

**2580–1**

**Joint ICTP–IAEA College on Identification and Assessment of  
Nationally Appropriate Mitigation Actions (NAMAs) in Energy  
System Development to Help Combat Climate Change**

***5 – 9 May 2014***

**Energy, Climate Change and Sustainable  
Development**

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# **Energy, Climate Change and Sustainable Development**

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**ICTP, 5 – 9 April 2014**

# United Nations Conference on the Human Environment (Stockholm 1972)

- Focus: Human interactions with the environment
- Objective: Stimulating and providing guidelines for action by national government and international organizations" facing environmental issues
- Output:
  - Stockholm Declaration containing 26 principles concerning the environment and development,
  - Action Plan with 109 recommendations, and
  - A resolution.
- Outcome: Lots of talk but little action

# Stockholm Declaration

1. *Human rights must be asserted*, apartheid and colonialism condemned
2. Natural resources must be safeguarded
3. The Earth's capacity to produce renewable resources must be maintained
4. Wildlife must be safeguarded
5. Non-renewable resources must be shared and not exhausted
6. *Pollution must not exceed the environment's capacity to clean itself*
7. Damaging oceanic pollution must be prevented
8. *Development is needed to improve the environment*
9. Developing countries therefore need assistance
10. Developing countries need reasonable prices for exports to carry out environmental management
11. *Environment policy must not hamper development*
12. Developing countries need money to develop environmental safeguards
13. *Integrated development planning is needed*
14. *Rational planning should resolve conflicts between environment and development*
15. Human settlements must be planned to eliminate environmental problems
16. Governments should plan their own appropriate population policies
17. National institutions must plan development of states' natural resources
18. Science and technology must be used to improve the environment
19. Environmental education is essential
20. Environmental research must be promoted, particularly in developing countries
21. States may exploit their resources as they wish but must not endanger others
22. Compensation is due to states thus endangered
23. *Each nation must establish its own standards*
24. *There must be cooperation on international issues*
25. International organizations should help to improve the environment
26. Weapons of mass destruction must be eliminated

Source: Clarke and Timberlake (1982), Stockholm Plus Ten: Promises, Promises? London: Earthscan

# Fifteen years later: World Commission on Environment and Development (WCED)

Report “Our Common Future” of the WCED (Brundtland Commission, 1987) defined sustainable development as

*“...development that meets the needs of the present without compromising the ability of future generations to meet their own needs”*

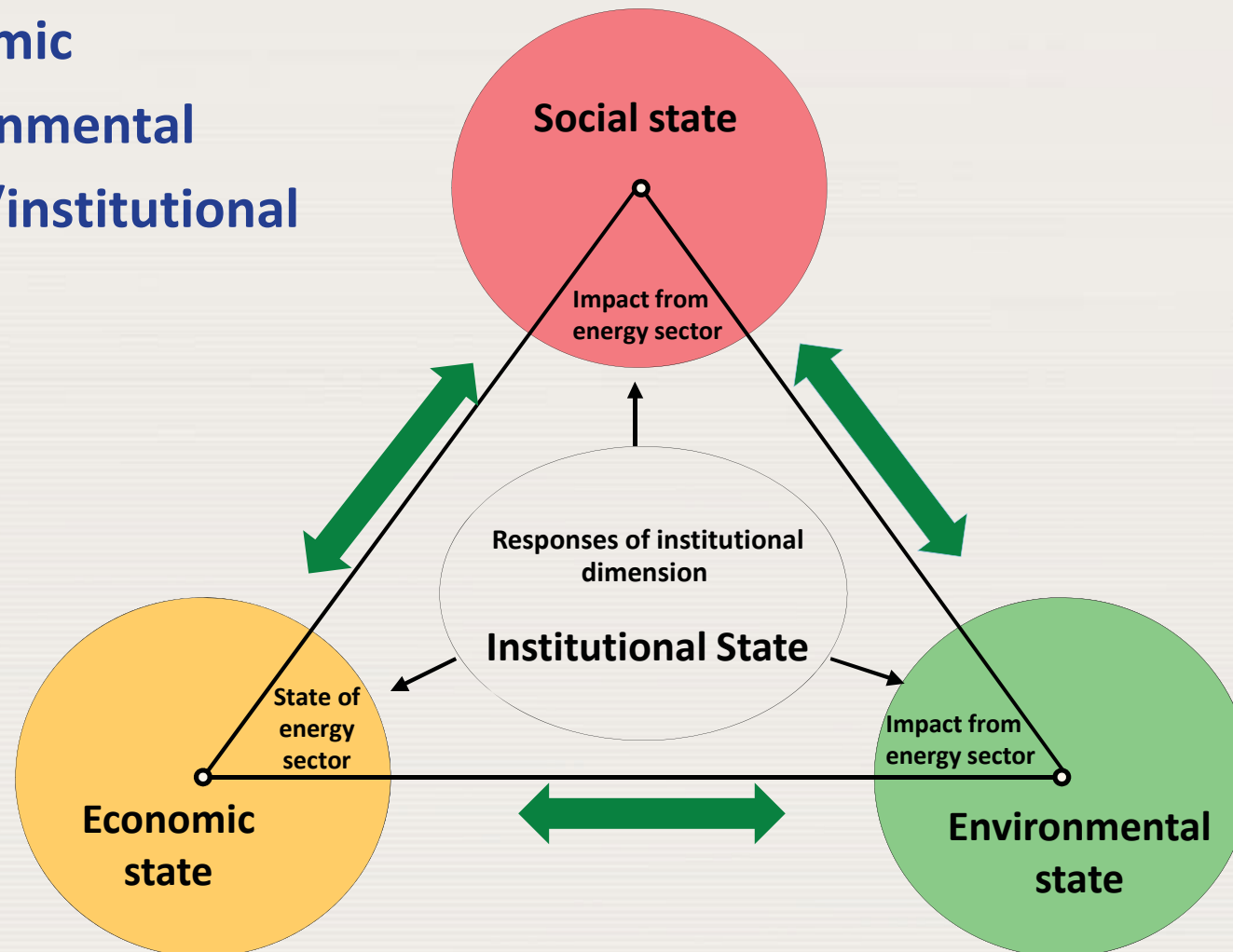
Widely accepted interpretation:

- Desirable equity within and across countries and generations
- Balanced consideration of economic development, environmental protection and social welfare

# Sustainability dimensions

## ➤ Three dimensions/pillars of sustainable development

- Economic
- Environmental
- Social/institutional



# Economic dimension

- Concerns the maintenance, growth and use of different categories of capital:
  - man-made (e.g., infrastructures, machines, technology);
  - natural (e.g., mineral resources, forests, clean air and water, the atmosphere); and
  - social/human (e.g., institutions, knowledge, intact societies, tradition).
- All three types of capital contribute to economic development
- They are inherently substitutable, the extent of which has led to the distinction of
  - strong sustainability and
  - weak sustainability

# Economics – Strong sustainability

- Assumes a limited level of substitutability – rather complements than substitutes
- Requires each of the capital categories to be maintained separately at some minimum level:
  - Exhaustible resources (fossil, uranium, minerals) cannot be consumed really
  - Renewable resources must be harvested within the regenerative capacity of the natural capital stock that produces them and its waste must not exceed the of ecosystem's carrying capacity



# Economics – Weak sustainability

- Refers to the maintenance of the total level of capital passed down through generations without regard to the particular form of capital
  - Allows the use of exhaustible resources as long as depletion is compensated by equivalent increases in man-made and social/human capital
  - It requires the efficient use of non-renewable resources that reflect full social costs and the timely development of inexhaustible energy systems

# Environmental dimension

- **Preservation of natural resources, biodiversity and protecting ecosystems and habitats**
  - **Minimize environmental pollution, the exploitation of exhaustible resources as well as the so-called 'use of the environment' (ecological footprint)**
    - **Reduce production and use of harmful substances to a minimum**
  - **Equitable access by different social/spatial entities (countries, regions, etc.) to common goods (e.g. atmosphere)**
  - **Observation of carry capacities of ecosystems**

# Social/institutional dimension

- Deals with the 'needs' of the Brundtland definition
  - Not limited to the materialistic needs of
    - food, water, energy, shelter, health and protection in case of old age and social hardship
  - But also includes
    - education, recreation, leisure, social relations, political activities, security, social justice both intra- and intergenerational, good governance and competent institutions, moral concepts, culture and religion
  - Sustainability in satisfying intra- and intergenerational needs is directed at the relationships between society and nature

