CZ-AT WINTER-SUMMER SCHOOL

INTRODUCTION TO "ENERGY SYSTEMS"

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CONTENT:

1. *Motivation: Energy problems*
2. *Basic principle: Providing energy services – not consumption of energy !*
3. *What is an energy system?*
4. *“Currencies”: Units & conversion factors*
5. *Dynamics: Why history is important*
6. *Drivers of energy consumption: How to head towards sustainability*

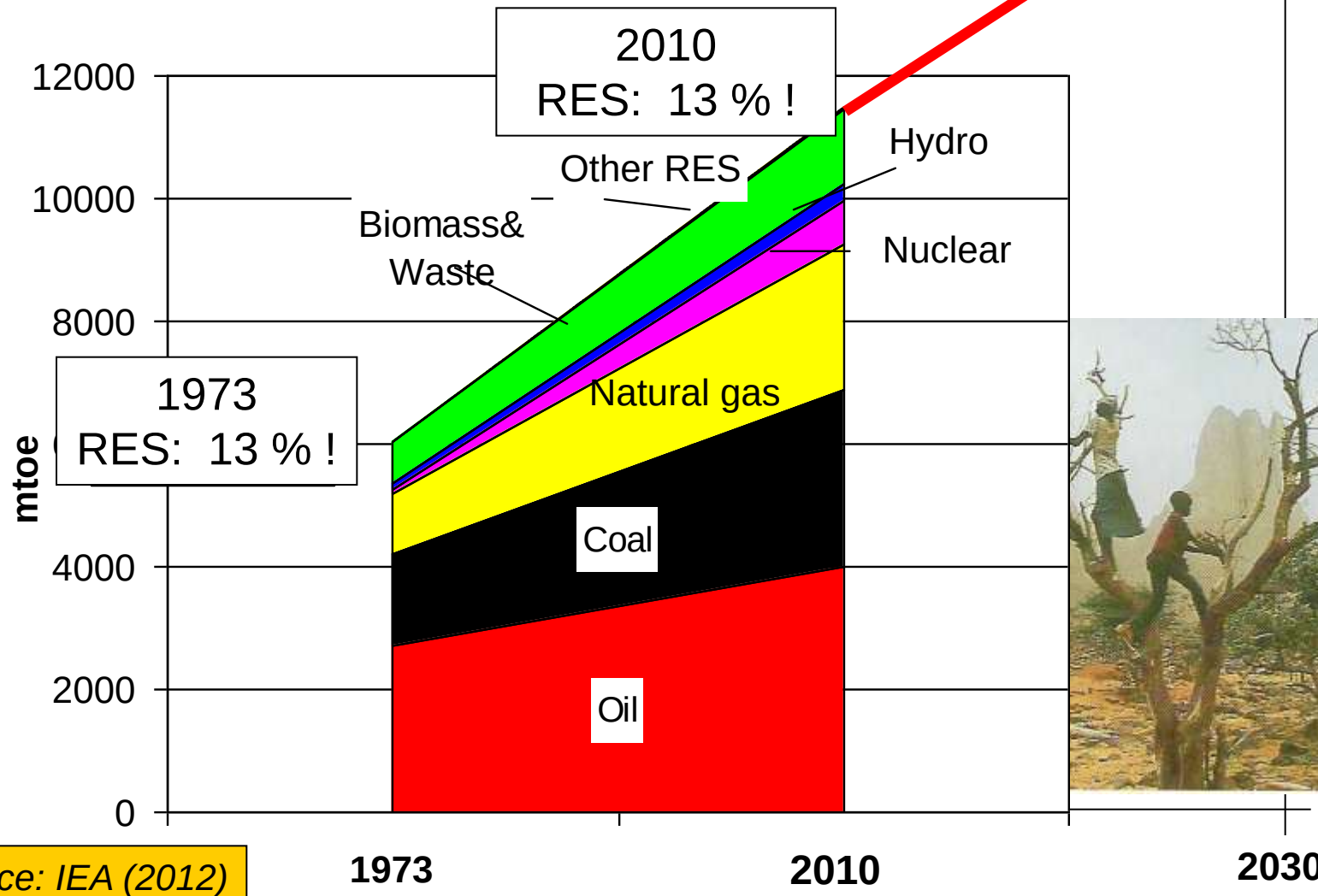
1. MOTIVATION:

Why are we here today?

- Energy is the fundament of our standard of life today
- Every second of our life – even in deep sleep – we „consume“ energy

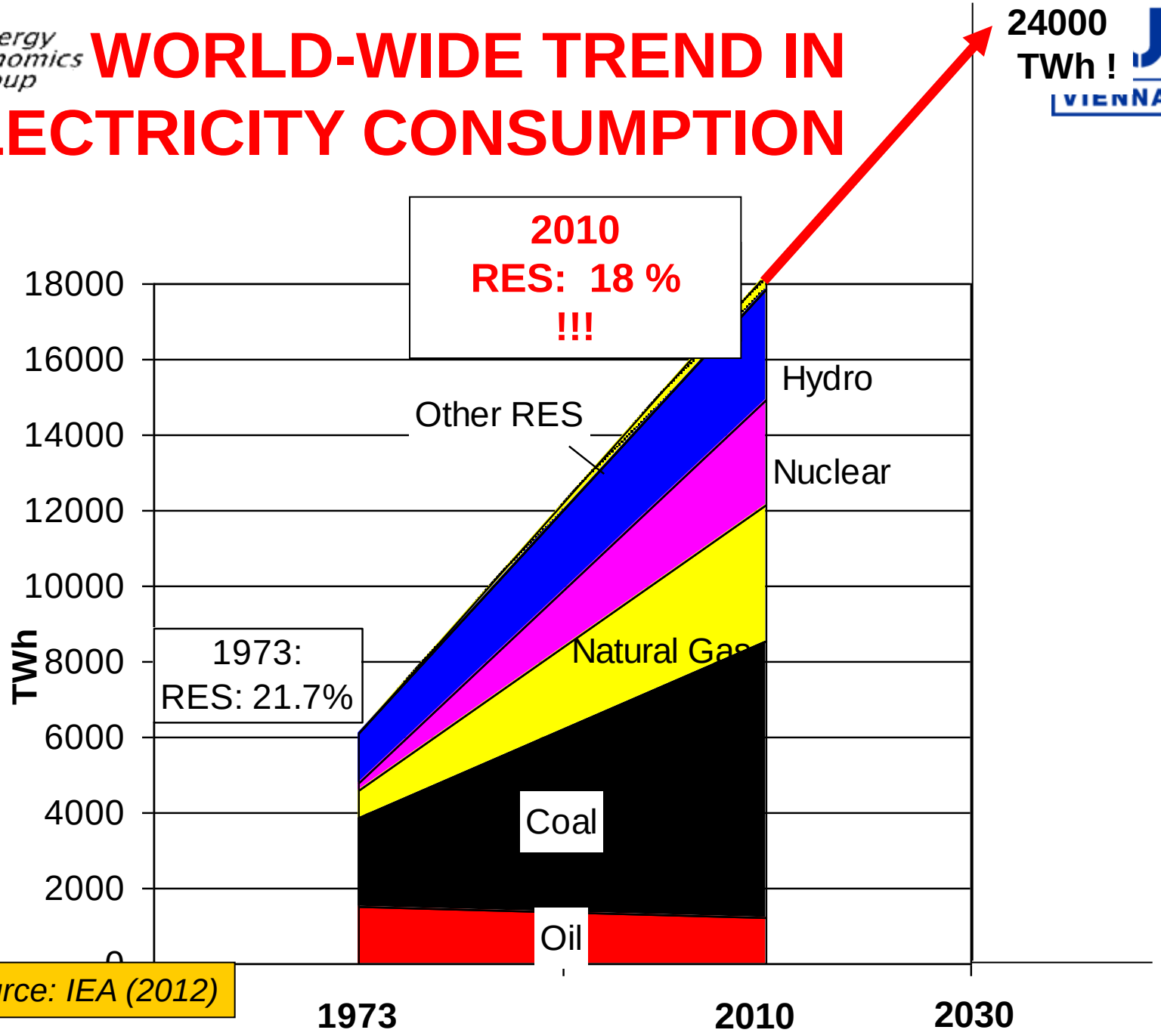
- Dramatic increase in energy consumption in recent years!
- Dramatic increase in energy consumption in the next decades expected!

WORLD-WIDE TREND IN PRIMARY ENERGY CONSUMPTION



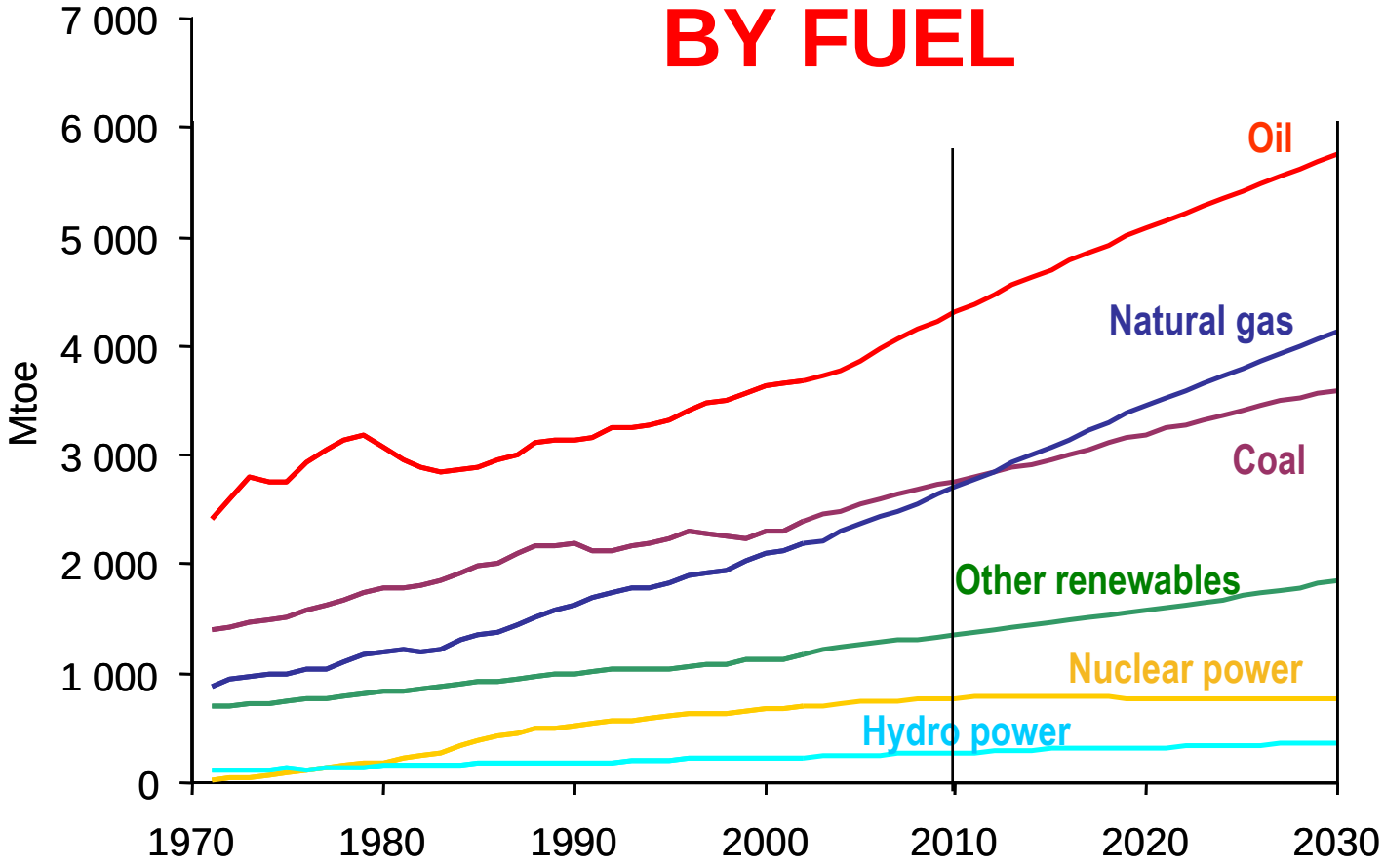
Source: IEA (2012)

WORLD-WIDE TREND IN ELECTRICITY CONSUMPTION



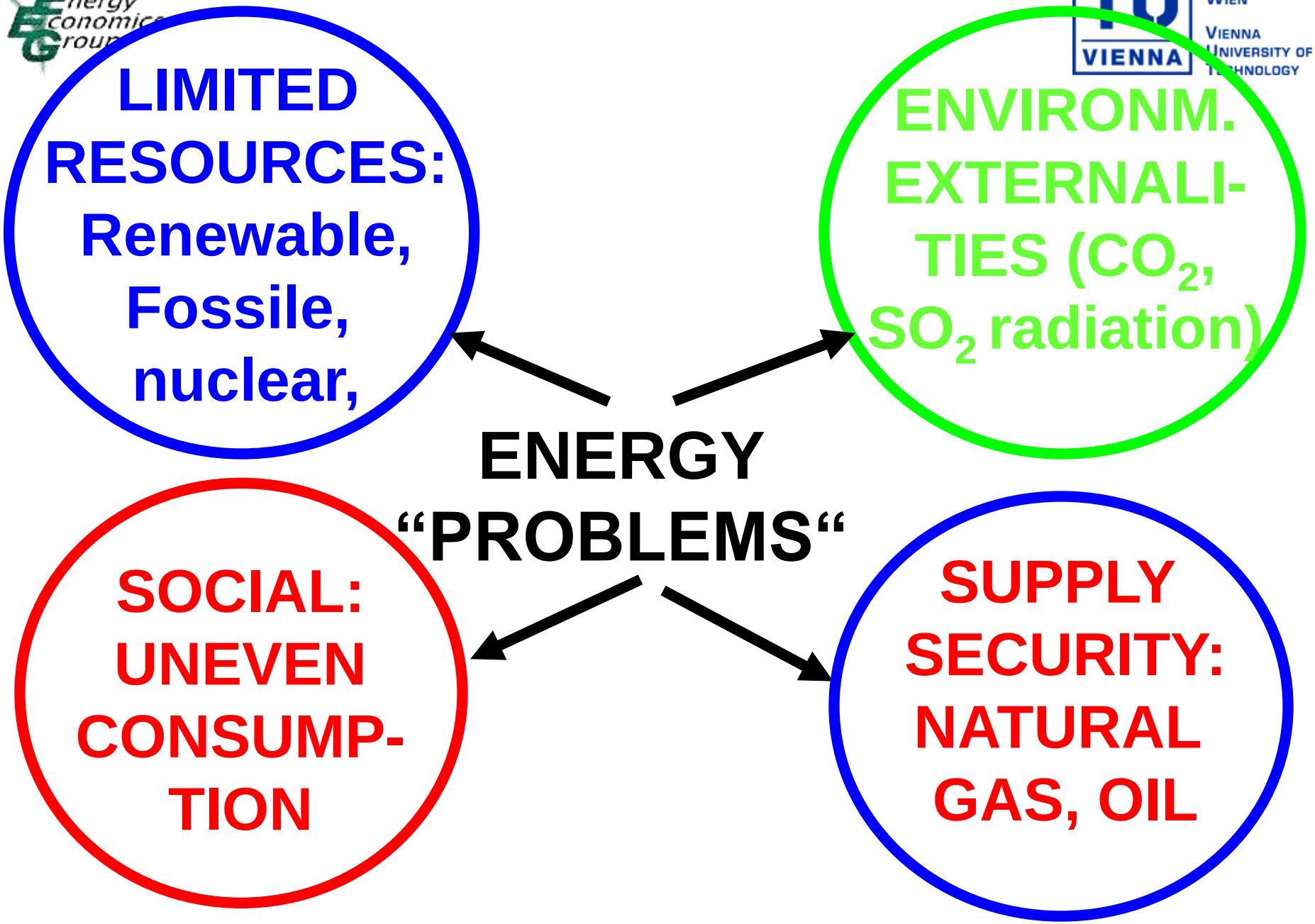
Source: IEA (2012)

