Science and technology: When does use become misuse?

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Scientists for Global Responsibility
Scientists • Architects • Engineers • Technologists

SGR
Promoting ethical science, design and technology

http://www.sgr.org.uk/

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Scientists for Global Responsibility

- Independent organisation of 1000 natural scientists, social scientists, engineers, architects, IT workers, sci/tech teachers
- Promotes science, design and technology which contributes to reduction of conflict, environmental protection, social justice
- Research, education, campaigning and support network

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Introduction

- Enormous changes to the world over the past century (and longer)
- Science & technology have played key role
- Major benefits but...
- ... also major costs

➢ Have we got the balance right?

Benefits

Rise in availability of energy

- Mining of fossil fuels (coal, oil and gas) led to massive rise in the energy available to society
- Global coal production
  - 1800 – 15 million tonnes
  - 2010 – 7,229 million tonnes
- Global oil production
  - 1890 – 10 million tonnes
  - 2010 – 3,973 million tonnes
- Global electricity generation (mostly from fossil fuels)
  - 1834 – first generators built
  - 2009 – 20,055 million kilowatt-hours

• Main technological developments in energy sector included steam engine, electricity generators/ turbines, internal combustion engine, turboprop engine, jet engine
• Figures for coal include hard coal and brown coal

References: Ponting (1989), Chap 13; IEA (2011)

Rise in availability of energy....

- ...allowed the Industrial Revolution to happen
- ...has been central to the huge expansion of buildings/housing, food production, transport, industry, consumer goods etc
- Fossil fuels still make up ~80% of the world's 'total primary energy supply'

IEA (2010a).

Expansion of food production

- Major technology changes from 1850 onwards...
  - Mechanisation of agriculture
  - Long distance transport & refrigeration
  - High-input farming
  - Monoculture & intensive animal farming
  - Selective breeding of high yield crops/ animals
  - NB also much more land converted to agriculture
- Between 1950 and 1980 food output in industrialised countries doubled

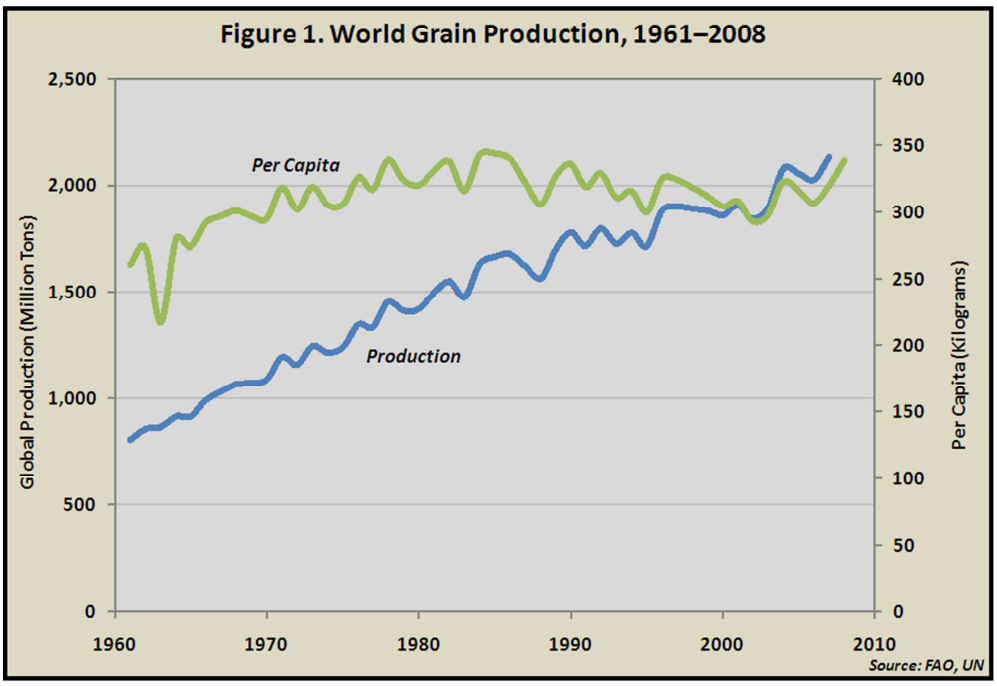
Mechanisation of agriculture – mechanical reapers, then tractors, then combine harvesters etc

Long distance transport – steam ships and trains, eventually oil driven lorries, ships, planes etc

High-input farming – use of artificial fertilisers (phosphates, then nitrogenous fertilisers), and pesticides

Expansion of land under agriculture has been critical

Ponting (1989), Chap 12.



Worldwatch Institute (2009).

