Sustainable Energy

Lecture 6: Sustainable Energy Systems

Sustainable Development

- Sustainable development means the ability of humanity to ensure that meets the needs of the present without compromising the ability of future generations to meet their own needs.
- Biophysical sustainability means maintaining or improving the integrity of the life-support system of earth.
- Sustainability means preservation of productive capacity for the foreseeable future.
- Sustainability includes a participatory process that creates and pursues a vision of community that makes prudent use of all its resources, natural, human, human-created, social, cultural, scientific, etc. .

Sustainable development....cont

- Daly (1990) proposed three operational principles of sustainable development:
  - For a renewable resource: the sustainable rate of use can be no greater than the rate of generation.
  - For a nonrenewable resource: the sustainable rate of use can be no greater than the rate at which a renewable resource, used sustainably, can be substituted for it.
  - For a pollutant: the sustainable rate of emission can be not greater than the rate at which the pollutant can be recycled, absorbed, or rendered harmless bay the environment.

Table from text/sustainability

Some things we might want to sustain	Some trends hindering sustainable living
Our standard of living	Widespread poverty
Our health	Population growth
Our food and water supply	Unnecessary or excessive consumption
The environment (climate, water quality and availability, diversity of species, natural and recreational spaces, etc.)	Social inequity (including lack of health care, education, and jobs for the poorest, widening gaps between the rich and poor)
Personal freedom	Political self interests and short-term focus
International stability	Irresponsible industrialization
A healthy economy	Loss of habitat and species
Opportunities to improve status (individually, as a community, or as a nation)	Inadequate institutional systems to manage change
Global communications and mobility	Mal-distribution of resources, depletion

Energy from a systems perspective

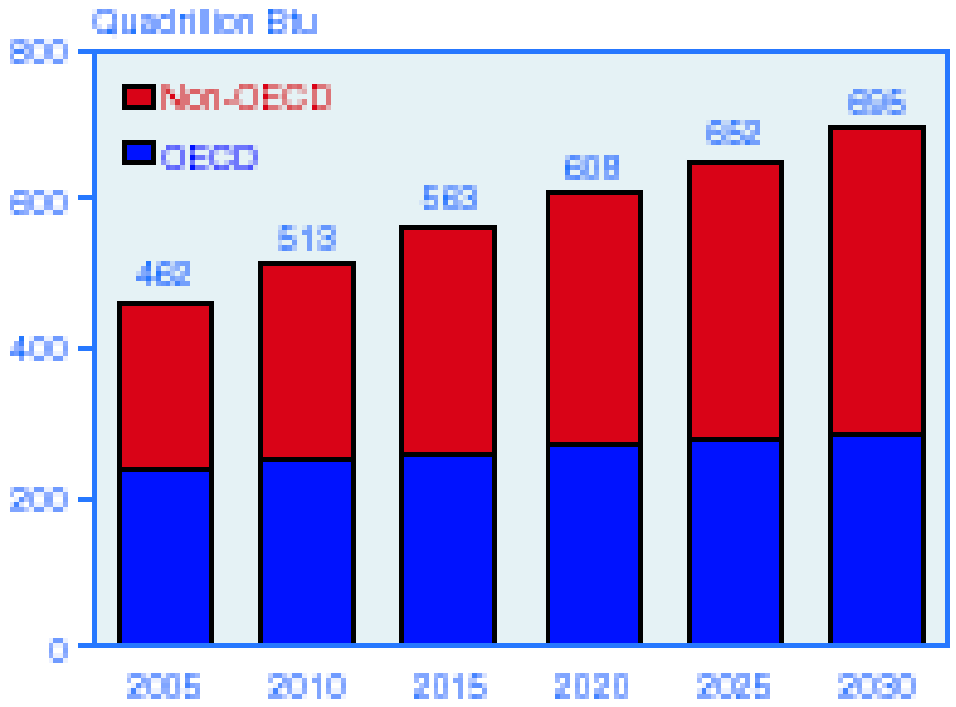
- About 85% of world commercial energy use is derived from carbon-based fossil fuels.
- The US produces about 20% of the total global CO_2 emissions.
- Our emissions are about twice that per capita of Japan and Europe and an order of magnitude higher than developing countries.
- Systems analysis has shown that our current energy system is unsustainable on various levels:
  - Use of nonrenewable fuel.
  - Pollution (particulates, ozone formation, SO_x and No_x and greenhouse gas emissions).
  - Habitat impacts and biodiversity.

Systems...continued

- A look at projected world energy use shows that an increase in fossil fuel use will continue.
- International panels on climate change have indicated a major impact from the use of fossil fuels is happening now. (see results of the latest IPCC report).
- It will require a comprehensive international effort to turn around global warming.