PRIMARY ENERGY: TRENDS BY FUEL

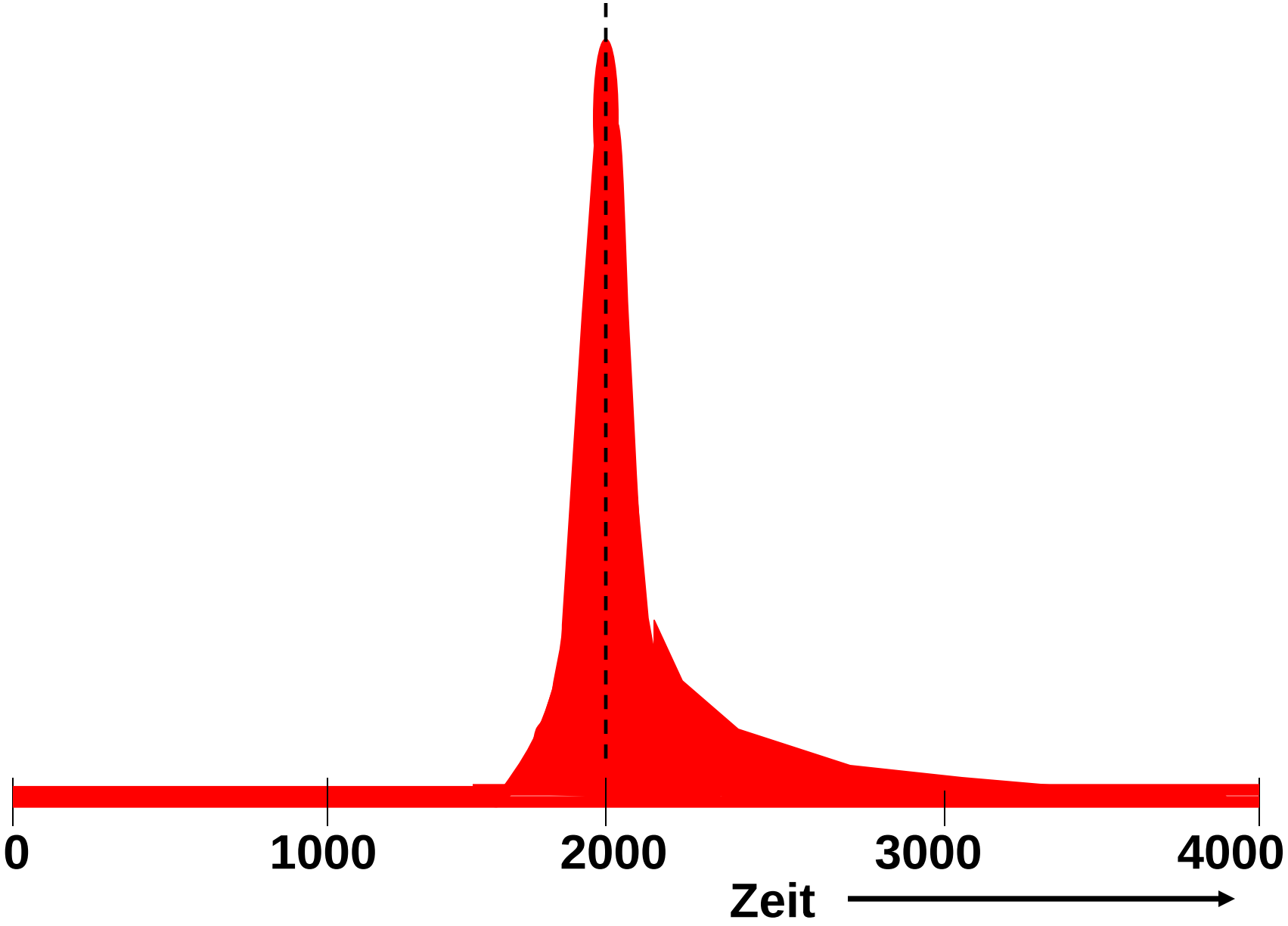


IEA: Fossil fuels will continue to dominate the global energy mix, while oil remains the leading fuel!

Source: IEA (2012)


LIMITED RESOURCES: Renewable, Fossile, nuclear,
ENVIRONM. EXTERNALI-TIES (CO_2, SO_2 radiation)
ENERGY "PROBLEMS"
SOCIAL: UNEVEN CONSUMP-TION
SUPPLY SECURITY: NATURAL GAS, OIL

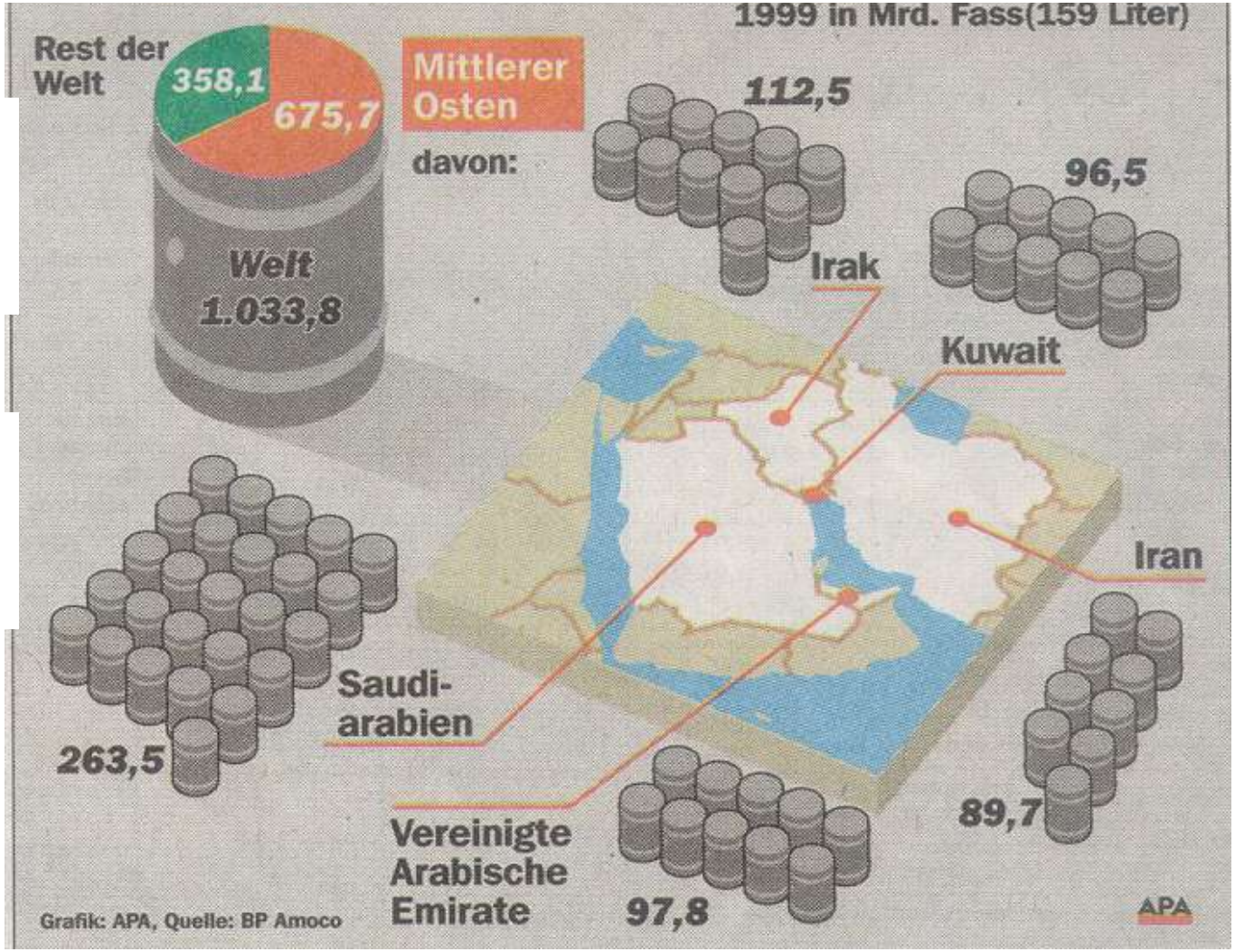
Oil consumption over time



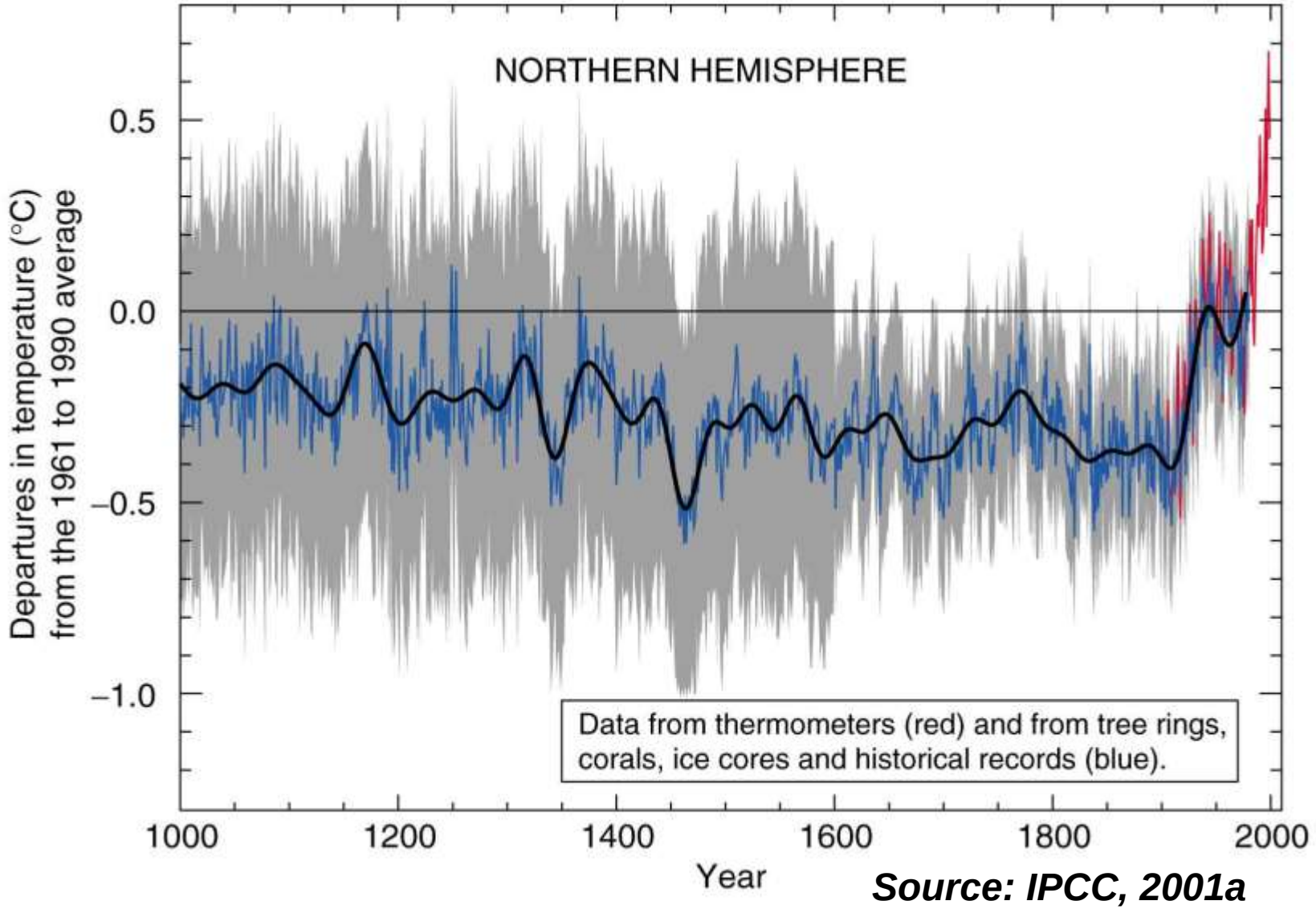
Oil reserves in the Middle East

Middle East: 2/3

Rest of world: 1/3



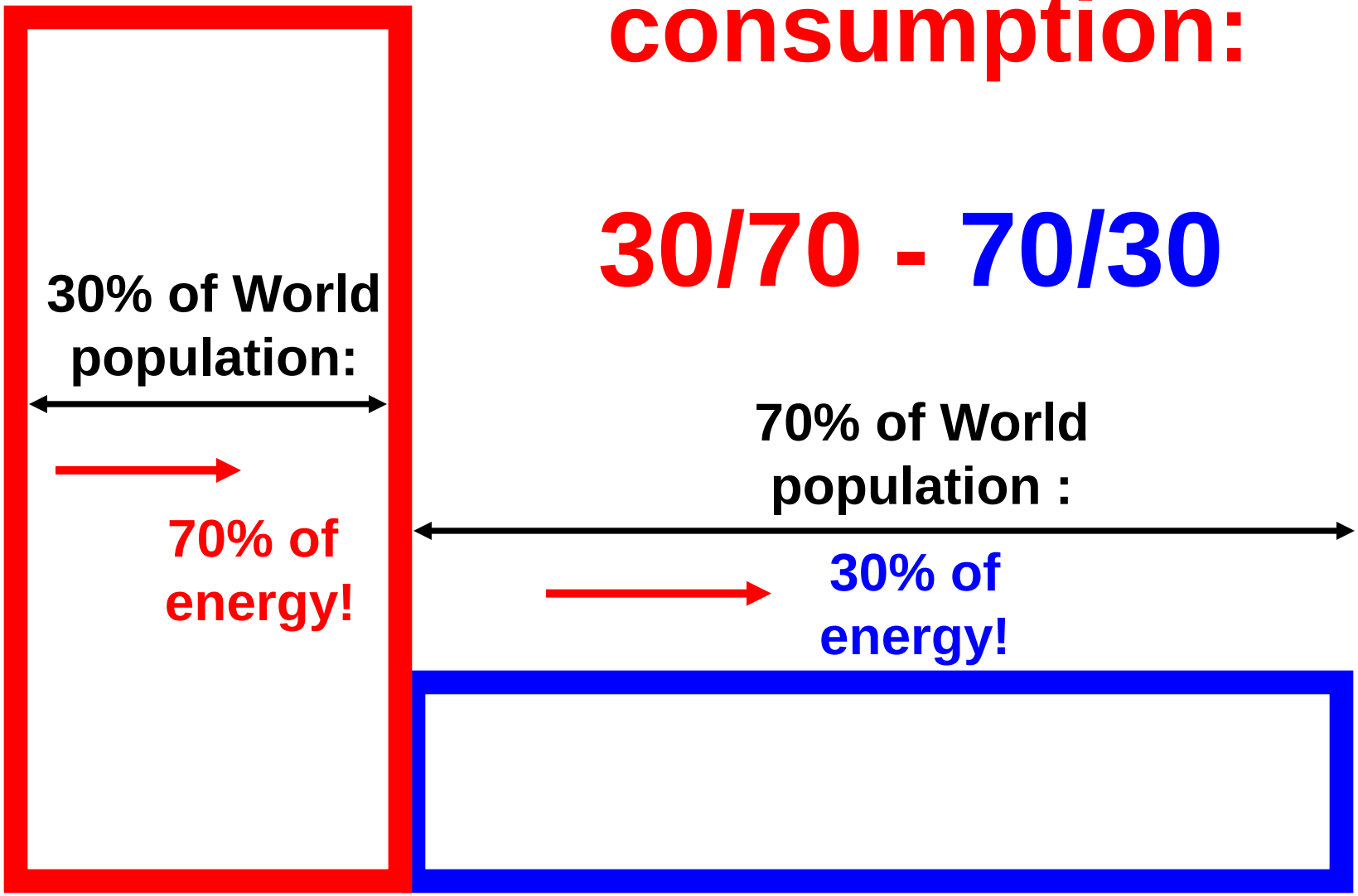
Variations of Earth's Surface temperature in the past 1000 years