Decline of infectious diseases

- One unintended effect of people living closer together (early farming communities, cities etc) was the rise in infectious diseases, but...
- Major technology changes
  - Better sanitation
  - Better housing
  - Better diet
  - Vaccines, drugs etc only a small role
- Life expectancy in industrialised countries has risen from ~35 to ~75 years over last 250 years

Better sanitation – construction of sewers, treatment of drinking water

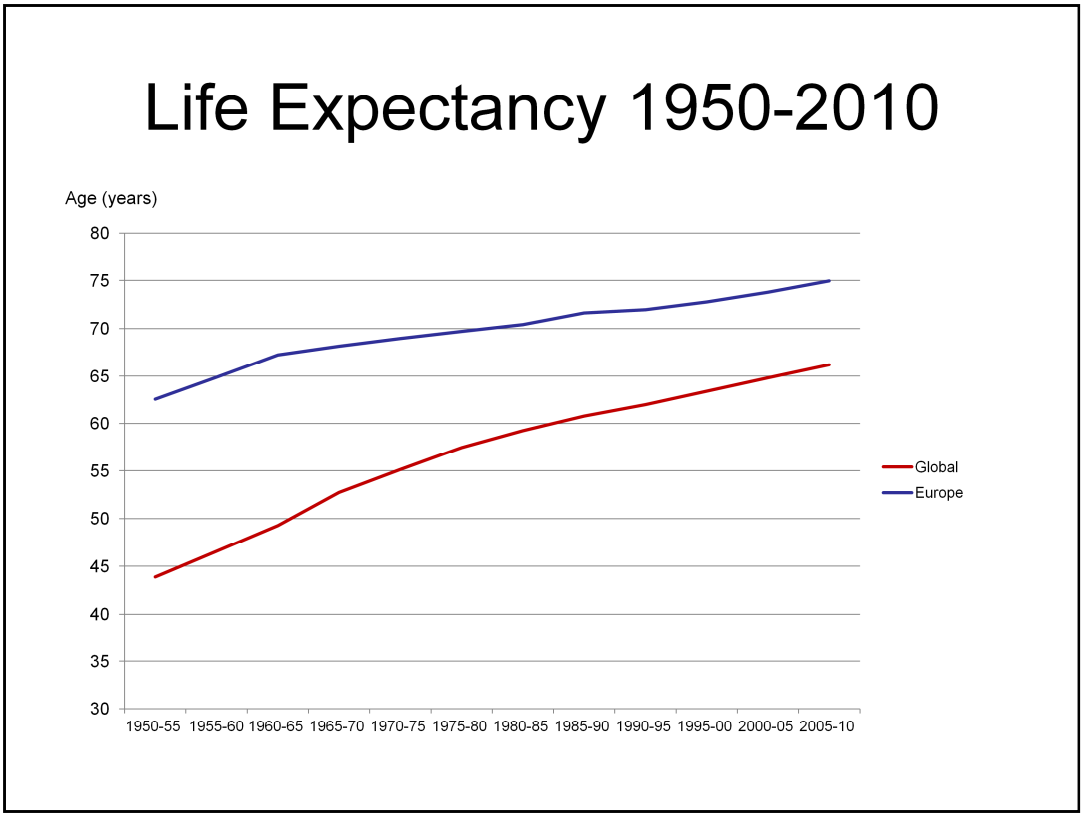
Better housing – to reduce overcrowding, damp and poor ventilation

Better diet – fresher food, pasteurisation of milk, food preservation (e.g. canning)

Medical intervention has contributed little to the decline in mortality – one major US study concluded probably as little as 3.5%

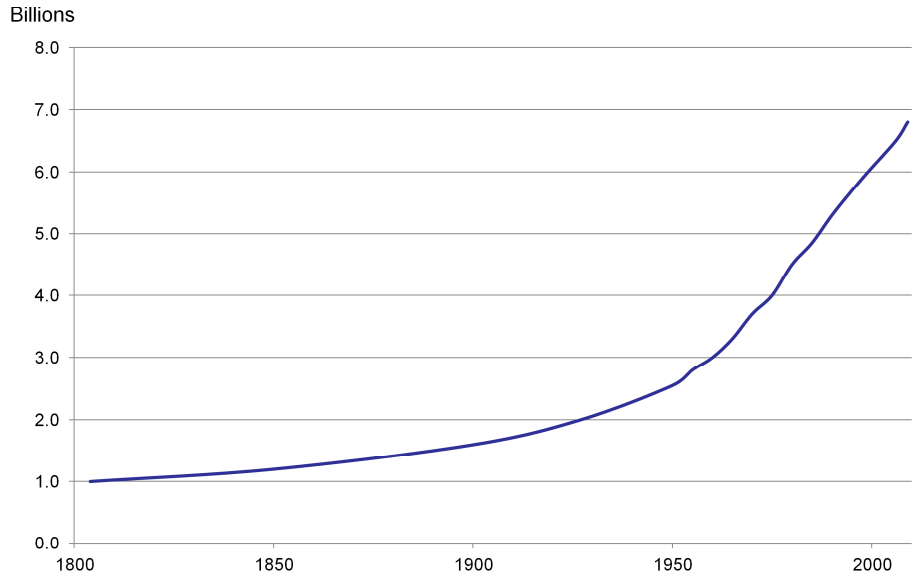
Tackling poverty has been much more important

Ponting (1989), Chap 11.



United Nations Environment Programme (2009a).

