TEACHING SUSTAINABILITY TO THE ENGINEERING STUDENTS

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POLAND

Warsaw University of Technology
Educational system

- Three-level system:
  - **First level courses** – university studies in engineering leading to B.Sc. degree,
  - **Second level courses** – leading to M.Sc. degree,
  - **Third level courses** – leading to Ph.D. degree.
- European Credit Transfer System, ECTS
  - one semester – 30 ECTS,
  - B.Sc. degree – 180 – 240 ECTS (7-8 semesters),
  - M.Sc. degree – 90 – 120 ECTS (3-4 semesters).

Sustainability development has been present in the Warsaw University of Technology (WUT) curricula for more than fifteen years.

1. The first notion of sustainability is given to the undergraduates at the first year of study, as a part of the „Introduction to Chemical Engineering” course

2. After this introductory course the problem of sustainability repeatedly returns in other courses, namely:

A. Mandatory courses

- Fundamental Processes (Unit Operations): process intensification, saving of materials and energy, reduction of waste streams
- Fundamentals of Environmental Protection: characteristics of air, water and soil pollution and processes for pollution removal
- Basic Biotechnology: biorafineries, biofuels, biological water treatment
- Membrane Separation Processes: application of membrane separation for water purification and reduction of waste streams.

B. Electives

A number of courses are specially devoted to the problems of sustainability, e.g.:

- Process integration
- Non-conventional energy sources
- Water ozonation methods
- Quality management systems
- Technologies of pollutants decontamination in natural environment

3. The above courses are supported by research projects, e.g. by projects on:

- aerosol capture from exhaust gases
- new applications of membranes for sustainable development
- waste plastics recycling
- algae cultivation
- CO_2 separation and sequestration
- biogas production
- biological production of hydrogen
- microbial fuel cells

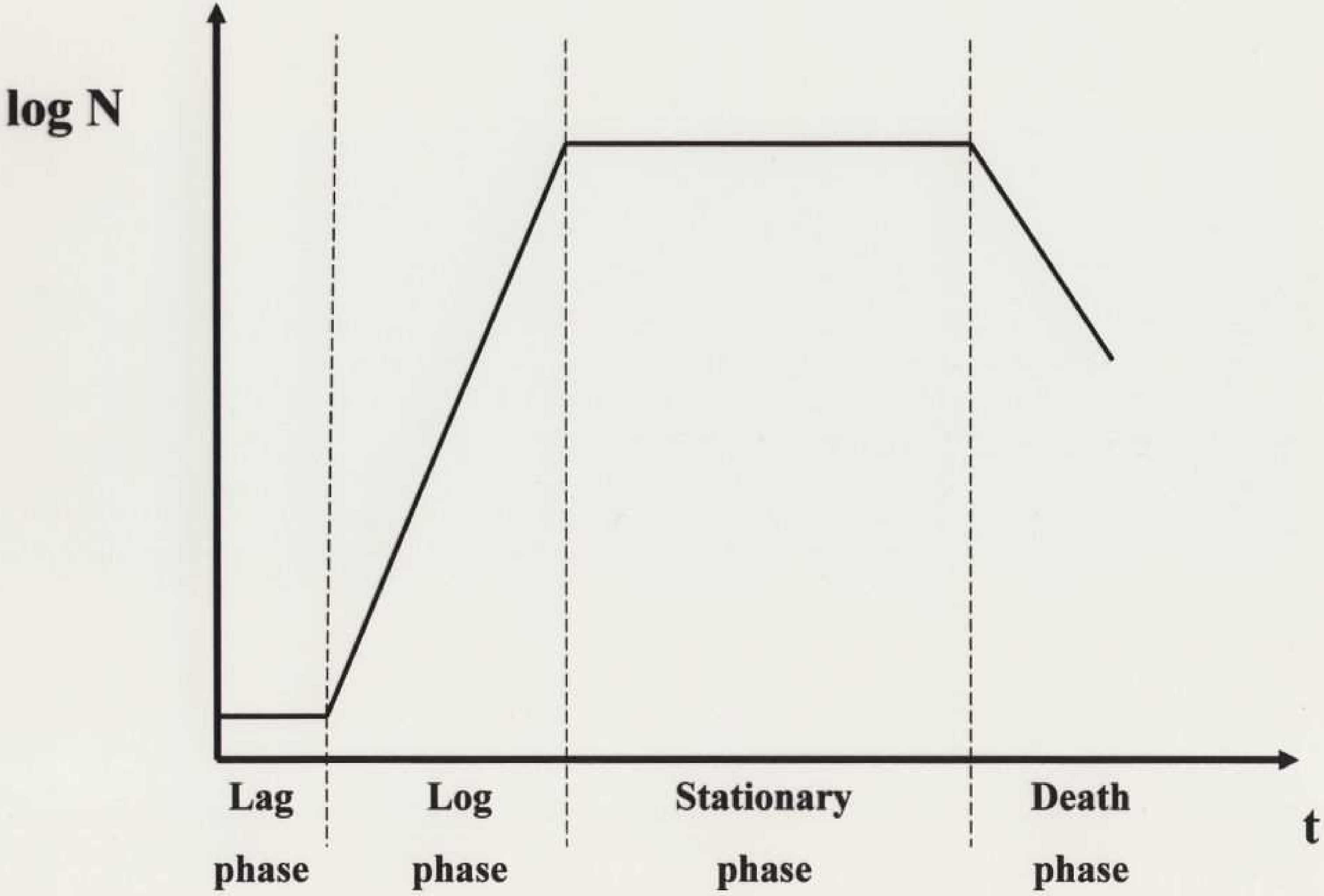
CAN ONE TEACH SUSTAINABILITY ?

