Challenges for Future Energy Usage

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Survey

1. Glance into the history of energy usage

2. Present situation
   - Population growth
   - Shortage of resources
   - Environmental damages and hazards

3. Identification of the biggest energy spenders

4. Boom of renewable energies

5. Promising options

6. Challenges

1. Glance into history of energy usage

Energy sources in past times: renewable (plants, animals, wood, charcoal, water, wind)

Power and heat from fire and muscles → slavery

Unusually benign climate for the last 12 thousand years → cultural evolution

Population 12 thousand years ago: a few million
in 1700 AD: 600 million

Start of industrialization about 300 years ago

Start of coal era

1712 coal fired steam engine of Thomas Newcomen (0.5 % efficiency)
1769 steam engine of James Watt (2 % efficiency)

Advent of electricity

1866 dynamo of Werner von Siemens → breakthrough of electr. motor
1879 light bulb of Thomas Alva Edison
1882 first electric power station (New York)
1890 first electrically driven subway (London)

Start of oil era

1859 first drilling for oil (Edwin L. Drake)
1870 foundation of Standard Oil Company (John Rockefeller)

Advent of the automobile

1877 Otto engine (Nikolaus A. Otto)
1886 first automobile with combustion engine (Call Benz)

Advent of natural gas

1785 first working gas lamp (Johannes P. Minckeleers)
1812 first gas company (London, Friedrich A. Winzer)
1814 first public gas illumination (London)

Broader use of gas started about 50 years ago

Advent of nuclear energy

1954 first nuclear power station in Obninsk (Russia)
1956 nuclear power station in Calder Hall (England)
1986 Chernobyl catastrophe

Growth of world population

population	year	time difference
0.25 billion	1	
		1650
0.5 billion	1650	
		200
1 billion	1850	
		75
2 billion	1925	
		40
4 billion	1975	

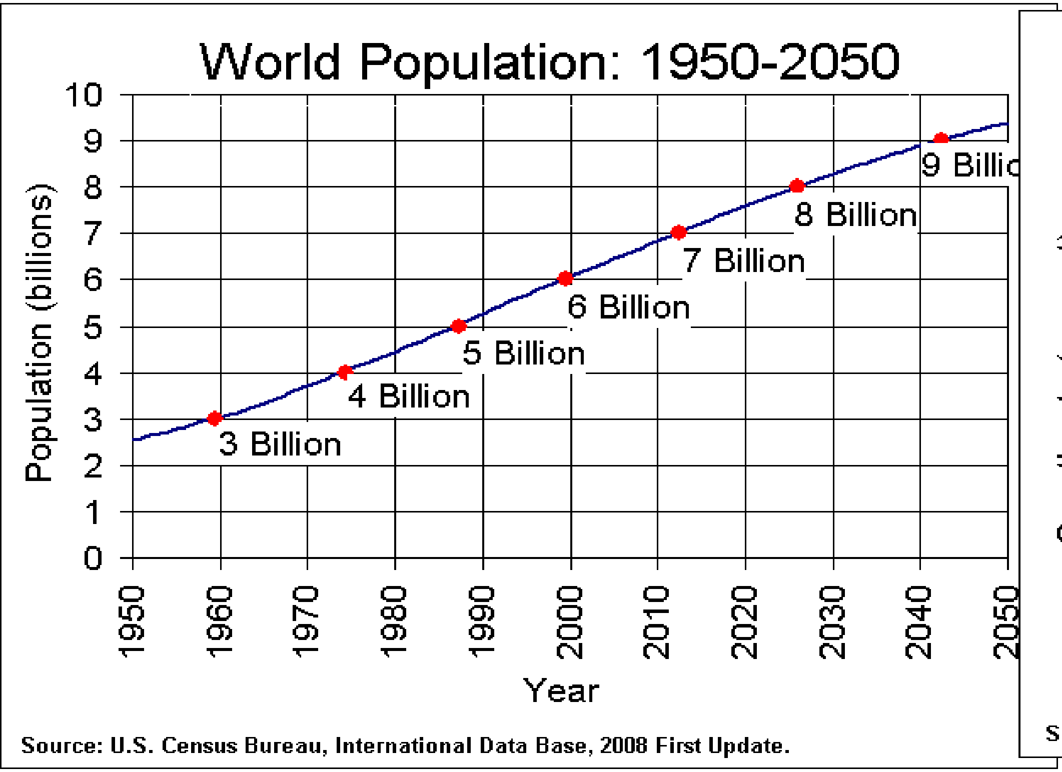
Worldwide energy consumption grew even faster

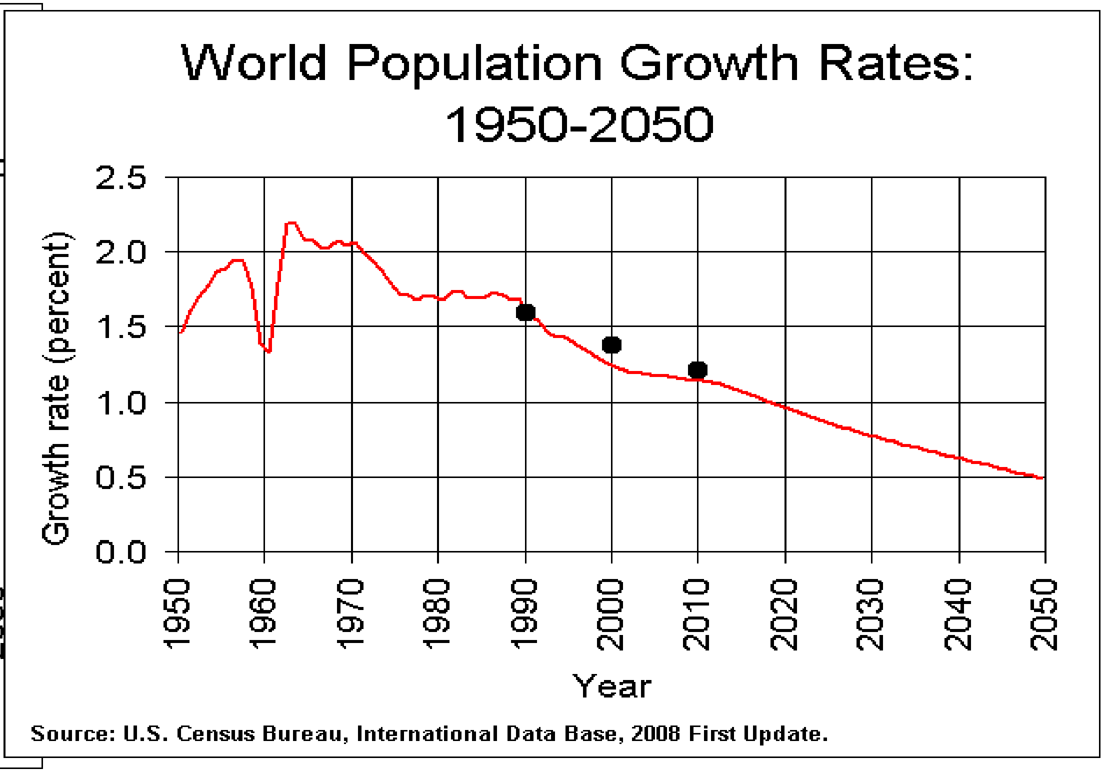
Year	world population	E/EJ	P/W
1	0.25 billion	1.5	190
1650	0.5 billion	10	635
2004	6.4 billion	472	2340

E = total energy consumption per year
P = energy consumption per capita per second
EJ = exajoule = 10^{18} J, W = watt