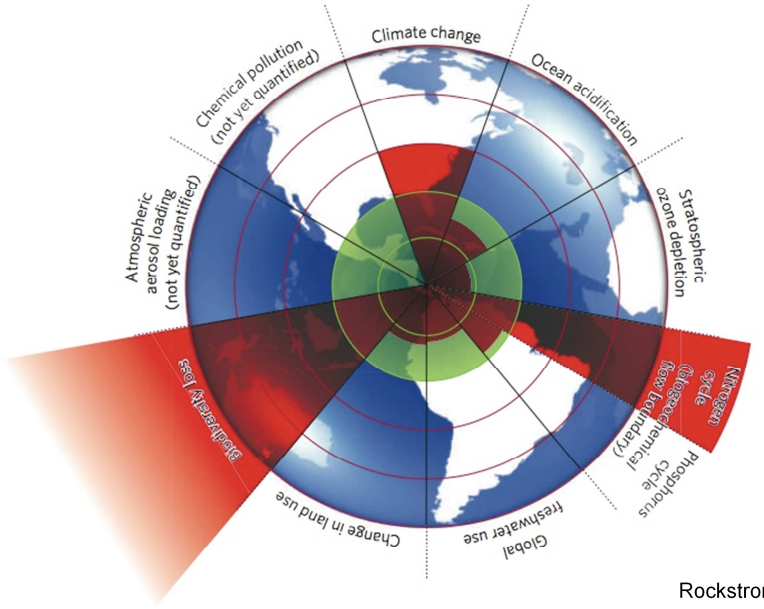
Global population 1804-2009



NYT (2009).

Costs

Breaching ‘planetary boundaries’



Rockstrom et al (2009)

• Over the last 10,000y, several key biophysical variables have remained relatively stable, allowing human civilisation to flourish

• Human activities – especially fossil fuel combustion and industrial agriculture – are causing these variables to change markedly

• There is now serious concern that we may breach ‘planetary boundaries’ – when the potential for rapid, irreversible change becomes very significant

• Three of nine interlinked planetary boundaries are believed to have already been overstepped:

  • atmospheric greenhouse gas levels due mainly to fossil fuel combustion (climate change – see later)

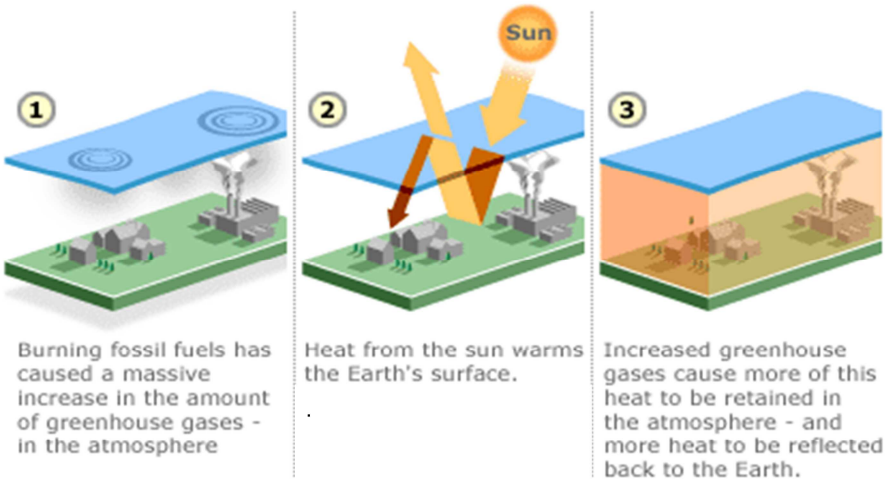
  • plant and animal extinction rates due to multiple factors (biodiversity loss - see later)

  • removal rate of nitrogen from atmosphere due to fertiliser manufacture (and other agricultural processes)

Source: Rockstrom et al (2009).

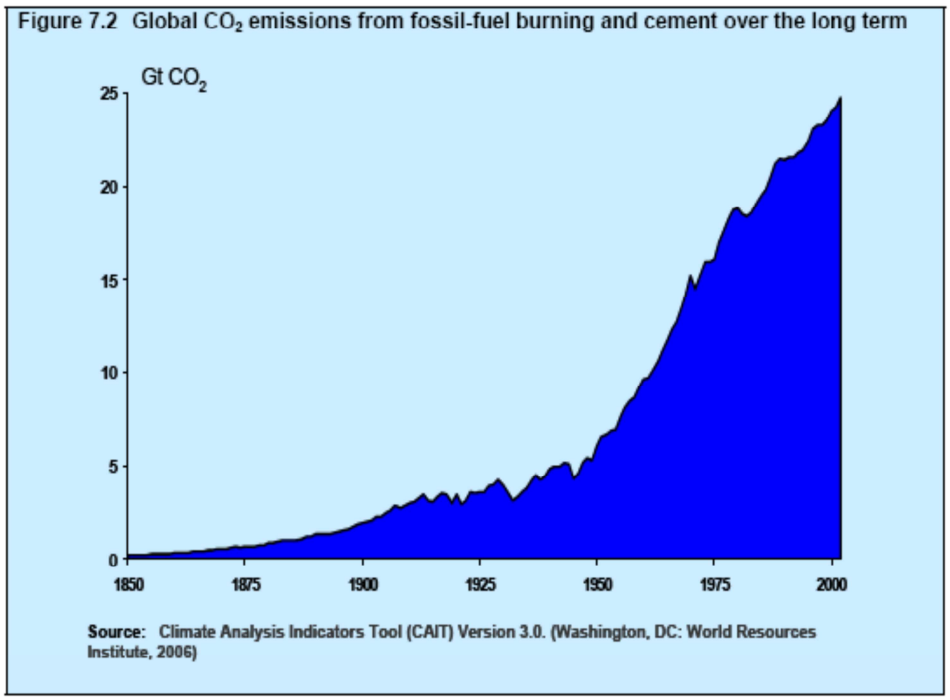
Climate change

Climate change – the basic physics



- Burning of fossil fuels releases carbon dioxide (CO_2) into atmosphere
- CO_2 is greenhouse gas (GHG) – traps heat – enhancing the natural 'greenhouse effect'
- Causes global temperature to rise disrupting climate system
- CO_2 also released by deforestation, cement production, other land use change
- Other GHGs – methane, nitrous oxide, CFCs etc