World Energy Consumption

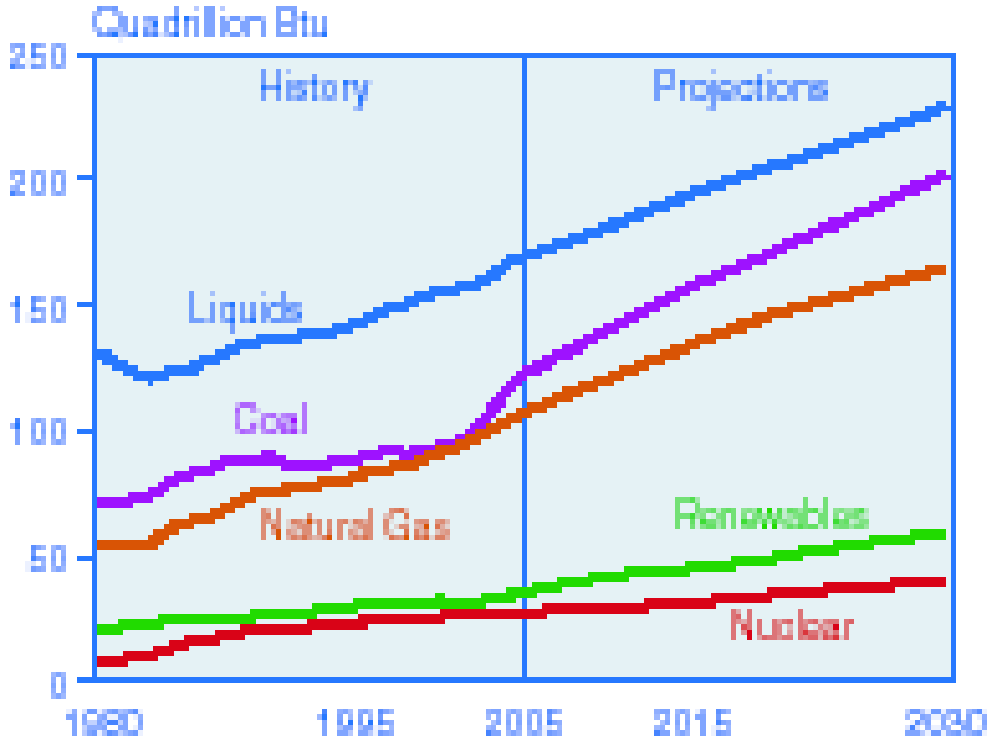
Figure 1. World Marketed Energy Consumption, 2005-2030



Sources: 2005: Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2008).

Energy Use by Fuel

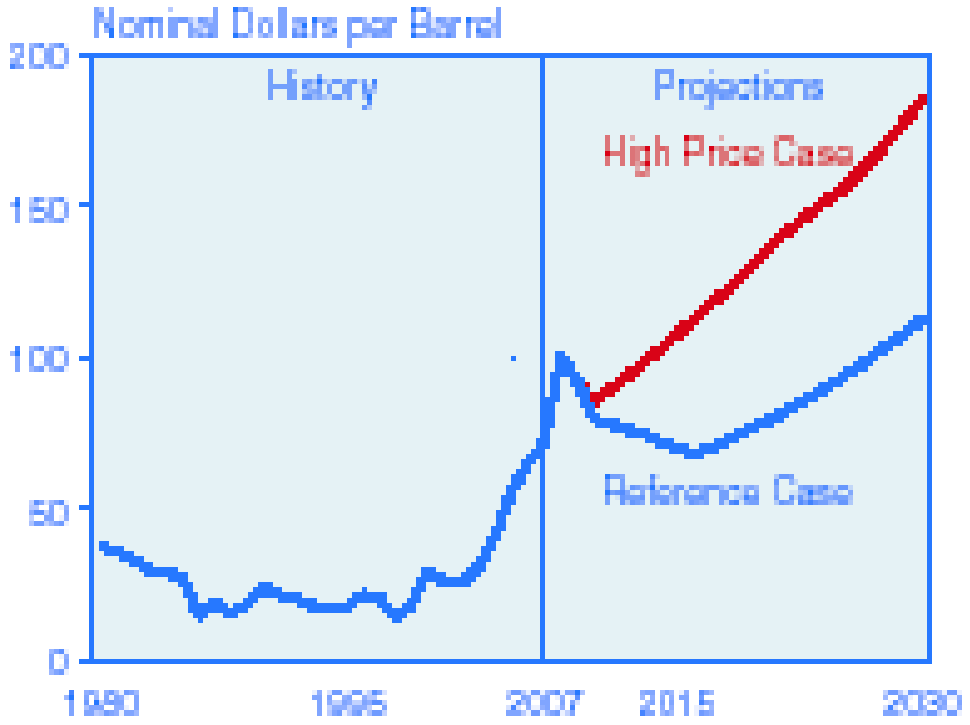
Figure 2. World Marketed Energy Use by Fuel Type, 1980-2030



Sources: 2005: Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2008).

World Oil Prices

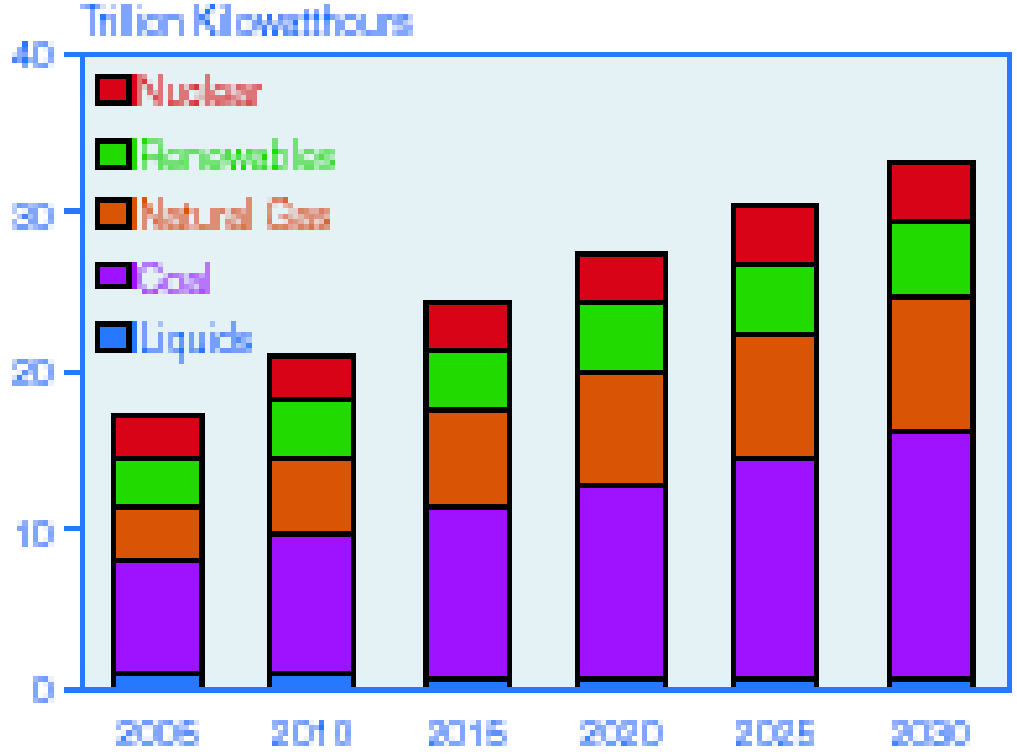
Figure 3. World Oil Prices in Two Cases, 1980-2030



Sources: History: Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. Projections: EIA, *Annual Energy Outlook 2008*, DOE/EIA-0383(2008) (Washington, DC, June 2008), web site www.eia.doe.gov/oiaf/aeo.

