B2 Engineering, Sustainability and the Environment

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Lecture 1

Learning outcomes

To acquire knowledge and understanding of

- The concept and consequences of sustainable development
    - social,
    - environmental,
    - economic

- The changing role of engineering in sustainable development

- The tools used to implement sustainable decision-making

Course outline

1. Why?
   – Global Issues
   – Why Engineering?

2. What?
   Brundtland Report
   Triple Bottom Line
   Stakeholders

3. How?
   – Legislation
   – Tools
   – Metrics

4. When?
   – Scenario Analysis
   – Structural Change?
   – A Sustainable Future

1. Why bother with Sustainable Development?

- "Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs." – UK sustainable development commission

- **Global Issues**
  - **Population**
  - **Resources**
  - **Environment**
  - **Climate Change**

- **Why do engineers need to bother with Sustainable Development?**

Humanity's Top Ten Problems for the next 50 years

1. ENERGY
2. WATER
3. FOOD
4. ENVIRONMENT
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

Five problems are sustainability issues

Richard E. Smalley, Nobel Laureate, Energy and Nanotechnology Conference, Rice University, Houston, May 3rd, 2003

State of the world
What are the concerns?

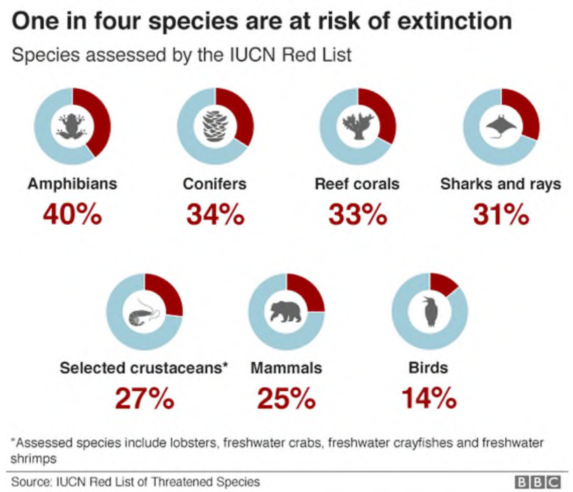
		1950	1972	1997
Population	**(billions of persons)**	**2.5**	**3.8**	**5.8**
Megacities	**(cities of more than 8 million people)**	**2**	**9**	**25**
Food	**(mean daily production in calories/capita)**	**1980**	**2450**	**2770**
Fisheries	**(annual fish catch in million tons)**	**19**	**58**	**91**
Water use	**(annual water use in cubic kilometres)**	**1300**	**2600**	**4200**
Rainforest cover	**(index of forest cover 1950=100)**	**100**	**85**	**70**
Biodiversity	**(eg millions of elephants)**	**6.0**	**2.0**	**0.6**
CO2 Emissions	**(billions tons of carbon per annum)**	**1.6**	**4.9**	**7.0**
Ozone Layer	**(atmospheric concentration of CFC's in parts/billion)**	**-**	**1.4**	**3.0**

Current issues

- **Population increase**
- *current 7.8 billion (2020) to 9.7 billion in 2050 - World Population Prospects in 2015*

- **Natural resources**
- ***~ 30-50% conventional oil resource already consumed,***
- ***fresh water availability limiting development, urban air quality.***
- ***Species extinction***

One million animal and plant species are now threatened with extinction. BBC 6th May 2019



Current issues

- **Environment**
- Three environmental elements: water, soil and air are all polluted. Our insatiable appetites are producing a mountain of waste.

- Water- Ocean: plastic pollution has increased ten-fold since 1980. Surface and ground water contamination. For example: every year we dump 300-400 million tonnes of heavy metals, solvents, toxic sludge and other wastes into the waters of the world.

- Air – Smog ozone layer depletion, acid rain, urban air quality.

- Land degradation - Deforestation, desertification, topsoil erosion, contaminated land (e.g. Remediation cost in EU is $81b). This has reduced the productivity of 23% of the land surface of the Earth.

Current issues

- **Climate change**
- Curbing CO_2 emission and keeping to the preferred target of 1.5C above pre-industrial levels by 2030. – BBC 2018.
- There must be rapid and significant changes in four big global systems: energy • land use • cities • industry
- Average investment in the energy system of around $2.4 trillion
- Five steps to 1.5