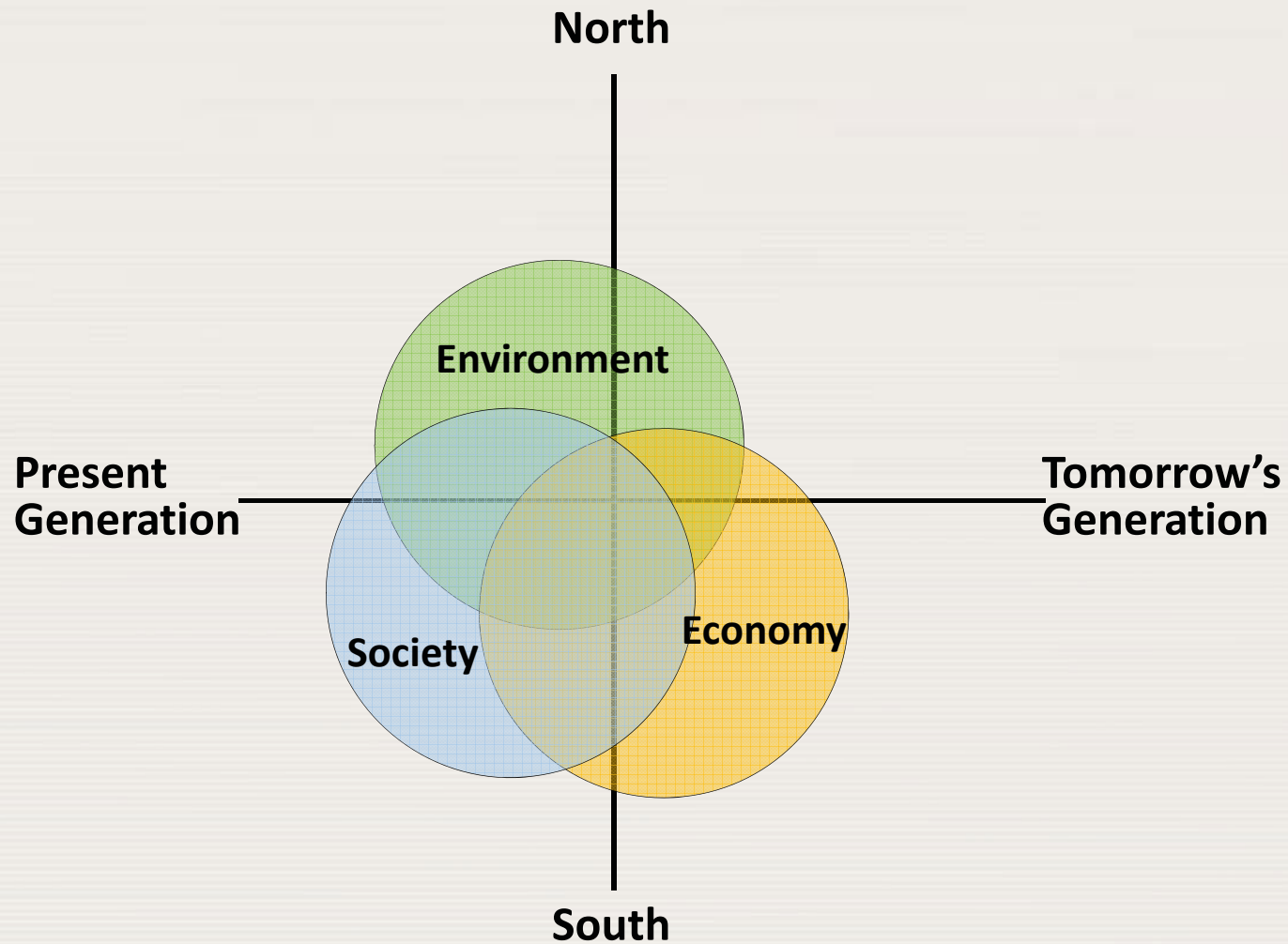
# 3Rs – Reduce, reuse, recycle

- Reducing waste production, recycling of wastes and reusing materials form the basis for sustainable waste management
  - Preventing waste generation in the first place through lower input of natural resources, smarter designs and more efficient manufacturing
  - Reusing, recycling and proper treatment of materials that would otherwise enter the waste stream
  - Replacing products with harmful wastes by environmentally friendly alternative materials

# Trade-offs: State of economic development

- Three pillars of sustainable development (SD) present conflicting objectives
- Environment protection versus development: **S**-d (North) versus **D**-s (South)
- Trade-offs are necessary
  - “Poverty is the biggest polluter” (I. Gandhi, 1972)
- Current environmental problems have been previous solutions
  - Technology – culprit or savior?

# Sustainability tradeoffs



# Trade-offs between the 3 dimensions

- Trade-offs between environmental, economic and social sustainability components are inevitable. They are influenced by value judgments.
- Emphasis on economy penalizes renewables; emphasis on environment penalizes fossil chains; emphasis on social aspects penalizes nuclear
- Developments towards strong limitation of consequences of hypothetical nuclear accidents along with radical reduction of waste confinement time will have a highly favorable impact on the overall sustainability ranking of the nuclear chain.

# Other major SD events

## ➤ RIO 1992: United Nations Conference on Environment and Development (UNCED) a.k.a Rio Conference or Earth Summit

- Agenda 21
- Framework Convention on Climate Change (UNFCCC)
- Convention on Biological Diversity (CBD)
- United Nations Convention to Combat Desertification (UNCCD)
- Commission of Sustainable Development (CSD)

## ➤ RIO+10 in Johannesburg (2002): World Summit on Sustainable Development (WSSD)

- Partnerships

## ➤ Rio+20 United Nations Conference on Sustainable Development (UNCSD)

- Green economy in the context of sustainable development poverty eradication;
- Institutional framework for sustainable development



# Energy and Sustainable Development: The issues

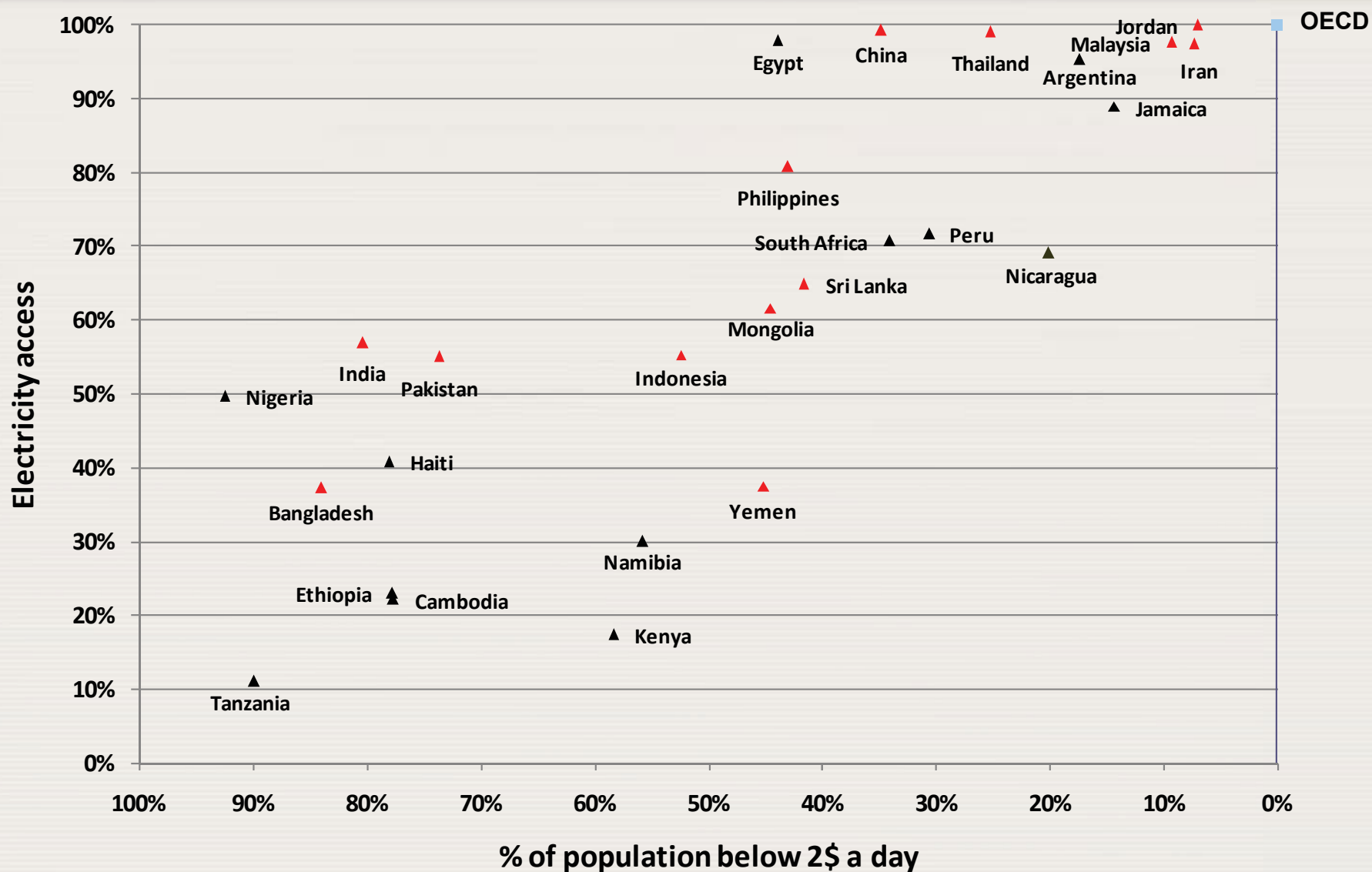
- Modern fuels and electricity are not universally accessible, and lead to inequity that has moral, political, and practical dimensions in a world that is becoming increasingly interconnected;
- The current energy system is not sufficiently reliable or affordable to support widespread economic development.
  - The productivity of one-third of the world's population is compromised by lack of access to commercial energy and perhaps another one third suffers from economic hardship and insecurity due to unreliable energy supplies;
- Negative local, regional and global environmental impacts of energy production and use threaten the health and well being of current and future generations.