World Electricity

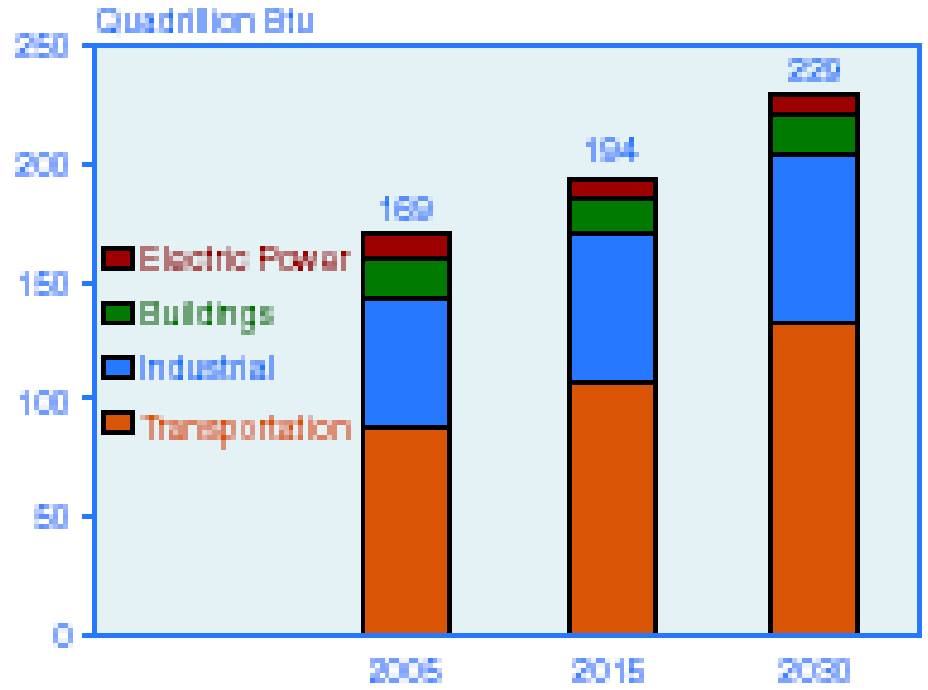
Figure 6. World Electricity Generation by Fuel, 2005-2030



Sources: 2005: Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. Projections: EIA, System for the Analysis of Global Energy Markets/Global Electricity Module (2008).