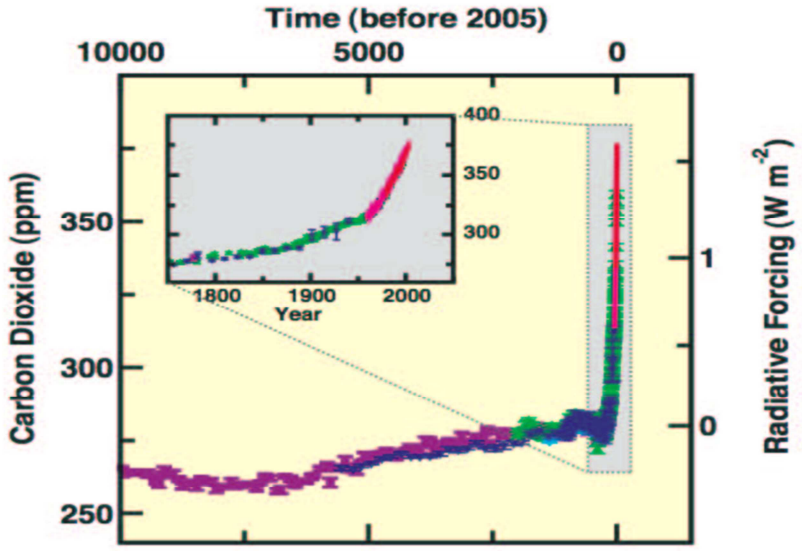
Diagram from BBC website



Gt – gigatonnes – billions of tonnes

WRI (2006).

Changes in atmospheric levels of CO_2 over last 10,000y



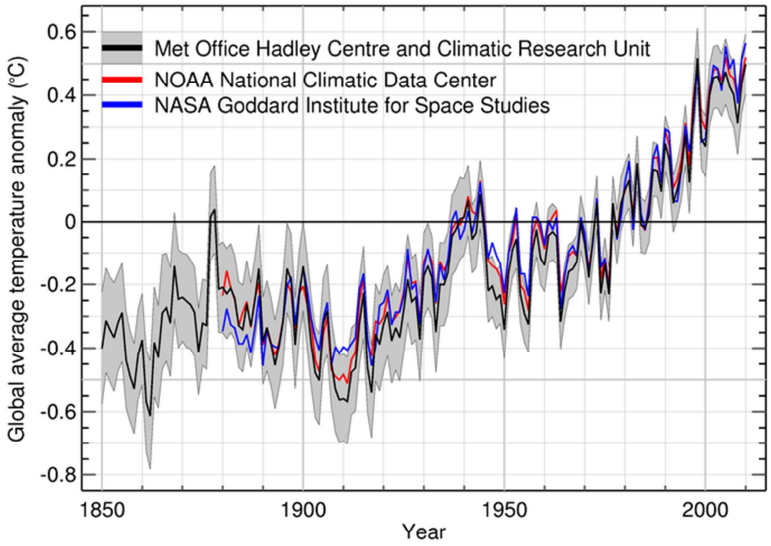
ppm – parts per million;
e.g. 300 ppm = 0.03% of atmosphere

• Rise in other GHG levels has been equally steep

Through fossil fuel burning and other activities, we have raised the CO2 level fair beyond any level seen for at least 430,000y

IPCC (2007a).

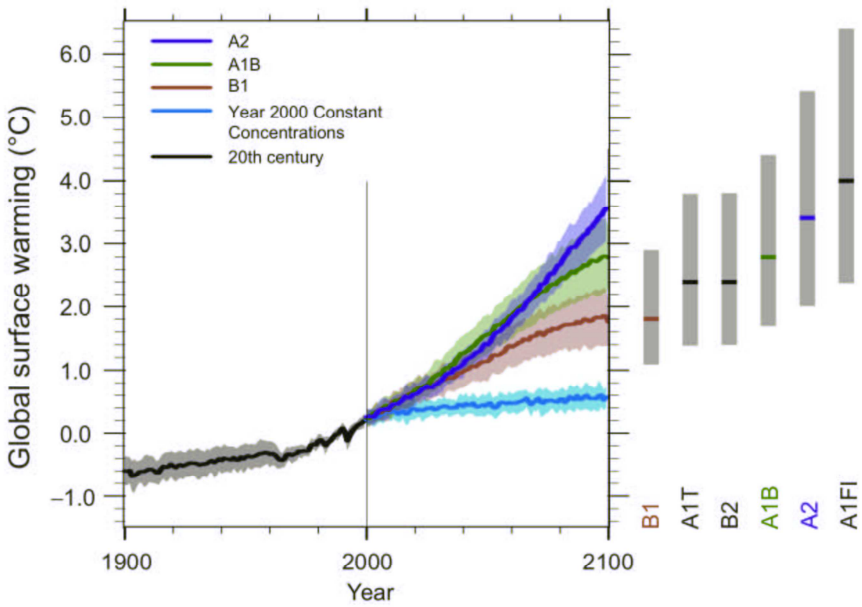
Global temperature rise



Source: World Meteorological Organisation (2011)

Other effects include rise in sea-level, decline in ice-cover, changes in ecosystems.