RATHER ATTITUDE THAN KNOWLEDGE

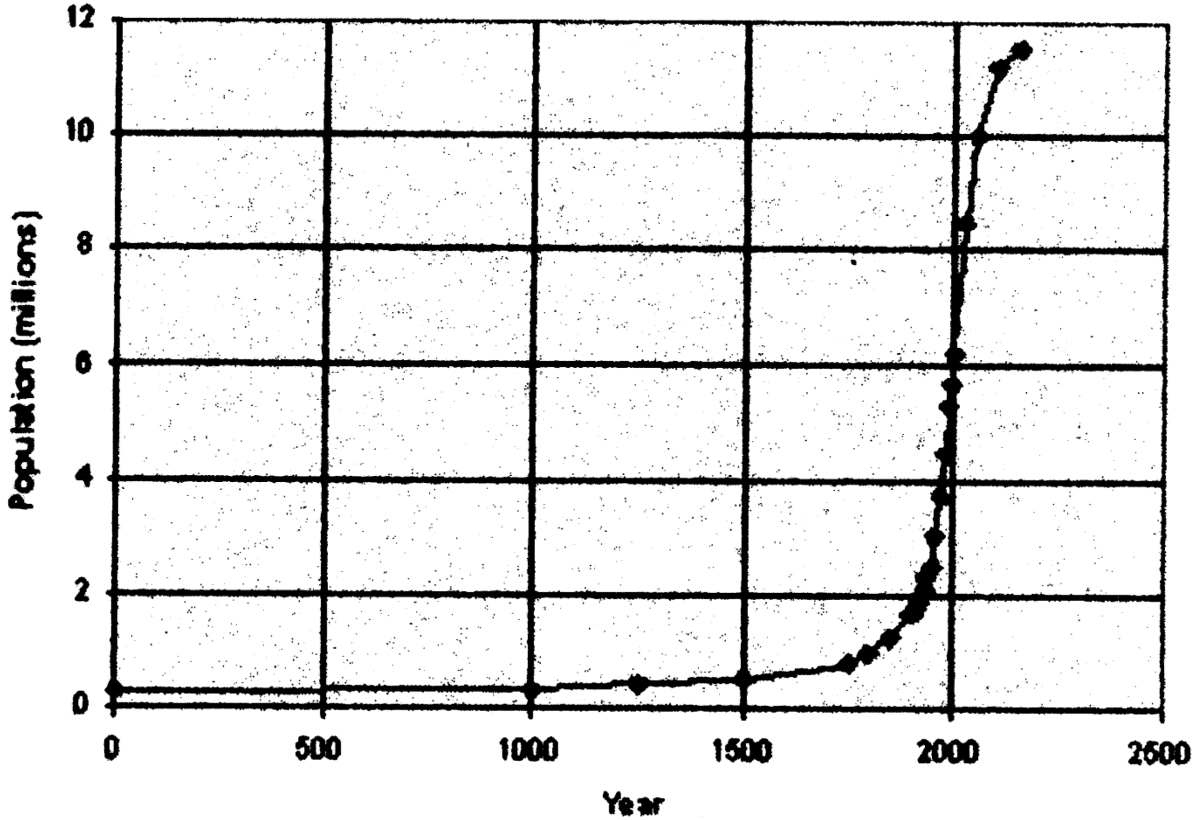
RAISE AWARENESS
SUPPLY RELEVANT INFORMATION
SHOW RELEVANCE TO CHEMICAL ENGINEERING

The Sombrero Galaxy – 28 million light years from Earth – was voted best picture taken by the Hubble telescope. The dimensions of the galaxy, officially called M104, are as spectacular as its appearance. It has 800 billion suns and is 50,000 light years across.

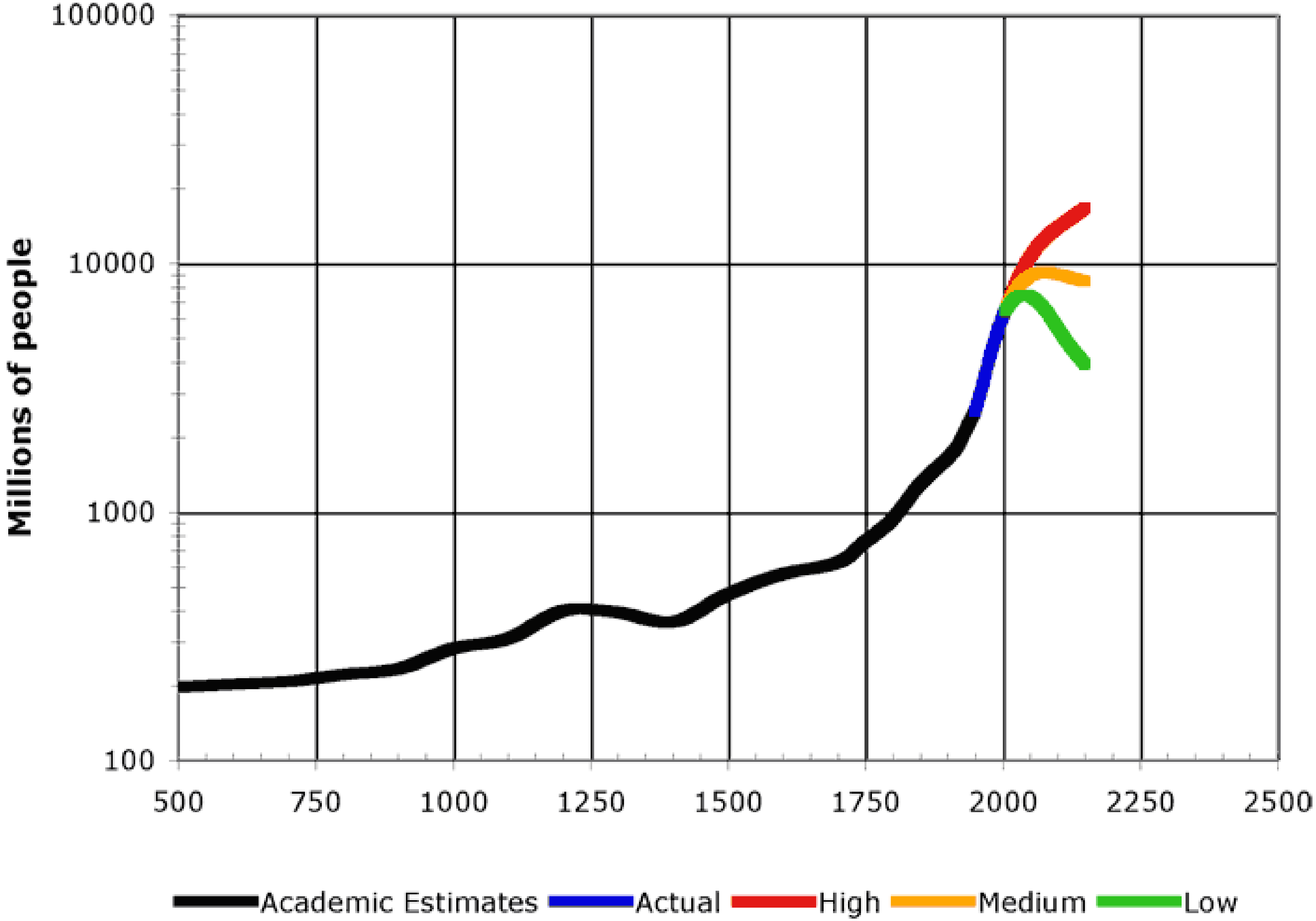
BATH CELL CULTIVATION



WORLD POPULATION



http://pieria.acs.southwestern.edu/econ/worldpop/sld016.htm


Millions of people
100000
10000
1000
100
500
750
1000
1250
1500
1750
2000
2250
2500
Academic Estimates
Actual
High
Medium
Low