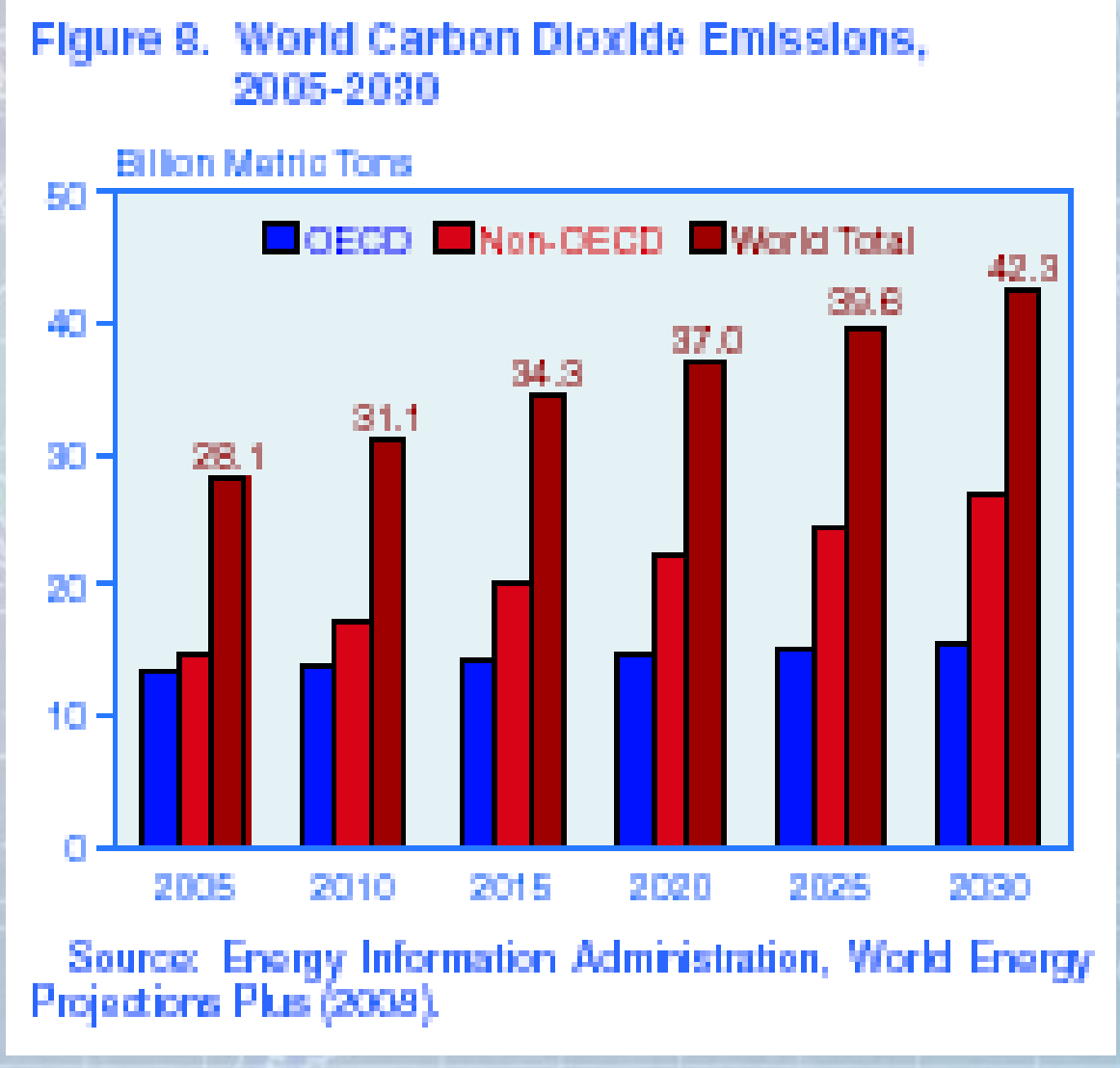
World Liquids Consumption

Figure 7. World Liquids Consumption by End-Use Sector, 2005-2030



Sources: 2005: Energy Information Administration (EIA), *International Energy Annual 2005* (June-October 2007), web site www.eia.doe.gov/iea. Projections: EIA, World Energy Projections Plus (2008).

World Carbon Dioxide Emissions



Systems Analysis Approaches

- Life-cycle analysis
  - Life cycle analysis attempts to inventory all the impacts associated with each and every stage of a process or product, from cradle to grave.
  - This technique allows environmental impacts to be evaluated quantitatively along with material flows and costs.
  - Example: McDonald's evaluation of styrofoam versus paper cups. Paper cups use 36 times more energy and 500 times more water during the manufacturing process than styrofoam.
  - LCAs can be used to evaluate and eliminate deleterious processes during manufacture or the life-cycle of a product.

Systems analysis continued...

- Simulation models use mathematical models to represent natural processes and make predictions.
  - Examples: Global Circulation Models, National Energy Modeling System (DOE), IPCC.
  - Risk-based models
    - EPA hazardous materials guidelines; MSDS sheets
    - OSHA regulations
    - NRC regulations
    - International Standards Organization (ISO; ISO 900; ISO 14000)

Measures of Sustainability

- **The United Nations and the World Bank have defined three broad categories with goals for the 21st century:**
  - **Environmental**
    - **Government and institutional commitment to sustainable development.**
    - **Water resources (access to safe water, intensity of freshwater use, percentage of annual available resource used)**
    - **Biodiversity (nationally protected area as a total land)**
    - **Energy use (GDP per unit of energy use, total and per capita carbon dioxide emissions)**

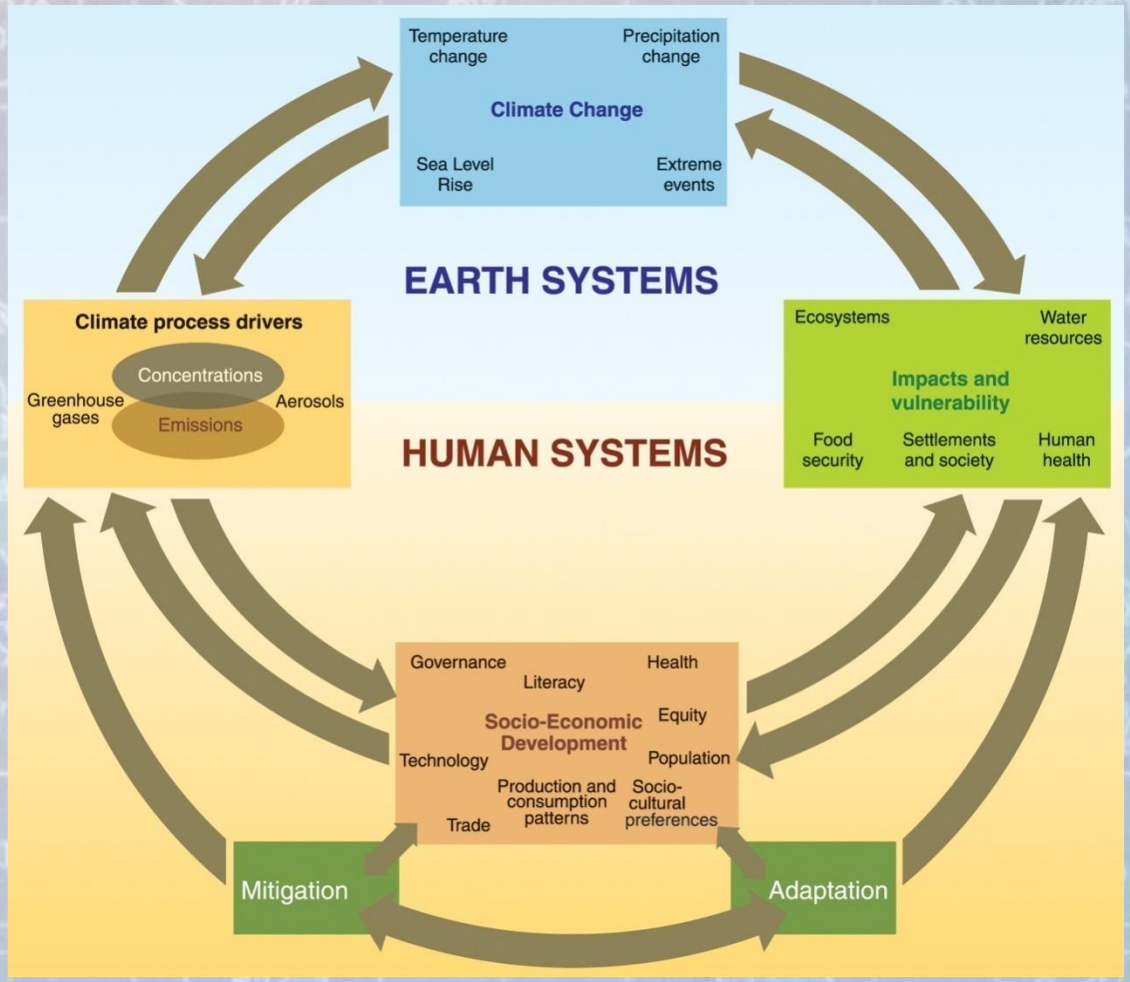
Intergovernmental Panel on Climate Change (IPCC)