# Energy Poverty

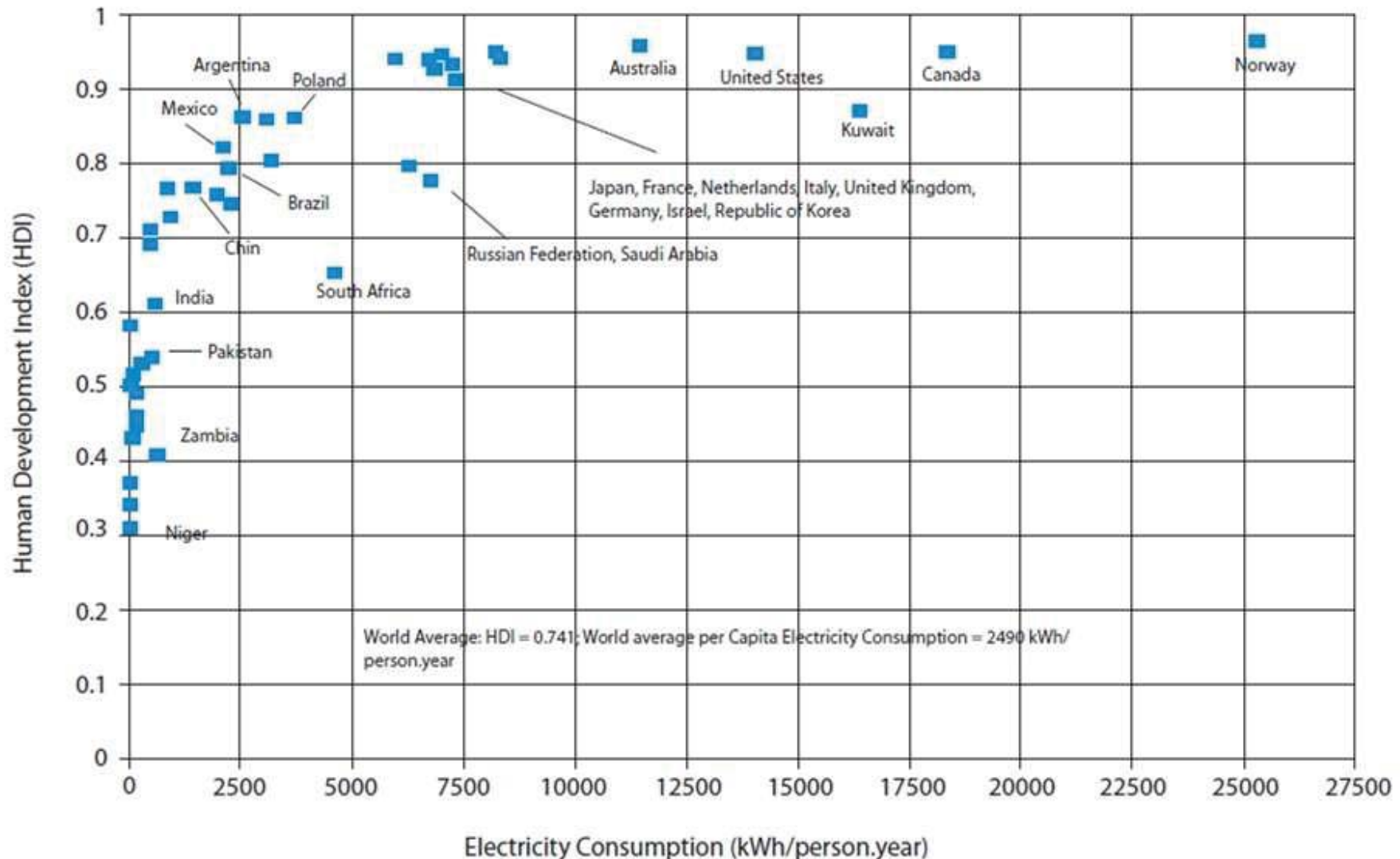
- **Due to dualism in the pattern of resource-use**
  - The consumption basket of the rich consists of goods & services with greater intensive use of fossil fuel, minerals, chemicals etc. than that of the poor.
  - Dualism also exists in the pattern of direct energy demand by households
    - Vast majority of rural and urban poor have to depend on unclean, unconverted and highly inefficient biomass fuel for cooking.
    - Significant lack of connectivity with electricity and/or its reliable supply for the rural households.
  - Energy Poverty removal is critical for decent quality of life and human development.

# Link between poverty and electricity access

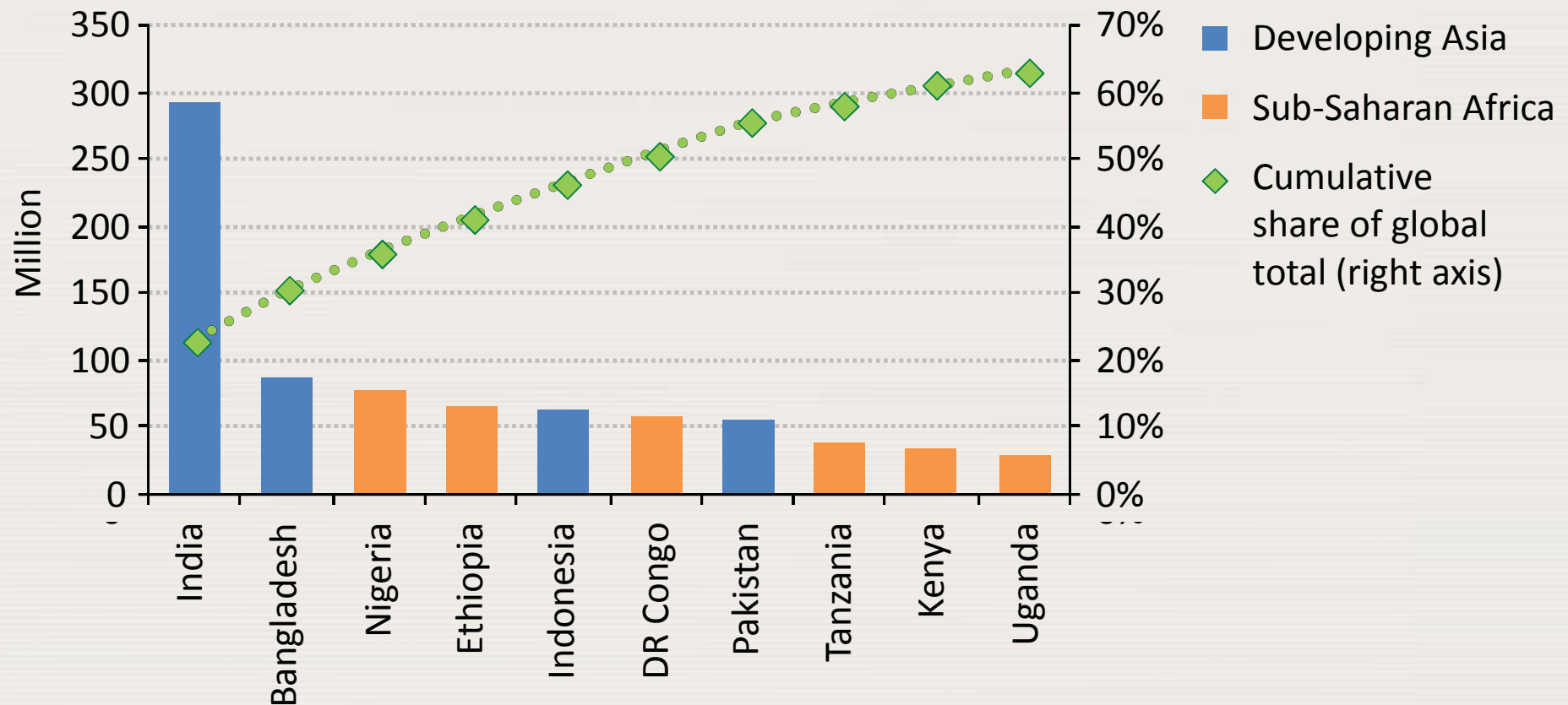
Source: UNDP – Human Development Report 2007/8