- Global emissions of CO_2 need to decline by 45% from 2010 levels by 2030

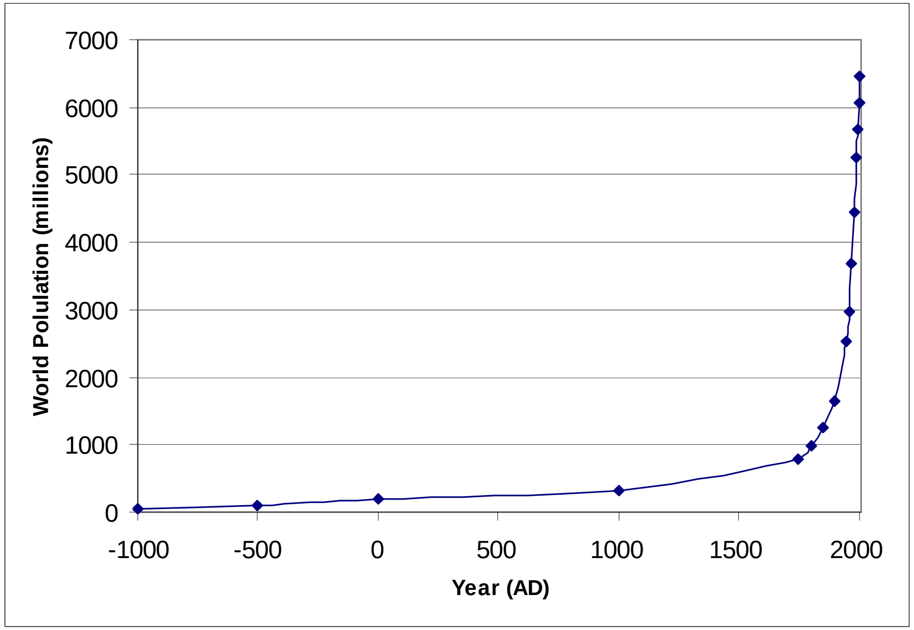
- Renewables are estimated to provide up to 85% of global electricity by 2050

- Coal is expected to reduce to close to zero

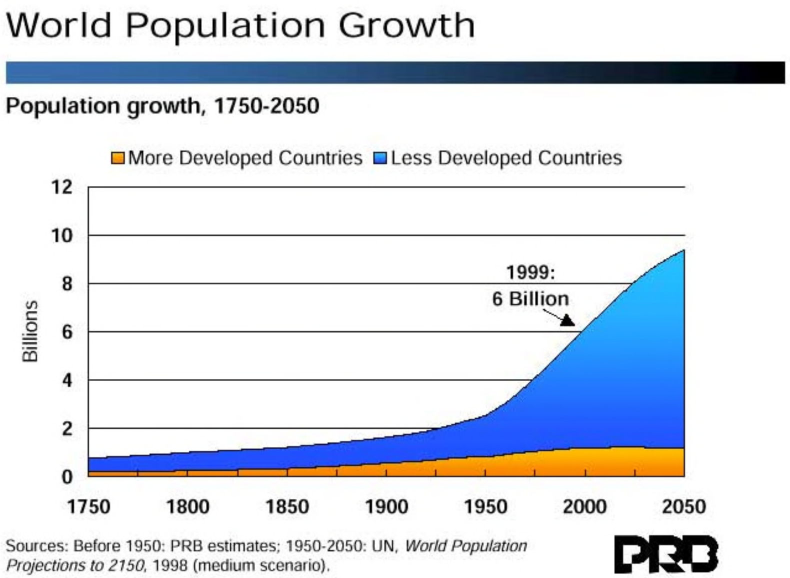
- Up to seven million sq km of land will be needed for energy crops (a bit less than the size of Australia)

- Global net zero emissions by 2050

How many of us are there?