2. Present situation

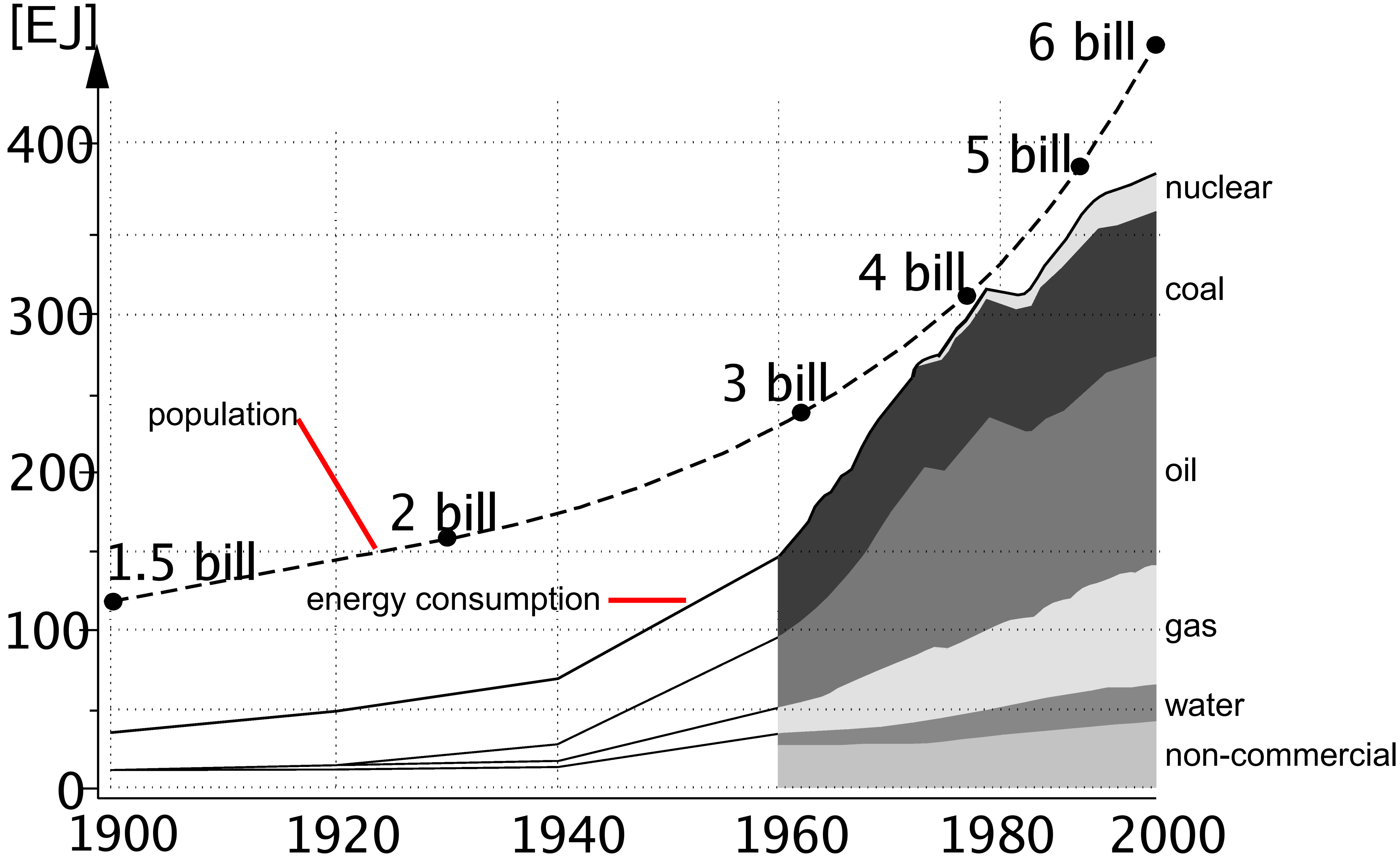
Evolution of world population





2045 about 9 billion, maximum 10 – 11 billion

Energy consumption grew faster than population



Daily energy requirement of one person:

2700 kcal corresponding to 130 W permanent power supply
(75 W radiated away)

Regional differences in power usage per capita

Region	USA	BRD	China	Africa
[W]	10 000	5 100	1 500	385 (170 without South Africa)

Running short of energy resources

85 % of energy consumption from fossil combustion

Peak oil problem and oil supply

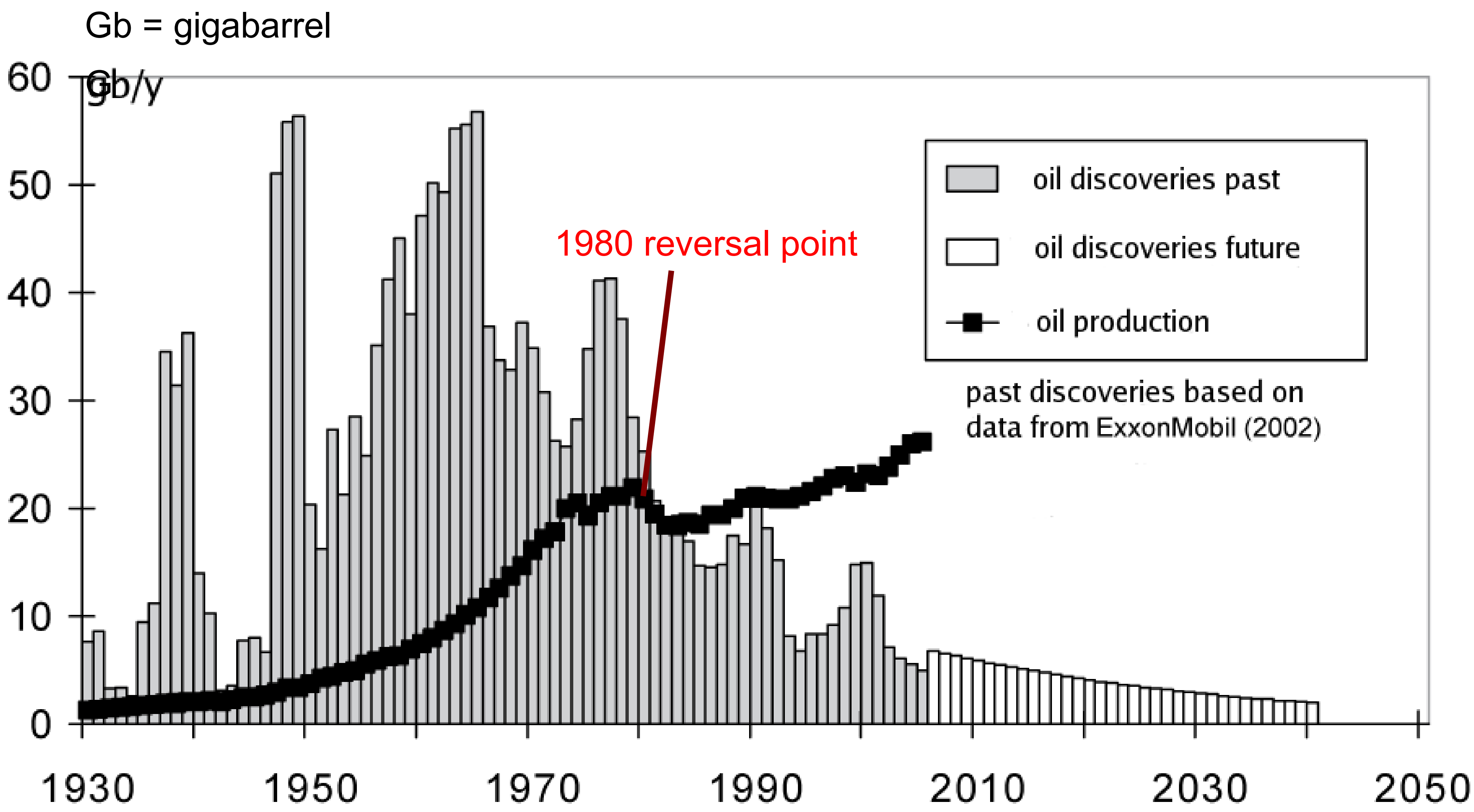
Today 0.7 billion automobiles, fuel essentially from oil