Four fundamental problems

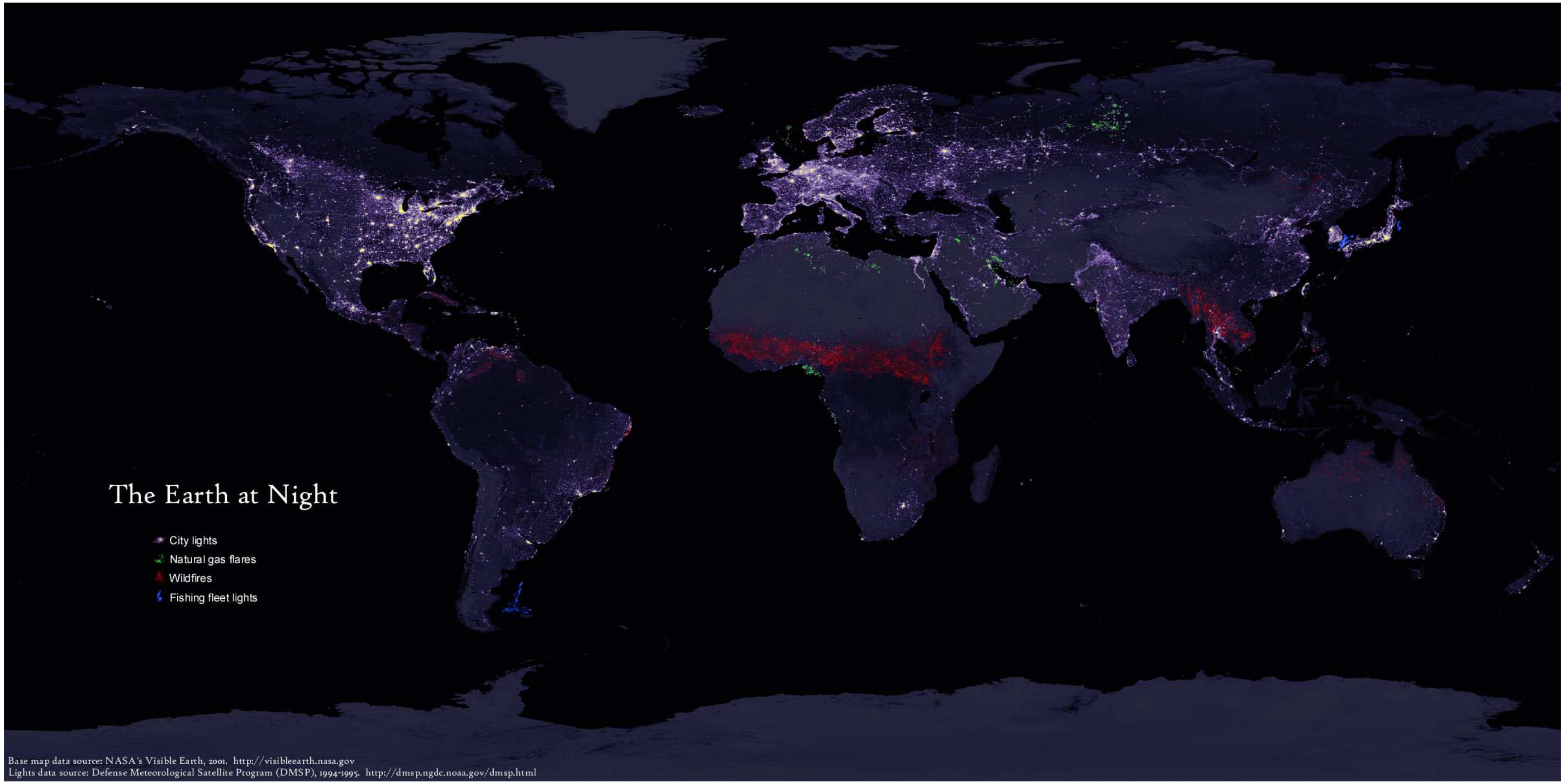
- shortage of energy
- shortage of resources
- shortage of food (including drinking water)
- excessive environmental pollution

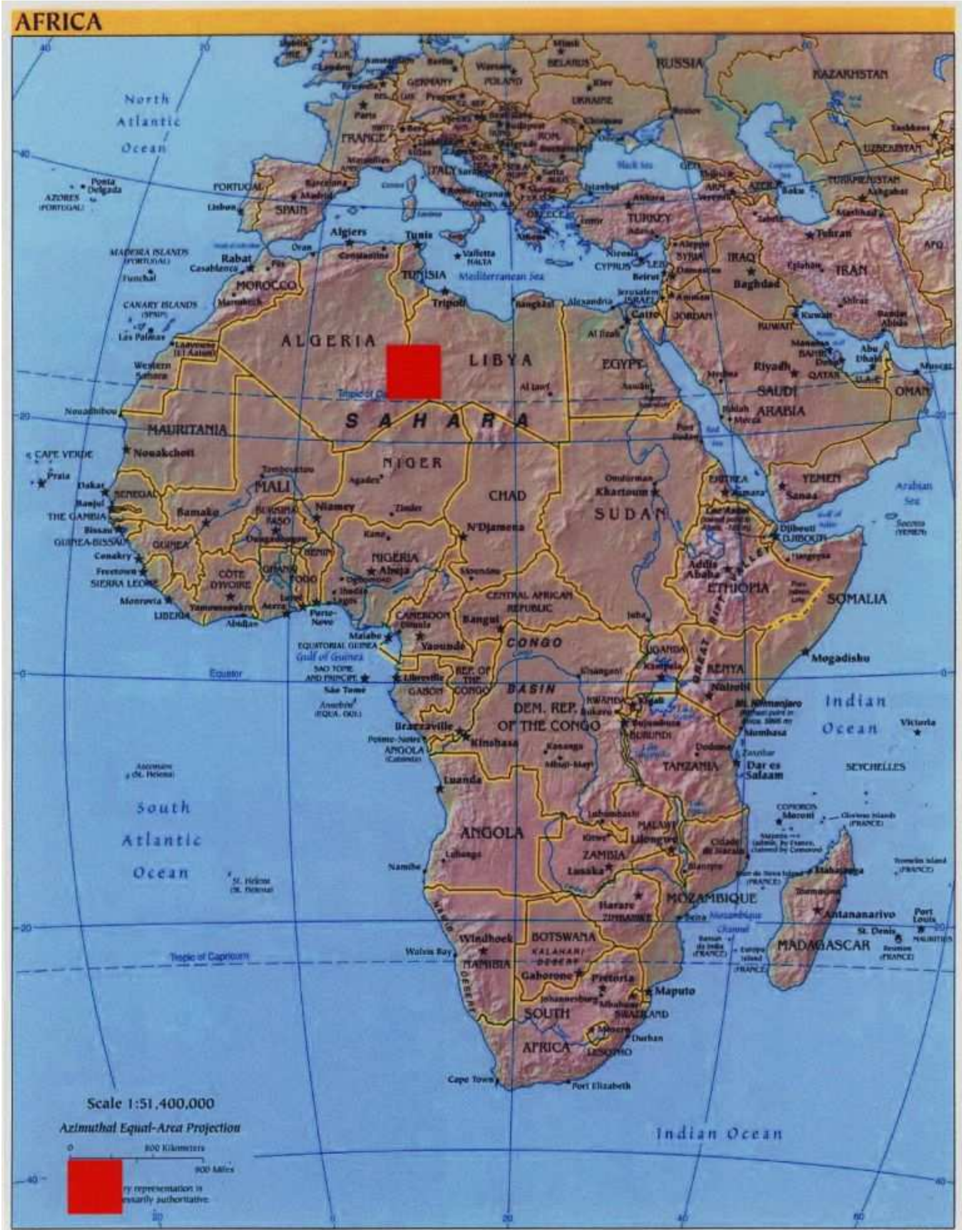
Energy resources ($Q=3.6 \cdot 10^{10}$ ton eq.fuel)