Source: IPCC, 2001a

Uneven consumption:

30/70 - 70/30



Material World: Natomo Family, Mali

Source: Menzel, 2001

Material World: Ukita Family, Japan

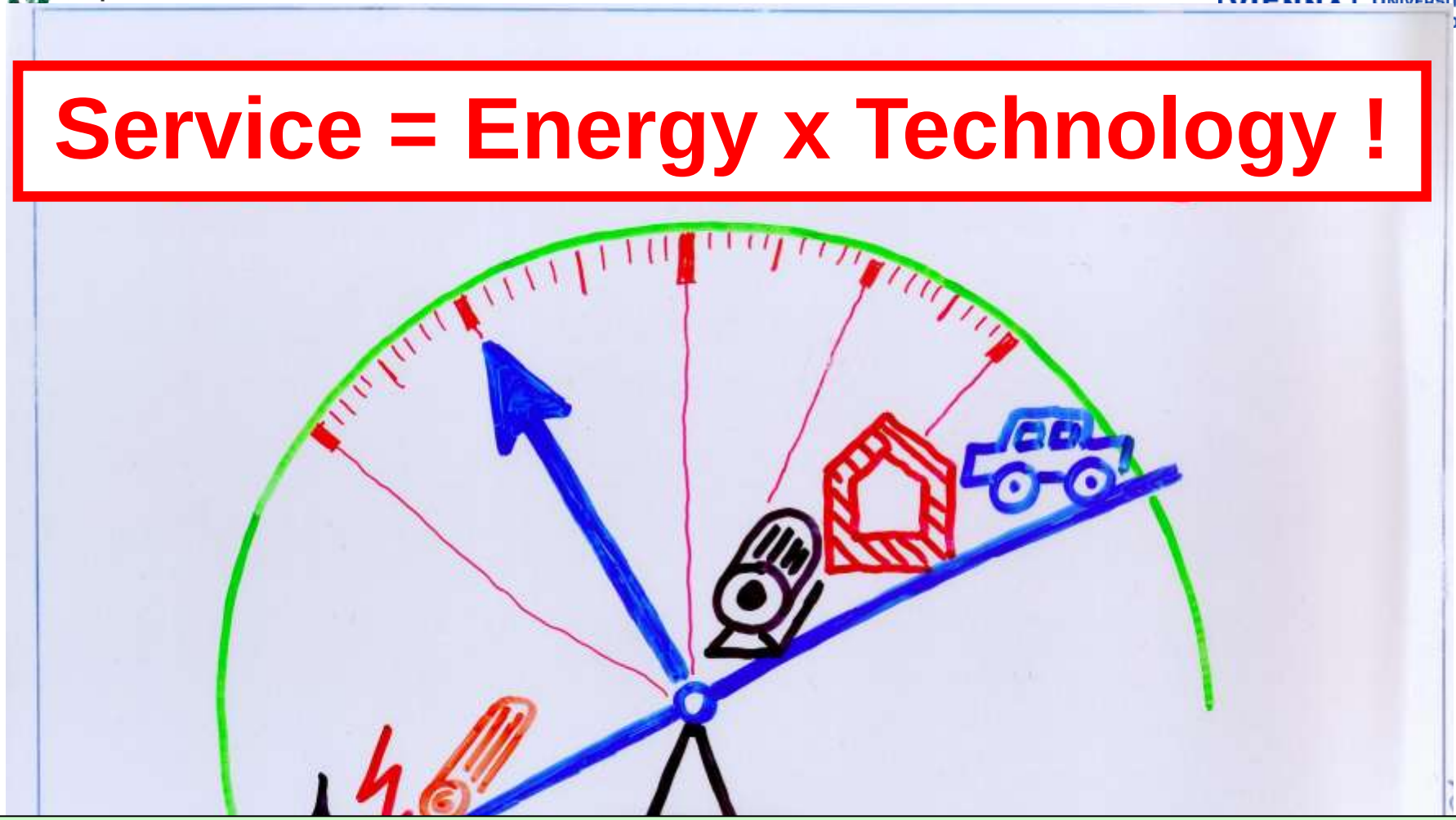
Source: Menzel, 2001

2. The basic concept of providing energy services

- There is no interest to consume energy. There is a demand for energy services: clean shirts, warm and bright rooms, cold beer, hot coffee.
- Inputs: Energy, Technology, human capital, environment
- Energy services are produced :

$$S = E \ \eta (T)$$

Service = Energy x Technology !



- ***But currently the balance is biased tremendously: To much energy, far to less technical efficiency!***

What are energy services?

Direct energy services:

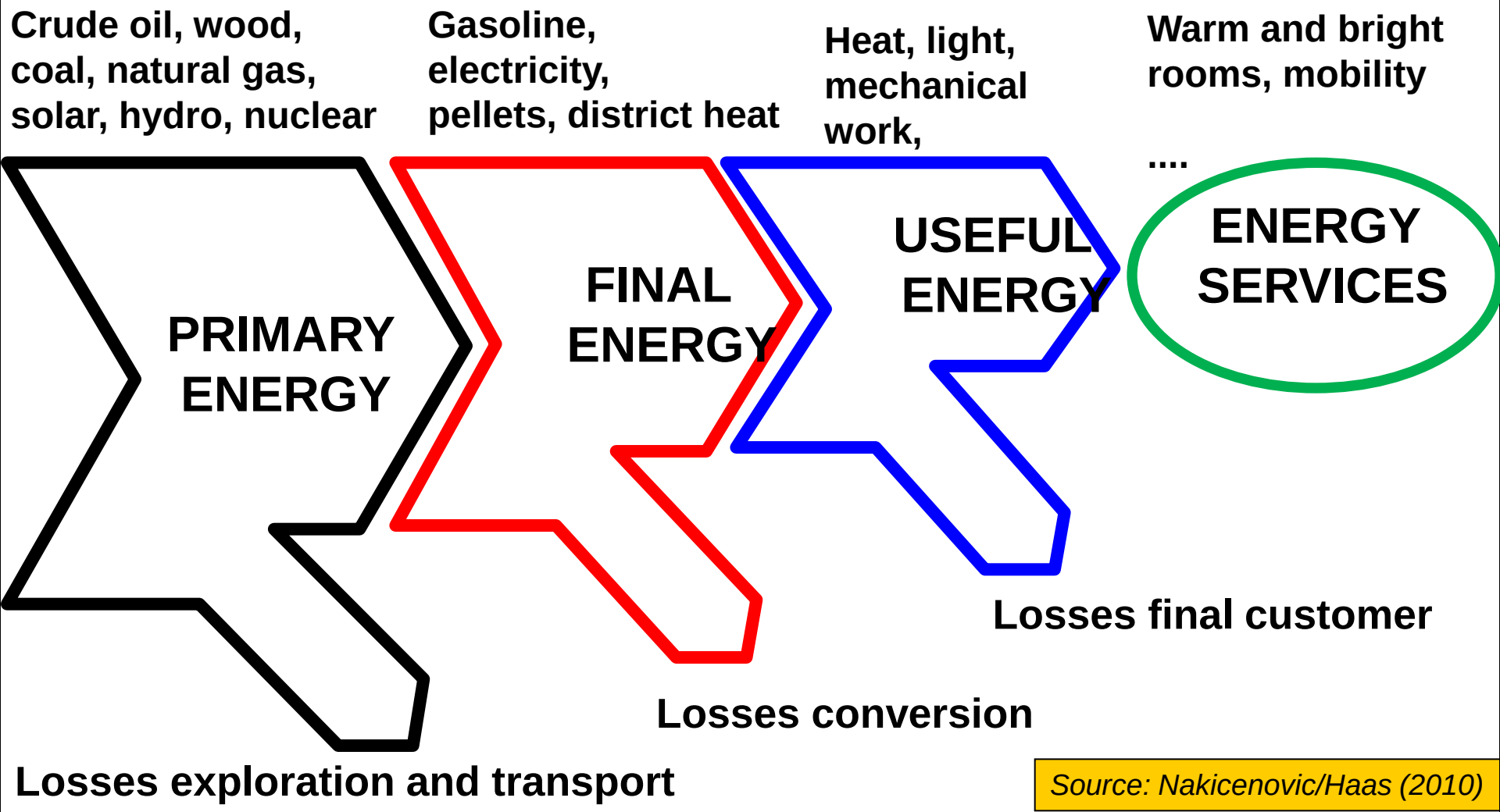
- Lighting
- Heating, cooking
- Mobility, Transport
- …

Indirect energy services:

- Food
- Shoes, Shirts
- Communication
- What you can buy in a super market!

The energy chain

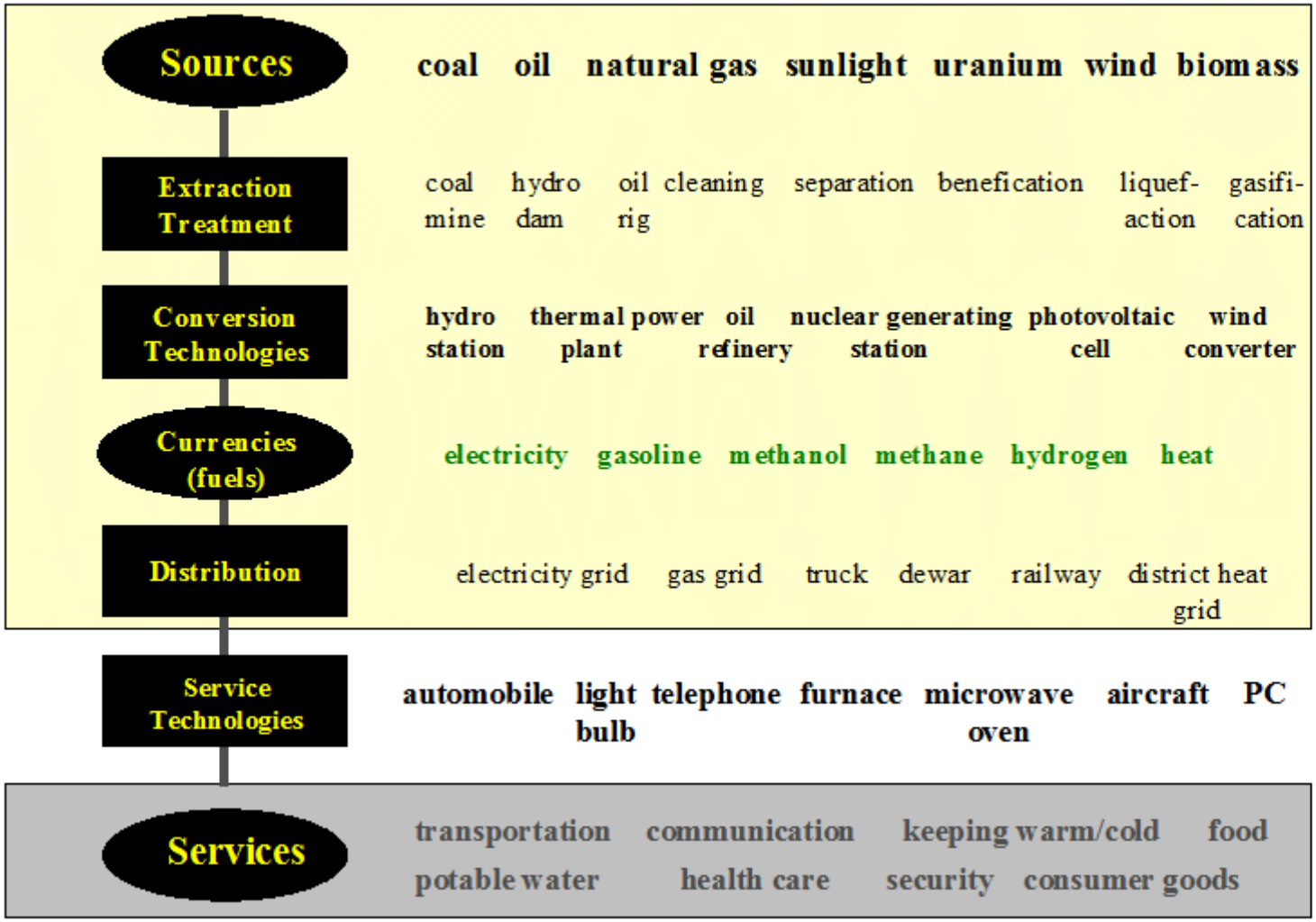
Categories of energy:



Source: Nakicenovic/Haas (2010)