2040 1.4 billion automobiles expected

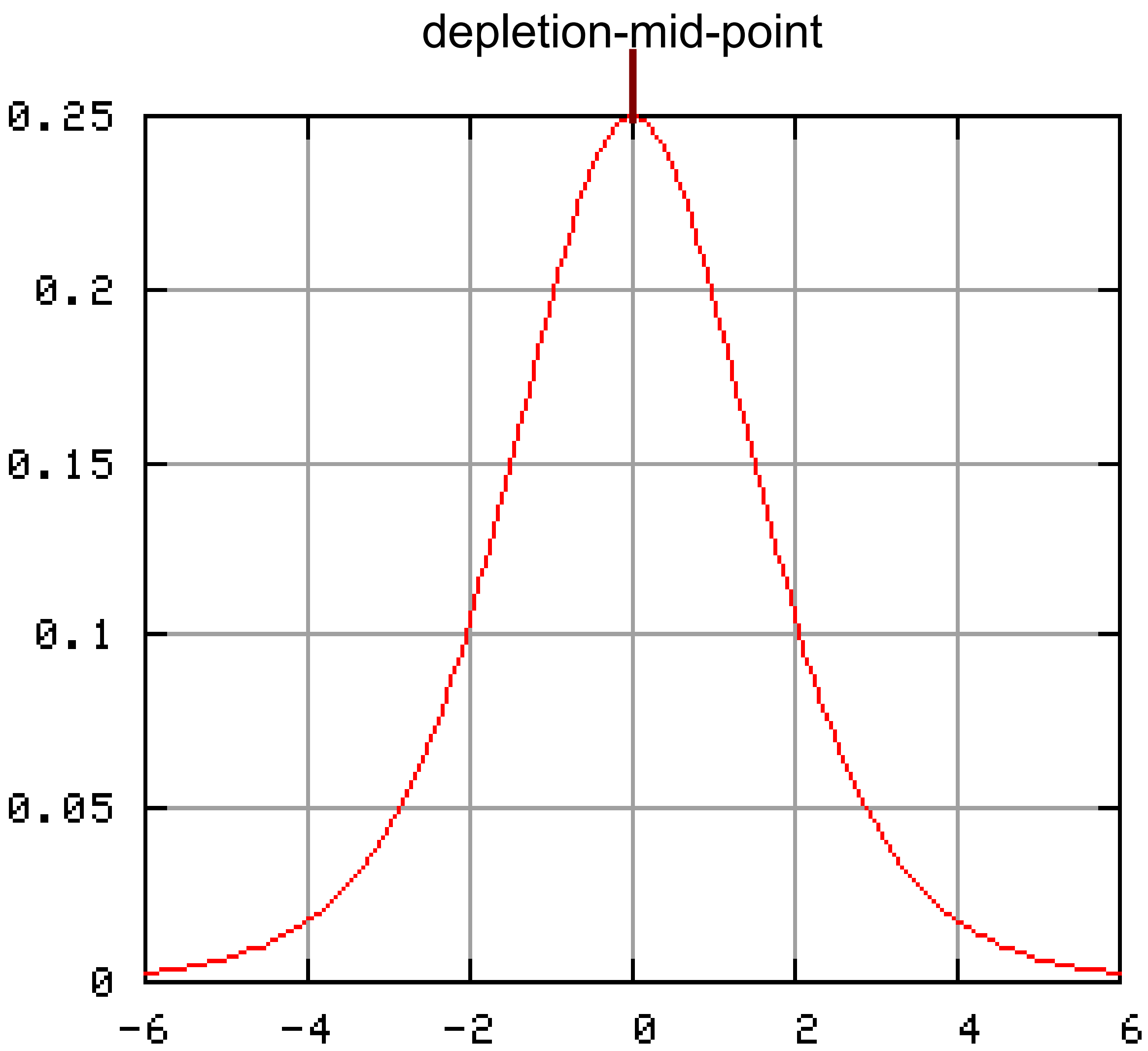
Regional differences in annual per capita oil consumption

Region	USA	BRD	China	India
barrels	26	11.7	1.7	0.8

Annual oil production and oil discoveries



Hubbert curve



Peak oil

1967 in Germany

1971 in USA

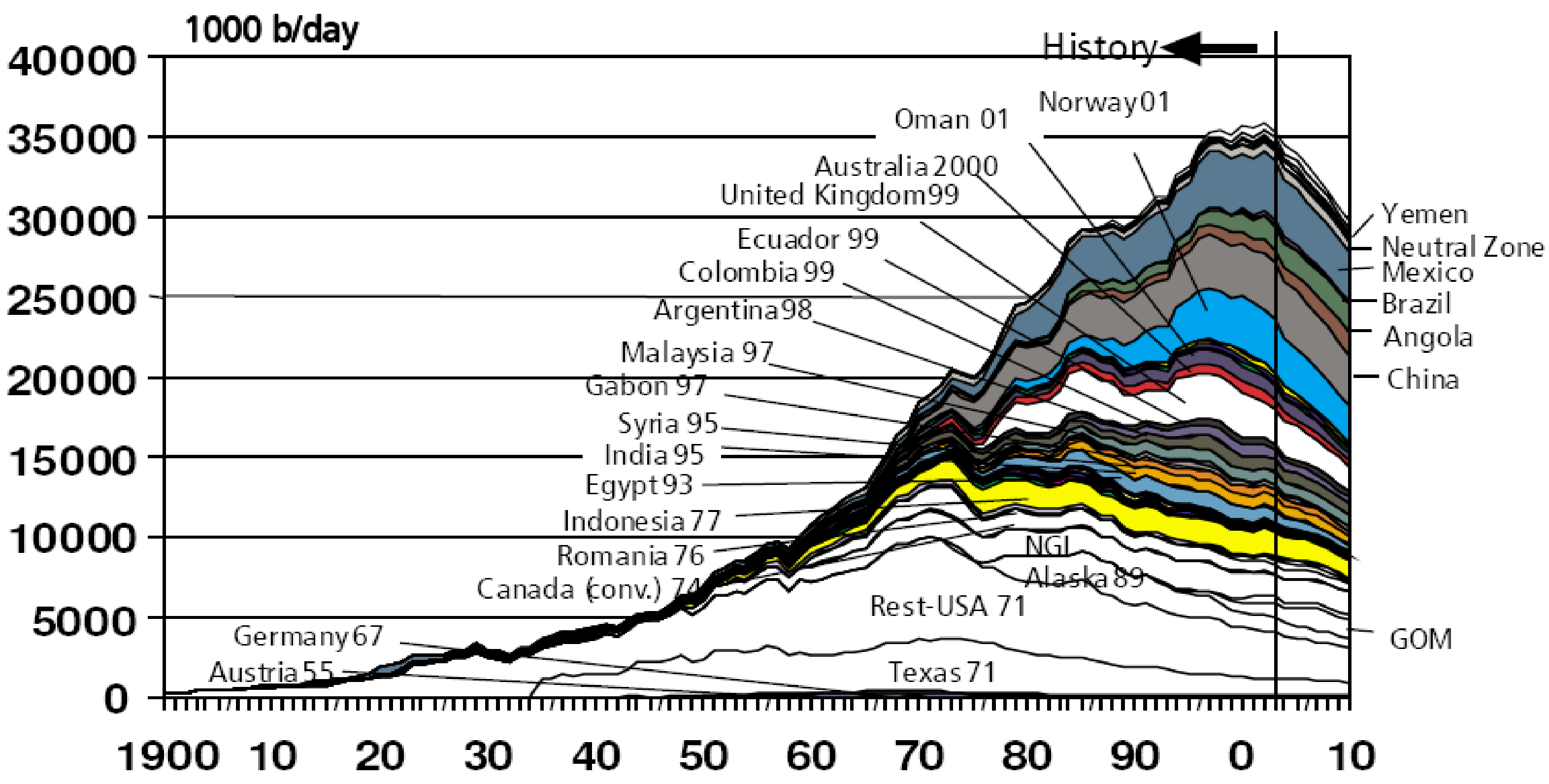
2004 worldwide with OPEC and former SU excluded