Global average surface temperature change 1900-2100



1990-2000 using historic data; 2000-2100 using IPCC scenarios. Source: IPCC (2007)

• Predicted temp in 2100 will be between 1.1ºC and 6.4ºC higher than 1990 (IPCC, 2007a)

• For comparison, the temperature difference between the Ice Ages and the warm interglacial periods such as at present has been 4-7ºC (IPCC, 2007b)

• Available evidence indicates that the upper end of this range would represent a faster change than at any time in the last 50 million years (IPCC, 2007b)

• Light blue curve – 'thought experiment' based on what would happen if we had stopped emitting GHGs in 2000

References: IPCC (2007a); IPCC (2007b).

Global Impacts on:

- Fresh water resources
- Coastal areas
- Food supplies
- Human health
- Wildlife

• Higher temperatures leads to more energetic/dramatic/extreme weather

• Fresh water resources - dry areas likely to get drier, wet areas get wetter; hundreds of millions more suffering from 'water stress' over next few decades; Increased storminess likely to increase flood risk

• Coastal areas - Sea-level rise will lead to major increase in flooding risk and loss of land; Huge numbers affected (Currently, half world population lives in coastal areas); Mega-deltas of Asia and Africa, and small island states, will be most affected

• Food supplies - major disruption as crop productivity falls in tropics & sub-tropics and, eventually, everywhere

• Human health – much more malnutrition, disease, 'heat stress'

• Potential for massive loss of plant and animal species – coral reefs, rainforests especially under threat

IPCC (2007c).

Climate impacts: general point

- Impacts felt most heavily by low income communities who are:
  - already the most vulnerable
  - least responsible for causing the problem

Major, irreversible climate shifts

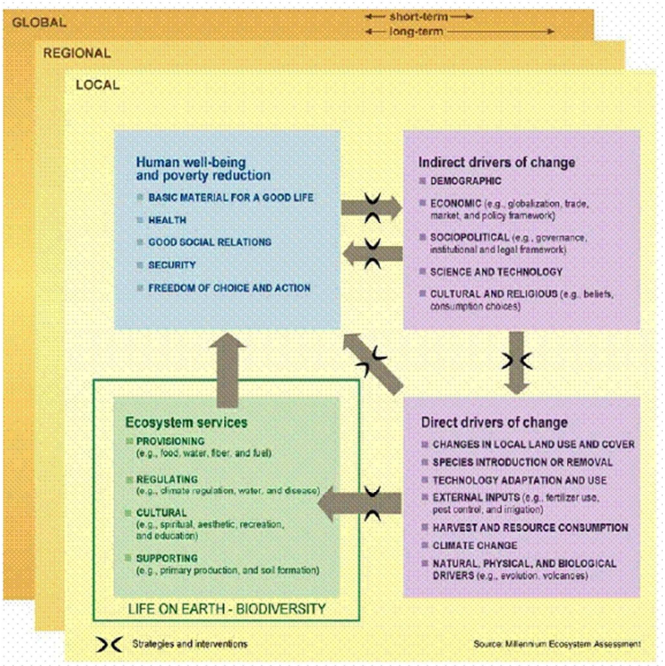
- These become significantly more likely after a temperature rise of 2°C
- Examples
  - Melting of major ice sheets
  - Major weakening of ocean currents
    - e.g. Gulf Stream
  - 'Die-back' of Amazon rainforest
  - Release of 'frozen methane'

1. Melting of Greenland ice sheet – if global temperature rises to between 1.9ºC and 4.6ºC above the pre-industrial level, and remains there, then the ice sheet will eventually disappear completely leading to a sea level rise of 7m. This could take centuries to millennia to complete, although some scientists argue it could happen as quickly as a single century. West Antarctic ice sheet is also at risk. Arctic ice sheet is melting rapidly. Although this will have little direct effect on sea-level rise, this could lead to more rapid warming in the Arctic (IPCC, 2007a; Hansen et al, 2007; Pearce, 2005).
2. Shutdown of Atlantic meridional overturning circulation (MOC) – The Atlantic ocean current that includes the Gulf stream (which keeps the UK warm) is very likely to weaken over the course of the century, due to increased meltwater from Greenland. It could shutdown eventually, but this is thought to be very unlikely this century (IPCC, 2007a; Pearce, 2005).
3. Die-back of Amazon rainforest – Climate models suggest that by mid-century temperature and rainfall changes will cause the shrinking of the Amazon rainforest, with major loss of wildlife. The entire forest could be lost eventually Pearce (2005).
4. Release of frozen methane – 5 trillion tonnes of methane locked away in frozen hydrates in deep oceans. Warming will start to release it accelerating the warming potentially very rapidly (Pearce, 2005).

References: IPCC (2007a); Hansen J et al (2007); Pearce F (2005).