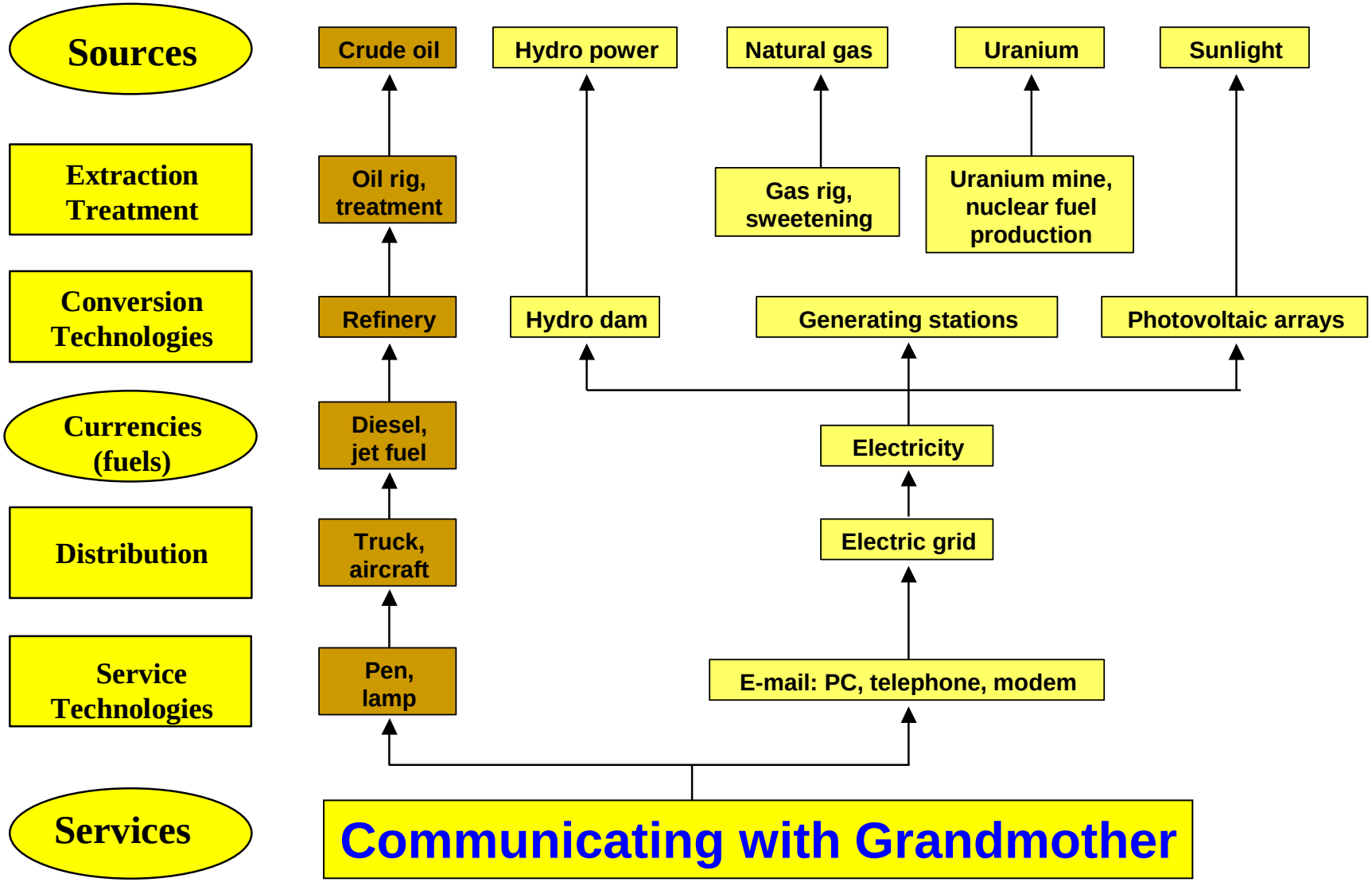
3. What is an energy system?

Architecture of the Energy System



Source: Nakicenovic et al (1997)

ARCHITECTURE OF THE ENERGY SYSTEM: EXAMPLE!



Source: Nakicenovic/Haas (2010)

4. Units ("Currencies") and conversion factors for measuring energy demand

Units for Orders of Magnitude

Symbol	Name	Magnitude	Number	Expression
P	Peta	1E+15	1 000 000 000 000 000	quadrillion
T	Tera	1E+12	1 000 000 000 000	trillion*
G	Giga	1E+09	1 000 000 000	billion
M	Mega	1E+06	1 000 000	million
K	Kilo	1E+03	1 000	thousand
h	Hekto	1E+02	100	hundred
da	Deka	1E+01	10	ten
-		1E+00	1	one
d	Dezi	1E-01	0.1	tenth
c	Centi	1E-02	0.01	hundredth
m	Milli	1E-03	0.001	thousandth
µ	Mikro	1E-06	0.000 001	millionth
n	Nano	1E-09	0.000 000 001	billionth
p	Piko	1E-12	0.000 000 000 001	trillionth

* UK: milliard = 1E+12

Source: Nakicenovic/Haas (2005)

Some basic reflections:

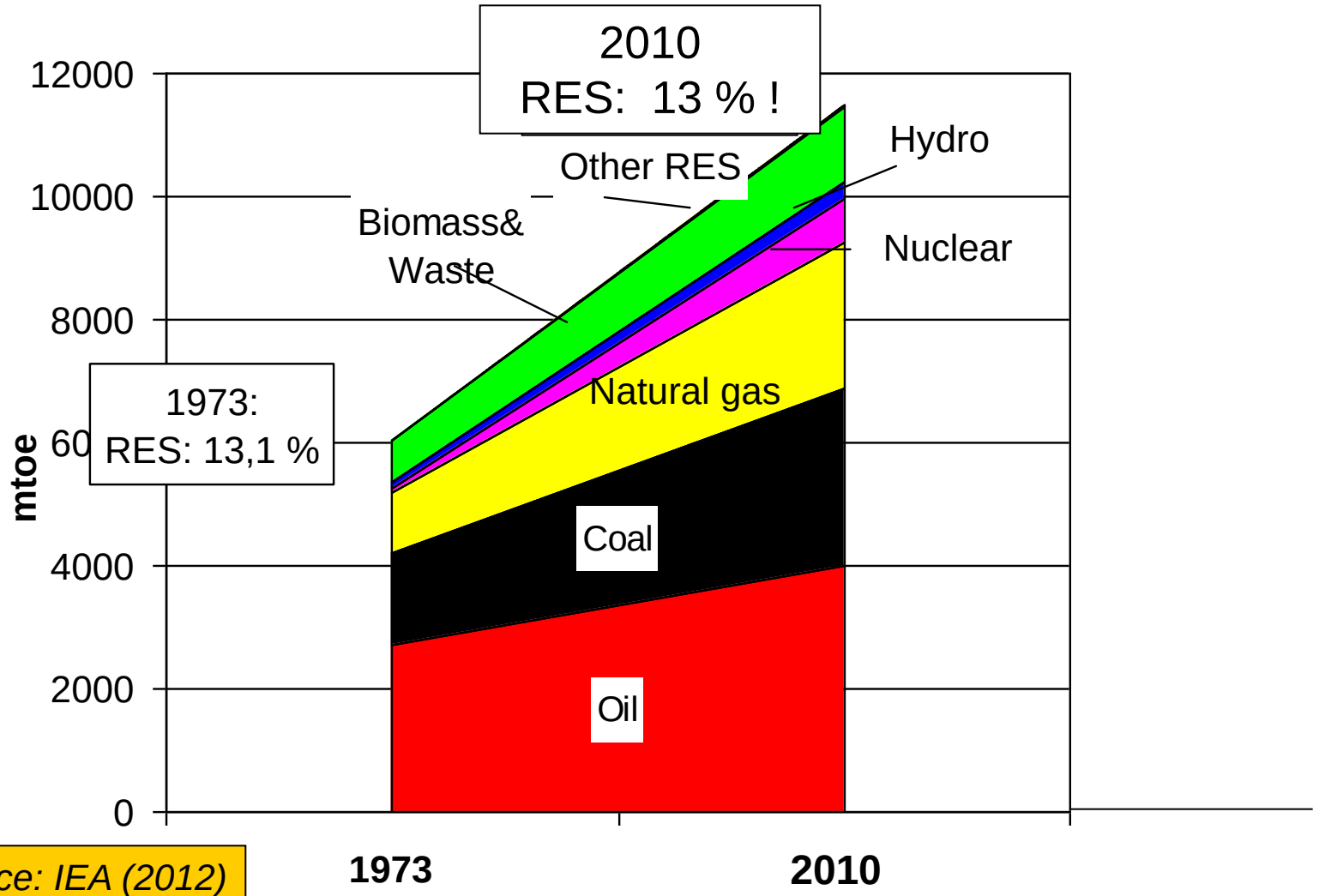
1 Wh = 3600 Ws = 3600 J =3.6 kJ

1 kg oe = 11.63 kWh = (X 3.6) 41.87 MJ

(1 BTU = 1055 J)

1 Cal = 4.19 J

WORLD-WIDE TREND IN PRIMARY ENERGY CONSUMPTION



Source: IEA (2012)

Useful conversion factors on country level

1 TWh = 3.6 PJ = 0.086 mtoe

1 PJ = 0.2778 TWh = 0.0239 mtoe

1 mtoe = 41.87 PJ = 11.63 TWh

(10^{12} BTU = 1.055 PJ)

Example 1:

World energy consumption (PE):

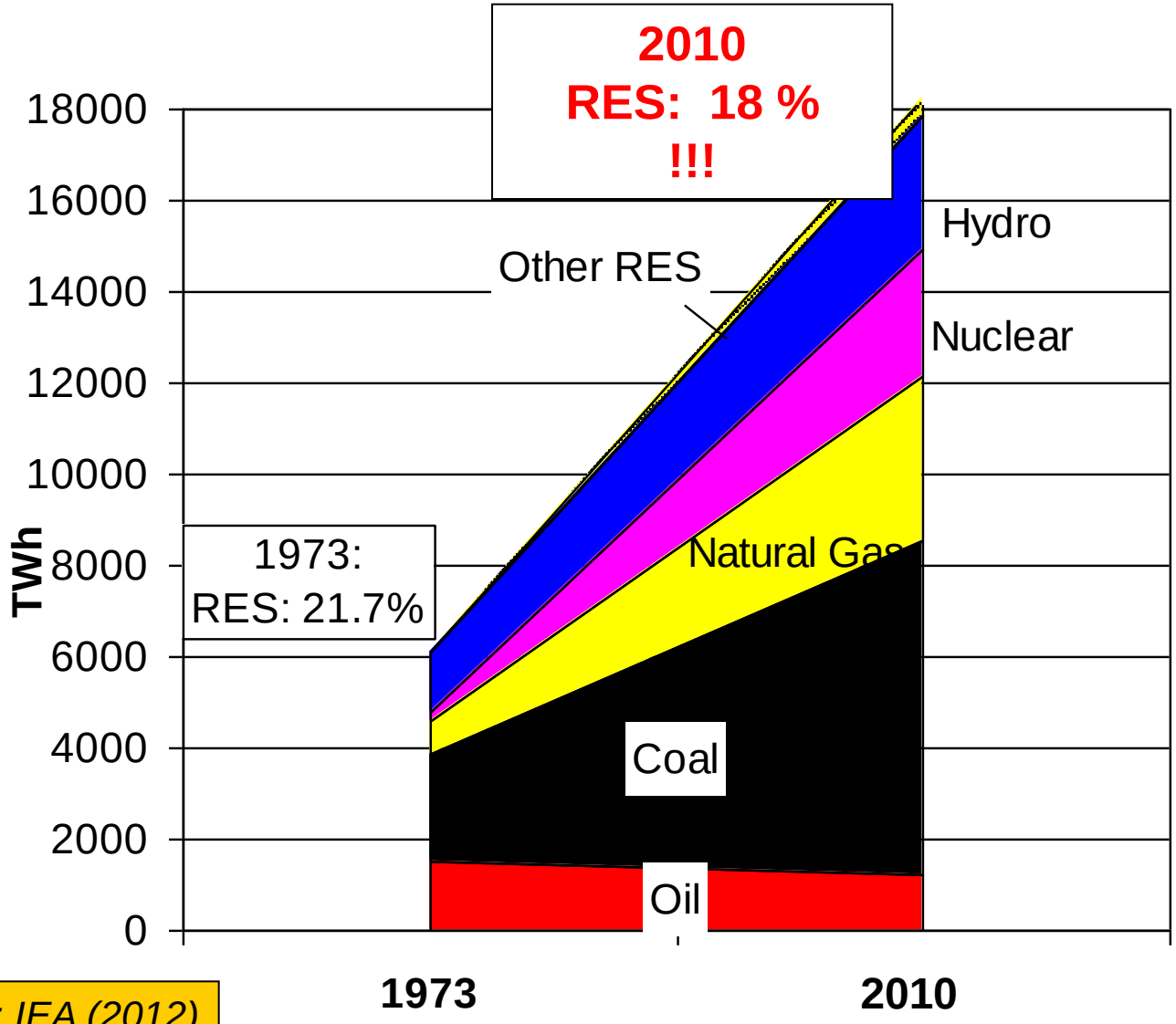
12000 mtoe = 500 000 PJ = 500 EJ (Exa-Joule)

Example 2:

World electricity consumption (PE):

15000 TWh = 54000 PJ

WORLD-WIDE TREND IN ELECTRICITY CONSUMPTION



Source: IEA (2012)

Examples:

Selected countries :

Austria: 33.2 mtoe PE, 65.8 TWh electricity

Czech Republic: 44.1 mtoe PE, 61.9 TWh electricity

Hungary: 26.3 mtoe PE, 36.8 TWh electricity

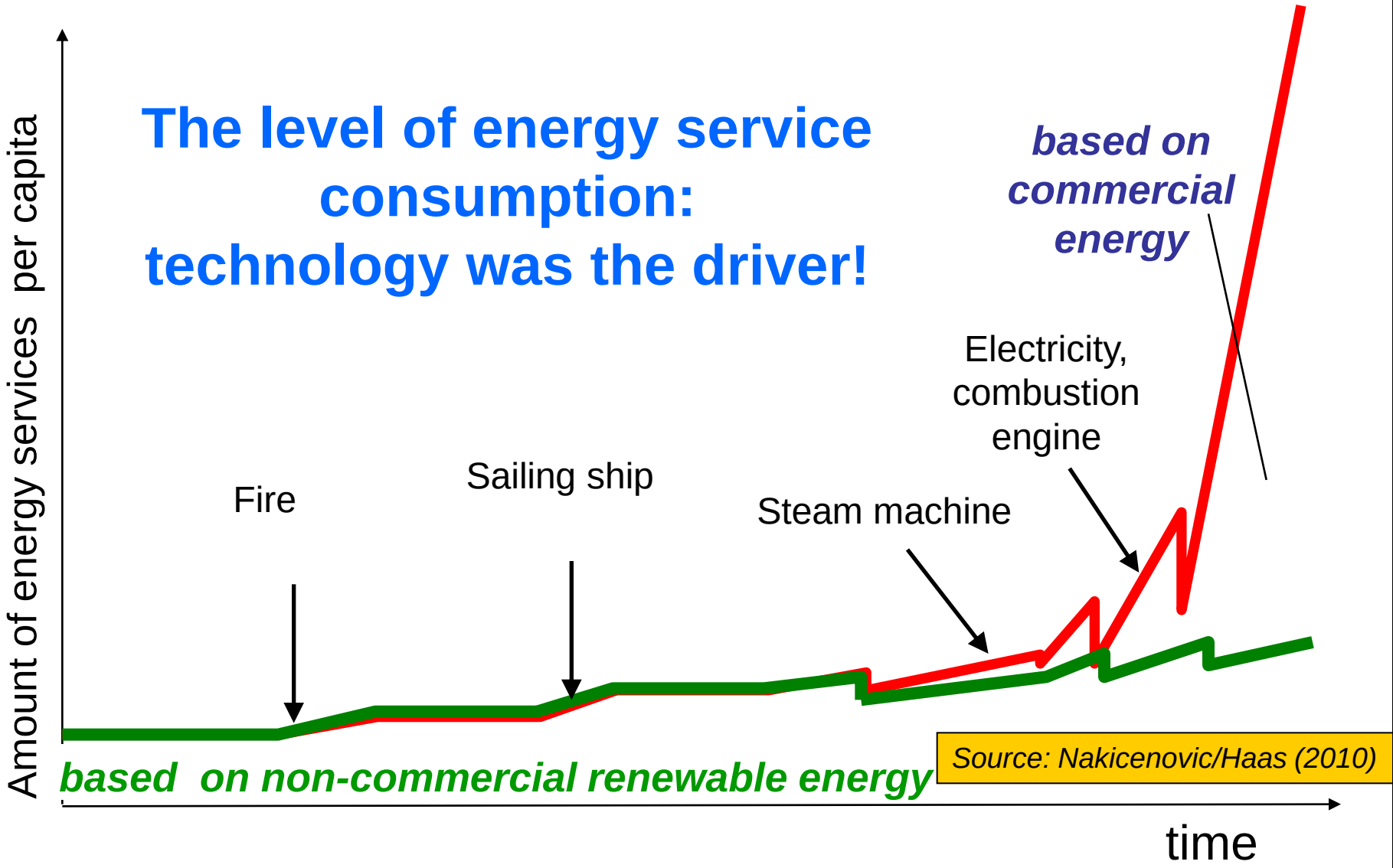
Slovac Republic: 18.5 mtoe PE, 27.0 TWh electricity