CARBON		150 – 400
OIL		40
NATURAL GAS		60
NUCLEAR:		
	Fission slow neutrons	17-23
	Fission fast neutrons	600-1200
	Nuclear synthesis	$1200\text{-}3.10^4$
SOLAR ENERGY		2700 per year

Energy consumption per capita

	Energy consumption (tons of oil eq./year)	Populations (bln) 2010
USA	7.5	0.31
RUSSIA	4.9	0.14
FRANCE	4.0	0.06
GERMANY	3.8	0.08
CHINA	1.5	1.34
INDIA	0.4	1.18


The Earth at Night
City lights
Natural gas flares
Wildfires
Fishing fleet lights
Base map data source: NASA's Visible Earth, 2001. http://visibleearth.nasa.gov
Lights data source: Defense Meteorological Satellite Program (DMSP), 1994-1995. http://dmsp.ngdc.noaa.gov/dmsp.html



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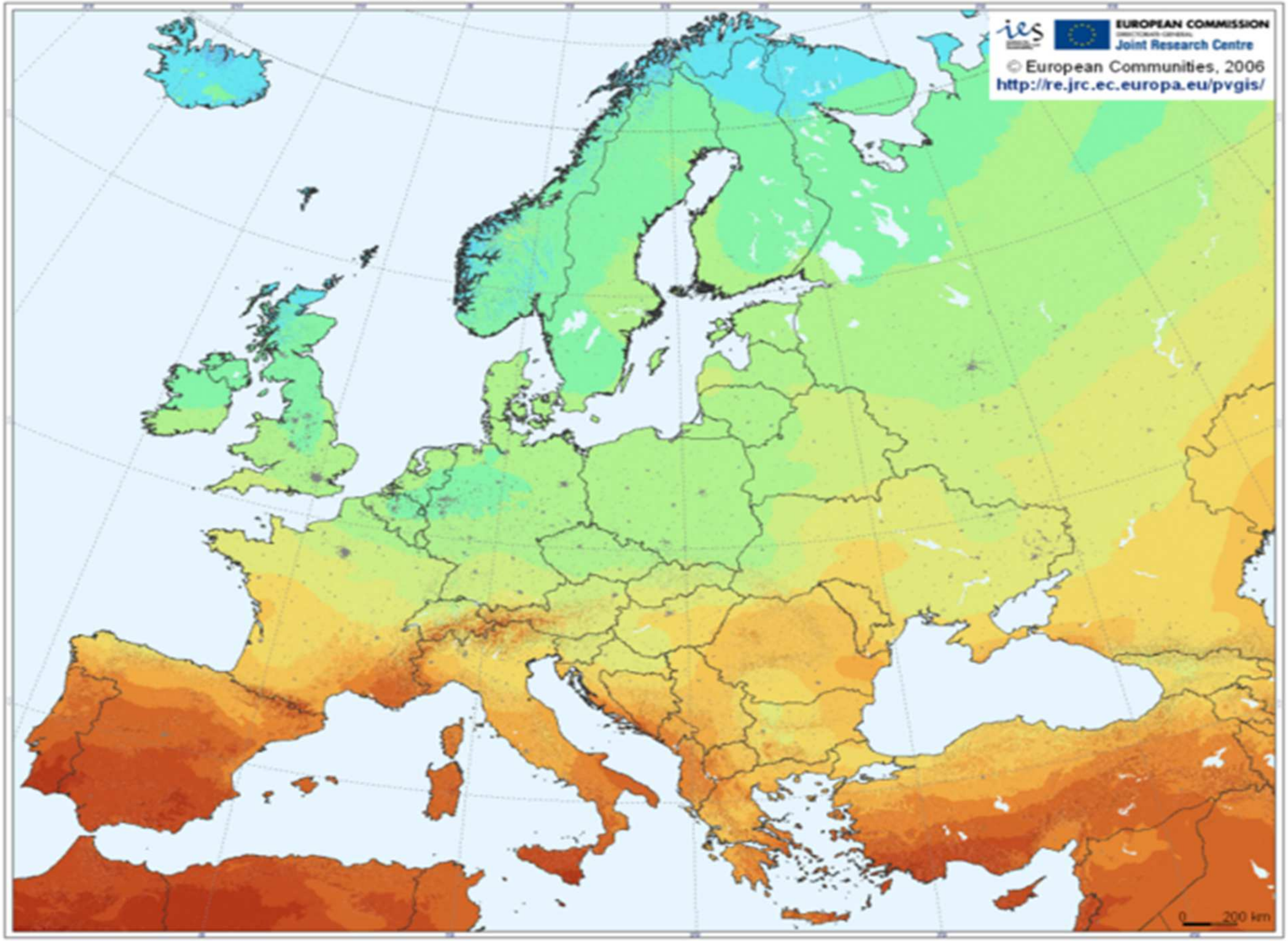
Photovoltaic Solar Electricity Potential in European Countries