- IPCC is an international scientific organization established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environmental Program (UNEP). Both are organizations of the United Nations.
- IPCC 4th assessment report on climate change 2007 had the following conclusions:
  - Warming of the climate system is unequivocal.
  - Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic (human) greenhouse gas concentrations.
  - Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilized, although the likely amount of temperature and sea level rise varies greatly depending on the fossil intensity of human activity during the next century

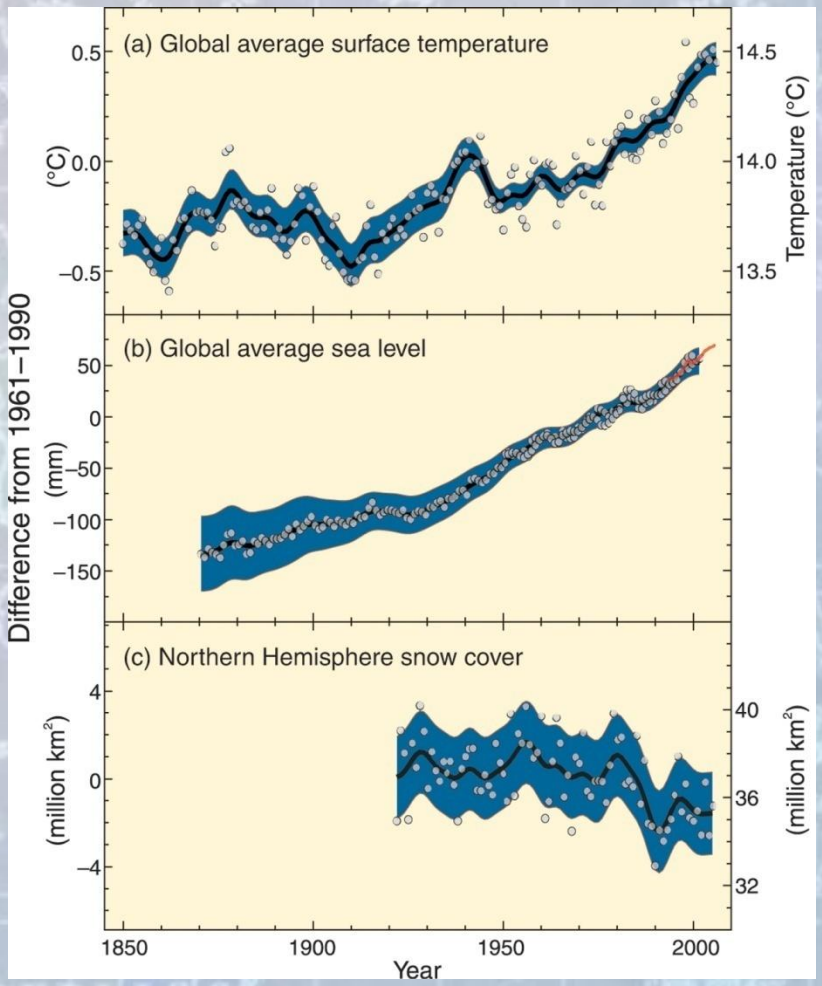
IPCC report continued

- The probability that this is caused by natural climatic processes alone is less than 5%.
- World temperatures could rise by between 1.1 and 6.4 °C (2.0 and 11.5 °F) during the 21st century and that:
  - Sea levels will probably rise by 18 to 59 cm (7.08 to 23.22 in) .
  - There is a confidence level >90% that there will be more frequent warm spells, and heavy rainfall.
  - There is a confidence level >66% that there will be an increase in droughts, tropical cyclones and extreme high tides.
- Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium.
- Global atmospheric concentrations of carbon dioxide, methane, and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values over the past 650,000 years