Slovenia: 7.0 mtoe PE, 13.6 TWh electricity

Conversion factors for energy

	To :	PJ	Gcal	Mtoe	10^12 BTU	TWh
		multiply by				
From :	PJ	1	238800	0.0239	0.9479	0.2778
	Gcal	4.1868×10^{-6}	1	10^{-7}	3.968×10^{-6}	1.163×10^{-6}
	Mtoe	41.868	10^{7}	1	39.68	11.63
	10^12 BTU	1.055	252000	0.0252	1	0.2931
	TWh	3.6	860000	0.086	3.412	1

5. Dynamics: Why history is important



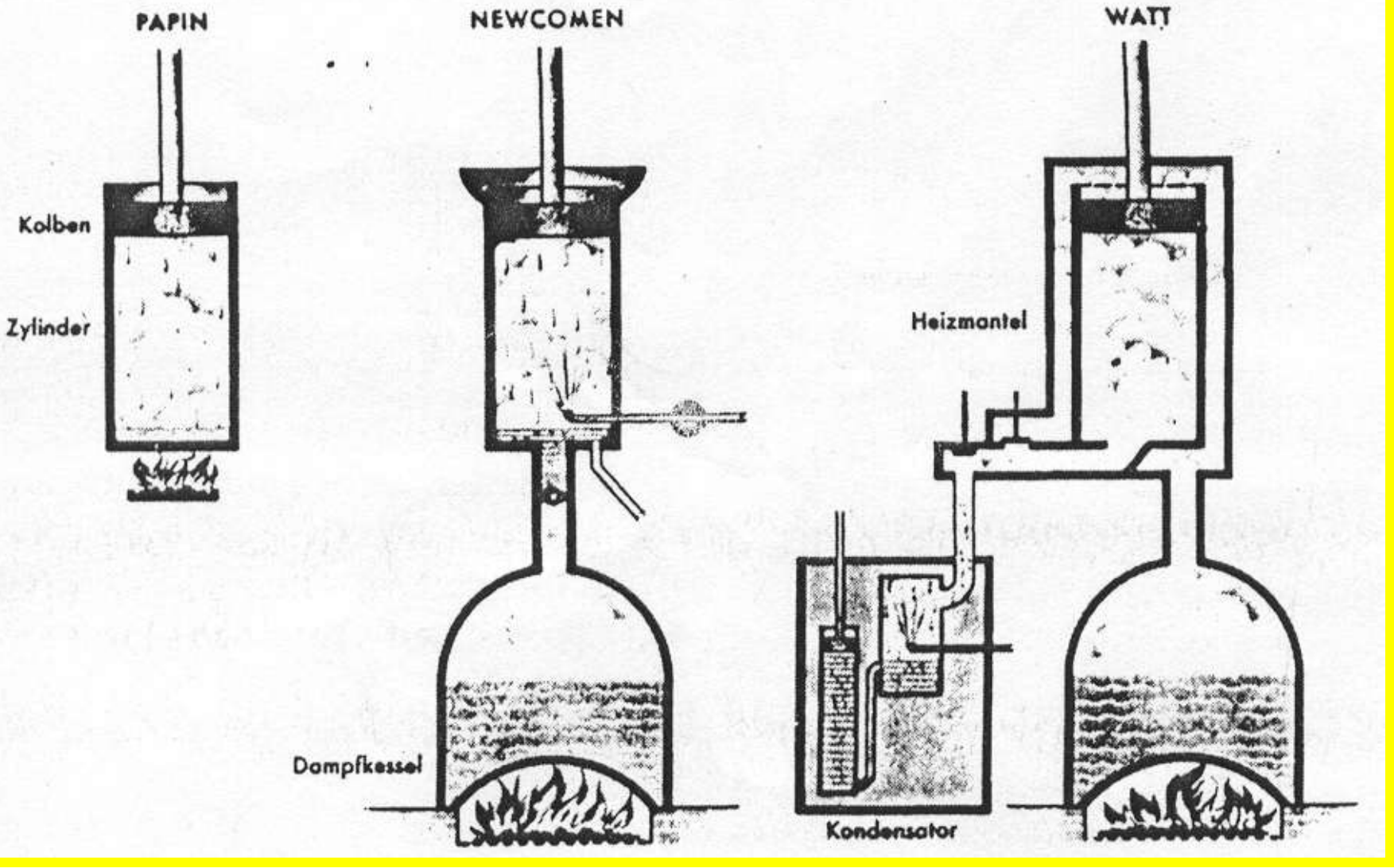
From Antiquity to the Steam Age

For the longest period in history:
Main sources of energy human and animal work, biomass (fire), mechanical wind and water.

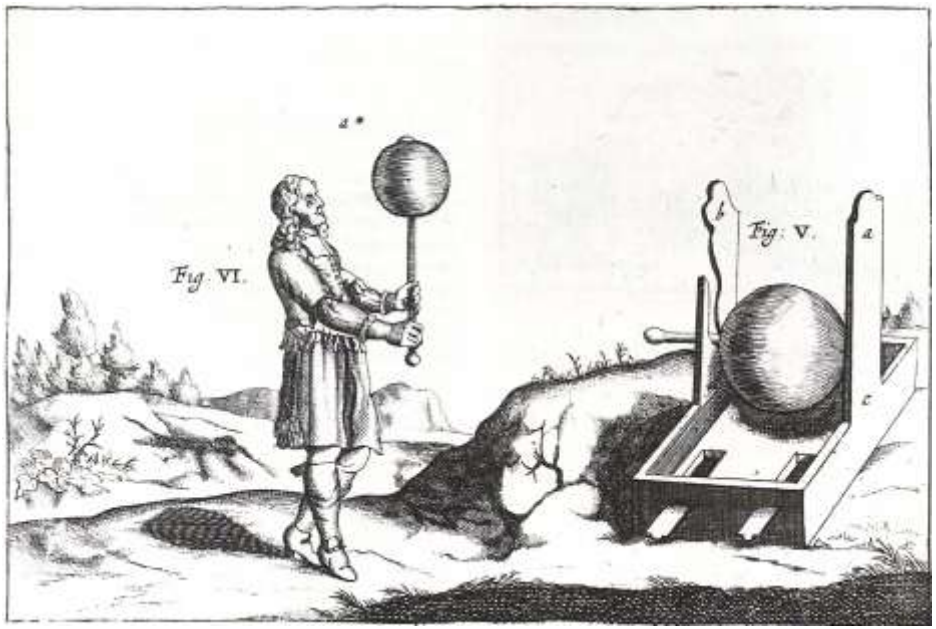
Reasons for the humble improvements in energy use and technologies:

- Work of many served only a few due to generally highly hierarchal social structures
- General dislike of purpose-oriented technology
- Low population densities and lack of population growth to accumulate knowledge!

Steam Engine



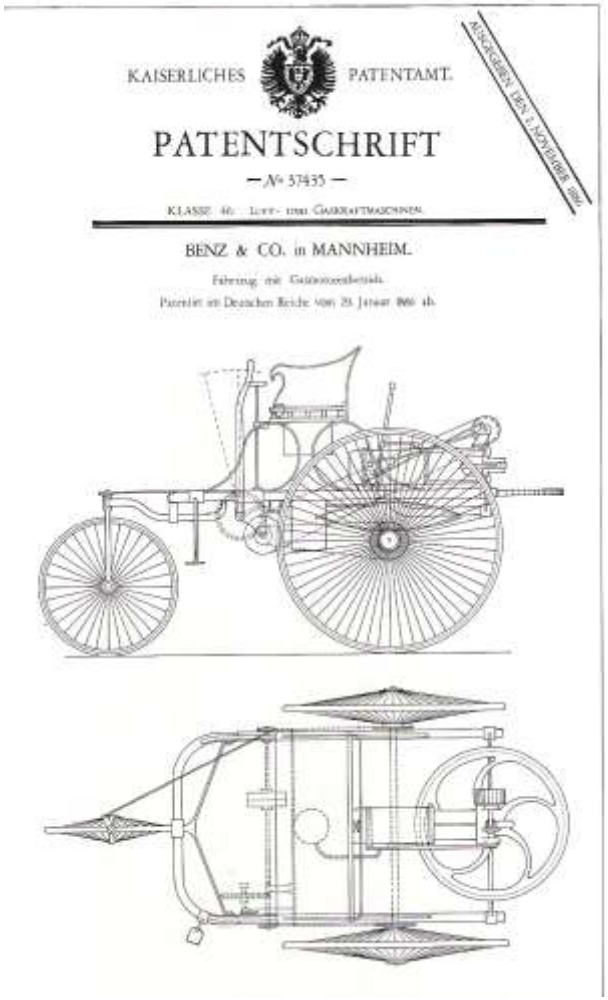
Electricity – THE energy carrier



Otto v. Guericke

Electricity – THE universal technology for providing energy services

A new era of mobility: oil and combustion engine


KAISERLICHES PATENTAMT.

PATENTSCHRIFT

— № 37435 —

BENZ & CO. in MANNHEIM.

Oil products in vehicles end of 19th century, begin of 20th century

Energy crises

Wood crises:

- 7000 – 0 BT: Deforestation along coasts;
- 1500 – 1700: England, Germany
- Today: Africa, India…

major reasons:

- non-sustainable use;
- distance to place of use, transport, lack of infrastructure,
- inefficient use;

Coal crises:

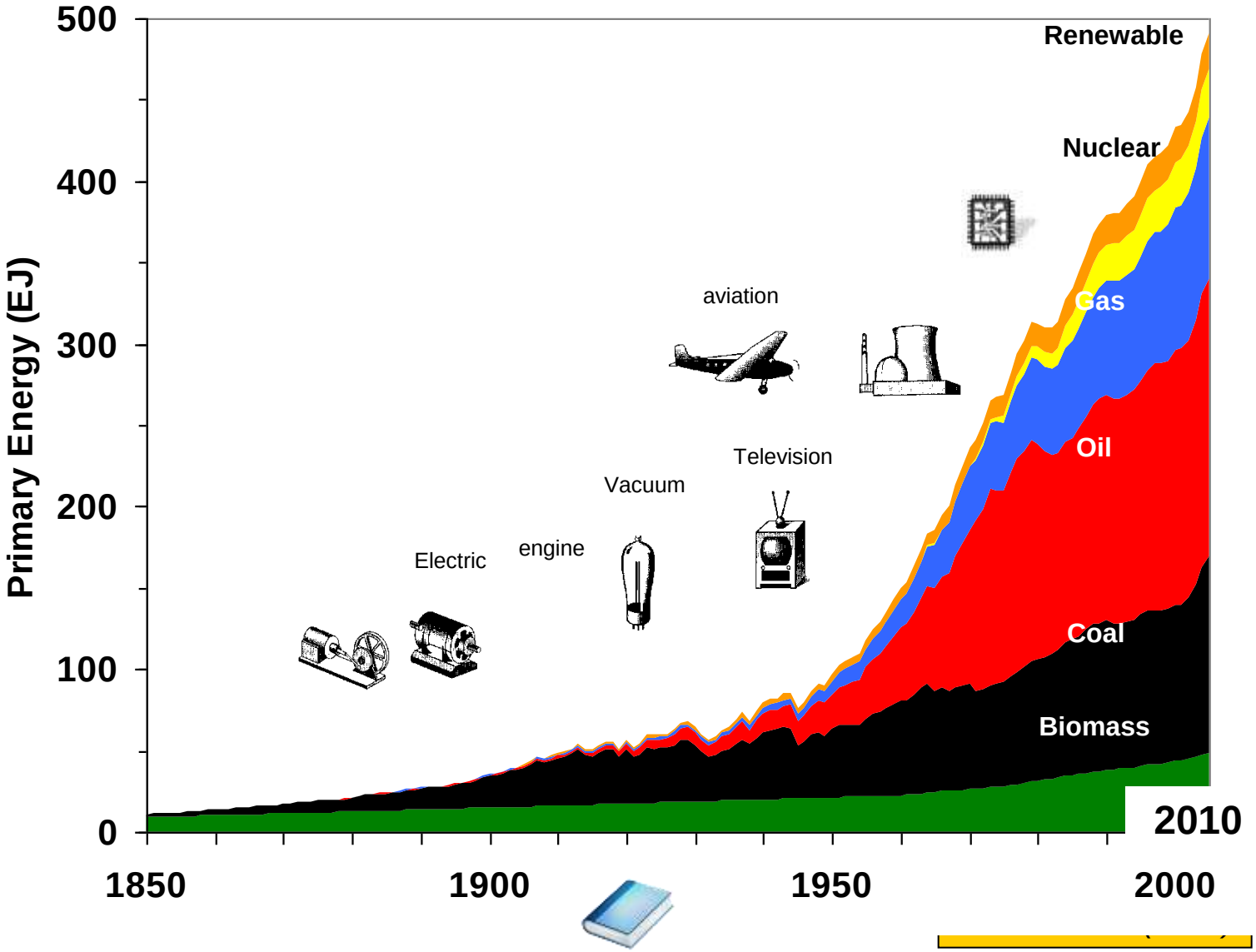
- 1870…

Oil crises:

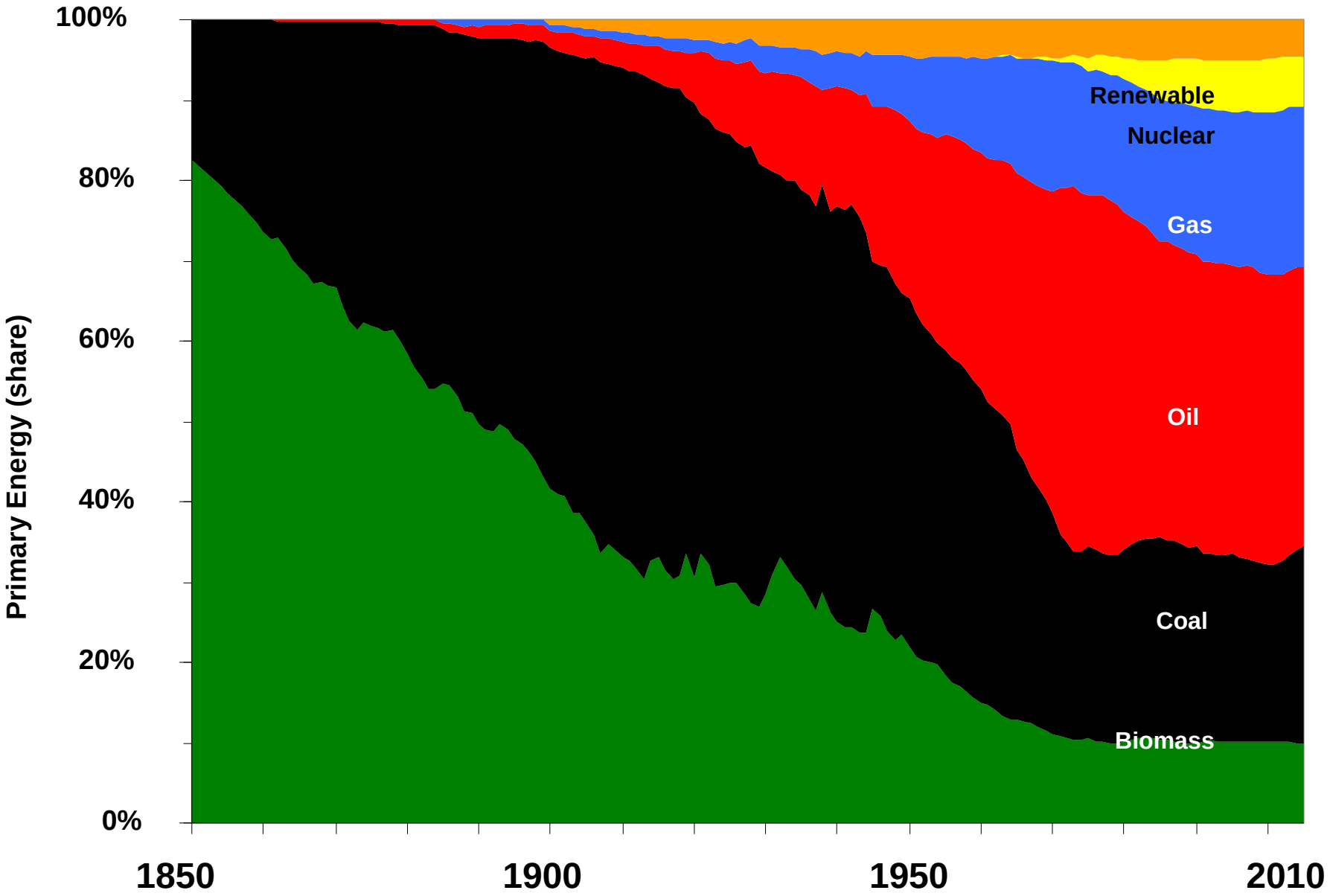
- 1973, 1979, 2005 (?) …

Source: Nakicenovic/Haas (2010)

5.1 World Primary Energy consumption



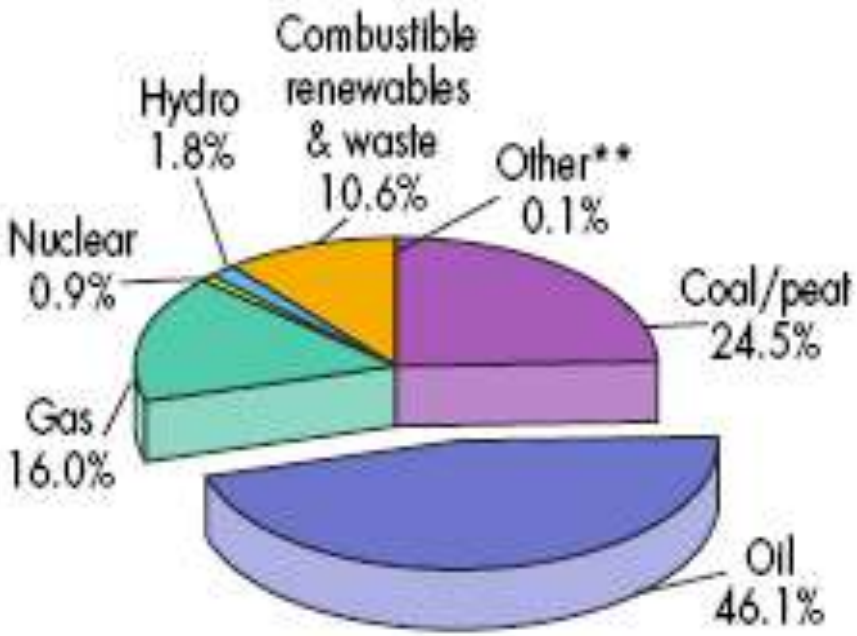
Shares of PE world-wide



Source: GEA (2012)

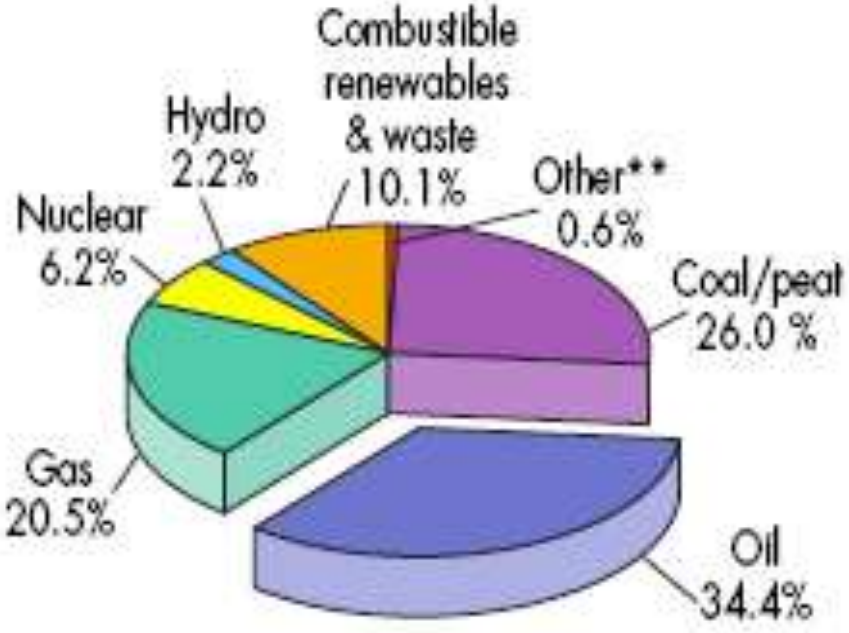
World: Primary energy

1973



6115 Mtoe

2009

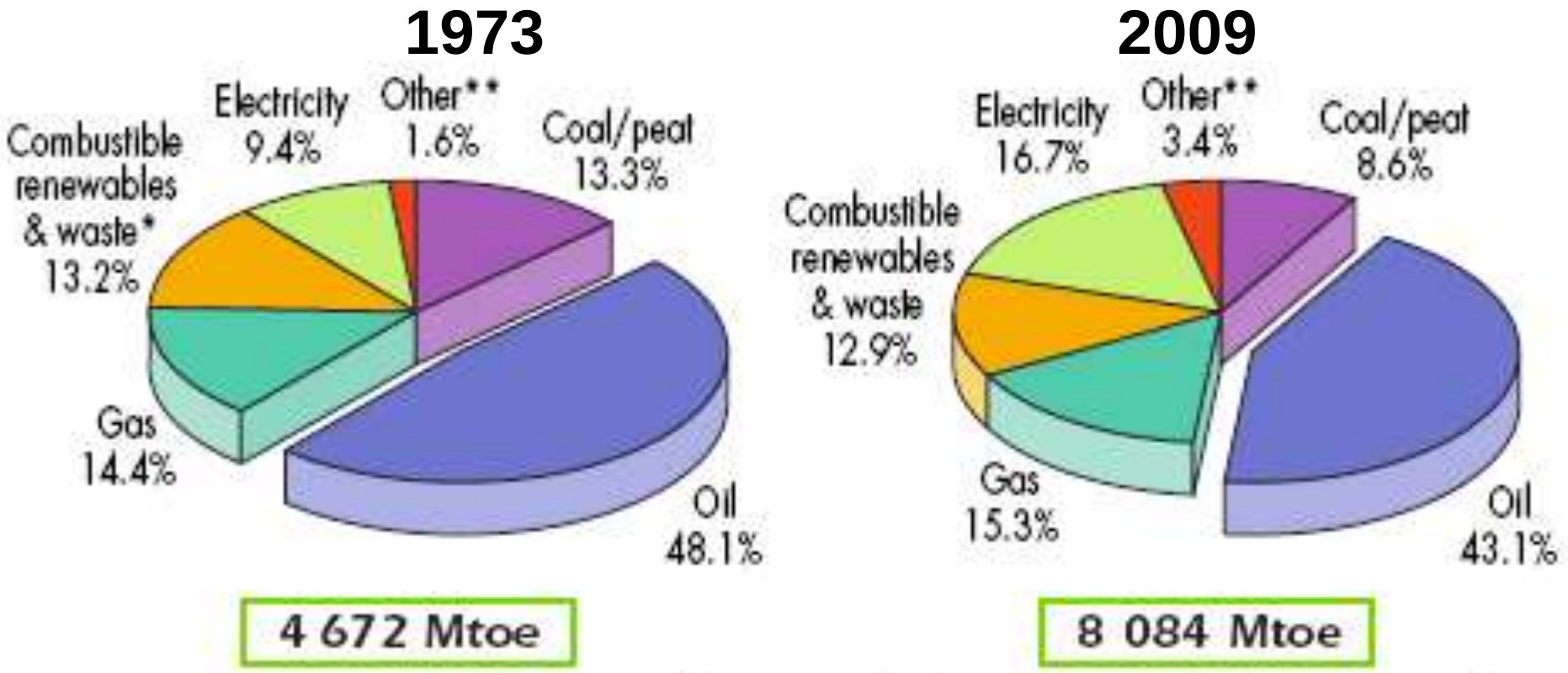


12500 Mtoe

- ***Total primary energy demand doubled between 1973 and 2009;***
- ***Oil down (-20%), Gas up (+25%)***

Source: IEA 2011

World: Final energy



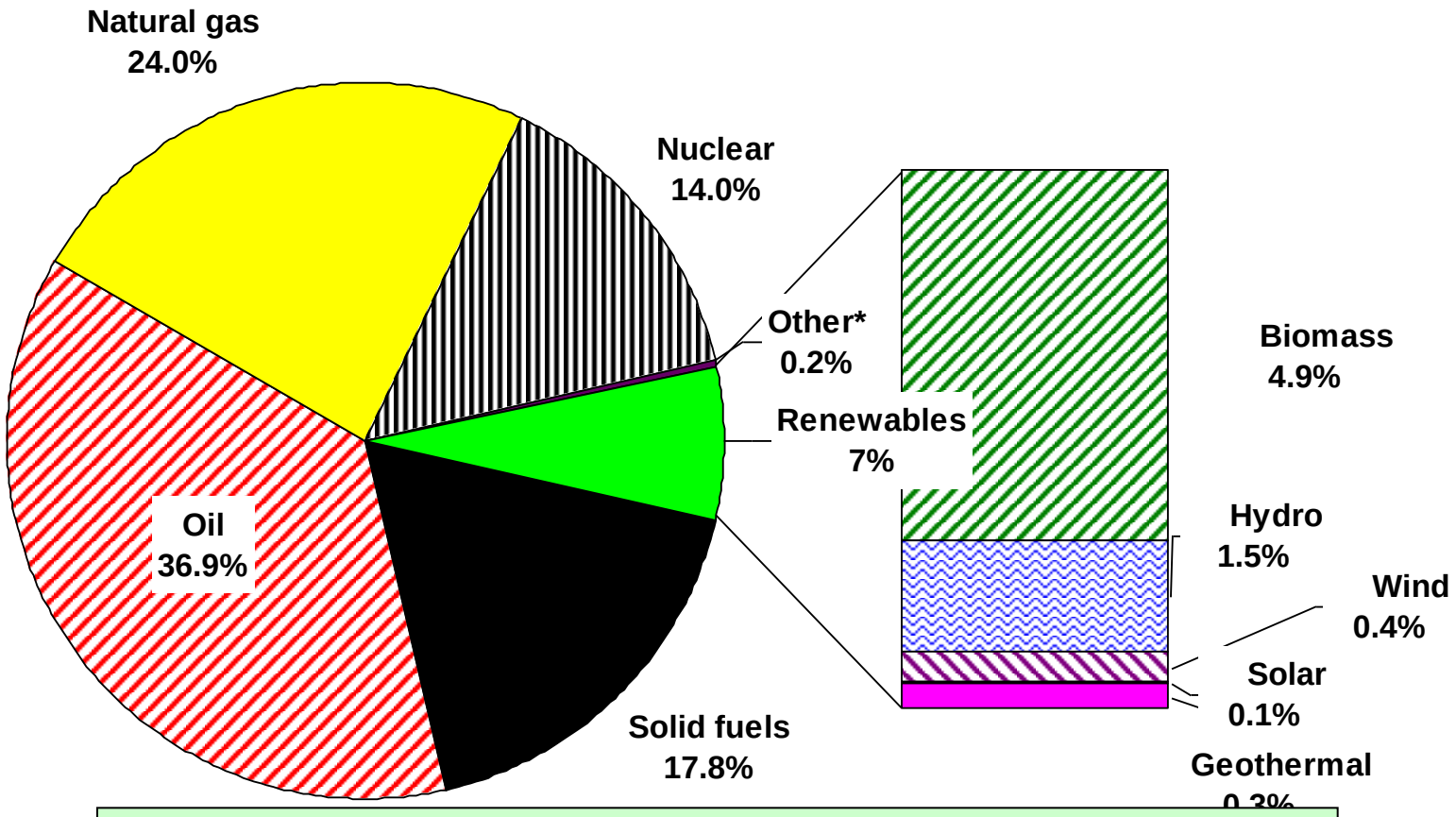
*Prior to 1994 combustible renewables & waste final consumption has been estimated.
**Other includes geothermal, solar, wind, heat, etc.