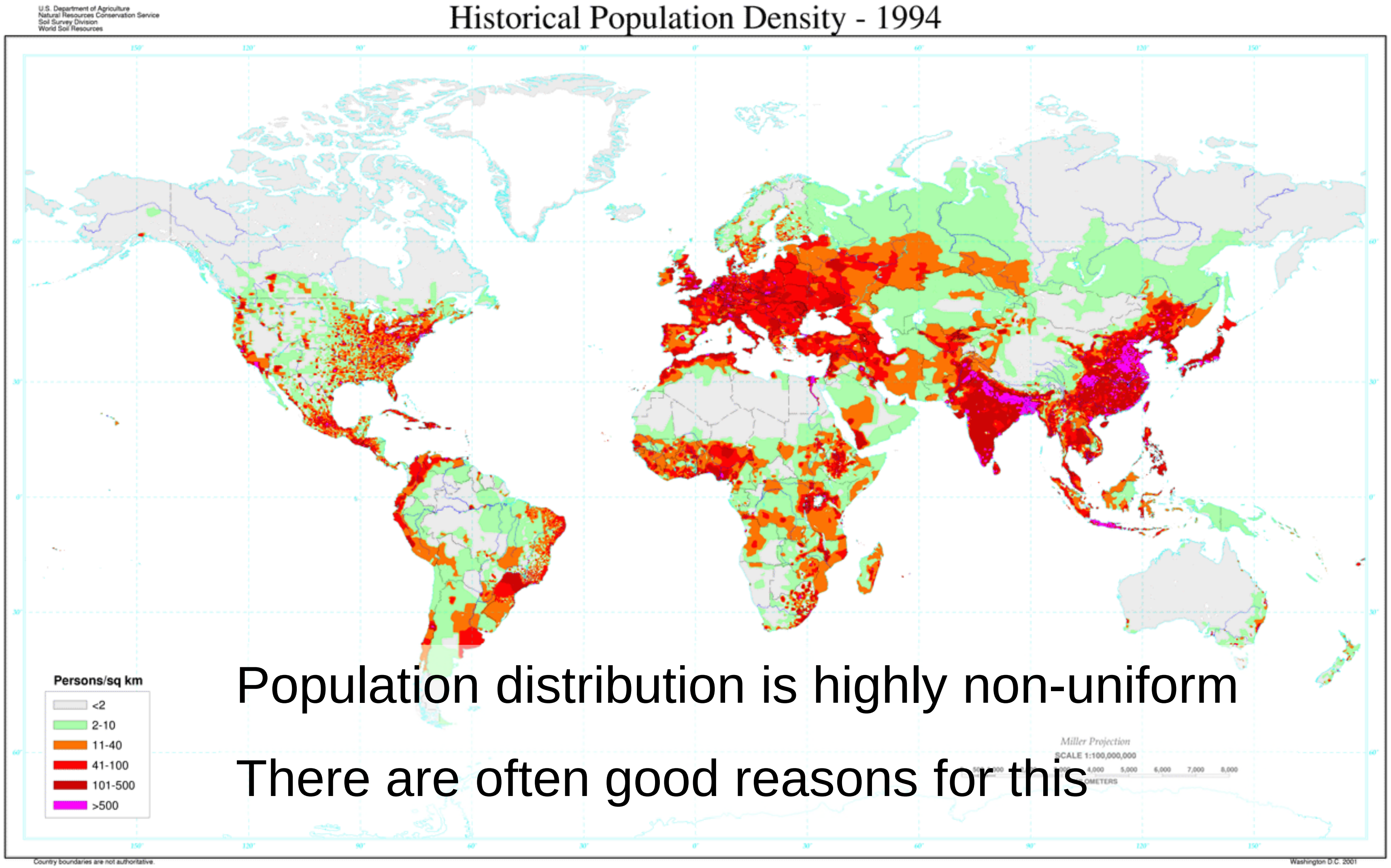
There are now 7.8 billion which is over twice as many people on the planet as in 1970 (3.7 billion)



However, data shows that in developed countries populations have generally ceased growing (at least if immigration is discounted)

Some studies show that world population may peak in the mid 21st century

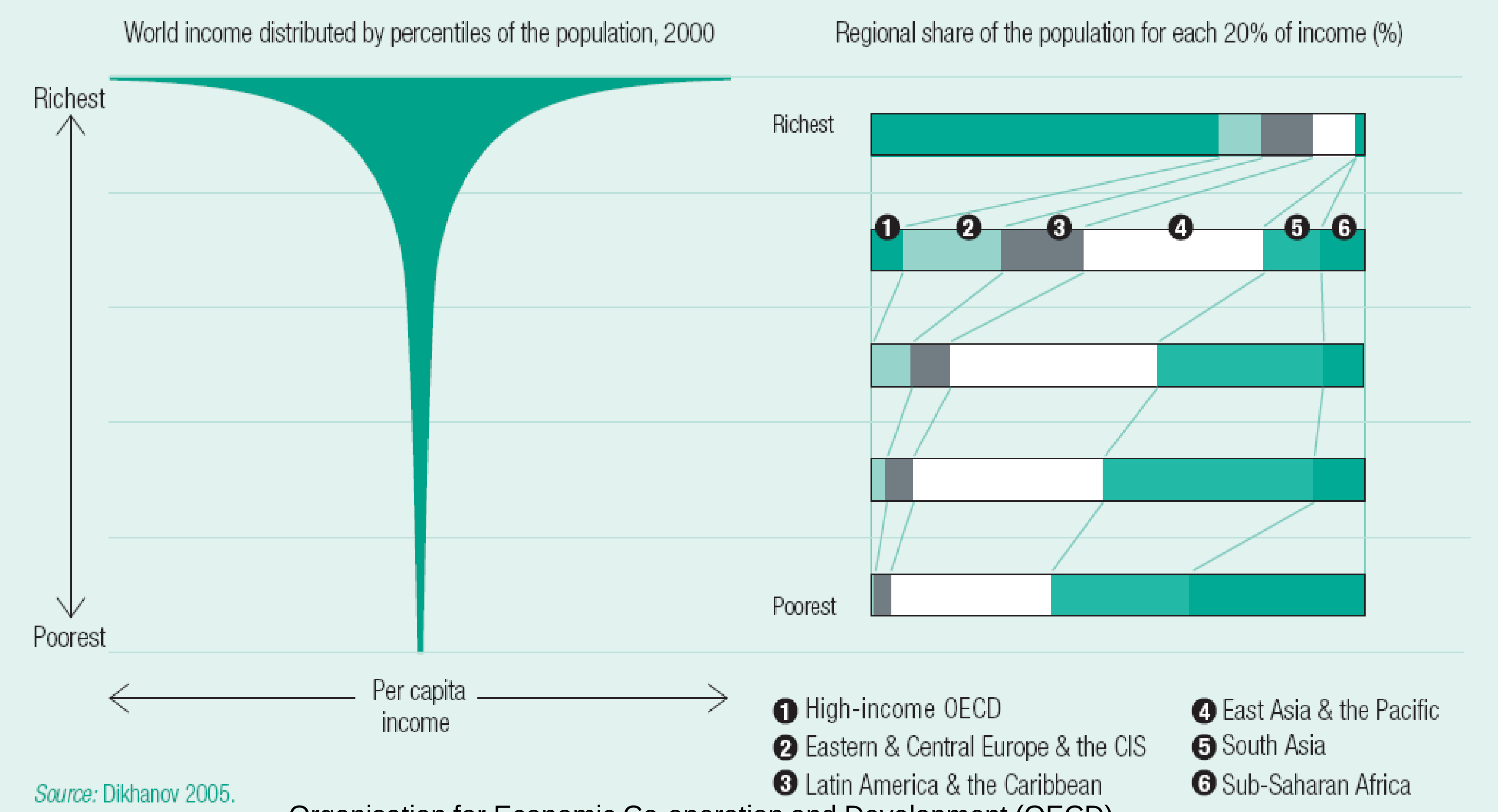
Where do people live?