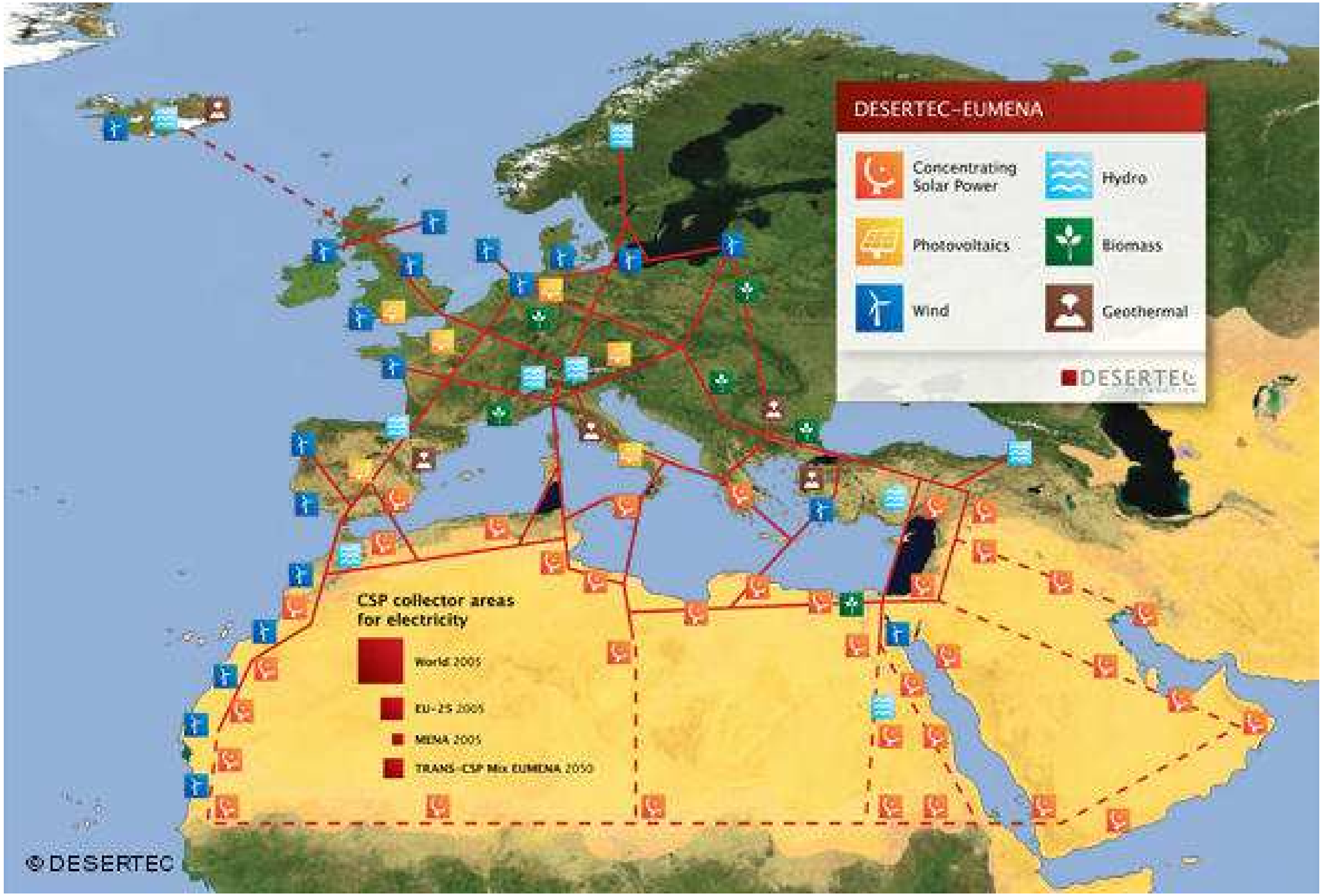


Yearly sum of global irradiation incident on optimally-inclined south-oriented photovoltaic modules

Global irradiation [kWh/m^2]: <600, 800, 1000, 1200, 1400, 1600, 1800, 2000, 2200>

Yearly sum of solar electricity generated by 1 kWp system with optimally-inclined modules and performance ratio 0.75

Solar electricity [kWh/kWp]: *<450, 600, 750, 900, 1050, 1200, 1350, 1500, 1650>*


DESERTEC-EUMENA
Concentrating Solar Power
Hydro
Photovoltaics
Biomass
Wind
Geothermal
DESERTEC
CSP collector areas for electricity
World 2005
EU-25 2005
MENA 2005
TRANS-CSP Mix EUMENA 2050
© DESERTEC

Mineral resources – metals (years)

	Total	50% recycle
Iron	100	300
Aluminium	30	80
Copper	25	90
Zinc	20	100

Food

Undernourished people

Asia	16%
Africa	29%
N. America	11%
Central America	20%

but:

30 – 35% of food is wasted

(National Inst. For Agricultural Research, France)

Methods - Food

Preparation & preservation

- Instant coffee
- UHT milk
- Fluidized bed freezing

Production

- SCP process (ICI) (methanol, brewery effluents)
- Pekilo process (paper industry effluents)

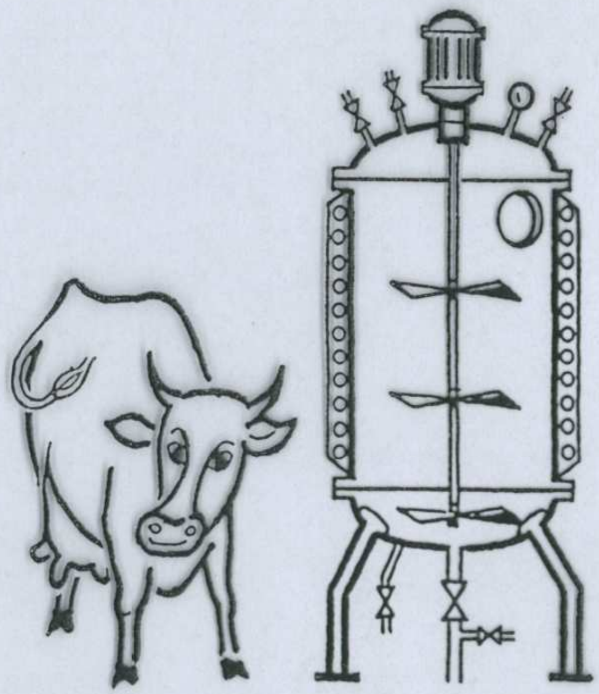


Abb. 9-4. Tagesproduktion an Protein: Rind und Einzellerprotein im Vergleich.

Water I 1338 000 000 km^3

Oceans and seas (saline)	97%				
Fresh	3%				
↓					
of this:	Glaciers	68.7%			
	Ground	30.1%			
	Surface	0.3%	→ of this:	Lakes	87%
	Other	0.9%		Swamps	11%
				Rivers	2%
				(0.0067% of total)	

Water II

People without access to clean drinking water

Developed countries	0%
Developing countries	22%
Underdeveloped countries	38%
World	18%

Water III

Use of water in cities

Toilet flushing	35%
Personal hygiene	32%
Cloth washing	12%
Vessel washing	10%
Consumption	3%
Other	8%