# Electricity – Human development link



# Countries with the largest population without access to electricity, 2010

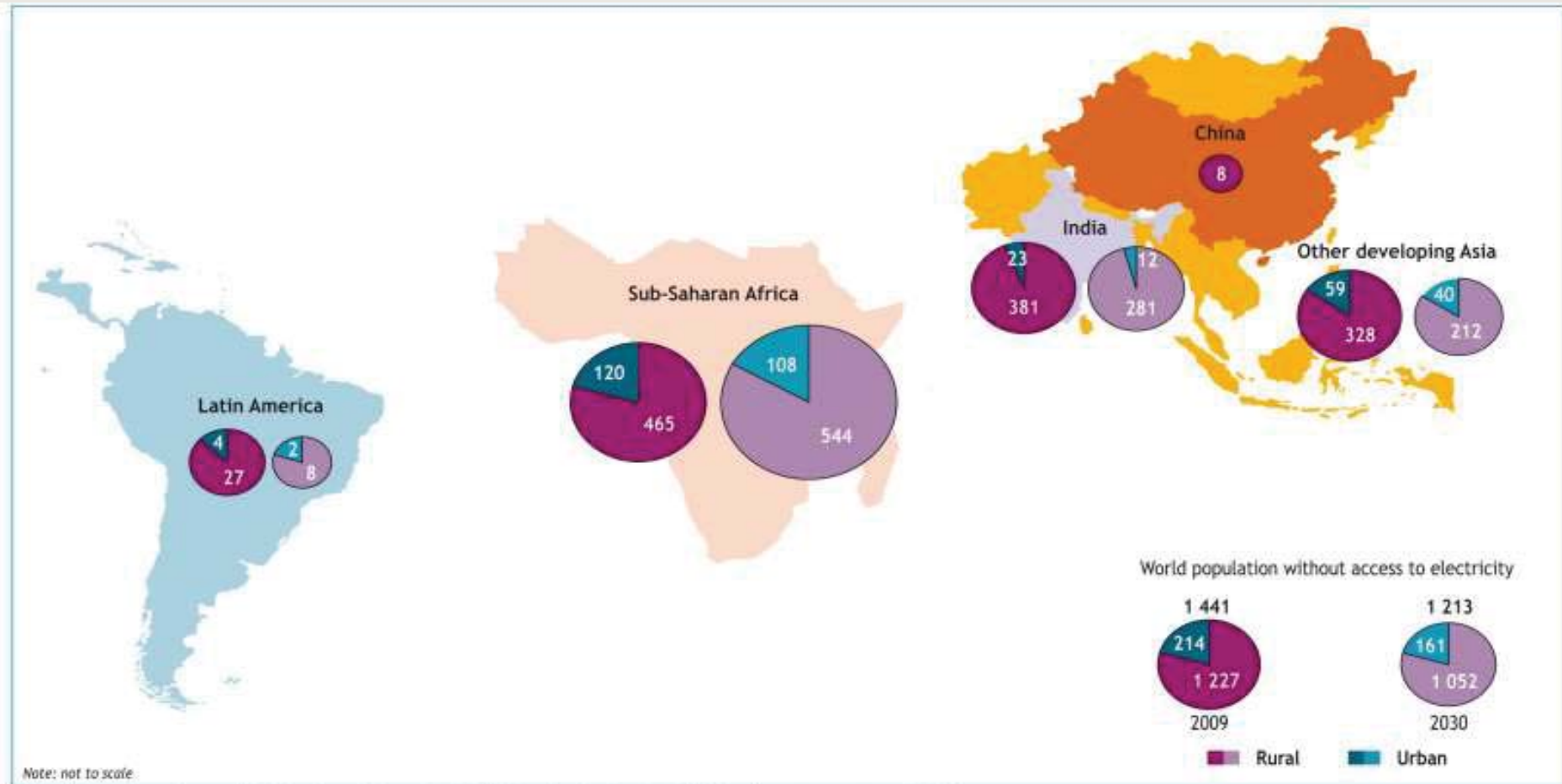


**Some 1 260 million people have no access to electricity**

**Over 95% of those without electricity are in developing Asia or sub-Saharan Africa & nearly two-thirds are in just ten countries**

Source: IEA, 2012

# Number of people without access to electricity (million)

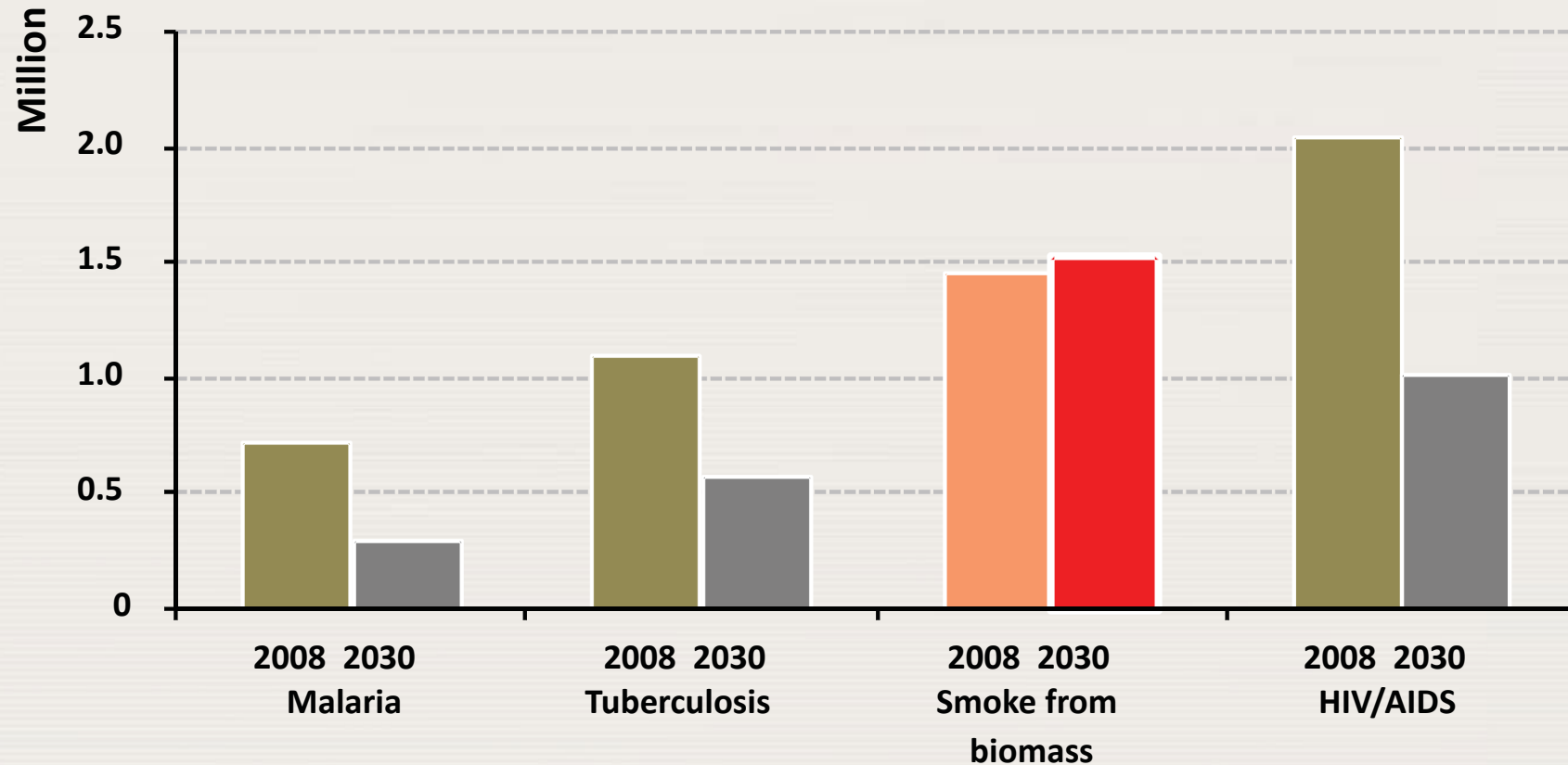


The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

***1.4 billion people lack access to electricity – achieving universal energy access requires investment of \$36 billion per year over the next two decades***

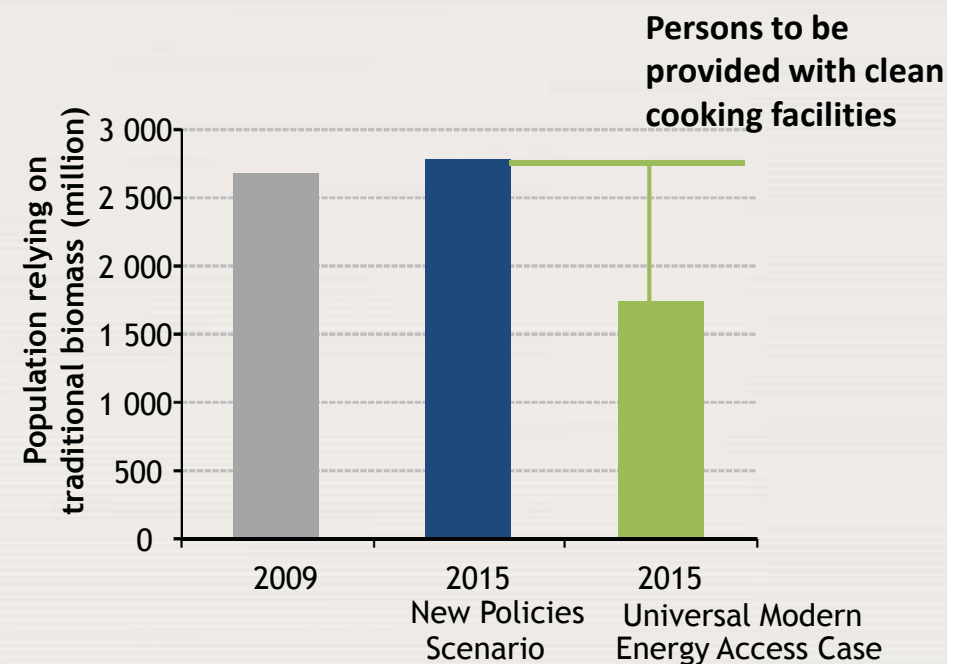
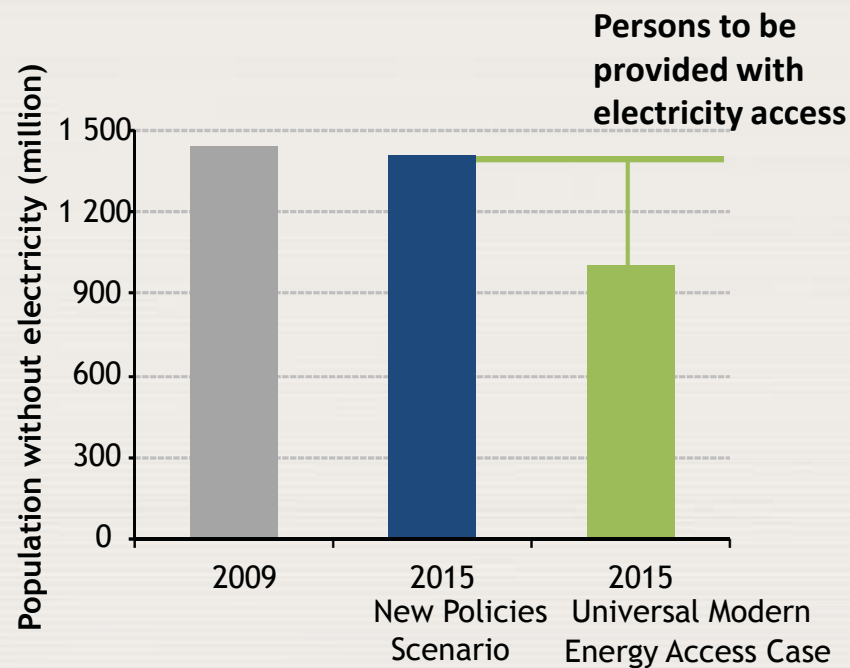
Source: IEA, 2012