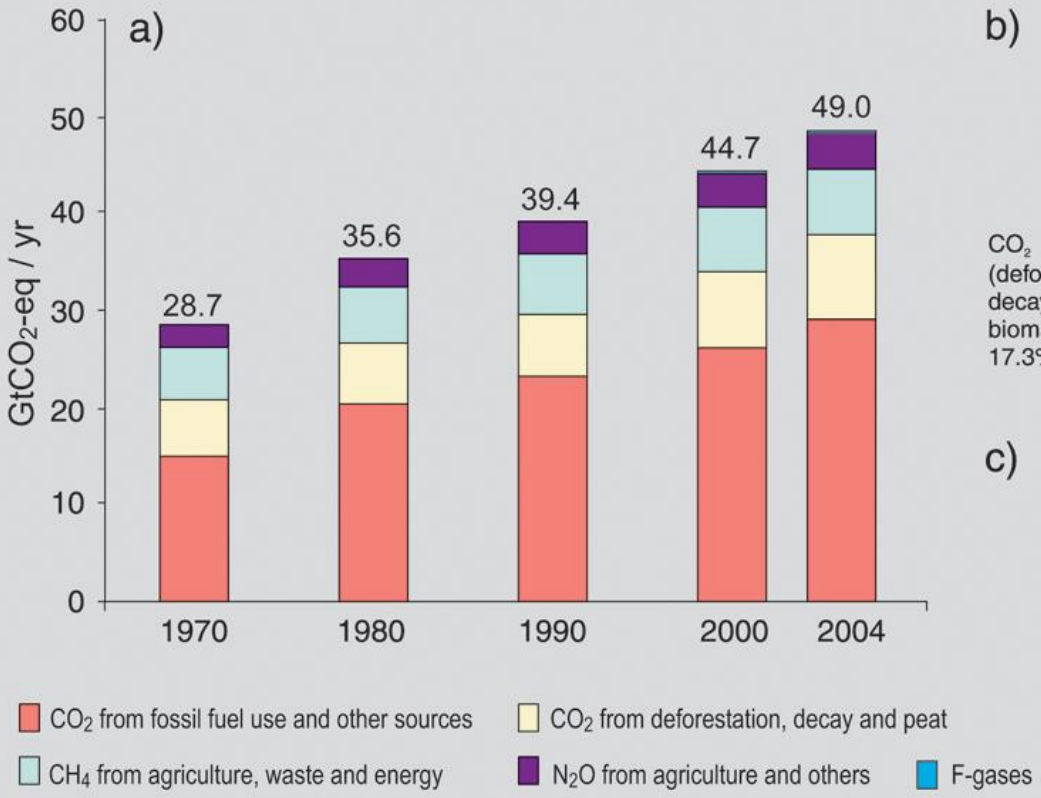
IPCC report

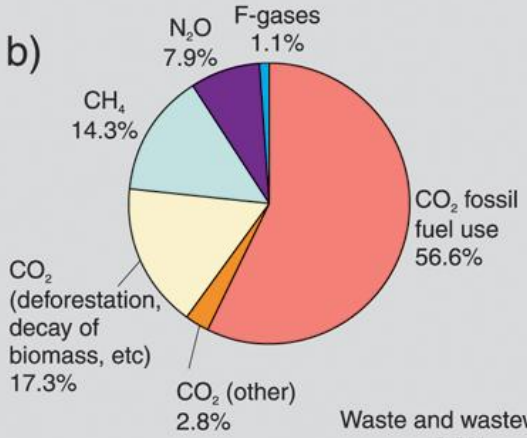

Temperature change
Precipitation change
Climate Change
Sea Level Rise
Extreme events
EARTH SYSTEMS
Climate process drivers
Concentrations
Greenhouse gases
Aerosols
Emissions
Ecosystems
Water resources
Impacts and vulnerability
Food security
Settlements and society
Human health
HUMAN SYSTEMS
Governance
Health
Literacy
Socio-Economic Development
Equity
Technology
Population
Production and consumption patterns
Socio-cultural preferences
Trade
Mitigation
Adaptation

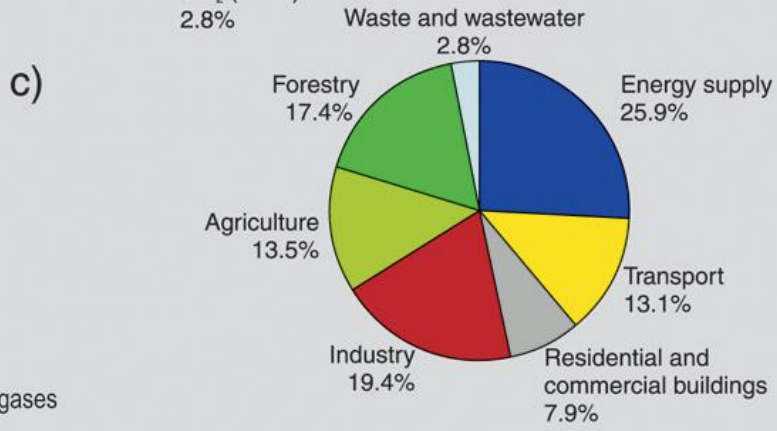
IPCC report


(a) Global average surface temperature
(b) Global average sea level
(c) Northern Hemisphere snow cover
Difference from 1961–1990
(°C)
(mm)
(million km²)
Temperature (°C)
(million km²)
0.5
0.0
−0.5
50
0
−50
−100
−150
4
0
−4
14.5
14.0
13.5
40
36
32
1850
1900
1950
2000
Year