Water IV

Water use for production

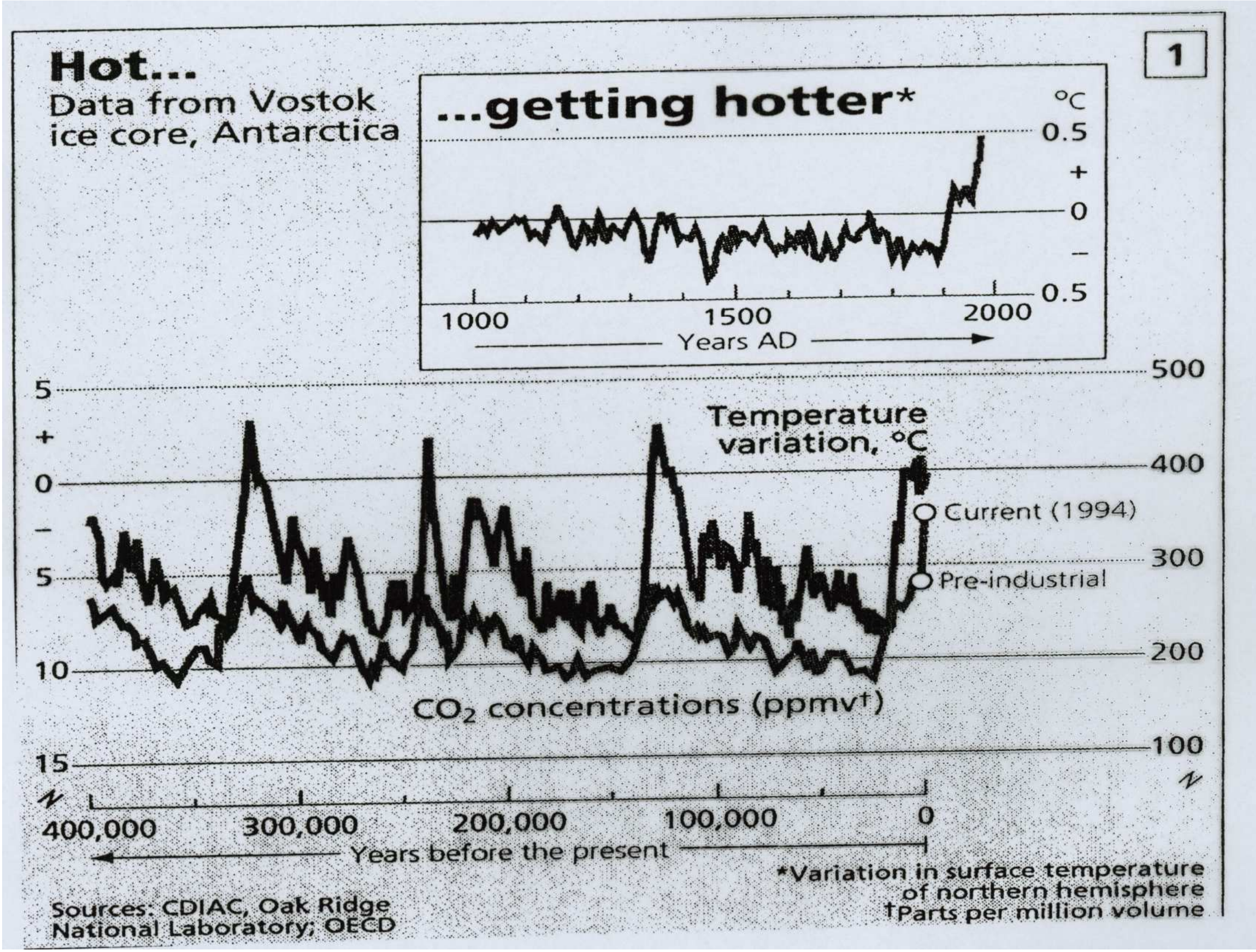
Pair of shoes	8 000 l
Hamburger	2 400 l
T shirt	2 000 – 4 000 l
Bottle of beer	150 l

Methods - Water

Desalination by:

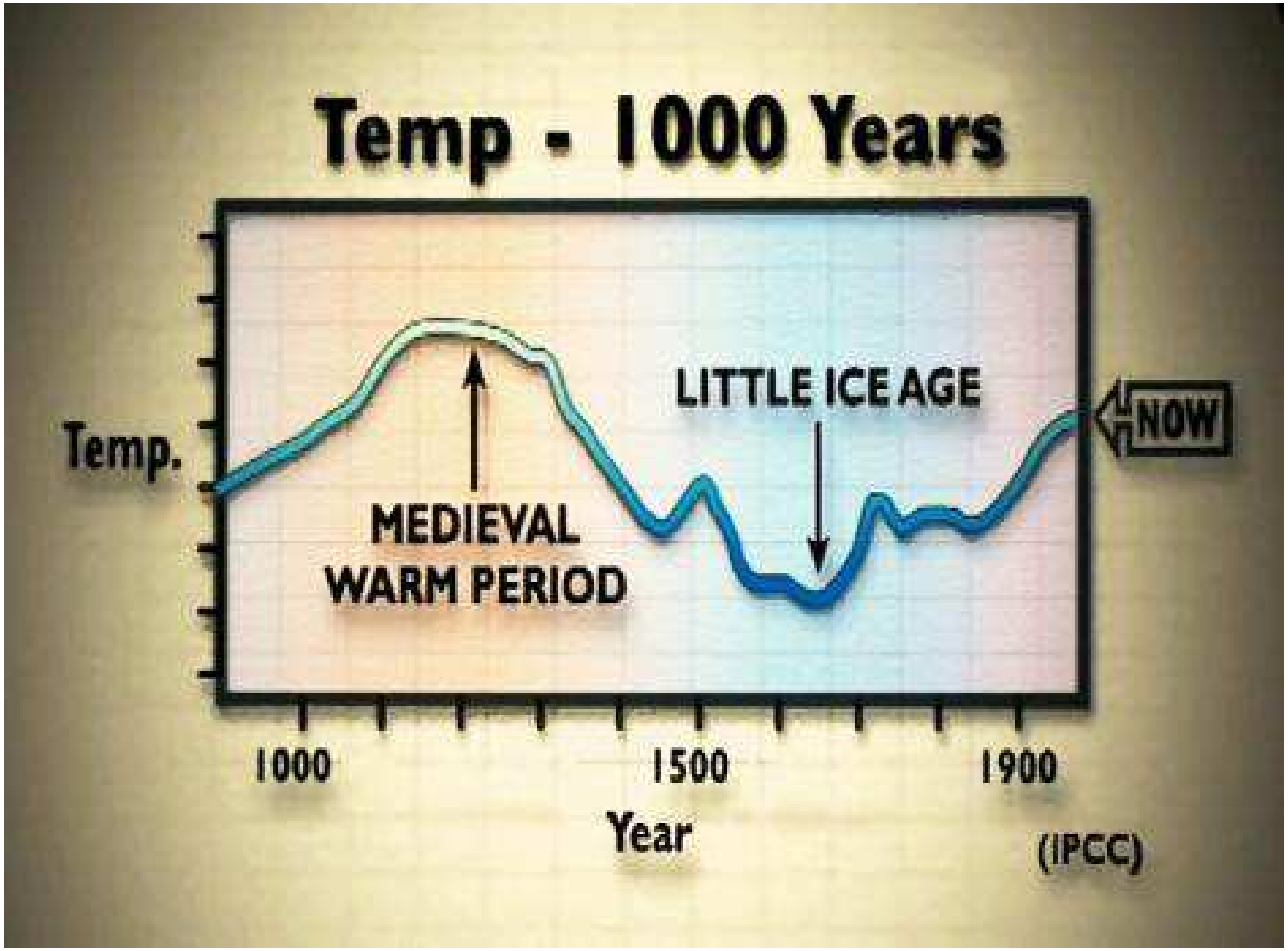
- Evaporation
- Membrane techniques

Waste reduction



1
Hot...
Data from Vostok ice core, Antarctica
...getting hotter*
°C
0.5
+
0
–
0.5
1000
1500
2000
Years AD
Temperature variation, °C
5
+
0
–
5
10
15
500
400
300
200
100
Current (1994)
Pre-industrial
CO₂ concentrations (ppmv†)
400,000
300,000
200,000
100,000
0
Years before the present
*Variation in surface temperature of northern hemisphere
†Parts per million volume
Sources: CDIAC, Oak Ridge National Laboratory; OECD