Species/ Biodiversity Loss

Role of biodiversity



Millennium Ecosystem Assessment (2005), p.vii

Causes of biodiversity loss

- Habitat conversion
  - e.g. land clearance for cities, farms, mines etc
- Overexploitation
  - e.g. industrial trawlers over-fishing
- Climate change
- Pollution
  - e.g. artificial chemicals, CO_2
- Invasive 'alien' species
  - modern transport has rapidly increased spread of species to different parts of the world

Examples

• Habitat conversion – between 1990 and 1997, 6 million hectares of tropical rainforest were lost each year (a bit less than the size of Ireland per year)

• Overexploitation - over-fishing – 30% of fish stocks have 'crashed'; 40% 'over-exploited'; 30% 'fully exploited'

• Pollution – 'the other CO2 problem'

• Invasive alien species – introduction of comb jelly fish into the Black Sea (Russia) caused the collapse of much commercial fishing

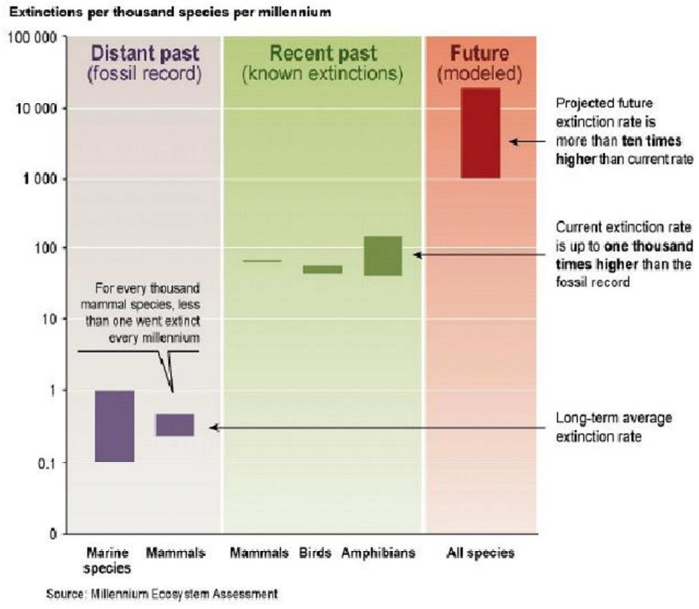
UNEP (2007), Chapters 4 & 5.

Species/ Biodiversity loss

- World's ecosystems services
  - ~60% degraded/ used unsustainably
- Between 5 and 30 million species
  - Current extinction rate is 100 to 1,000 times the 'background' rate

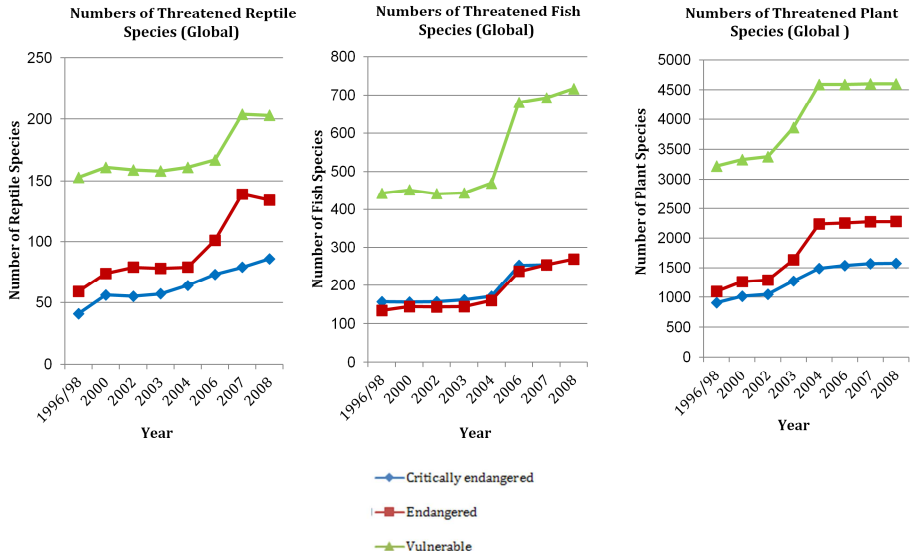
Millennium Ecosystem Assessment (2005); UNEP (2007), Chapter 5

Species extinction rates



Millennium Ecosystem Assessment (2005), p.5

Threatened Species



Source: IUCN (2009)

IUCN (2009)

- *"All available evidence points to a sixth **major extinction event** currently underway. Unlike the previous five events… the current loss of biodiversity is mainly **due to human activities**"*

UN Environment Programme 2007

Life has existed on planet Earth for about 3.8 billion years. During that time 5 major extinction events have been recorded (due to natural disasters and planetary change). A 6th is now underway due to human activities.

UNEP (2007), Chapter 5 (Quote from p162)

Food and agriculture problems

Impacts of industrial agriculture

- Major contributor to climate change
  - Due to deforestation, artificial fertilisers, methane from animals, fuel use (machinery)
- Major contributor to species loss
  - Due to deforestation & land-use change, pesticides
- Extensive soil erosion
- Water pollution & drinking water scarcity
- Animal welfare compromised

Climate change - ~14% of emissions directly + several % indirectly (IPCC, 2007a)

There's enough food but...

- ...only if it's equally distributed
- Over 1,000,000,000 people currently malnourished across the world
- Approx 1,600,000,000 adults currently overweight
- Poverty is a major factor in both hunger and obesity
- Over 1/3 of the world's cereals are being used as animal feed

Of the cereals fed to livestock, half of the energy is lost in maintaining the animals biological functions.