Population distribution is highly non-uniform

There are often good reasons for this

Income distribution



Organisation for Economic Co-operation and Development (OECD)

http://hdr.undp.org/reports/global/2005/pdf/HDR05_chapter_1.pdf

Wealth (e.g income) is very unevenly distributed

We are at different stages of development

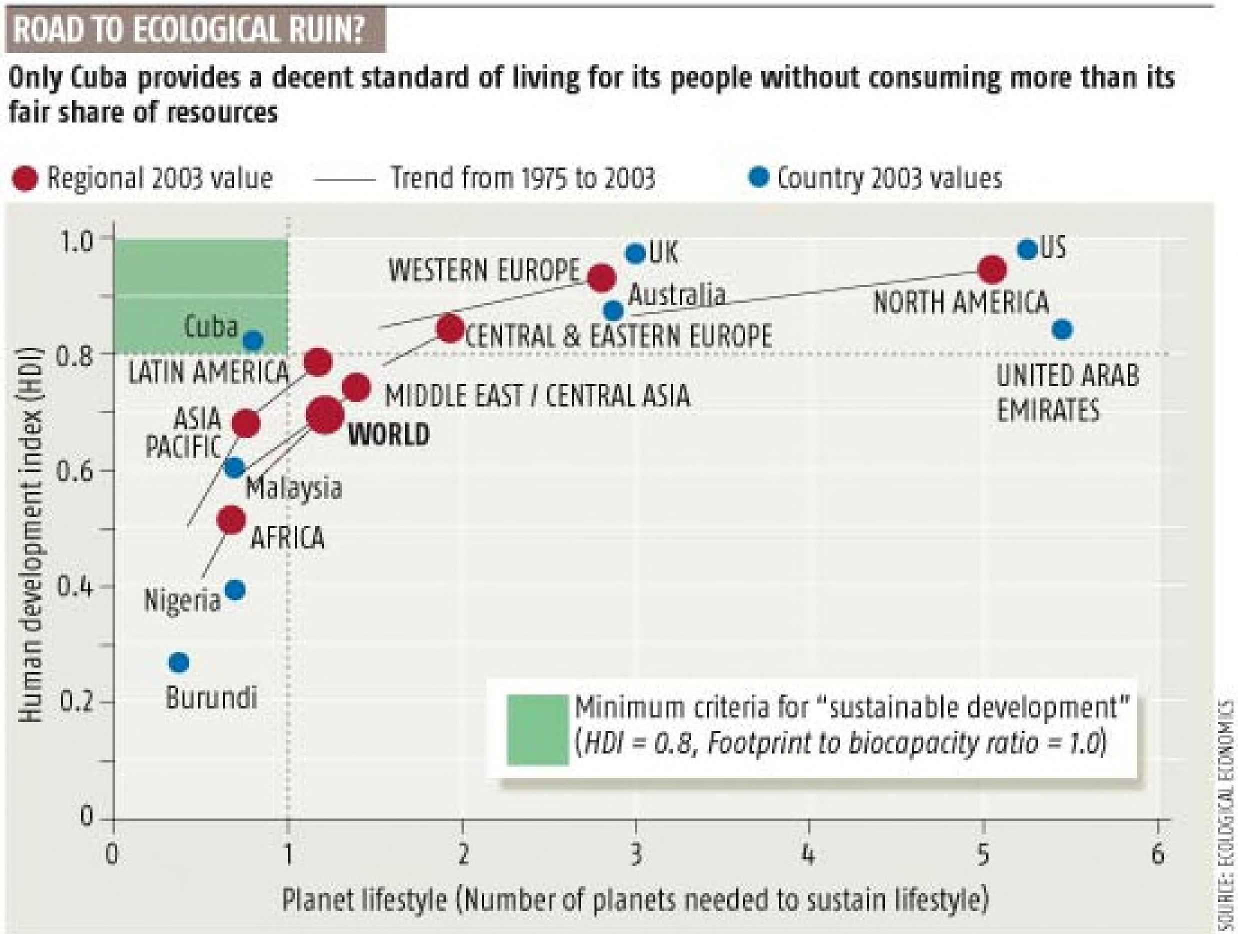
Three richest people have same assets as poorest 600 million.