TEMPERATURE CHANGES – LAST THOUSAND YEARS

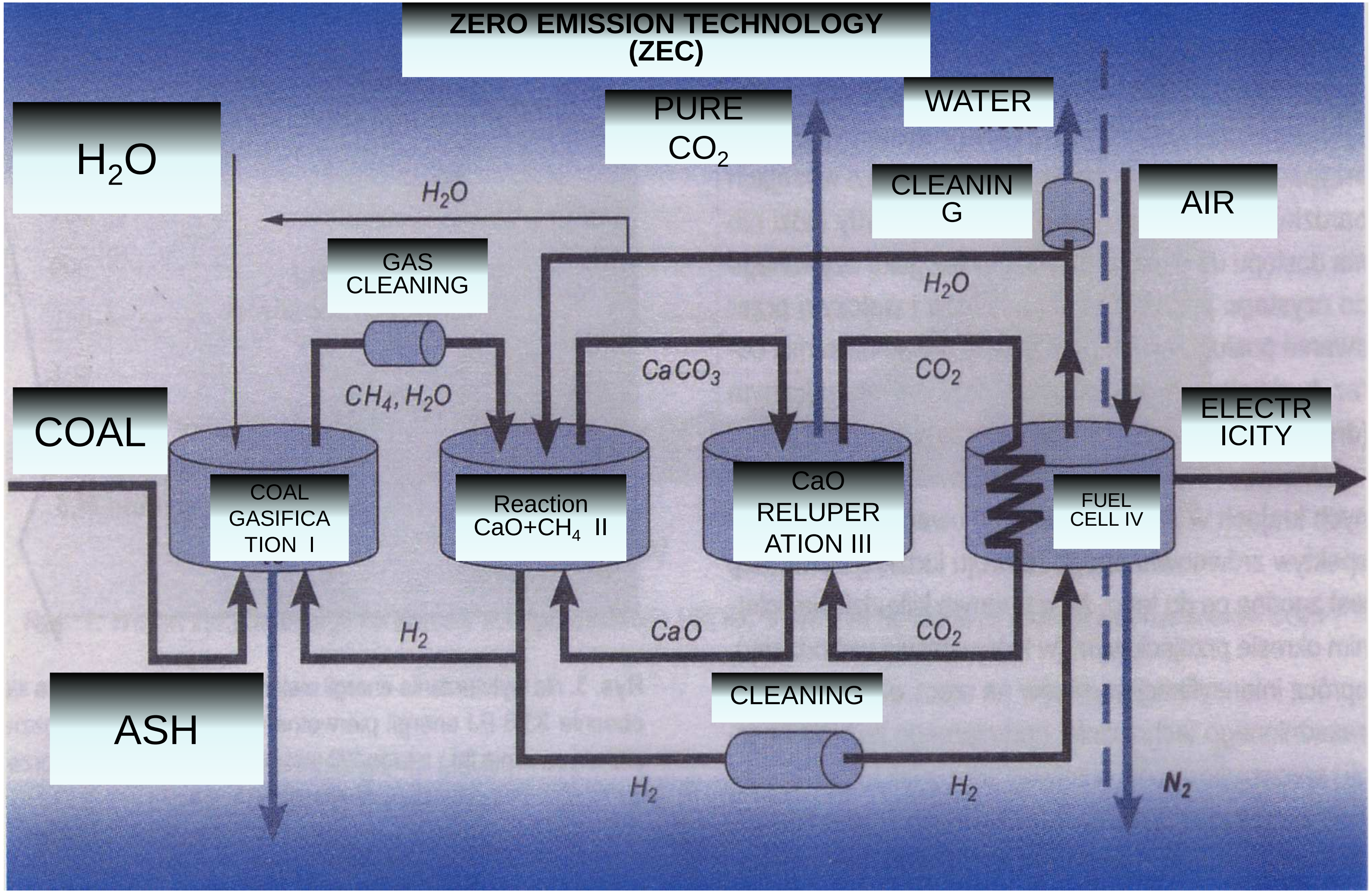


Environmental & climate

CO_2 concentration in the Paleocene and early Eocene (60 to 52 Myr ago) :

>2000 ppm

Since the early Miocene (24 Myr ago) **< 500 ppm**



ZERO EMISSION TECHNOLOGY
(ZEC)
H2O
PURE CO2
WATER
CLEANIN G
AIR
H2O
GAS CLEANING
H2O
CaCO3
CO2
CH4, H2O
COAL
ELECTR ICITY
COAL GASIFICA TION I
Reaction CaO+CH4 II
CaO RELUPER ATION III
FUEL CELL IV
H2
CaO
CO2
CLEANING
ASH
H2
H2
N2

ZEC Technology

I
$$C + 2H_2 \rightarrow CH_4$$
$$(C + 2H_2O \rightarrow CO + H_2 + H_2O \rightarrow CO_2 + 2H_2)$$

II
$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$$
$$CaO + CO_2 \rightarrow CaCO_3$$

III
$$CaCO_3 \rightarrow CaO + CO_2$$

IV
$$2H_2 + O_2 \rightarrow 2H_20$$

Carbon compounds energy of formation

	Δ H° (kcal/mole)
C	0.0
CO	-26.416
CO_2	-94.052
$CaCO_3$	-289.5
$CaCO_3 \cdot MgCO_3$	-558.8

CO_2 as a source of carbon

(Vogel, Chem. Eng. Technol., 31, 730,2008)

1st strategy

✓Mimicking natural photosynthesis (algae ?)