- ***The share of electricity increases continuously: In 2009 almost double of 1973***

Source: IEA 2011

5.2. Energy in Europe

EU-27: Primary energy consumption

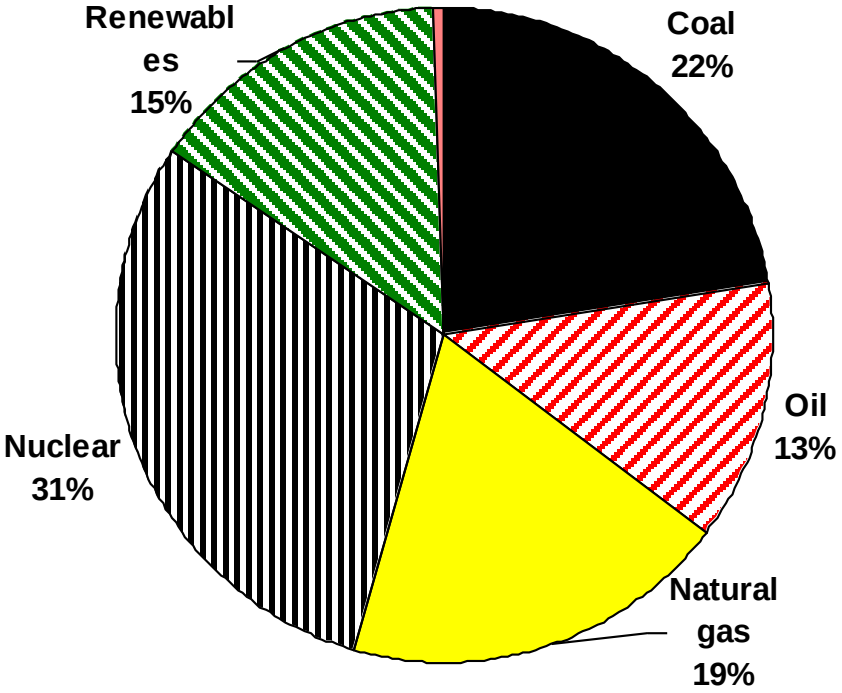


- ***about 8% share of RES in 2010;***
- ***EU-target from 1997: 12% by 2010!***

Source: EUROSTAT (2011)

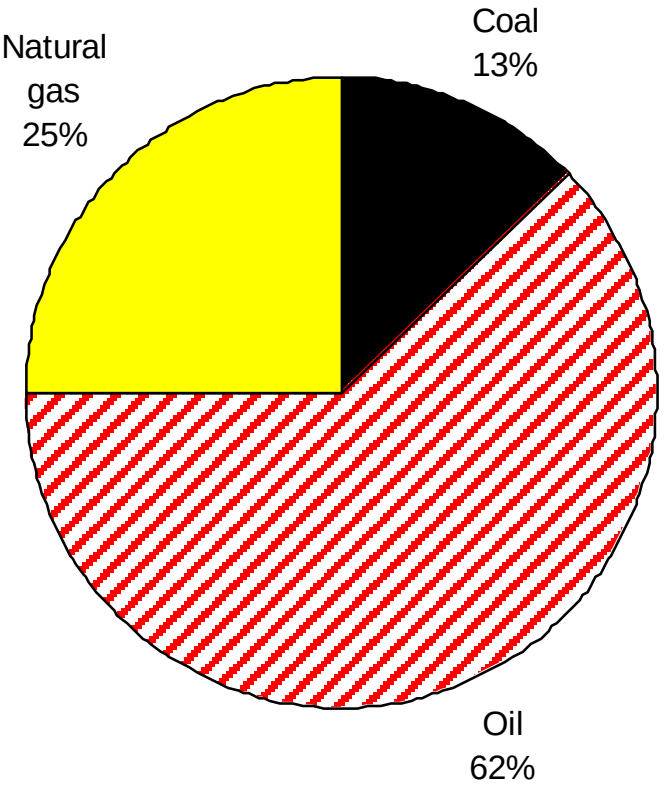
Primary Energy EU-27: origin of resources

Indigenous:



Total 2010: ca. 870 Mtoe

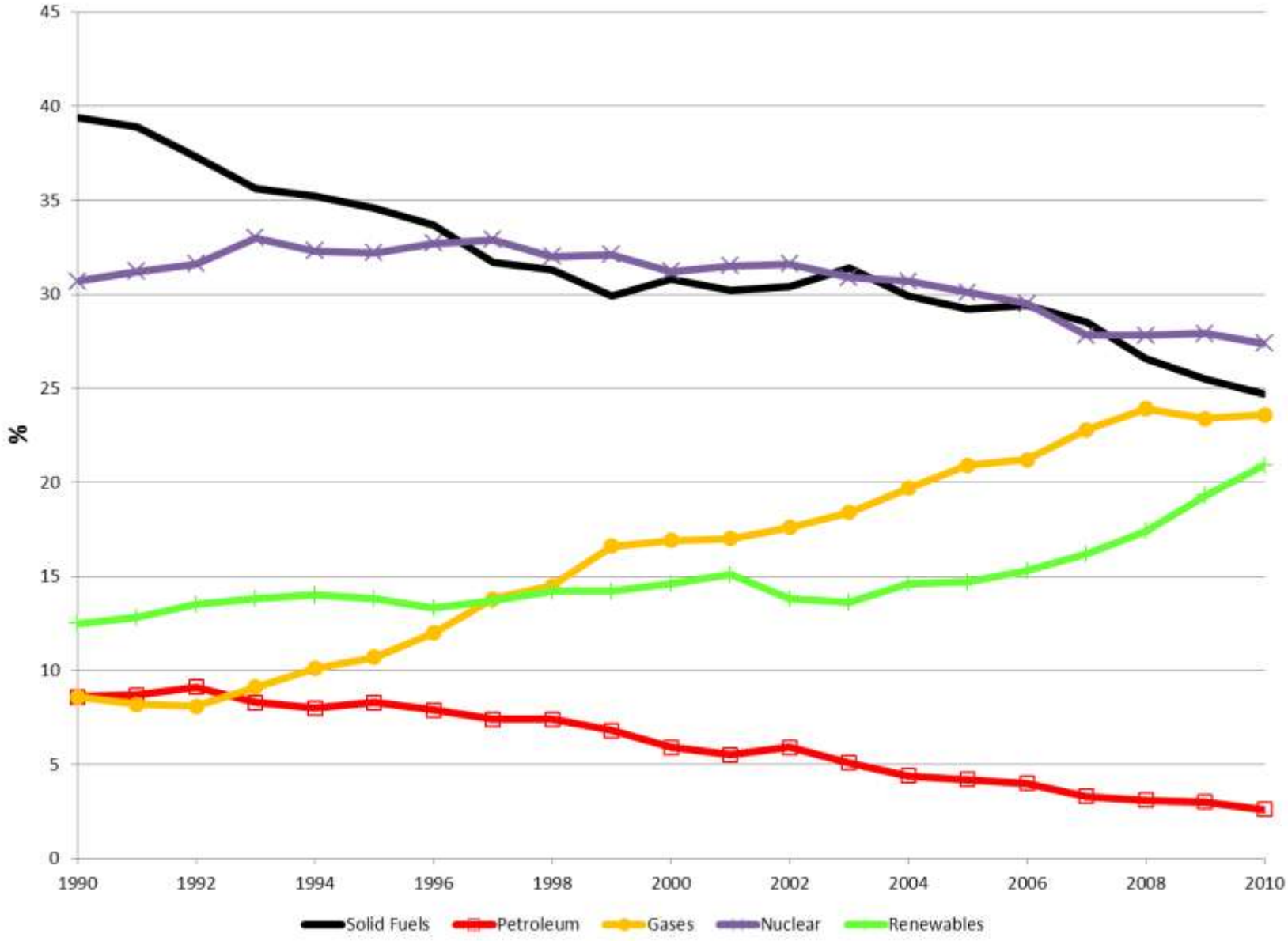
Imports:



Total 2010: ca. 1000 Mtoe

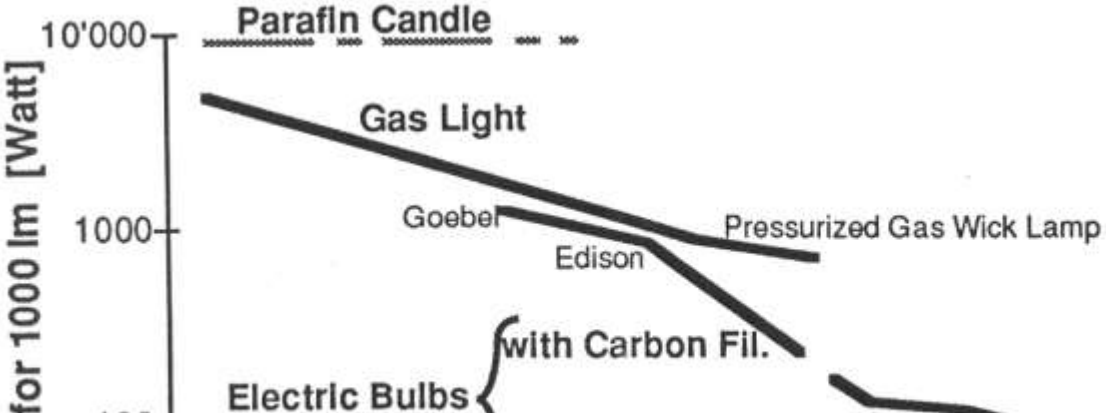
Source: EUROSTAT (2011)

EU-27: Share of fuels in electricity generation



6. Drivers of energy consumption

The example of LIGHTING



Most Important driver: Technological progress!

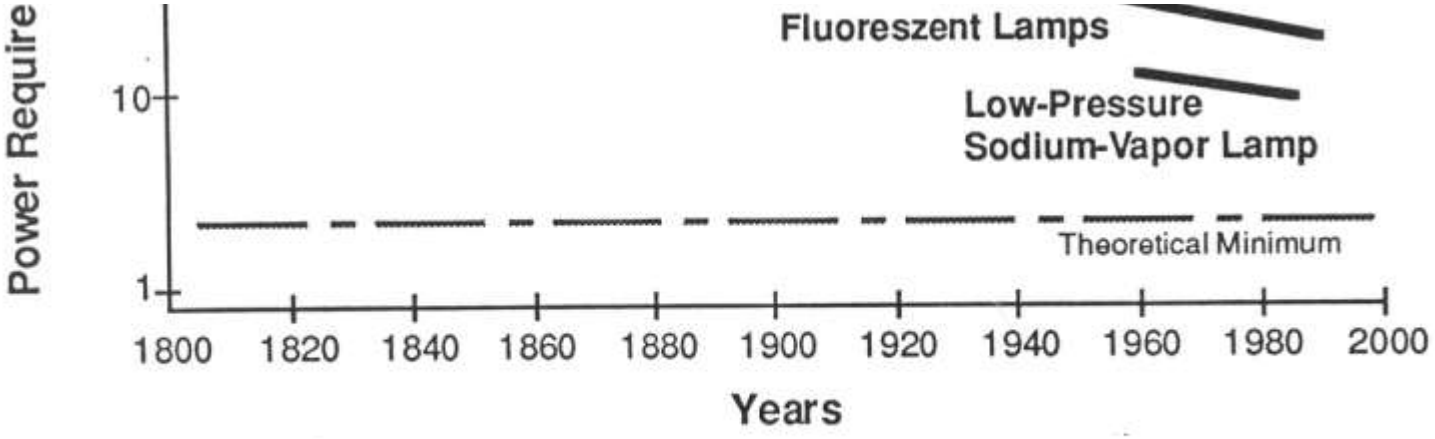
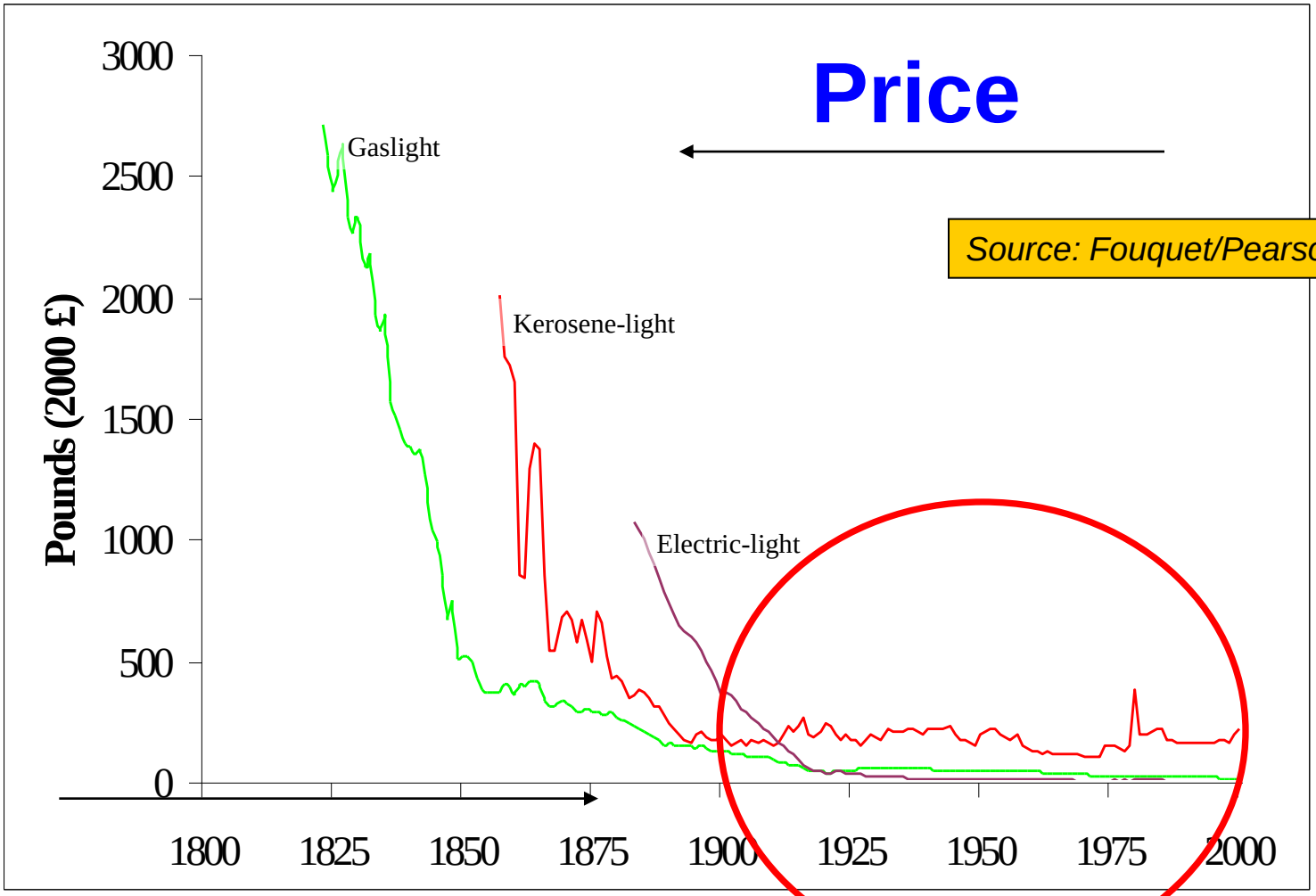


Figure 1: Technical development lead to a rapid decrease of power requirement for producing the same amount of light