not yet in Iraq, Kuwait and Saudi Arabia

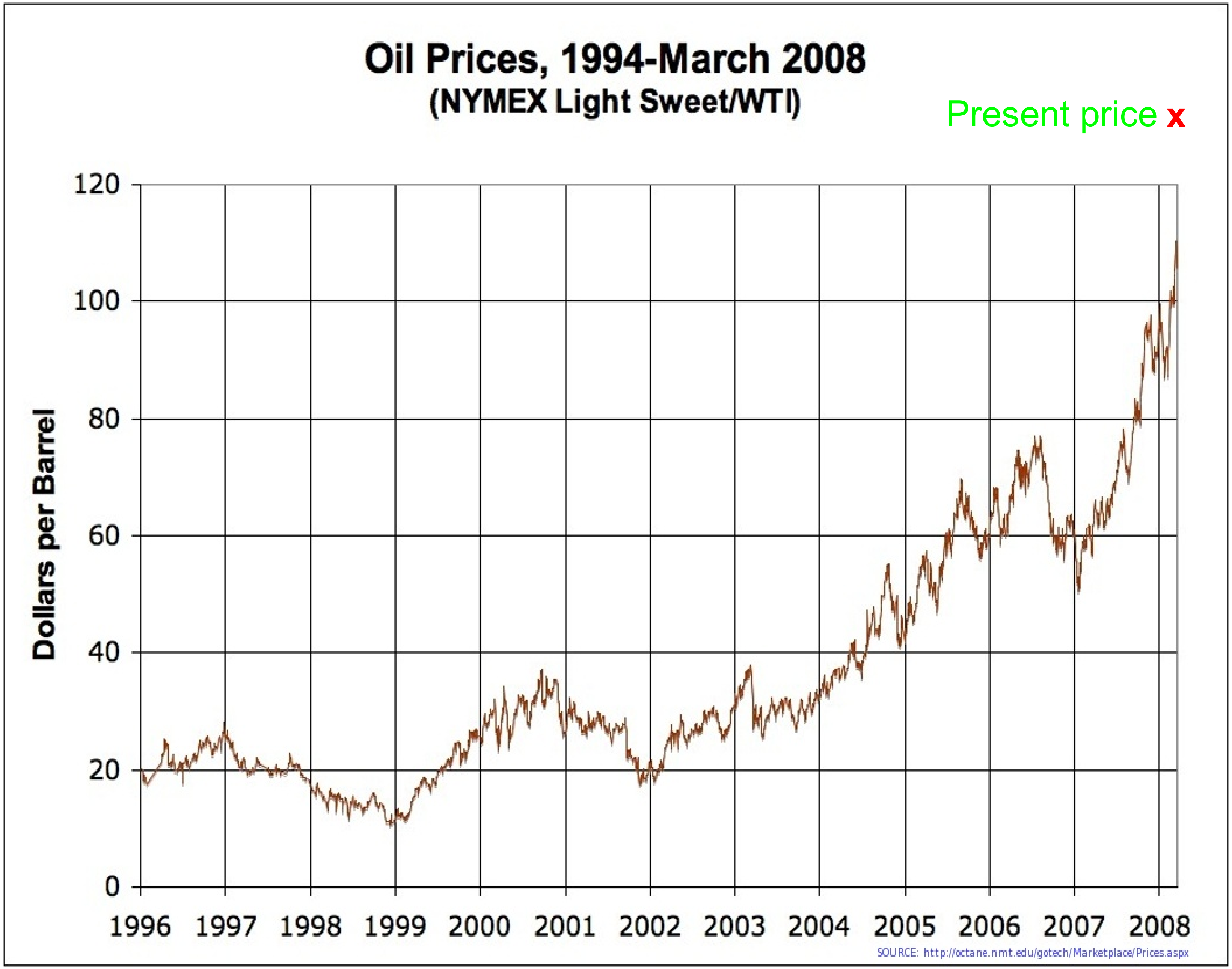
Worldwide peak oil expected between 2005 and 2020

Expected consequences: sharp rise in price and energy crisis

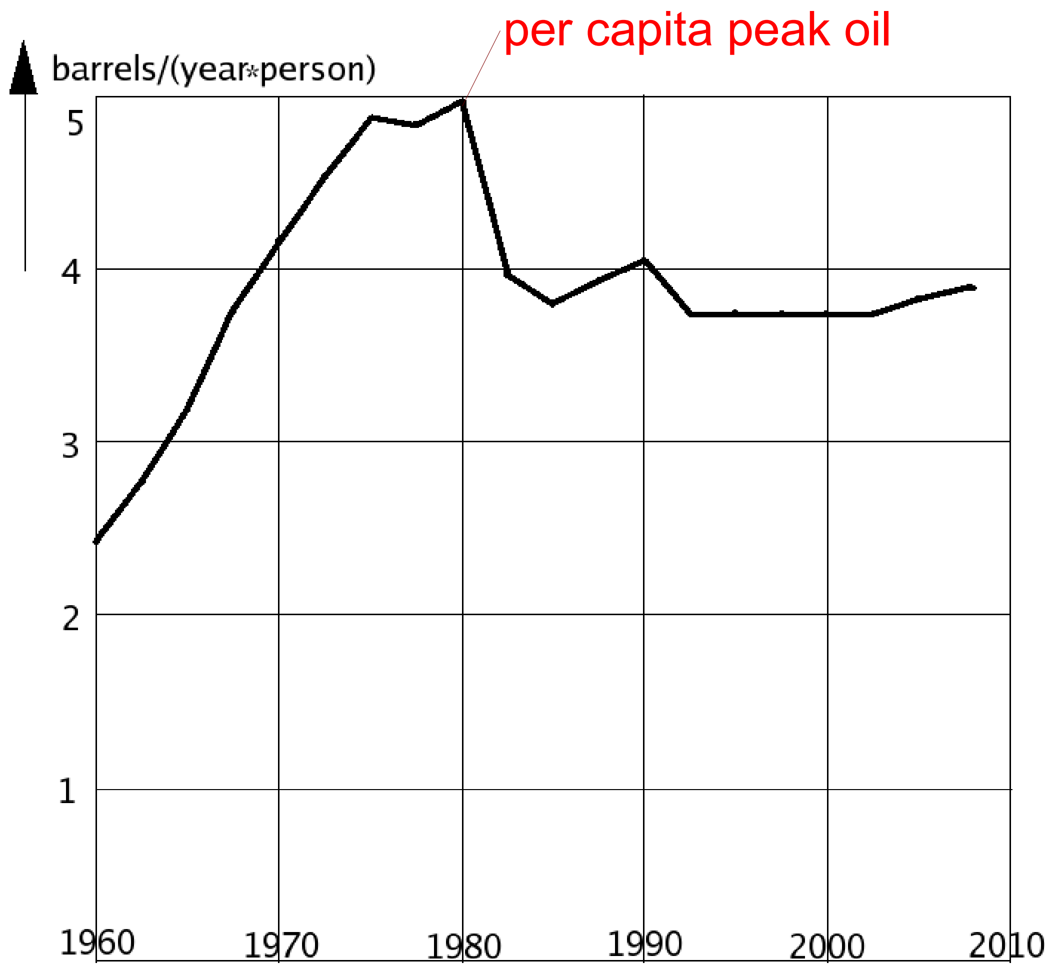
Peak oil of nations



Source: Industry database, 2003 (IHS 2003)
OGJ, 9 Feb 2004 (Jan-Nov 2003)


Oil Prices, 1994-March 2008
(NYMEX Light Sweet/WTI)
Present price x
Dollars per Barrel
120
100
80
60
40
20
0
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
SOURCE: http://octane.nmt.edu/gotech/Marketplace/Prices.aspx