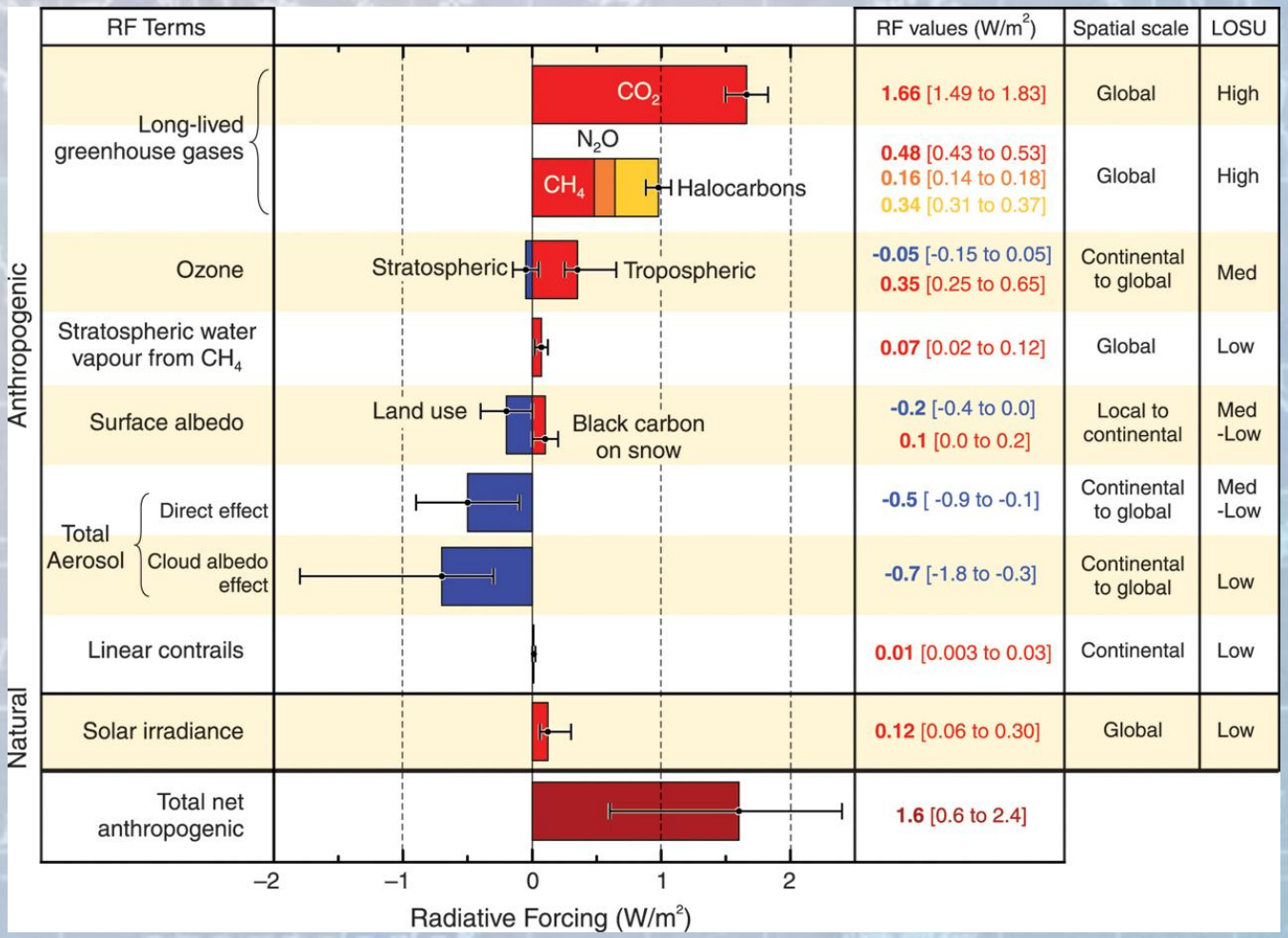
IPCC Report


a)
60
50
40
30
20
10
0
GtCO2-eq / yr
28.7
35.6
39.4
44.7
49.0
1970
1980
1990
2000
2004
CO2 from fossil fuel use and other sources
CO2 from deforestation, decay and peat
CH4 from agriculture, waste and energy
N2O from agriculture and others
F-gases