$$CO_2 + H_2O + h\nu \rightarrow [\text{—}C(H_2O)\text{—}] + O_2\uparrow$$

biomass

✓Biomass gasification

$$[\text{—}C(H_2O)\text{—}] \rightarrow CO/H_2$$

and $CO + 2H_2 \rightarrow [\text{—}CH_2\text{—}] + H_2O$

or $CO + 2H_2 \rightarrow CH_3OH$

✓Biomass liquefaction by decarboxylation and dehydration

$$3[\text{—}C(H_2O)\text{—}] \rightarrow 2[\text{—}CH_2\text{—}] + CO_2 + H_2O$$

or by dehydration and hydrogenolysis

$$[\text{—}C(H_2O)\text{—}] + H_2 \rightarrow [\text{—}CH_2\text{—}] + H_2O$$

2nd strategy

$h\nu + 3H_2O \rightarrow 3H_2 + 1.5\ O_2$ electrolysis

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$$

BIOMASS

THERMAL PATH

BIOLOGICAL PATH

BIOCRUDE

BIOSYNGAS

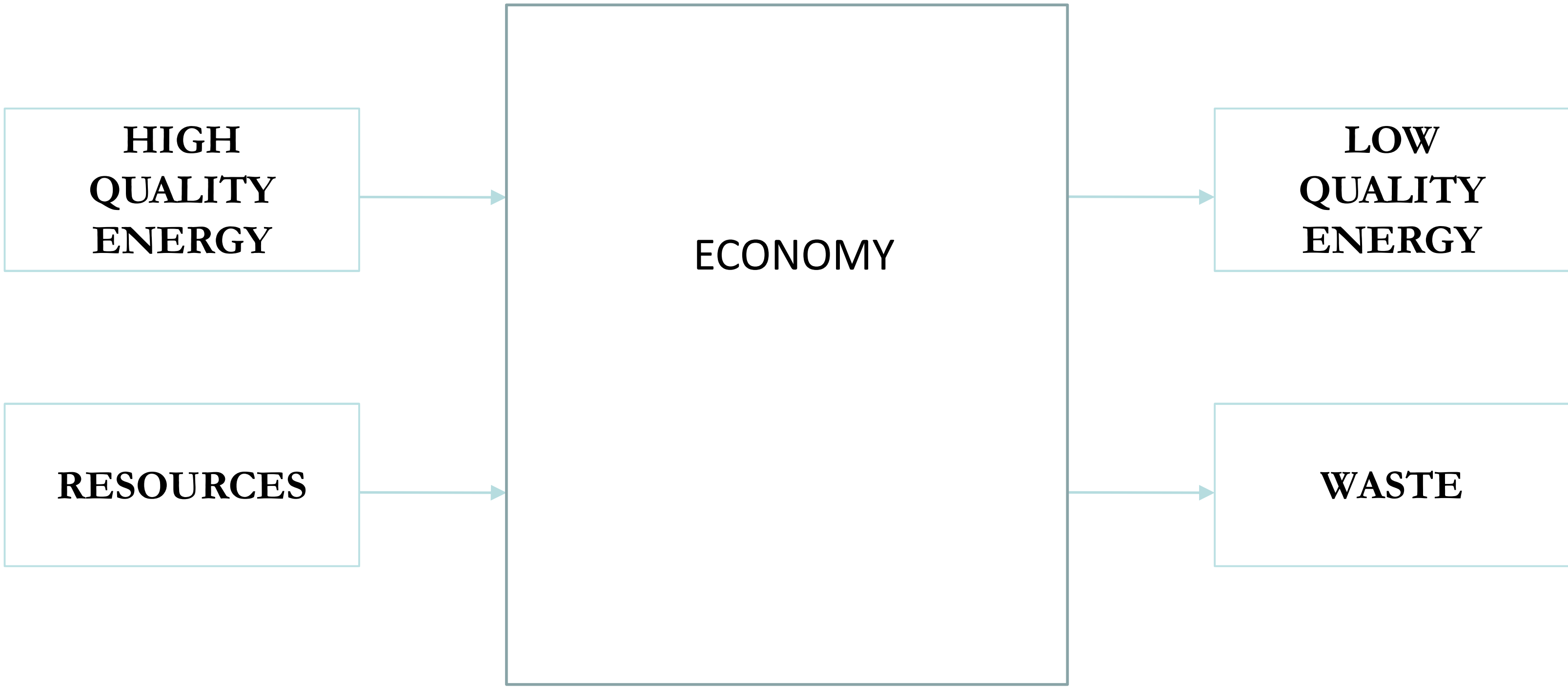
BIOCASCADE

BIOREFINING

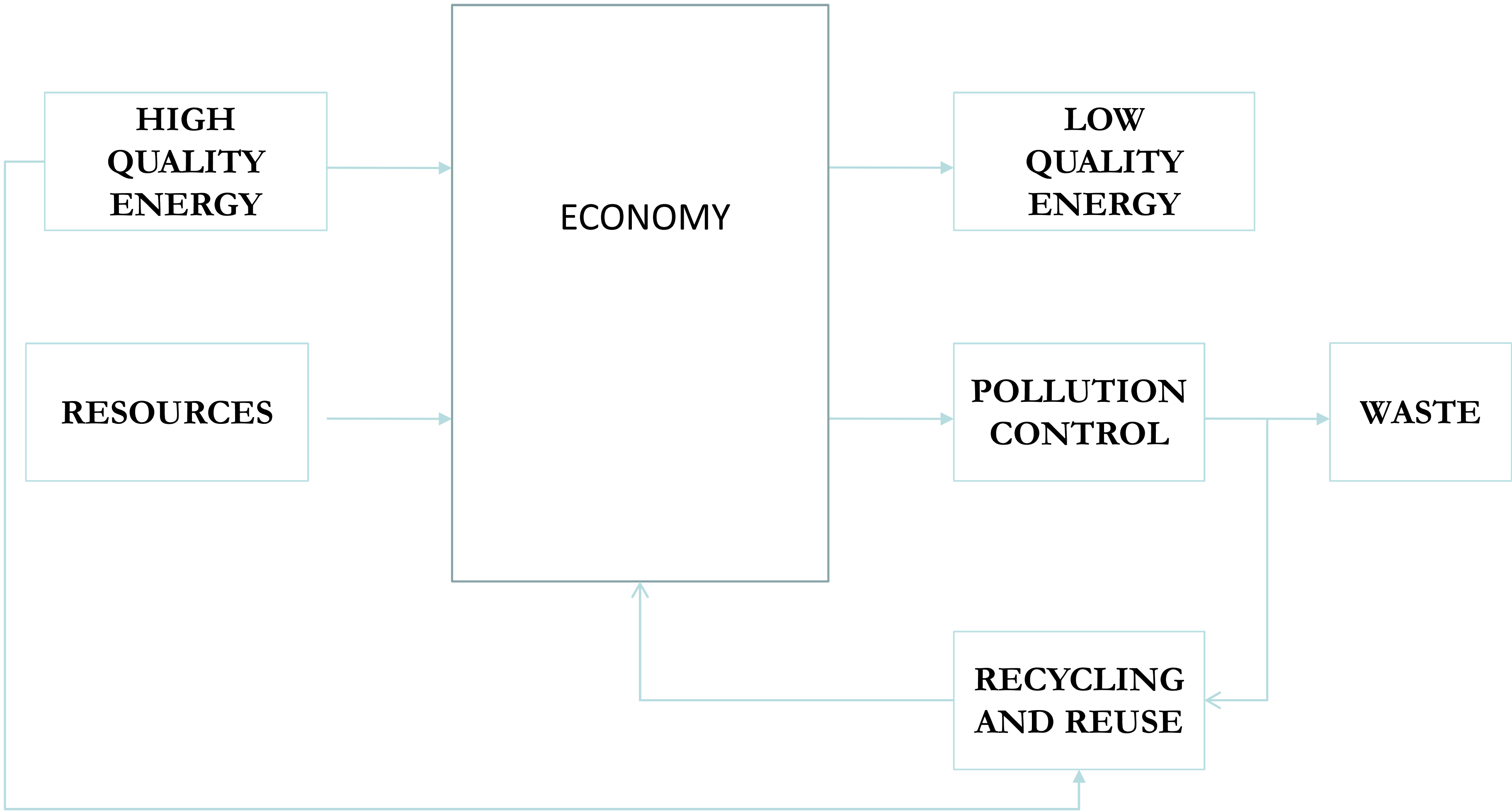
SUSTAINABILITY (G. Brundtland)

Strategies and actions that have the
objective of meeting the needs and
aspirations of the present without
compromising the ability to meet those
of the future

THROWAWAY SOCIETY (after G.T. Miller JR)



SUSTAINABLE SOCIETY (after G.T. Miller JR)



MEANS

- use of renewable resources
- reduction resource waste
- preventing pollution
- recycling and reusing
- optimum use of energy

METHODS

- monitoring and forecasting
- end pipe technologies
- new sustainable technologies

THANK YOU