Per capita oil production rate



Per consumer oil peak even before 1980

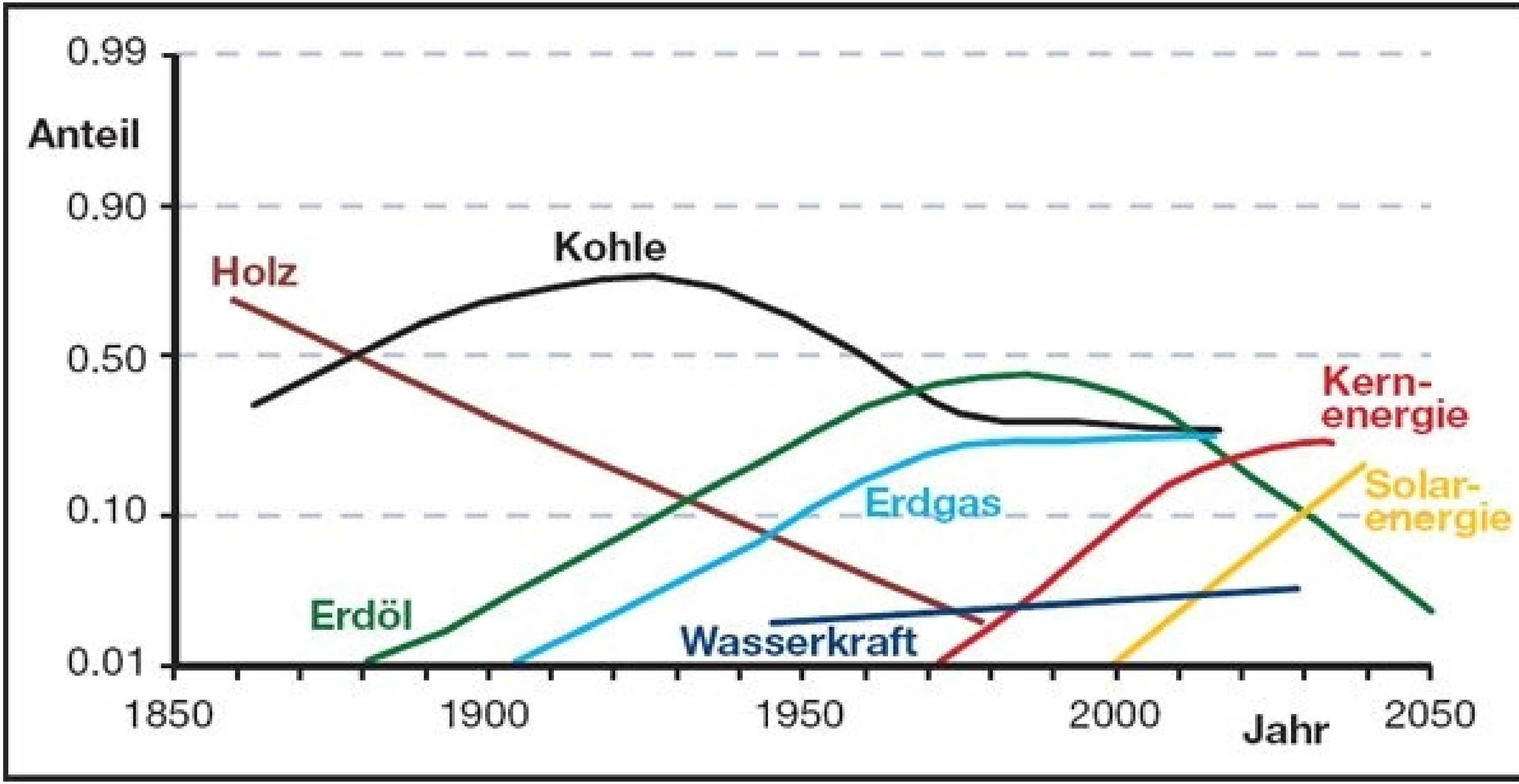
Oil reserves in 2004: 1200 gigabarrels (BP Statist. Rev. of World Energy)
Annual production rate: 27 gigabarrels
Projected reserve life time : 40 years (22 years taking account of rising demand)

Crude oil consists of about 17 000 chemical constituents
→ pharmaceuticals, solvents, fertilizers, pesticides, paints and coatings, detergents, plastics, ...

What a shame to just burn it!

Supply of coal, gas and uranium

energy carrier	peak of production in	reserve life span
oil	2005 - 2020	40 y
natural gas	2015 - 2035	65 y
coal	2020 – 2035	165 y
uranium	?	70 – 220 y



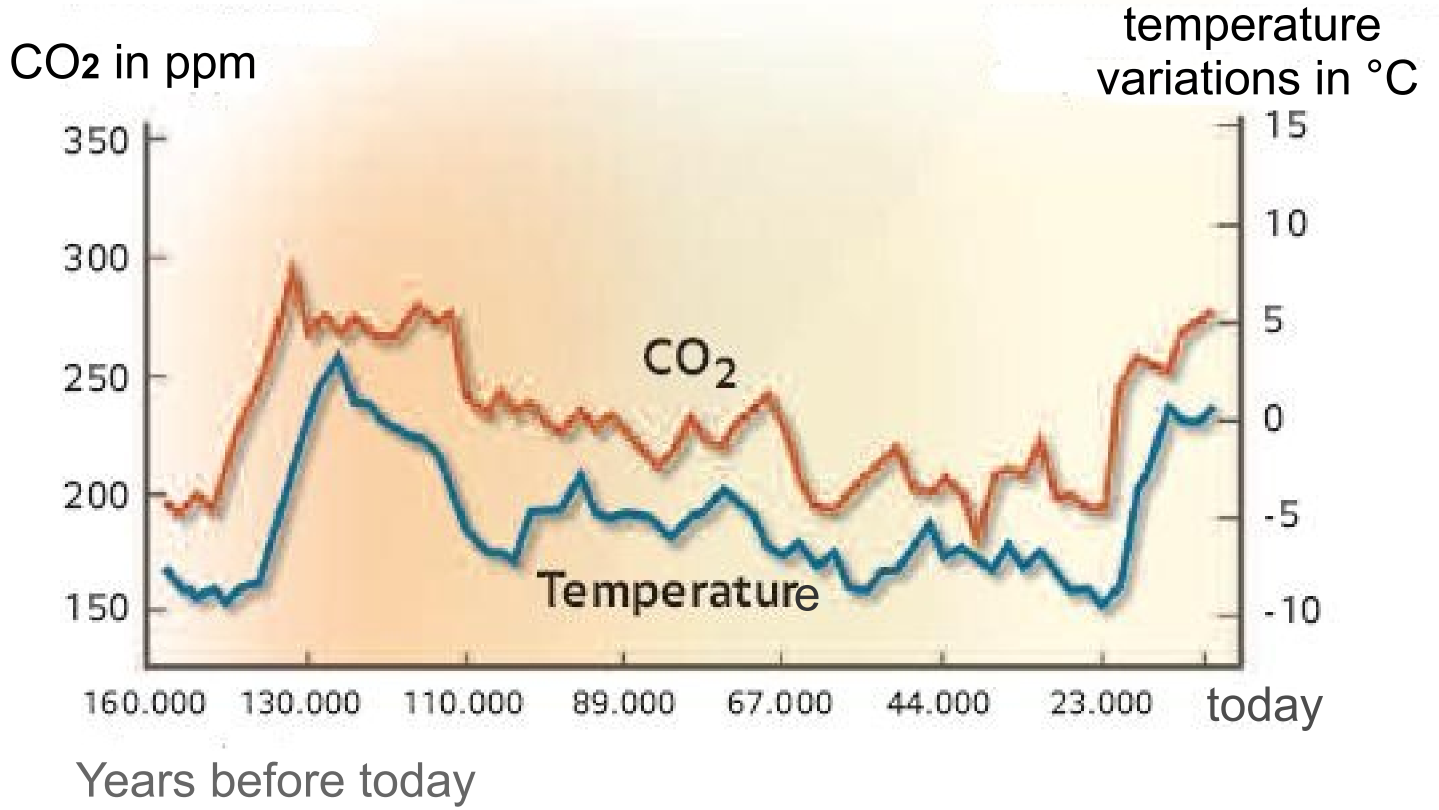
0.99
Anteil
0.90
Kohle
Holz
0.50
Kern-
energie
Erdgas
Solar-
energie
0.10
Erdöl
Wasserkraft
0.01
1850
1900
1950
2000
Jahr
2050

Environmental problems caused by conventional energy usage

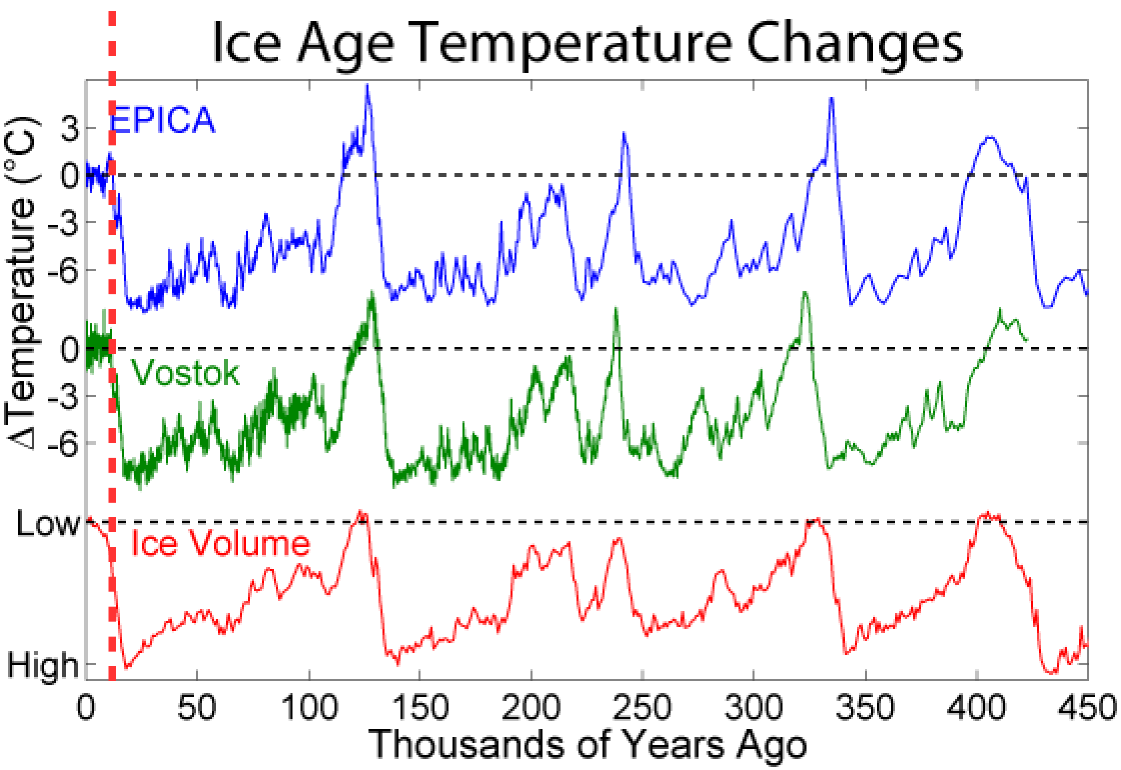
- Pollution, erosion, contamination and flooding of soils
- Pollution and contamination of waters
- Local and global pollution + contamination of atmosphere with consequential damage to fauna and flora
- Environmental burdens through the release of heat
- Local and global climate changes, especially through man made enhancement of greenhouse effect