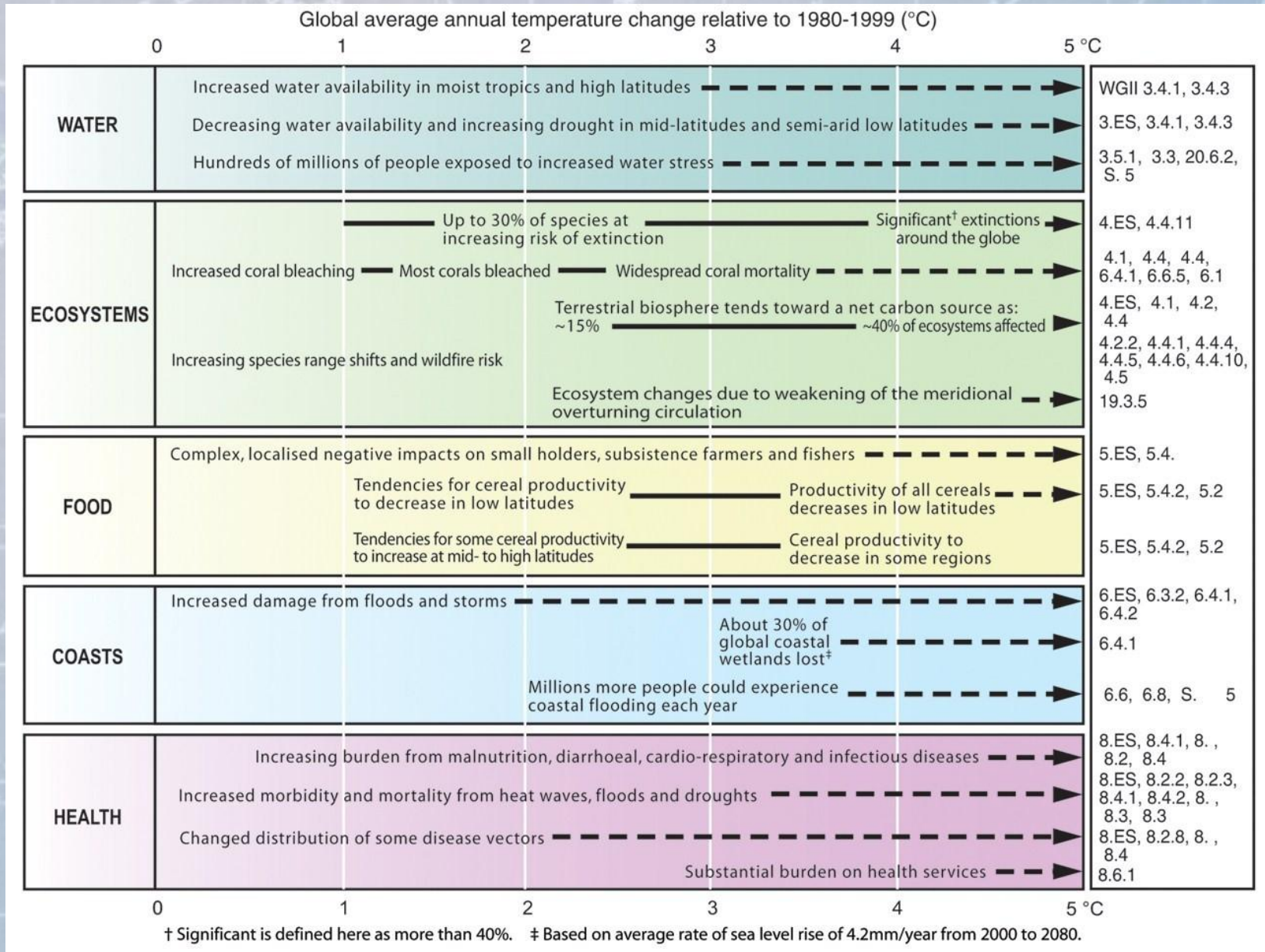

b)
N2O 7.9%
F-gases 1.1%
CH4 14.3%
CO2 fossil fuel use 56.6%
CO2 (deforestation, decay of biomass, etc) 17.3%
CO2 (other) 2.8%


c)
Waste and wastewater 2.8%
Forestry 17.4%
Energy supply 25.9%
Agriculture 13.5%
Transport 13.1%
Industry 19.4%
Residential and commercial buildings 7.9%

IPCC Report


RF Terms
RF values (W/m²)
Spatial scale
LOSU
Anthropogenic
Natural
Long-lived greenhouse gases
CO2
N2O
CH4
Halocarbons
1.66 [1.49 to 1.83]
Global
High
0.48 [0.43 to 0.53]
0.16 [0.14 to 0.18]
0.34 [0.31 to 0.37]
Global
High
Ozone
Stratospheric
Tropospheric
-0.05 [-0.15 to 0.05]
0.35 [0.25 to 0.65]
Continental to global
Med
Stratospheric water vapour from CH4
0.07 [0.02 to 0.12]
Global
Low
Surface albedo
Land use
Black carbon on snow
-0.2 [-0.4 to 0.0]
0.1 [0.0 to 0.2]
Local to continental
Med -Low
Total Aerosol
Direct effect
-0.5 [-0.9 to -0.1]
Continental to global
Med -Low
Cloud albedo effect
-0.7 [-1.8 to -0.3]
Continental to global
Low
Linear contrails
0.01 [0.003 to 0.03]
Continental
Low
Solar irradiance
0.12 [0.06 to 0.30]
Global
Low
Total net anthropogenic
1.6 [0.6 to 2.4]
–2
–1
0
1
2
Radiative Forcing (W/m²)

IPCC Report


Global average annual temperature change relative to 1980-1999 (°C)
0
1
2
3
4
5 °C
WATER
Increased water availability in moist tropics and high latitudes
Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes
Hundreds of millions of people exposed to increased water stress
WGII 3.4.1, 3.4.3
3.ES, 3.4.1, 3.4.3
3.5.1, 3.3, 20.6.2, S. 5
ECOSYSTEMS
Up to 30% of species at increasing risk of extinction
Significant† extinctions around the globe
Increased coral bleaching
Most corals bleached
Widespread coral mortality
Terrestrial biosphere tends toward a net carbon source as:
~15%
~40% of ecosystems affected
Increasing species range shifts and wildfire risk
Ecosystem changes due to weakening of the meridional overturning circulation
4.ES, 4.4.11
4.1, 4.4, 4.4, 6.4.1, 6.6.5, 6.1
4.ES, 4.1, 4.2, 4.4
4.2.2, 4.4.1, 4.4.4, 4.4.5, 4.4.6, 4.4.10, 4.5
19.3.5
FOOD
Complex, localised negative impacts on small holders, subsistence farmers and fishers
Tendencies for cereal productivity to decrease in low latitudes
Productivity of all cereals decreases in low latitudes
Tendencies for some cereal productivity to increase at mid- to high latitudes
Cereal productivity to decrease in some regions
5.ES, 5.4.
5.ES, 5.4.2, 5.2
5.ES, 5.4.2, 5.2
COASTS
Increased damage from floods and storms
About 30% of global coastal wetlands lost‡
Millions more people could experience coastal flooding each year
6.ES, 6.3.2, 6.4.1, 6.4.2
6.4.1
6.6, 6.8, S. 5
HEALTH
Increasing burden from malnutrition, diarrhoeal, cardio-respiratory and infectious diseases
Increased morbidity and mortality from heat waves, floods and droughts
Changed distribution of some disease vectors
Substantial burden on health services
8.ES, 8.4.1, 8. , 8.2, 8.4
8.ES, 8.2.2, 8.2.3, 8.4.1, 8.4.2, 8. , 8.3, 8.3
8.ES, 8.2.8, 8. , 8.4
8.6.1
0
1
2
3
4
5 °C
† Significant is defined here as more than 40%. ‡ Based on average rate of sea level rise of 4.2mm/year from 2000 to 2080.

Indicators continued...

- Economic
  - Standard economic indicators include total and per capita GDP, GNP, national debt, employment rates, investment rates, new housing starts, stock market averages, balance of trade, etc. .
- Social
  - Social indicators include poverty, education and health.
  - Reduce poverty by half.
  - Provide universal primary education.
  - Improve gender equality in education.
  - Reduce maternal mortality.
  - Expand access to reproductive health services.

Drivers of Societal Change

- If a society is to start a transition to more sustainable living some potential mechanisms are:
  - Technological innovation.
  - Substitution of alternatives.
  - Policy and regulatory requirements.
  - Changes in consumer preferences.

Principles of Sustainable Development

- International Institute for Sustainable Development suggested 10 principles in 1996:
  - Clarity
  - Holistic Perspective
  - Essential elements
  - Adequate Scope
  - Practical focus
  - Openness
  - Effective Communication
  - Broad participation
  - Ongoing assessment
  - Institutional capacity