Over 2 billion people are without grid connected electricity.

Around 1 billion people rely on wood or animal waste as primary energy source.

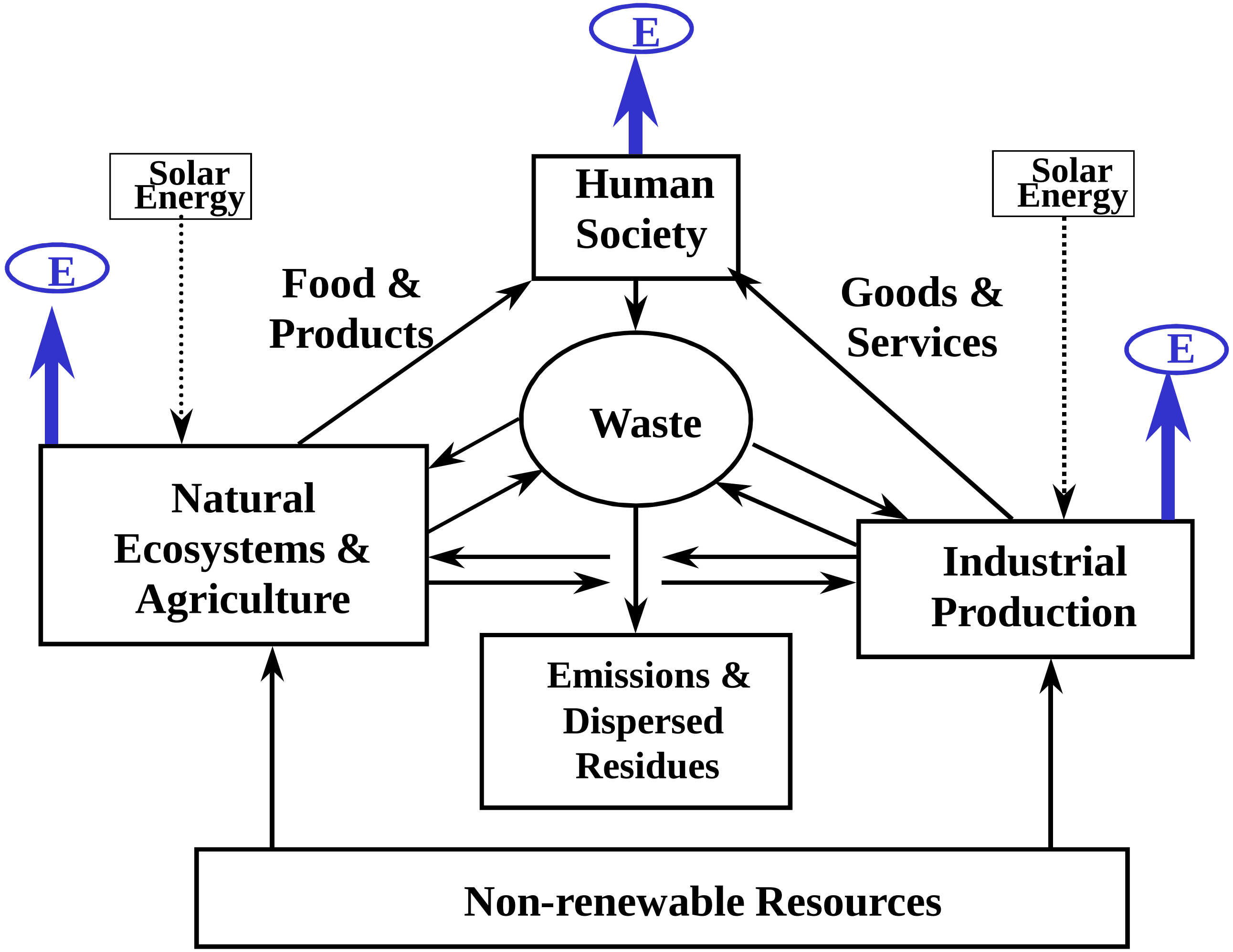
Resources

- Very few of us are living a sustainable lifestyle



Source: New Scientist, October 2007

Resource flows



E = Emissions to air and water

(Clift R, TICE B2 151 1998)

US Material Flow

(The US as an example of a developed economy)
US Economy: only 6% of materials flow ends in products