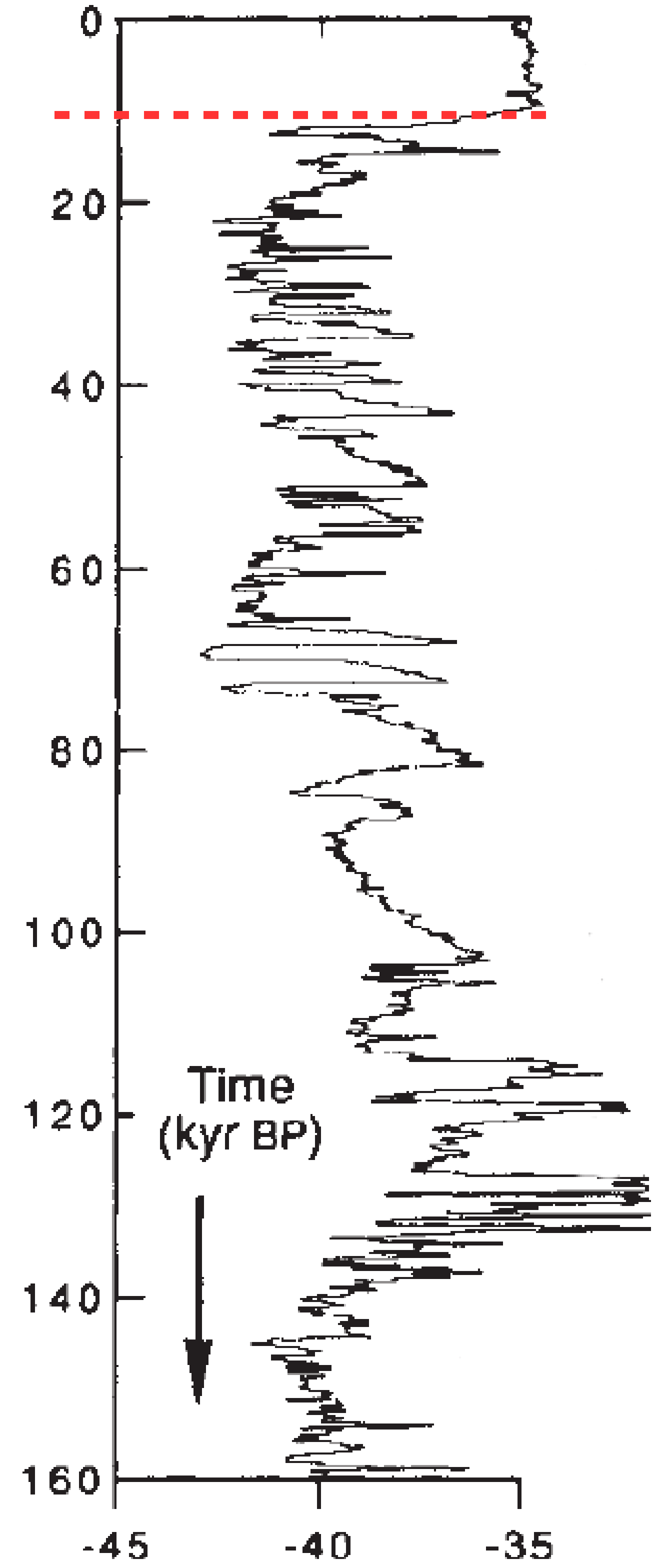
Since 1850 in atmosphere concentration of methane doubled, of CO_2 increased by 30 %

Temperature and CO_2 concentration correlated



Increase of	temperature	sea level
last 100 years	0.7 °C	18.5 cm
next 100 years	2 – 6 °C	20 – 90 cm





3. Identification of the biggest energy spenders

Percentage of the different kinds of primary energy (worldwide)

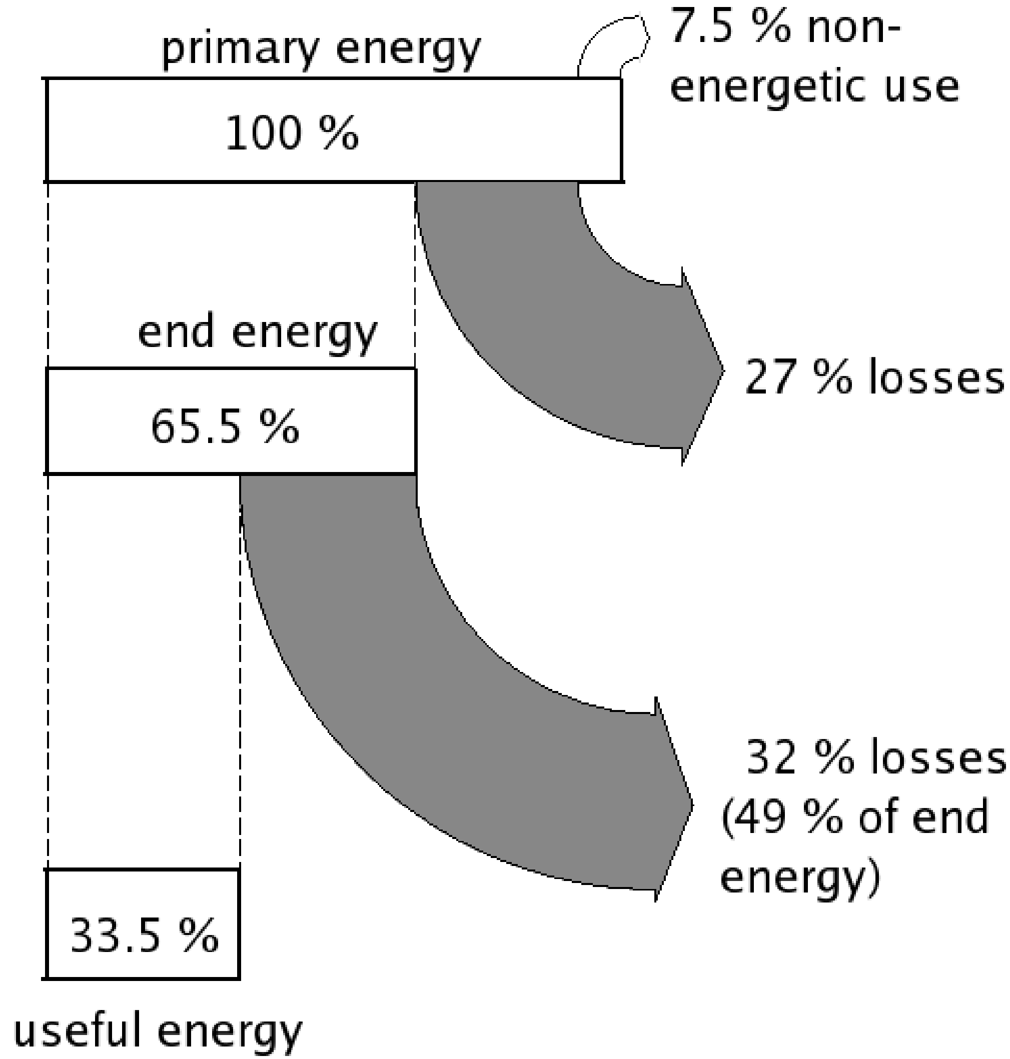
Oil	gas	coal	hydroelectric	nuclear	renewables
38 %	23.2 %	25.3 %	6.3 %	6.3 %	0.9 %