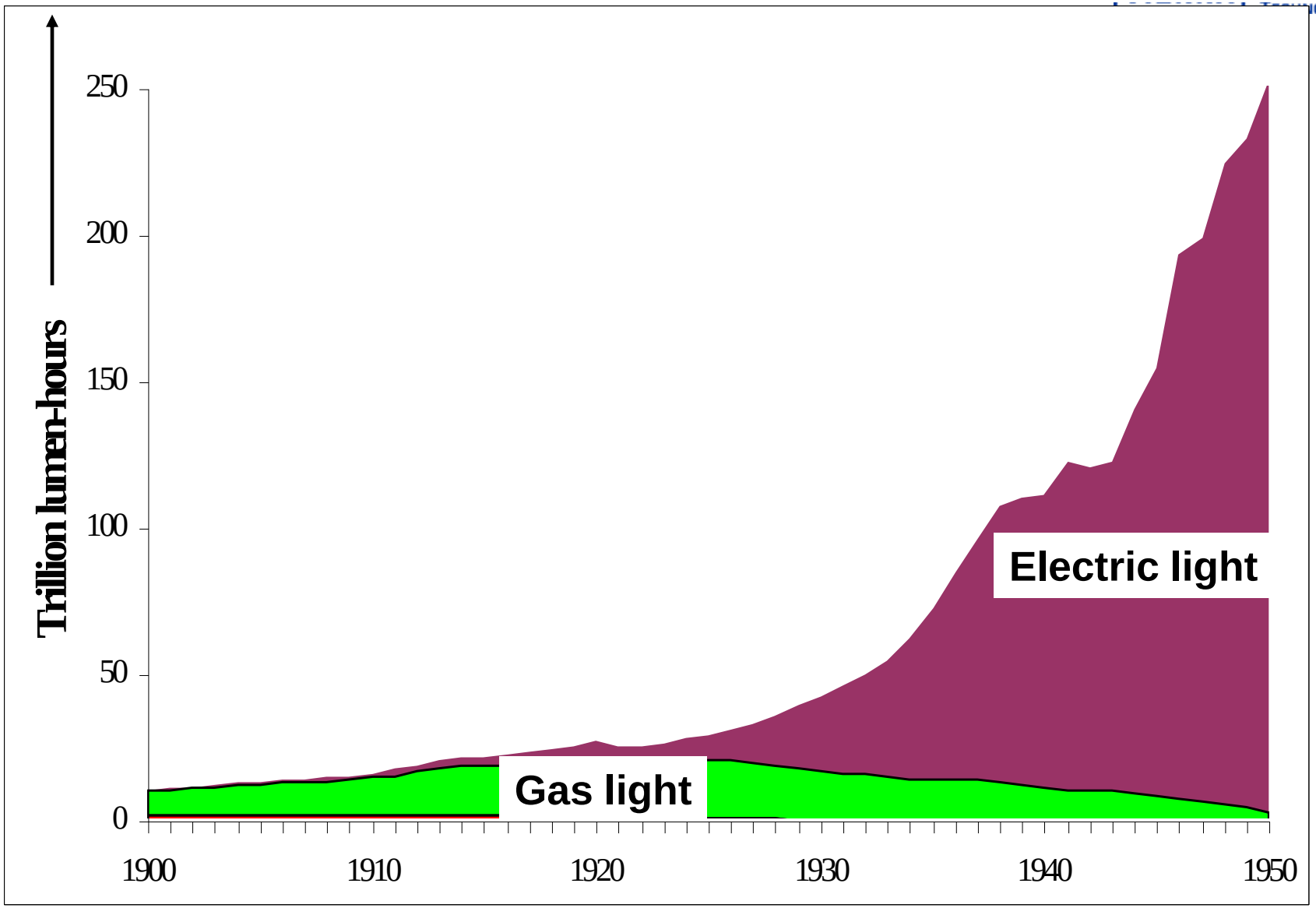
The example of LIGHTING

Figure 6. Price of Lighting from Gas, Kerosene and Electricity in the United Kingdom (per million lumen-hours), 1800-2000



Source: authors' own estimates – see Sections II.1.3-5 and II.3

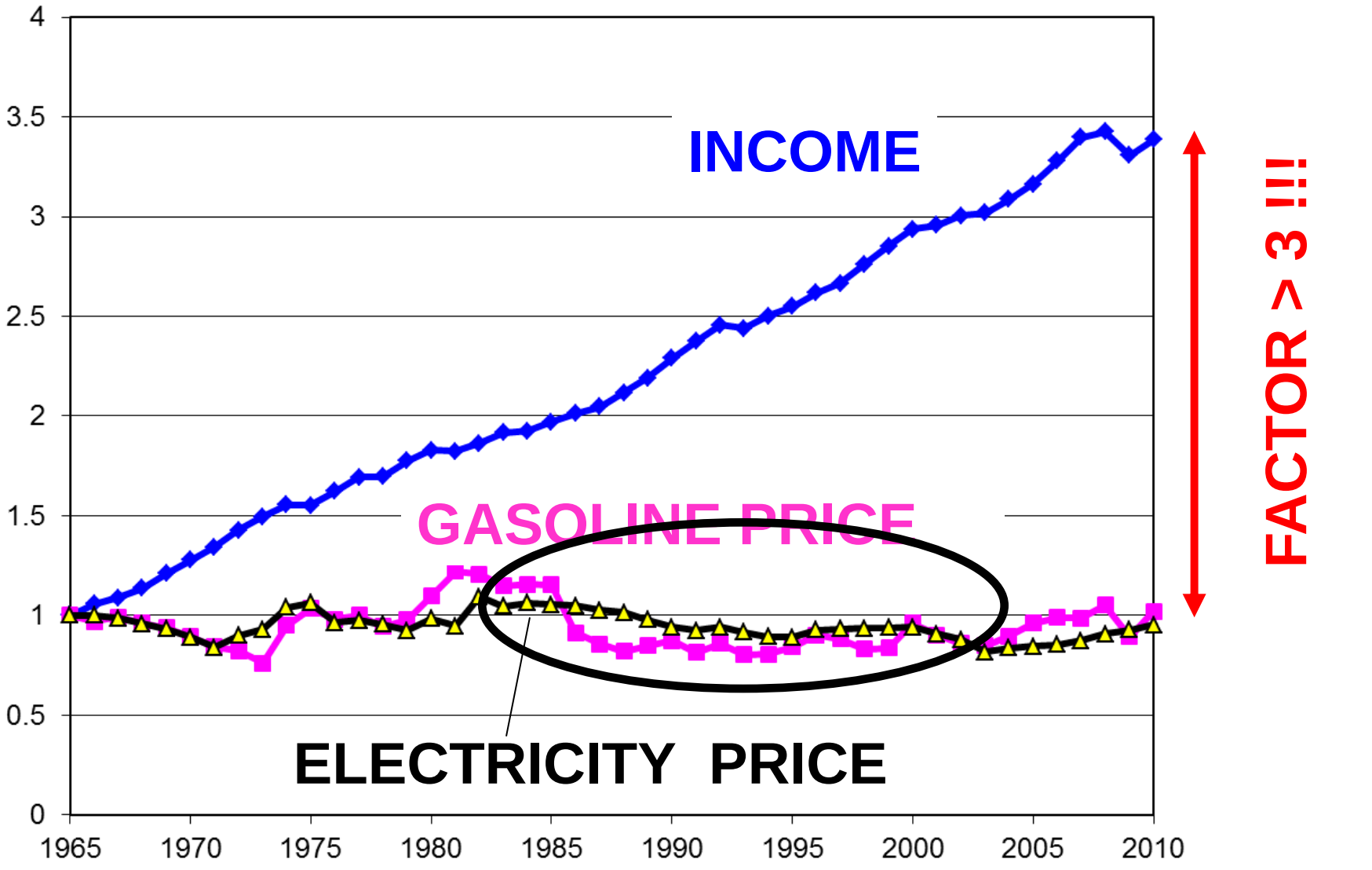
The example of LIGHTING



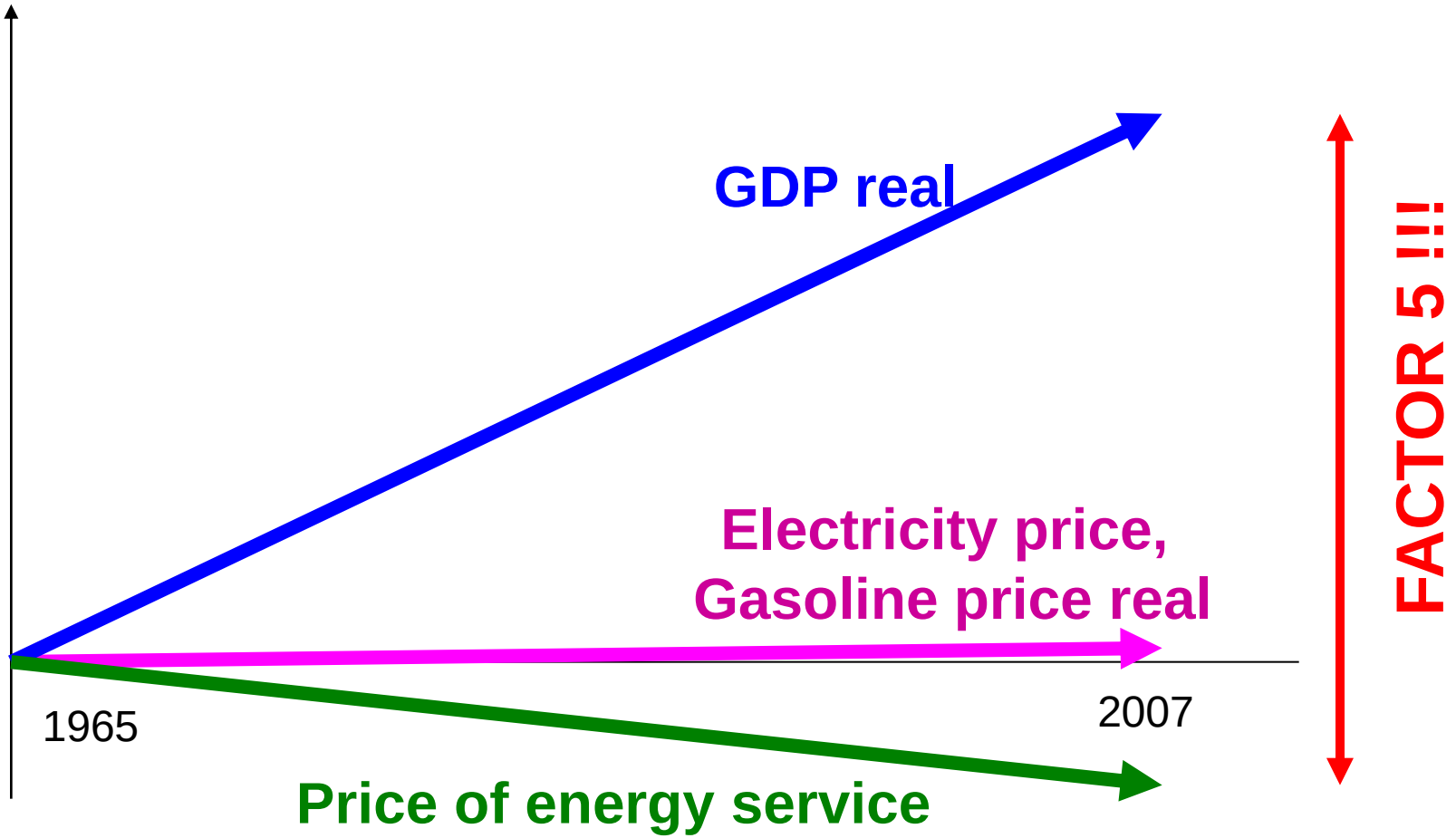
Source: authors' own estimates – see Sections II.2.3-5 and II.3 Trillion: 10^{12} (i.e. one million million)

Source: Fouquet/Pearson (2005)

Income vs Energy prices



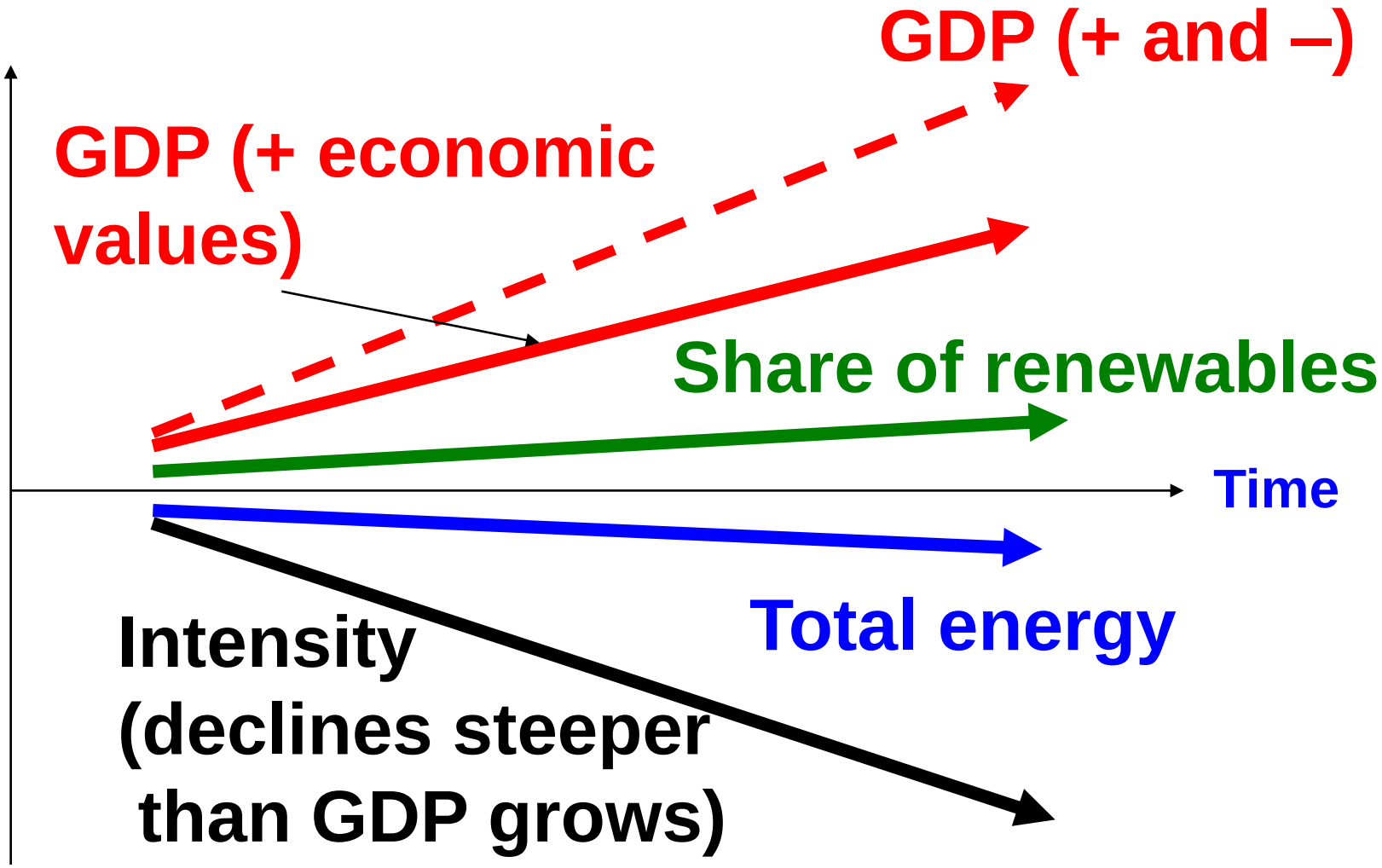
Indicators Austria: Income vs price of energy service



In the long run: technology was the driver:

- → Cheaper energy (better exploration transport, Infrastructure technologies
- → Cheaper services (better lighting, heating, cooking technologies
- → Higher GDP: More services are produced in shorter time with less man-hours

Towards sustainability:



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