Computing waste: Laptop ~ 4,000 times; microchip ~ 100,000

1 tonne paper consumes 98 tonnes of various resources

US industry handles ~ 1,800 tonnes per year per average household

Materials flow per average American : 56 kg/day
(21 fuel, 21 construction materials, 7 farm products, 2.7 forestry, 2.7 industrial minerals, 1.4 metals)
PLUS: 1,000 kg water and 170 kg rock *(tailings, overburden, waste water from fuel and minerals extraction)*

Total waste flow (inc waste water) > 100 x 10^9 tonne per year,
Less than 2% recycled

Climate Change issues

- Average global temperatures seem to be increasing
  - Effect not uniform
  - Threats to biodiversity and agricultural production
- Extreme weather events seem to be becoming more frequent
  - Loss of life
  - Damage to property
  - Economic disruption
- Sea levels are rising
  - Reduction in available land mass
  - Many large cities are coastal

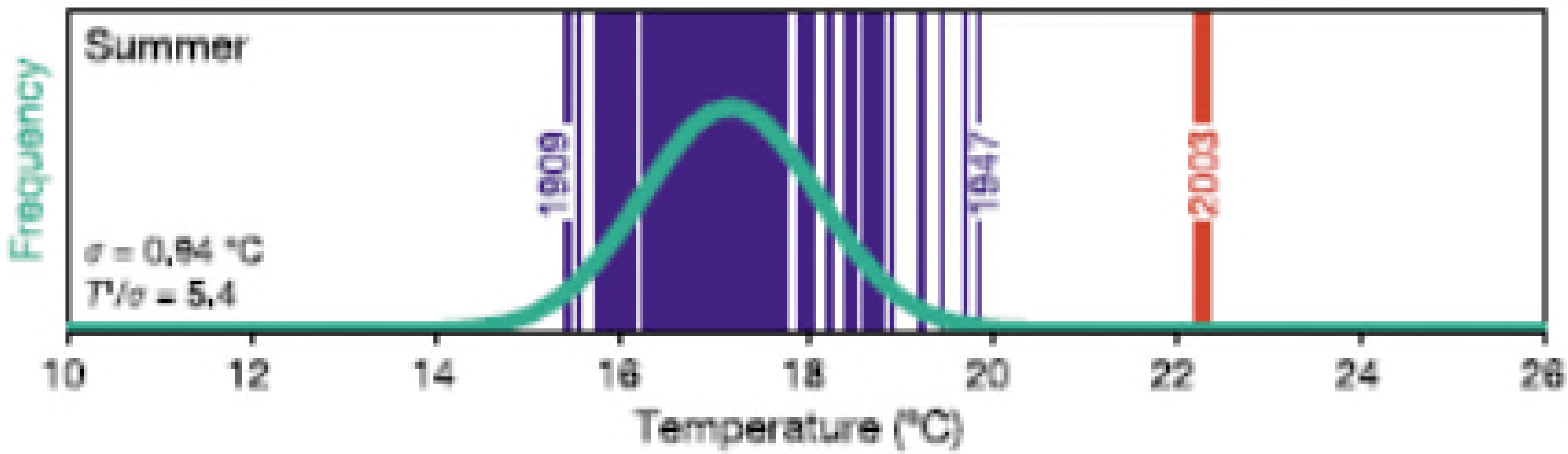
Are these changes natural?