References:

Food and Agriculture Organization of the United Nations (2009); World Health Organisation (2006); United Nations Environment Programme (2009b).

Food issues are getting worse

- Up to 25% of world food production may be lost due to 'environmental breakdowns' by 2050
  - e.g. climate change, soil erosion, overfishing
- Rising meat consumption means proportion of cereals fed to livestock could rise to 50% by 2050
- Use of liquid biofuels have been rising rapidly
- Population projected to pass 9 billion by 2050
- Food prices may increase by 30-50 per cent within decades

Liquid biofuels are substitutes for petrol made from refining crops such as soya, maize and sugar cane.

United Nations Environment Programme (2009b).

Other resource issues

- Mineral resources being depleted
  - e.g. ‘Peak oil’
    - If ‘conventional’ oil extraction reaches a peak before alternative energy sources are in place, prices could rise rapidly
    - Next 10-20y critical

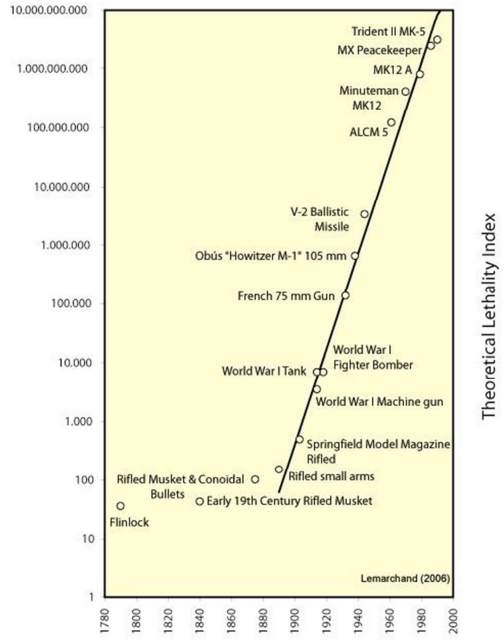
References:

The Guardian (2009); IEA (2010)

War

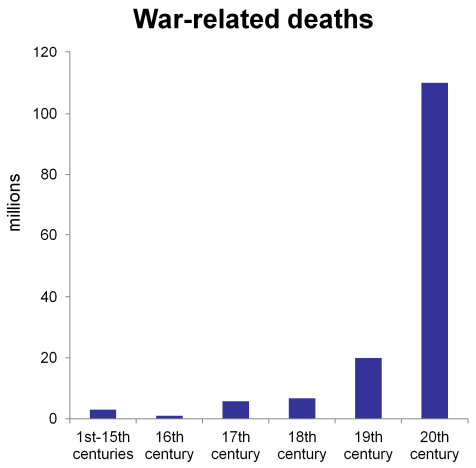
Weapons – how deadly?

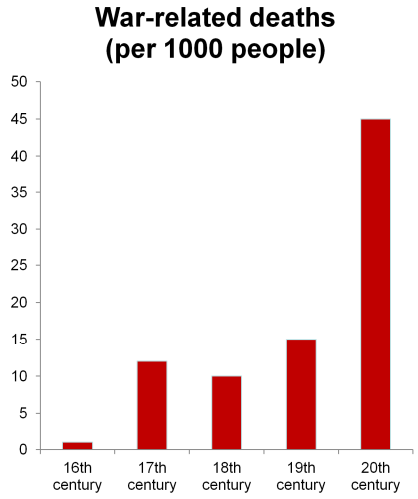
- Technological development has led to exponential growth in lethality of weapons during 20th Century
- Theoretical Lethality Index
  - maximum number of casualties per hour that a weapon can generate



Theoretical 'Lethality Index' includes consideration of: rate of fire, number of targets, relative effectiveness, range effects, muzzle effects, accuracy, reliability, etc.
Graph from Lemarchand (2007).

Casualties in war





Webb (2005)

Nuclear weapons

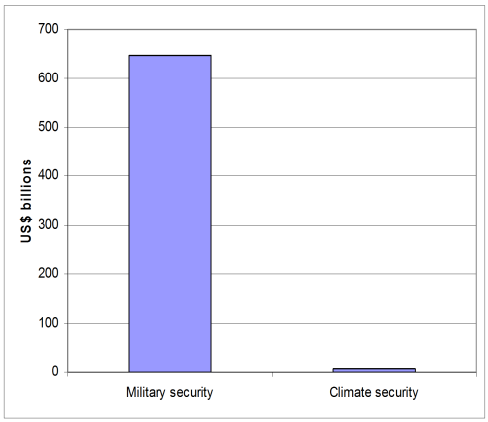
Country	Nuclear Warheads
Russia	11,000*
United States	8,500*
France	300
China	240
United Kingdom	225
Israel	80
Pakistan	90 – 110
India	80 – 100
North Korea	fewer than 10
TOTAL	*about 20,500*

* With a large fraction awaiting dismantlement

Source: Federation of American Scientists (2011)

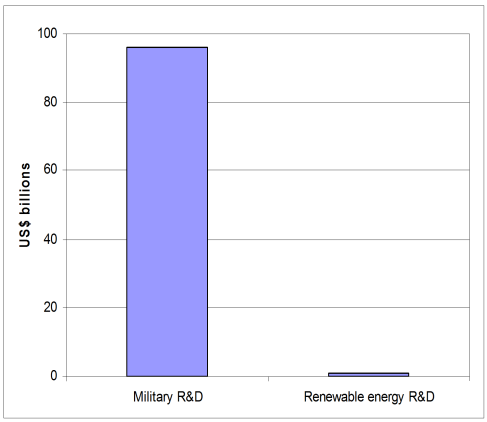
Military spending v climate spending

US Government spending (FY 2008)



