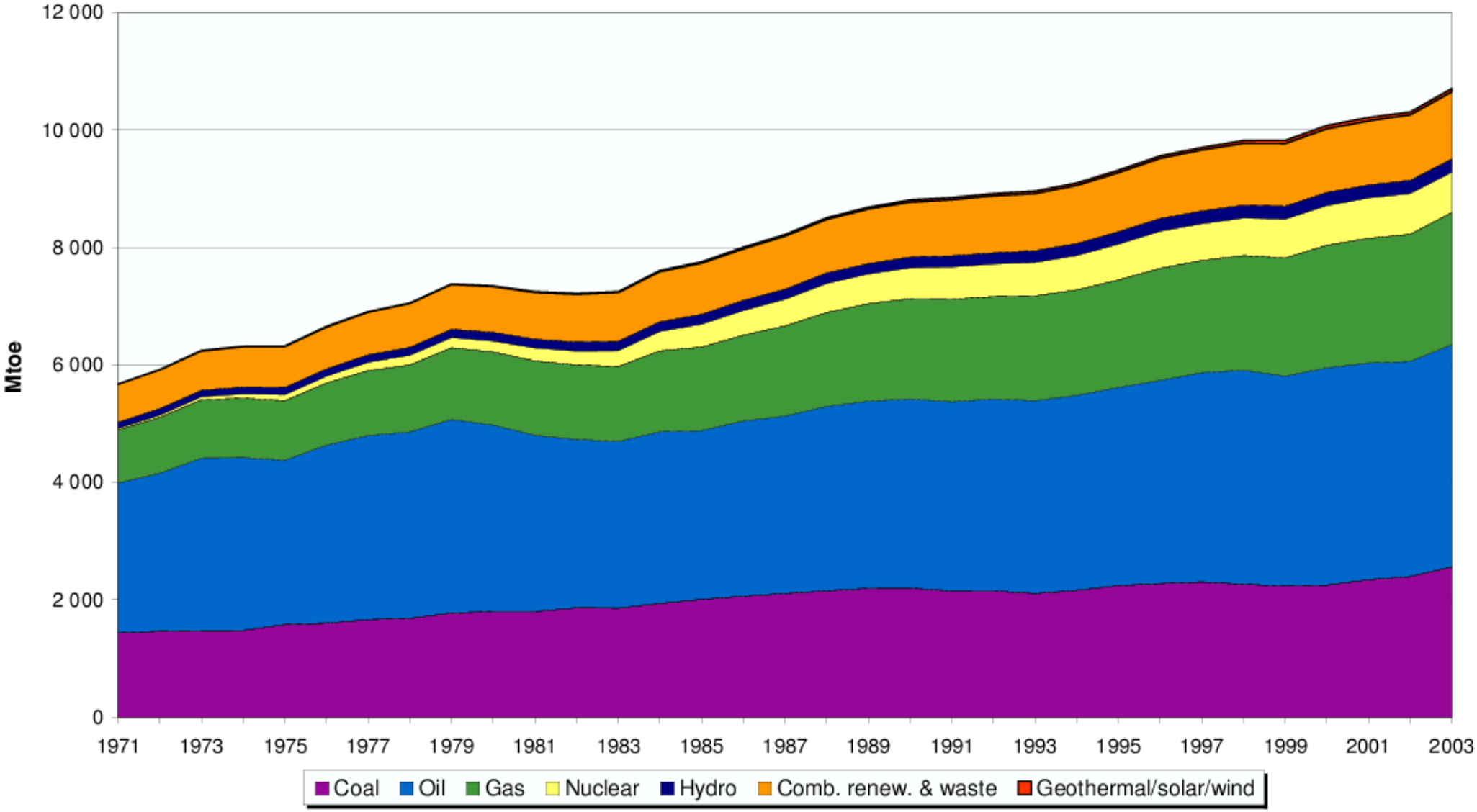


(*) plots from: http://www.eia.doe.gov/emeu/aer/ep/ep_frame.html

Ondřej Chvála, ASAP, March 6th 2008

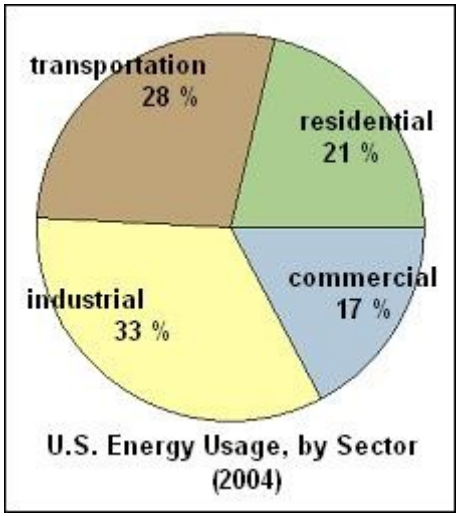
Evolution of Total Production of Energy from 1971 to 2003

World



Question of energy for transportation

- In USA 28% of all energy consumption is transportation
- Personal transport nearly 100% dependent on fossil fuel combustion
- Large growth expected in India, China etc.
- Fossil fuel combustion not sustainable
- A different power source is needed
  - Electric vehicles superior to gasoline cars even with fossil powered grid: average thermal efficiency of internal combustion engines in cars is about 20-25 %, efficiency of modern fossil plants is about 40-50 %



- Vehicle mileage ~ energy used: $E = F * d = \boldsymbol{m} * a * d$
  - Distance *d* and acceleration *a* are constants, thus for high mileage get a **lighter vehicle!** (n.b. car aerodynamics and engine efficiency are ~ constant as well)
  - Chevy Tahoe Hybrid (green car of the year 2007) with 20 mpg is <u>not</u> the way to go...
  - e-scooters, e-bicycles, light e-cars – for details see
    - http://bnl-asap.org/wiki/index.php?title=Electric_propulsion

- Is a lightweight electric vehicle feasible?
- What would it take in terms of
  - Battery capacity – range
  - Motor power – agility
  - Weight

Electric Propulsion Club

- Proposed to field-test the feasibility and increase awareness of the issue
- Possibly test BNL energy program gadgets in a nearly real life situation
- Many ideas to consider (see the Wiki)
  - Battery – chemistry, capacity; or a fuel cell?
  - Engine type – standalone or in wheel; gearbox?
  - Frame – old motorcycle?
  - If interested, email me - chvala@bnl.gov

- example: X-Treme scooter XB-508, what one can get now for ~ $770,-
  - http://www.x-tremescooters.com/electric_bicycles/xb-508/xb508.html
- 550 W in-wheel motor
- 4x 12V 14A lead-acid batteries
- Charge up time 6-8 hours
- Top speed ~20 mph
- Range about 20 miles per charge
- Drum breaks, lights, horn, ...

- Test drive now :-)

- Thanks for patience, thats all for now