# Health implication of the use of traditional biomass



*Based on analysis carried out jointly with the WHO, there are more people dying from smoke from biomass for cooking than from malaria or tuberculosis today. By 2030 over 4000 people will die prematurely every day from the effects of indoor smoke.*

# Implication of halving poverty on energy access by 2015



*To meet the UN MDG of eradicating extreme poverty by 2015, an additional 395 million people need to be provided with electricity and an additional 1 billion provided with access to clean cooking facilities*



# The Millennium Development Goals (MDG)

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality
4. Reduce Child mortality
5. Improve maternal health
6. Combat AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

# Energy is not on the MDG list!

- However, without access to modern forms of energy it will be virtually impossible to reach any of the MDGs.
- Clean energy is a key element for achieving all of the MDGs—poverty, hunger, education, gender equality, health, communicable diseases, and environmental sustainability.
- Thus, energy is an entry point to achieve broader societal objectives
- Many objectives must be pursued simultaneously!

# Possible definition of sustainable energy

- **‘Energy produced and used in ways that support human development over the long term, in all its social, economic and environmental dimensions’, has been accepted as what is understood by the term ‘sustainable energy’.**
- **This term does not refer simply to a continuing supply of energy, but to the production and use of energy resources in ways that promote –or at least are compatible with – long term human well being and ecological balance**

# Some rules for sustainable energy supply

- The use of renewable resources should not exceed their rate of regeneration
- Non-renewable energy resources and raw materials should be consumed at a rate that corresponds to physically and functionally equivalent substitution by economically viable renewable resources, increased efficiency in utilizing the available resources or discovery/development of new reserves
- Pollution and waste flows into the environment should not exceed the absorption capacity of the natural environment
- Non-acceptable risks for the human health due to man-made impacts should be mitigated
- Consumption of limited resources is an essential indicator for the evaluation of sustainability of options. Total (“true”) costs can serve as a suitable measure in this context

# Moving towards sustainable energy systems

- No energy system configuration can fulfill all criteria concerning sustainability. One-sided promotion is not justified
- Ranking of technologies may change depending on specifics of the case (country, location, status of reference technologies)
- Internalization of external costs is desirable and economically and socially efficient.
  - Total cost as measure of sustainability often favors nuclear power
- Critical issues for nuclear energy are risk aversion and necessity to confine small waste volumes over extremely long time.
  - Associated social concerns are not well reflected by total costs.

# Architecture of the Energy System

**What  
Nature  
Provides**

## Sources

coal oil natural gas sunlight uranium wind biomass

## Extraction Treatment

coal mine hydro dam oil cleaning rig separation beneficiation liquefaction gasification

## Conversion Technologies

hydro station thermal power plant oil refinery nuclear generating station photovoltaic cell wind converter

## Currencies (fuels)

electricity gasoline methanol methane hydrogen heat

## Distribution

electricity grid gas grid truck dewar railway district heat grid

**Energy  
Sector**

## Service Technologies

automobile light bulb telephone furnace microwave oven aircraft PC

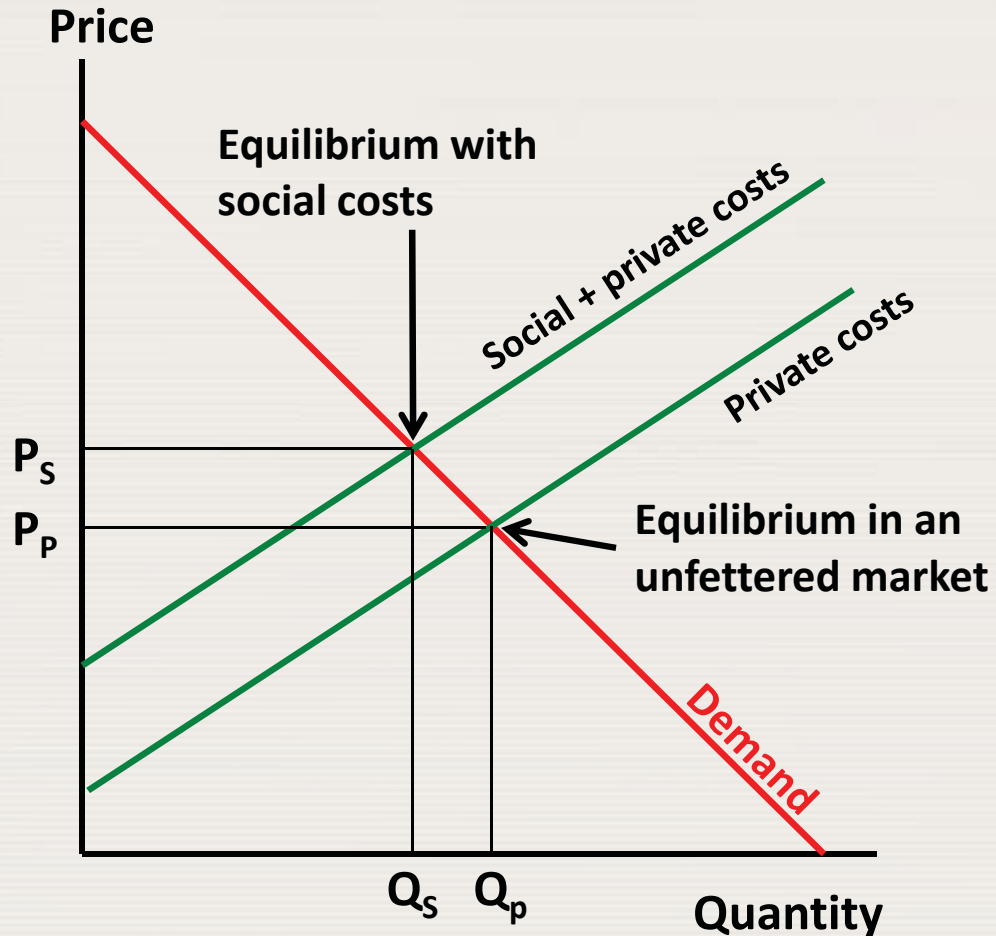
**Efficiency &  
Infrastructure**

## Services

transportation communication keeping warm/cold food  
potable water health care security consumer goods

**What  
People  
Want**

# Contemporary challenges: The environment



What is an externality?

A cost that is 'external' to the transaction...

Any examples?

OK, so we damage the environment... how much are you willing to pay to:

- avoid the damage?
- fix the damage?
- live with the damage?

# What are externalities?

- Externalities are changes of welfare generated by a given activity without being reflected in market prices.
  - They may be positive (benefits) or negative (costs)
- A cost (benefit) is external when it is not paid (enjoyed) by those who have generated it
- Negative externalities are borne by society: they should be reduced, and passed on to those who generate them (application of the “polluter pays principle” through internalisation)



# Examples of external costs

## Adaptation to climate change

### Air pollution increases hospital admissions for respiratory illness

- Costs of health care
- Lost productivity
- Own pain and suffering
- Pain and suffering of others