Distribution of Swiss seasonal summer temperatures 1864-2003

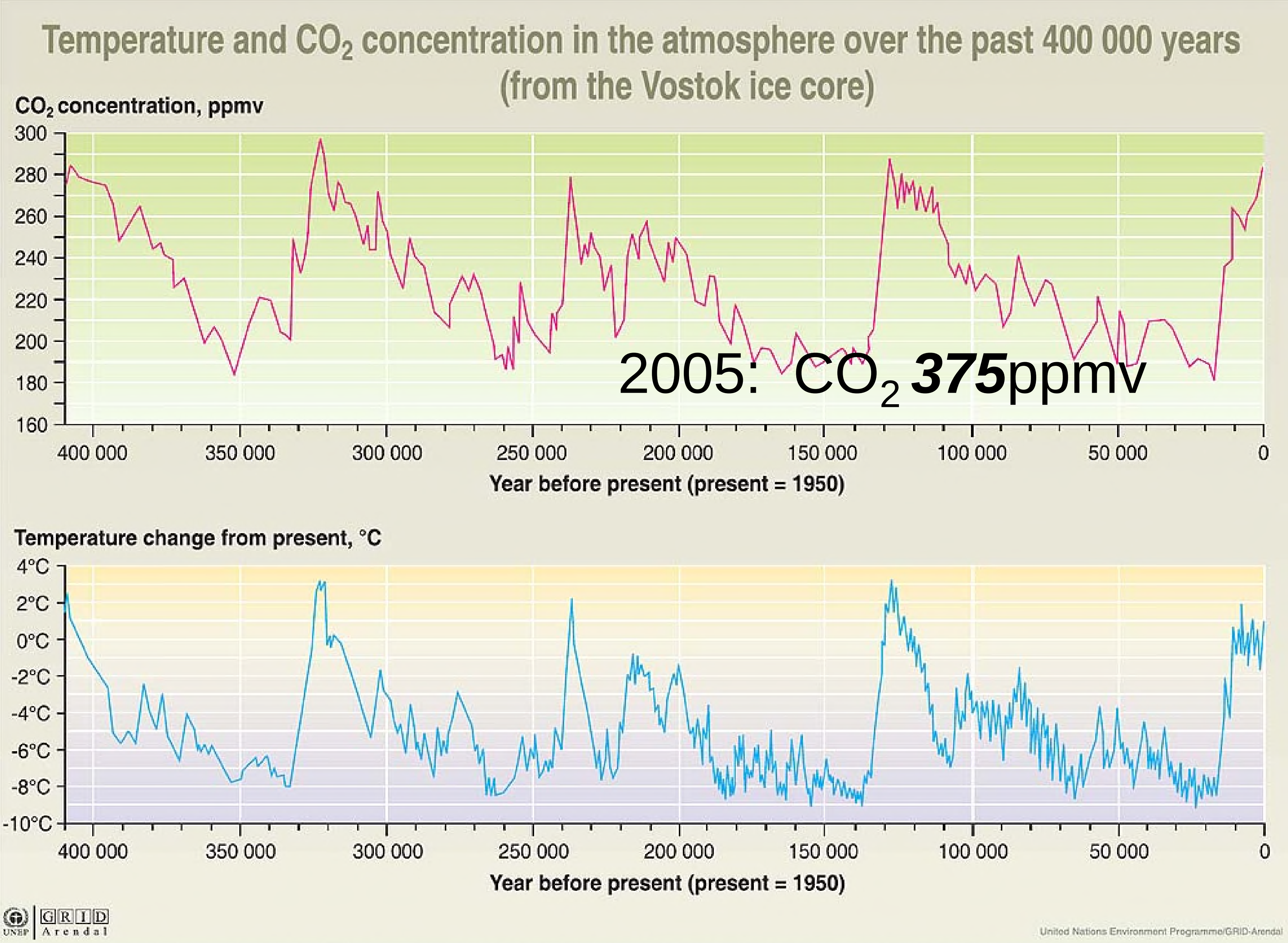
2003 temperature is **5.4** std deviations away from norm

$\mathbf{Pr = 1.899 \times 10^{-8}}$

Reference: *The role of increasing temperature variability in European summer heatwaves*, Christoph Schar et al, Nature **427**, (22 January 2004), 332



Statistically extremely unlikely



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3 June), pp 429-436, 1999.

Extreme weather - effect on society

- European heatwave 2003
  - ~30,000 deaths
  - $13.5bn direct costs
- European floods 2002
  - 37 deaths
  - $16bn direct costs
- UK floods, autumn 2000
  - Insurance pay-out £1bn
- UK floods, summer 2007
  - Estimate cost £2bn
  - 11 fatalities
- New Orleans – Hurricane Katrina, 2005
  - Estimated cost $82 bn
  - 1836 deaths

Tewkesbury Flood – Summer 2007

Not all is Doom and Gloom

We live in a time of unprecedented wealth

- **Life expectancy increasing**
- **Poverty declining (at least on average)**
- **Health improving**
- **Have not (yet) run out of any natural resource**
- **Some problems could be opportunities: such as pollutants/wastes are resources in the wrong places, CO_2 could be resource for new bioeconomy and biomanufacturing.**

Humanity's lot has vastly improved (on average) –
But this does not mean everything is good enough.

See: The Skeptical Environmentalist, Bjorn Lomborg

The 21st Century?

Imagine a world of 10 billion people, consuming resources
and generating waste at the same rate as 0.325 billion Americans.
This is hardly sustainable for one generation, let alone ten!

Options:
1. Change in thinking to become more efficient in use of resources
2. Colonise and exploit sea bed and/or space.
3. Reduce population (How?)

Option 1 seems the more realistic!

We need
- to improve quality of life for the current global population
- to start to live within the carrying capacity of the planet
- to ensure a better world for future generations (inter-generational equity).

Why Engineering?

Engineering is the knowledge required, and the process applied, to conceive, design, make, build, operate, sustain, recycle or retire, something with a significant technical content for a specific purpose: a concept, a model, a product, a device, a process, a system, a service, a technology.

Royal Academy of Engineering

This means optimising a solution within constraints and uncertain data.

But what do we mean by ‘optimise’?