Percentage of the different forms of energy (Germany in 2000)

mechanical energy	industrial heat	room heating	light, information + communication
40 %	26 %	31 %	4 %

Percentage of end energy consumed by different users (Germany in 2000)

traffic	homes	small-scale consumers	industry
30 %	28.5 %	16 %	25.5 %

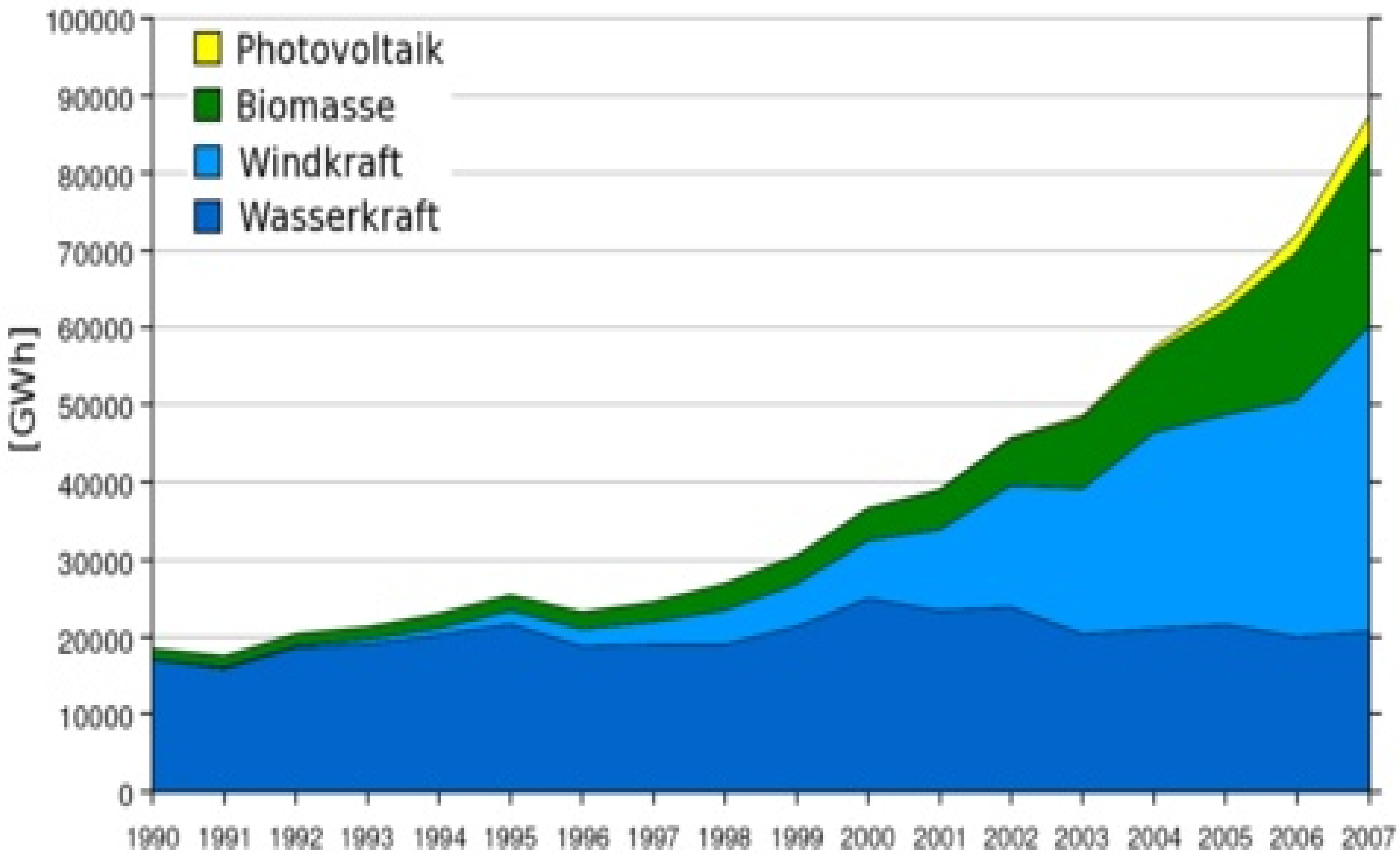

primary energy
100 %
7.5 % non-energetic use
end energy
65.5 %
27 % losses
32 % losses (49 % of end energy)
33.5 %
useful energy

Traffic: biggest spender,
only 20 % end energy finally used (14 % of primary energy)
(Other fields: about 50%)

More than 50 % of end energy → heat

1. 2/3 energy losses from source to final usage → energy saving!
2. Energy saving especially important in traffic and heating

4. Boom of renewable energies



Hydroelectric power

- Water storage power plants
- Damless hydraulic power stations

Worldwide 17 %, Germany 4 % electricity production water powered

Worldwide big enhancement possible (not in Germany)

Wind power

Worldwide 1 %, Germany 6 %, Denmark 19 % electricity prod. wind powered

Up to 5 mW per turbine

Within 15 years wind energy price reduction by factor 2.5, but still subsidized

Financial break even expected in 2010 – 2015

1991 first offshore wind farm in Denmark → high potential expected

Solar power

Solarthermal applications (non-electric)

- Heating of air in homes and greenhouses
- Heating of water in solar thermal collectors
- Cooking
- Water distillation, desalination and disinfection
- Solar chemical processes