### Water pollution leads to loss of fish

- Reduced recreational opportunity
- Commercial losses
- Impact on biodiversity

### Congestion leads to loss of time, productivity

### Consequence of large scale accidents

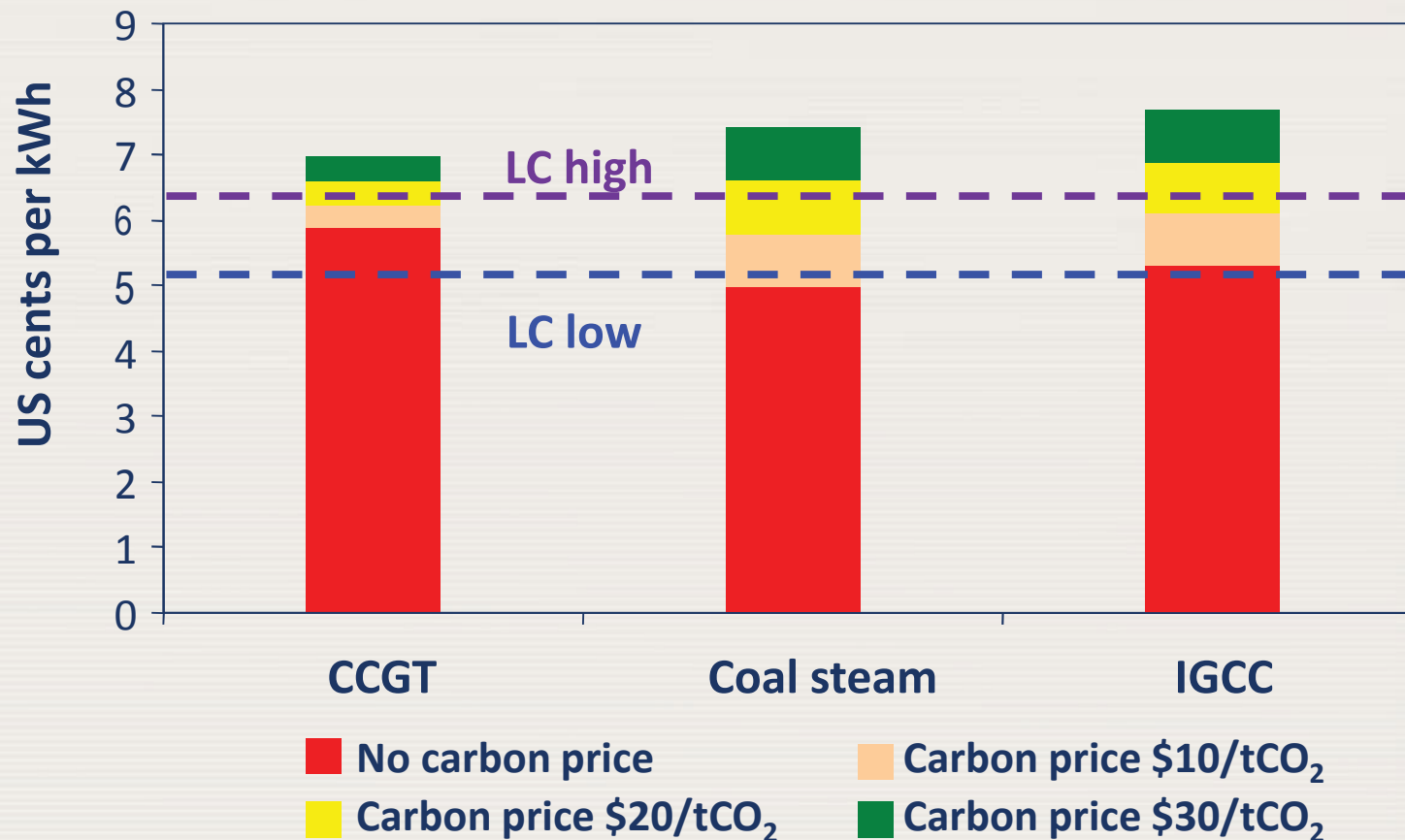
- Evacuation, loss of income
- Increased health costs, psychological impacts, etc.

## Examples of controversial/difficult to estimate external effects

- Impact of climate change
  - Severe accidents, terrorism, risk aversion
  - Value of loss of life
  - Visual intrusion
  - Resource depletion
  - Nuclear proliferation
  - Biodiversity losses
  - Security of supply
  - Social justice and conflict potential
- Serious attempts to estimate the corresponding costs mostly lead to low estimates but this does not resolve the controversy!

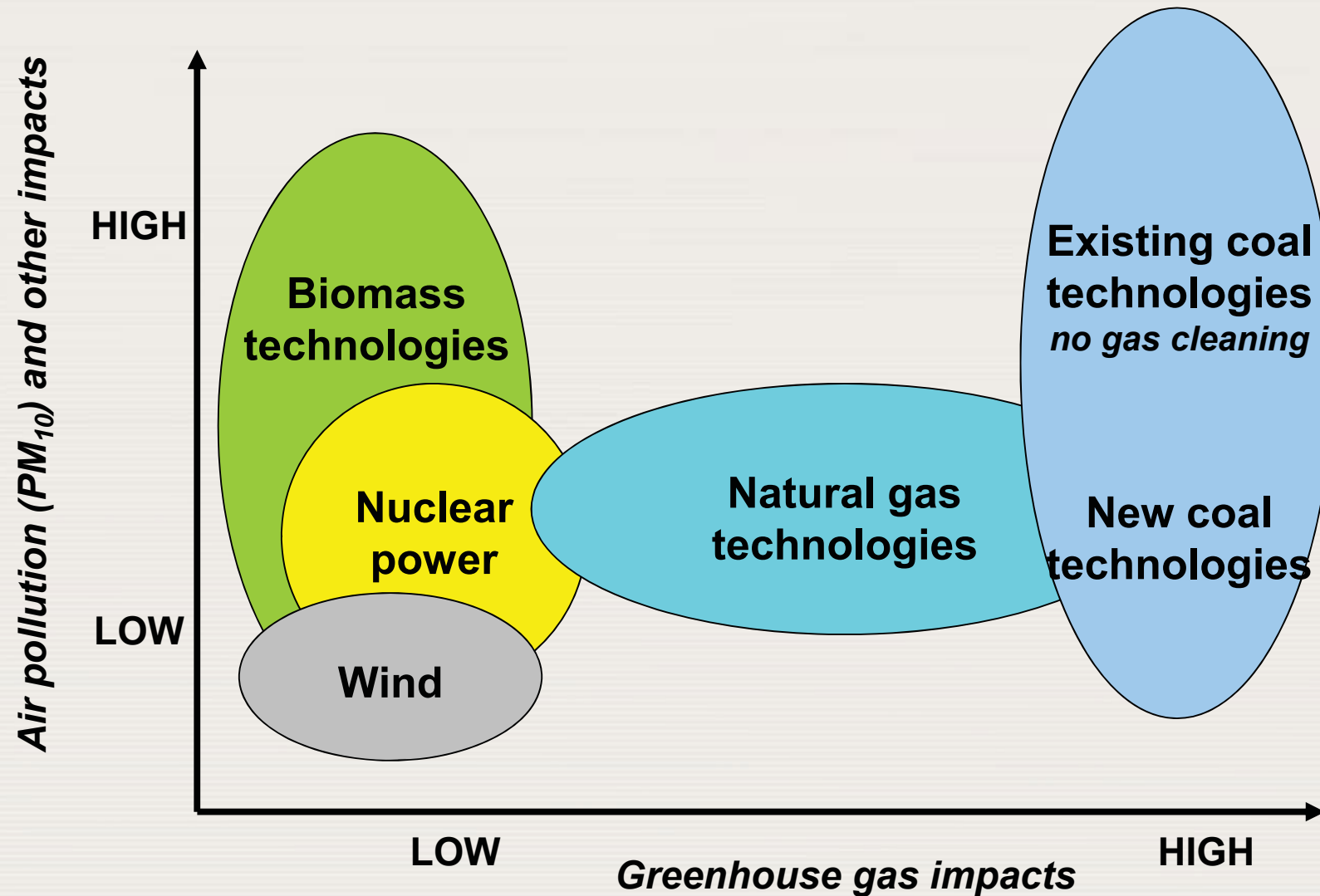
# Impact of CO<sub>2</sub> penalty on competitiveness of low carbon electricity (LC)

LC = Most renewables (hydro, wind, solar, geothermal, biomass), nuclear power, CCS, efficiency improvements