The Mark I engineer

Mark 1: ‘best’ technology - using available materials and energy to optimise economic returns

The Royal Albert Bridge at Saltash

1859 Isambard Kingdom Brunel at the launching of the Great Eastern

However, this approach had consequences:

- Plentiful supplies of cheap energy (wood, then coal) fuelled the industrial revolution but let to severe local climate conditions.
- Economists would consider that externalities had not been included in the optimisation
- In developed countries, legislation was introduced to limit these problems

The Mark II engineer

- Makes an economic return on capital invested
- Complies with HSE legislation
- Delivers product “fit for purpose” as specified by client

- Emphasis has shifted to include wider factors

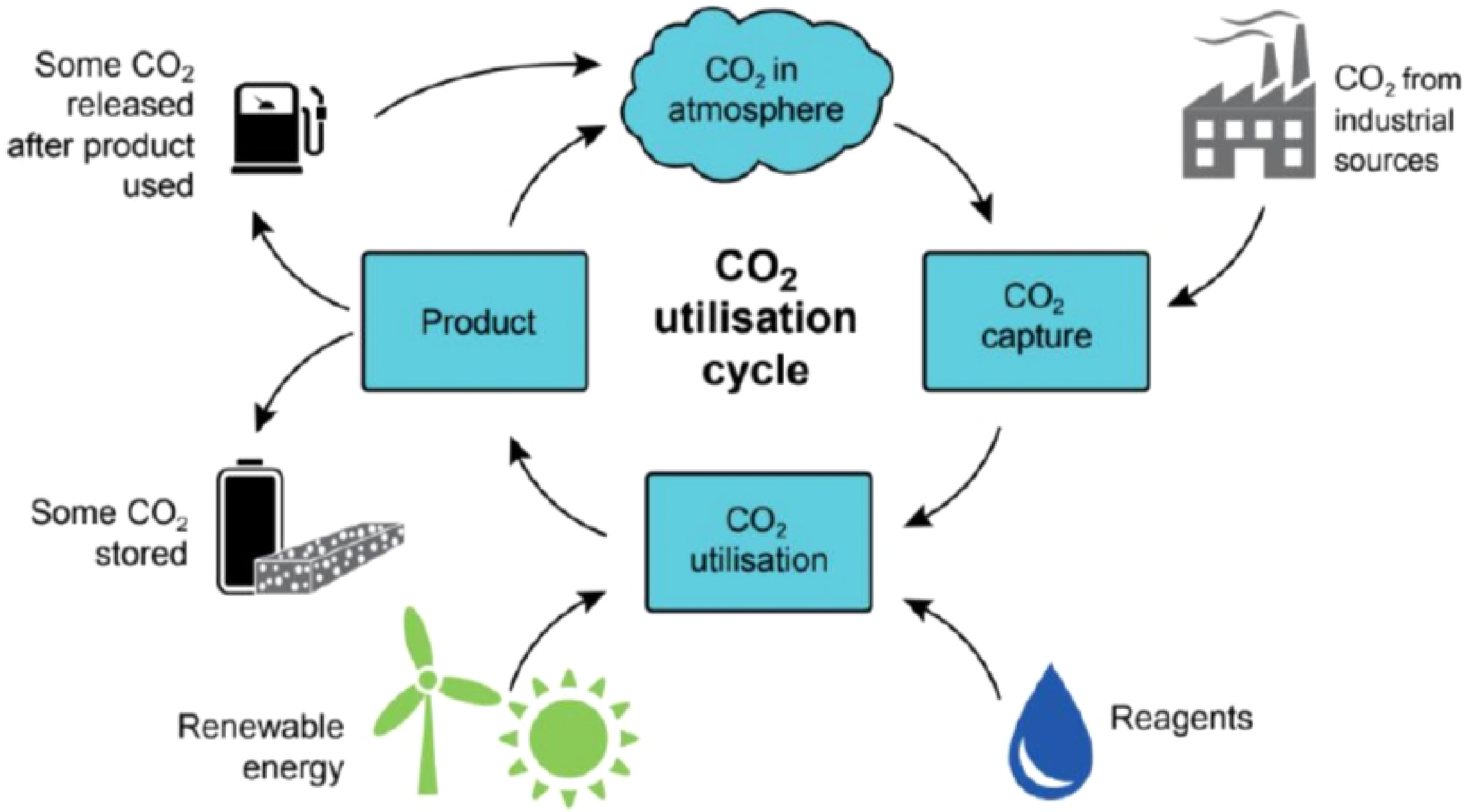
But what of the future?

Minority Report © DreamWorks

The Mark III engineer must consider economic and environmental impacts, as well as the needs of society.

This will be sustainable engineering

Engineering opportunity



Courtesy from Cameron Hepburn, Oxford

Summary

- At present, the human race is not living sustainably on the Earth
- Engineering progress has contributed significantly to this problem, whilst delivering vastly improved standards of living
- The challenge of the 21st Century is to continue to improve living standards (at least for the majority of the population) whilst reducing our impact on the world's resources
- Engineering must be part of the solution

References and Suggested Reading

- **Our Common Future, *World Commission on Environment and Development 1987, ISBN 0-19-282080 OUP***

- **The New Model Engineer and Her Role, R Clift *Trans IChemE* Vol 76, Part B 151- May 1998**

- **Engineering, Ethics and the Environment, PA Vesilind and AS Gunn *ISBN 0-521-58918-5 CUP***

- **Clean Production Strategies, Tim Jackson (Ed) 1993, *ISBN 0-87371-884-4 CRC Press LLC***