Source: Pemberton (2008)

Government R&D spending
in wealthier countries (2006)



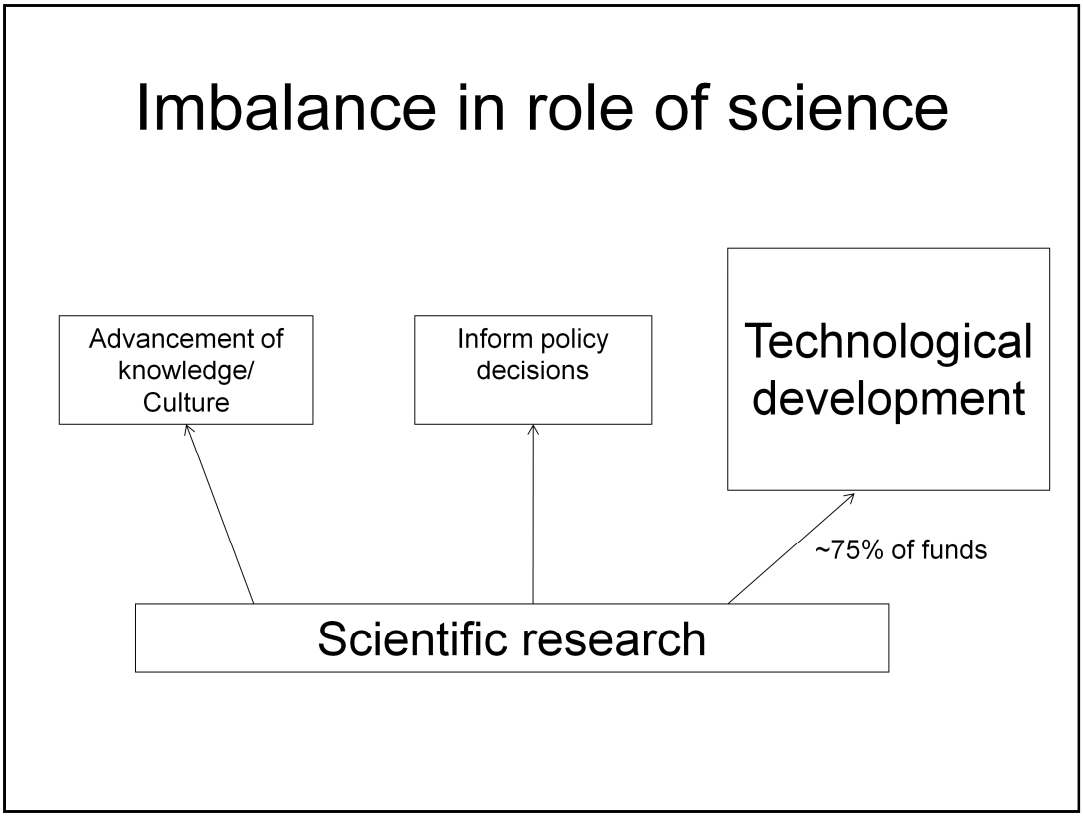
Source: SGR (2008)

Figures for R&D spending are for OECD nations.

Skilled workers are key; often these are in even shorter supply than money.

Pemberton (2008); SGR (2008).

Overarching concerns



- ~75% of the funding for research and development is spent on technological development
- estimate based on official UK science and technology statistics

Imbalances of technology

- Technological development is mainly driven by:
  - Economic interests
  - Military interests
- Technology is used by society:
  - as the dominant way of trying to deal with social problems
  - to establish status/identity through materialism

Dealing with the problems

What needs to change?

- Scientific research
  - More emphasis on *informing policy* and *advancement of knowledge*, less on technological development
  - Better balance between disciplines, including more interdisciplinary research

What needs to change?

- Technological development
  - Use a combination of social measures and technology to tackle problems
  - Focus on developing technologies which are useful for environmental/ social goals
  - Preference for simpler technologies
    - More affordable and less risks

What needs to change?

- Ethical values
  - Greater priority for peace, social justice, environmental sustainability
- Economic systems
  - Major reform to tackle poverty, inequality and unsustainable growth
- Political systems
  - Greater accountability and co-operation to reduce conflict/ military spending

Some implications for science education

- More focus on robust knowledge
  - ‘Nature’s wonders’
- More focus on ethical concerns
  - Helping to ‘save the world’
- Less focus on technology
  - No ‘magic bullets’

➢ Science helps us to understand the world, in order to make better choices

Conclusions

- Science and technology can and does bring enormous benefits, but only if developed and used with regard for society and environment
- Misuse of technology could bring down civilisation
- Science education can help us make better choices

Reminder of benefits of tech change:

Massive rise in food production; Huge fall in infectious diseases; Greater life expectancy; Ability to support large population

Reminder of contribution to major problems:

Massive increase in destructiveness of weapons and war; Global environmental problems such as climate change; Serious depletion of natural resources such as forests, fisheries, minerals; Overpopulation; Poverty & inequality remain huge problems

References (p1)

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