Source: Adapted from EA, 2006

# Externalities of different electricity generating options



# Today's popular climate change mitigation ladder

**Efficiency improvements**

**Renewables**

**Reducing Emissions from Deforestation and Forest Degradation (REDD)**

**New and advanced technologies**

**Clean fossil (coal technology)**

**Carbon capture & storage (CCS)**

**Next generation of nuclear power**

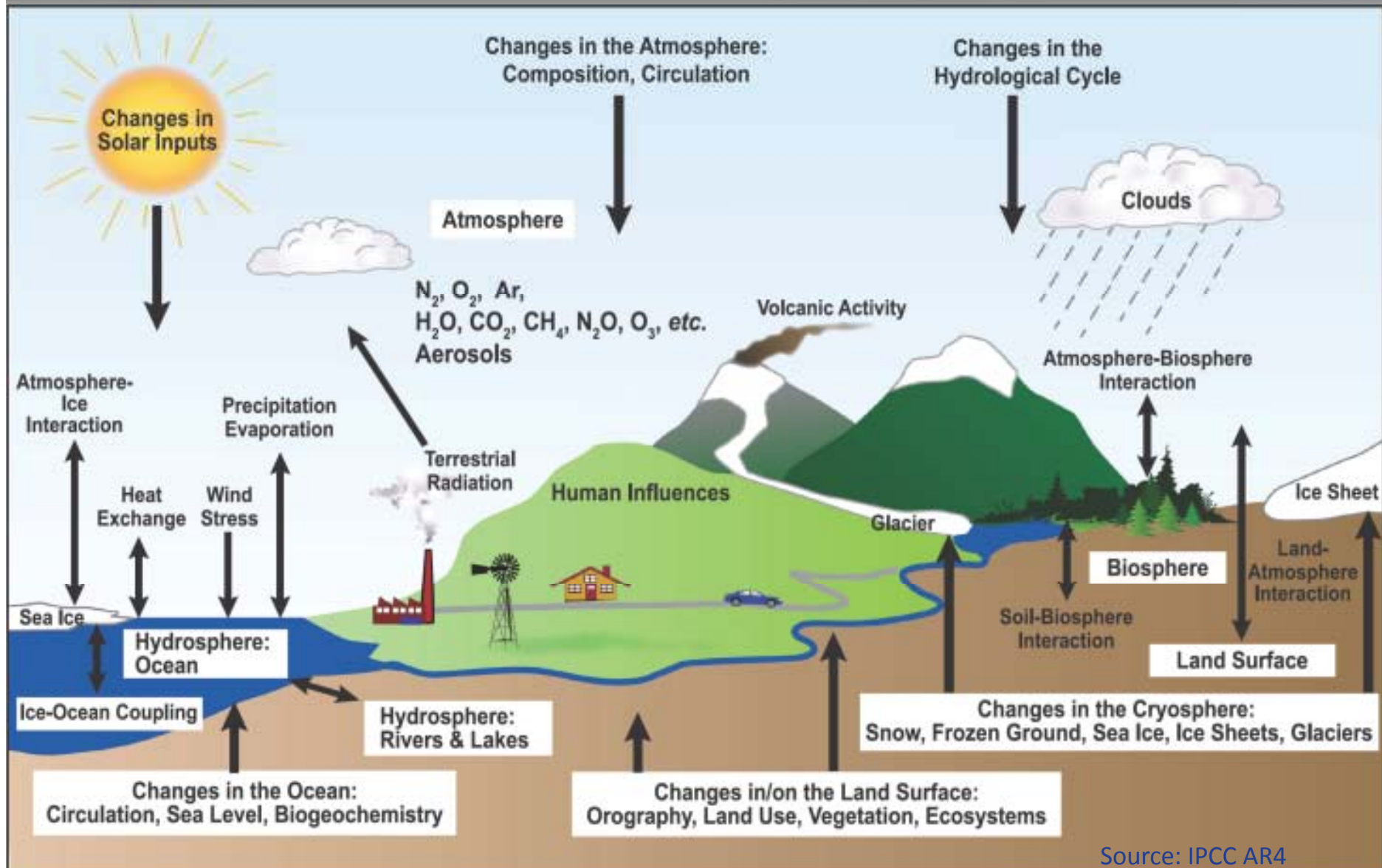
# *Climate change – The greenhouse effect*

- **Climate: Average weather over a period of 30 years, e.g. 1961-1990**
- **Driving force for weather and climate: Energy from the sun**
- **Atmosphere and surface of the Earth intercept solar radiation**
  - Short wave, including visible part of the spectrum
  - 1/3 is reflected, the rest is absorbed ( $\sim 240 \text{ W/m}^2$ )
- **To balance the absorbed incoming energy, the Earth must, on average, radiate the same amount of energy back to space.**
  - In the form of long-wave invisible infrared energy

# The greenhouse effect

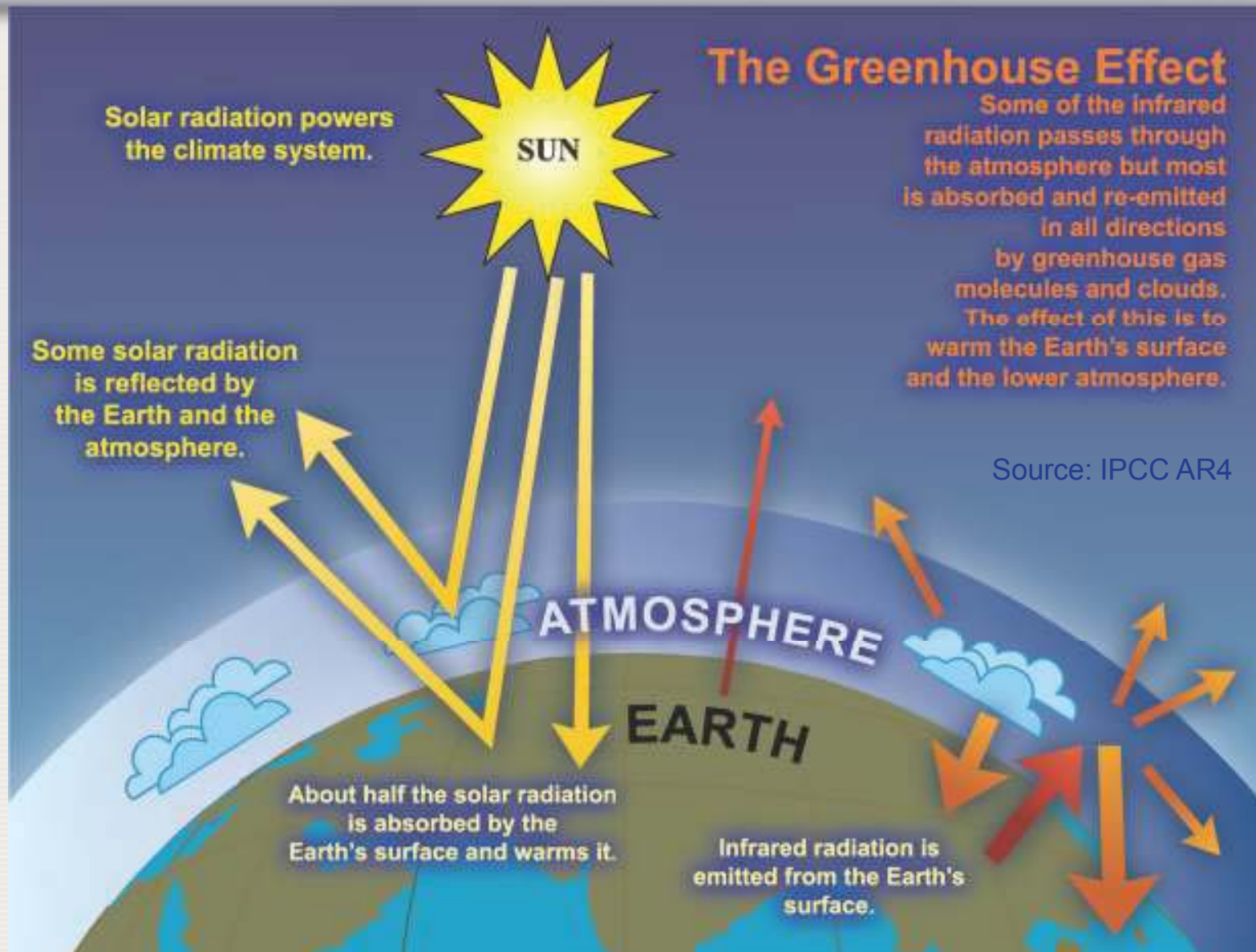
- Trace gases or greenhouse gases (GHGs) act analogously to the glass in a greenhouse
- GHGs include water vapour ( $\text{H}_2\text{O}$ ), carbon dioxide ( $\text{CO}_2$ ), methane ( $\text{CH}_4$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), F-Gases
- Global climate change (global warming): enhanced greenhouse effect due to human (anthropogenic) emissions of GHGs
- Sources of anthropogenic GHG emissions:
  - $\text{CO}_2$ : fossil fuel combustion and land-use change
  - $\text{CH}_4$  and  $\text{N}_2\text{O}$ : agriculture, waste, industrial processes
  - F-Gases: Air conditioning, industrial processes
  - Others