Solar electricity

- Photovoltaic electricity
- Solar thermal power plants

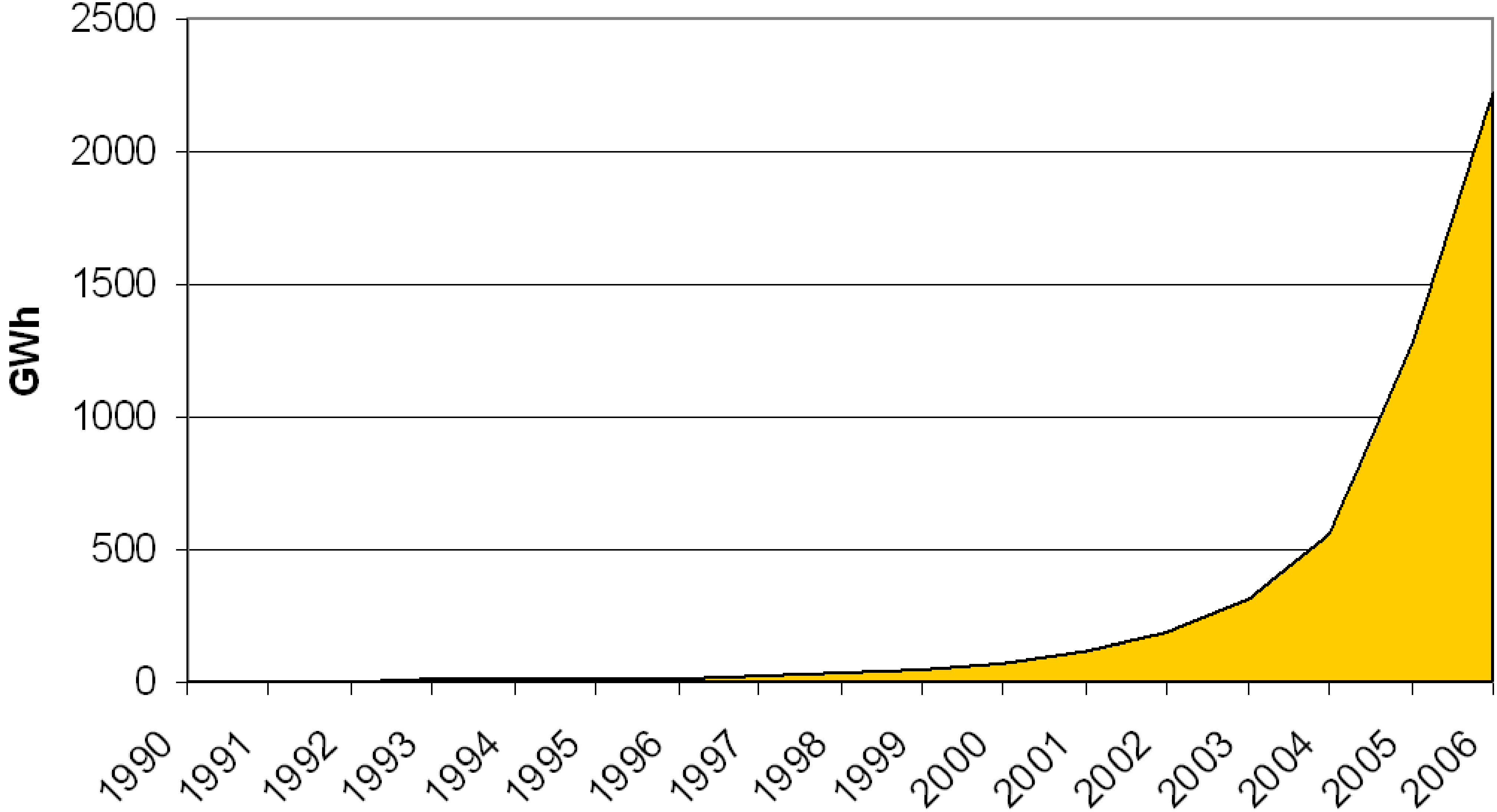
Photovoltaic electricity

No direct sunlight needed, very flexible
--> from pocket calculator to multi-MW PV-station
Cell efficiency 15 %, durability 20 – 40 years
Energetic amortisation after 1.5 – 6 years --> PV not completely CO_2 free
Cost reduction by factor > 2 since 1990, still too expensive (high subsidy)
New materials (organic polymers, metal alloys) --> higher efficiency,
lower costs
Concentrator cells --> large power from small systems

Solar thermal power plants

Direct sunlight needed --> southern countries
High efficiency, energetic amortization after few months
Medium subventions,
Higher manufactoring numbers --> steep reduction in costs

Photovoltaic electricity generation in Germany



Bioenergy

Energy in 3 tons biomass = energy in 1 ton petroleum

Biomass --> production of heat, electricity, liquid fuels and biogas

First generation biofuels : not sufficient and sustainable
(shugar cane, corn etc.) --> food versus fuel debate

Second generation biofuels: sustainable,
(non-food crops, waste biomass) financially not yet competitive (subsidy)
--> biogas and liquid fuel (sundiesel)

Third generation biofuels: algae

Geothermal heat (widely neglected)

Close to Earth´s surface heat from Sun → heat pumps

In deeper layers heat from radioactivity → electric power +
industrial process heat

Concentrated to areas of geothermal anomaly

Appropriate for base load power plants

High drilling costs → high financial risks

Contribution to worldwide power supply $< 1\ \%$

High potential: supply of whole mankind for 30 000 years

5. Promising options

CO_2 sequestration

Role of coal will increase, but highest CO_2 emissions,
exceeding those of oil by factor 1.4 and of gas by factor 1.8

Enhancing efficiency not sufficient: same emissions as gas fired plant of 58 % efficiency requires efficiency of 96 % → CO_2 sequestration

Energy penalty of sequestration: efficiency reduction by about 10 %

CO_2 deposition + enhancement of oil recovery → cost reduction
Successful example: Sleipner platform (Norway)

Nuclear fusion

Fuels: Lithium + Deuterium from stones and water
First fusion power plant in 50 years → too late for present problems

June 2005 decision: ITER will be built in Cadarache (France)

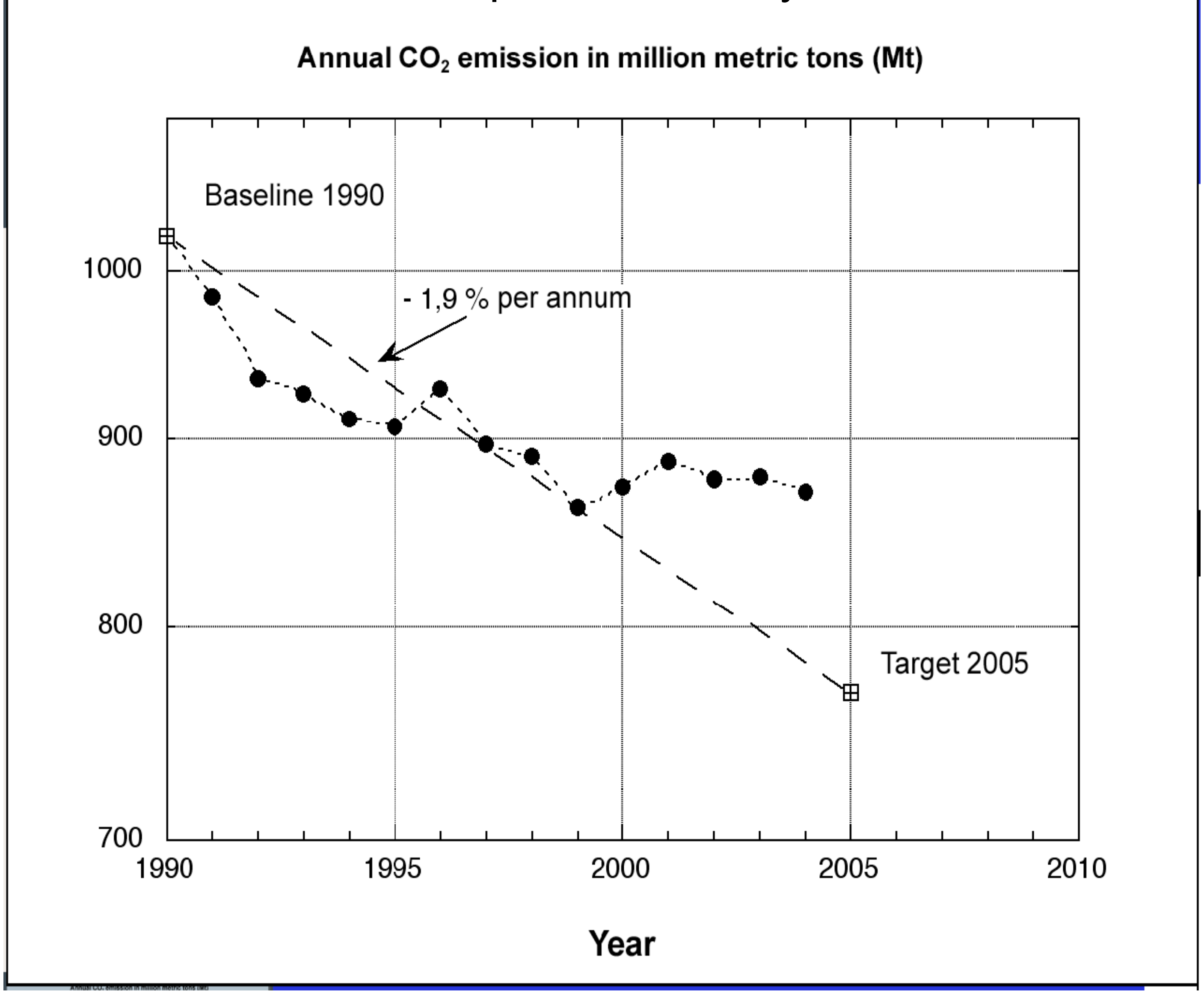
Further options

- Pebble bed reactor
- Transmutation
- Combined heat and power production in homes
- Hydropowered fuel cells: for cars?
  Stationary fuel cells for small scale heat and power production
  (more promising)

6. Challenges

- Highest priority: reduction of greenhouse gases
  Hard to achieve →

Example of Germany



- Limitation of temperature rise to < 2°C in one century
  only for
  cut down of CO_2 emissions worldwide by 50 % ,
  in industrialized countries by 80 %
  until 2050 (IPCC)

- Immediate action required, waiting for climatic damage
  raises cost by factor up to 20 (Stern report)

- Decoupling of energy consumption from economic growth

- Energy saving by
  - Raising efficiency
  - Streamlined energy usage → energy management
  - Substitution of energy sources and energy consuming devices
  - Sacrificing energy use wherever possible

- Global dimension of energy shortage and environmental hazards
  → avoid wars!