# *Schematic view of the components of the climate system, their processes and interactions*

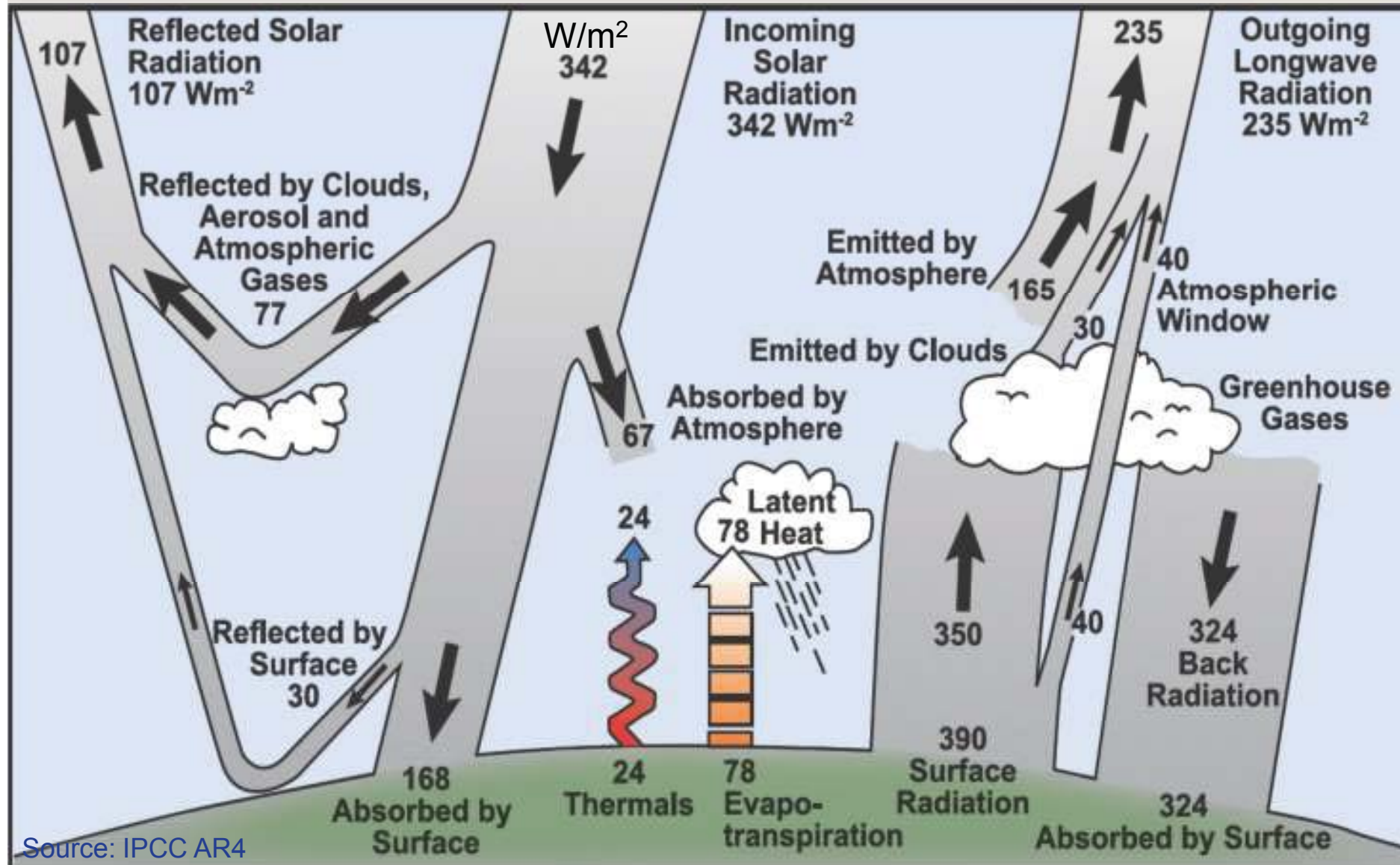




# The greenhouse effect

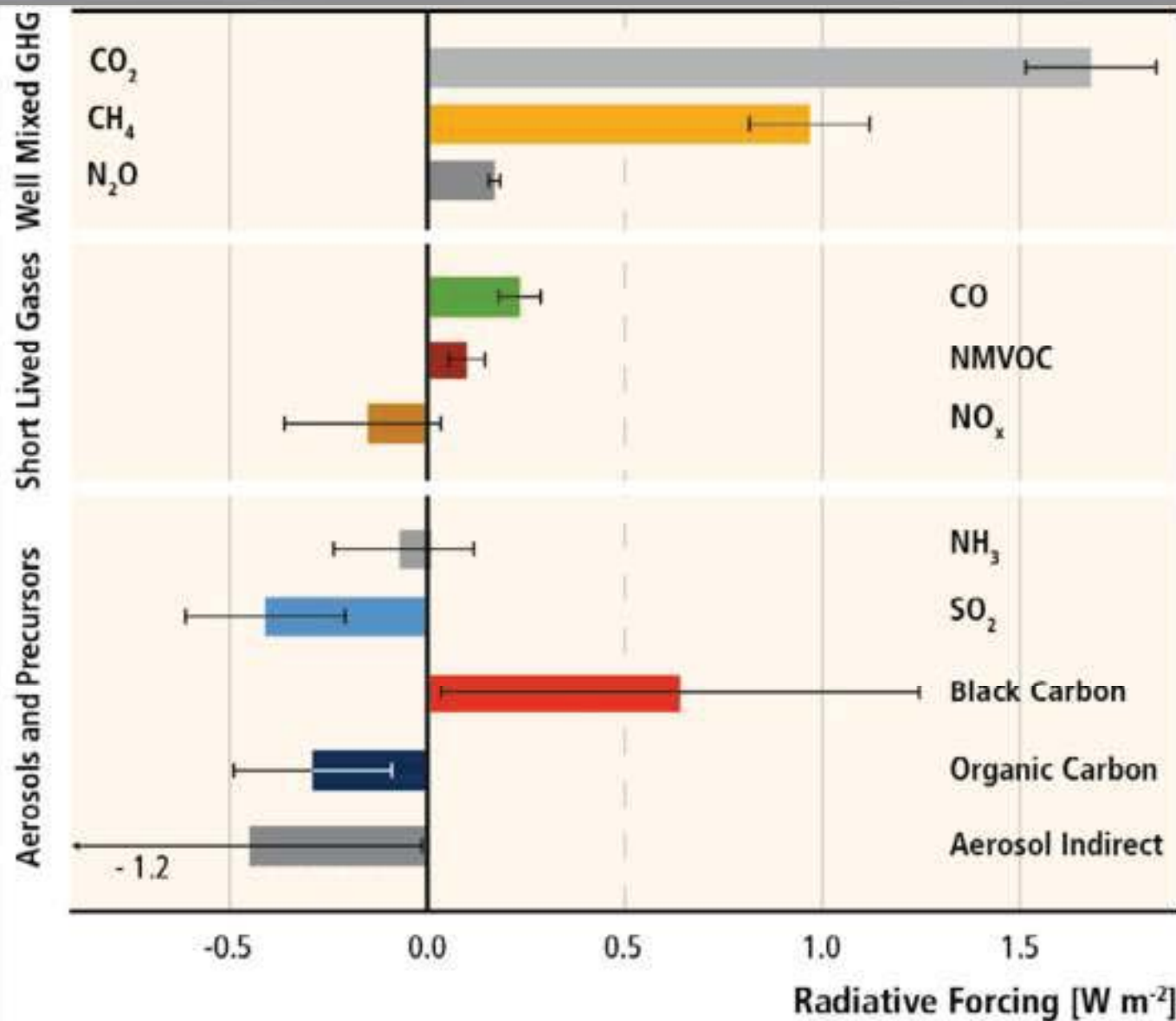


# The greenhouse effect



Source: IPCC AR4

# Radiative forcing components

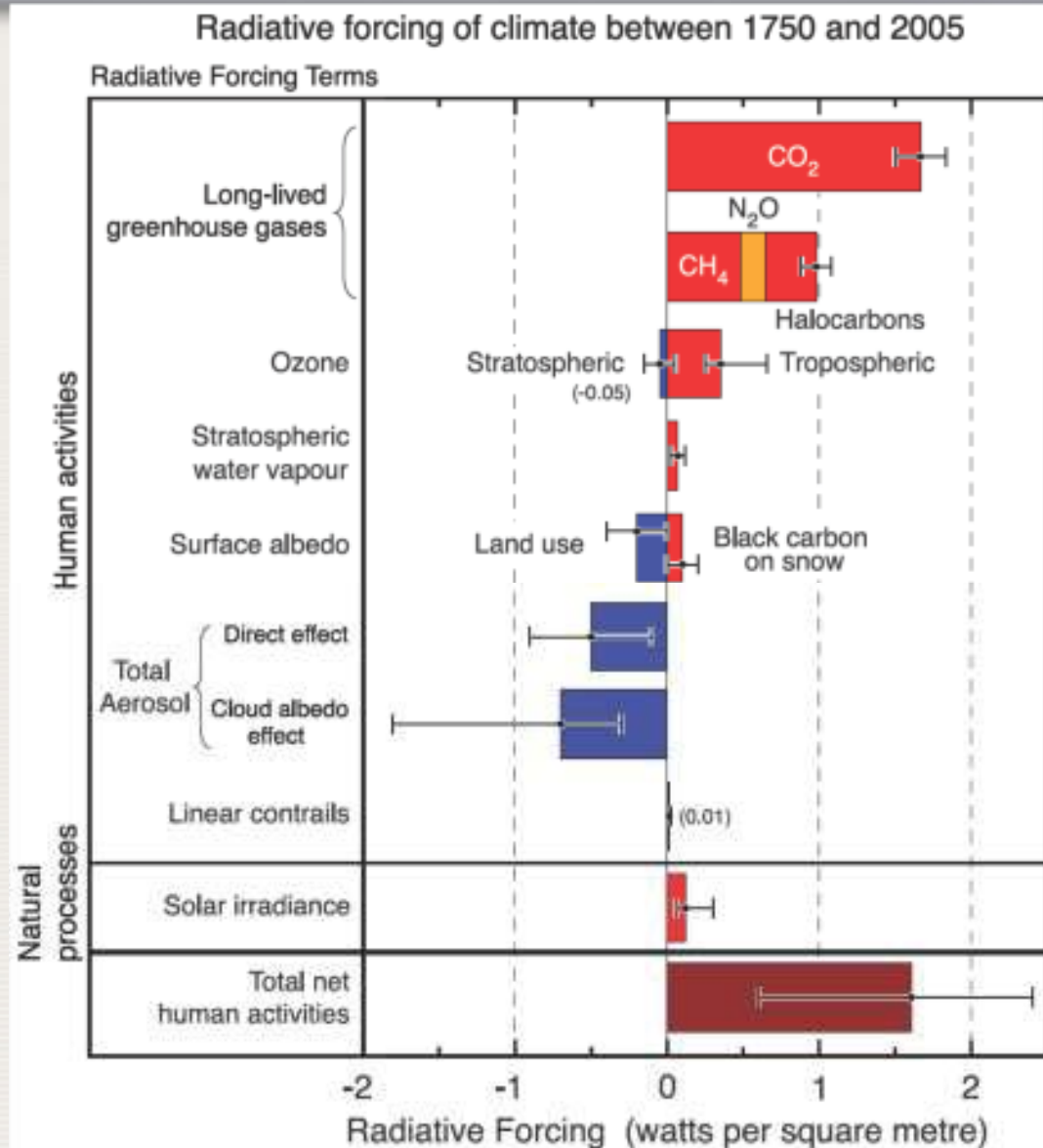


Radiative forcing is the net change radiative flux (expressed in  $\text{W/m}^2$ ) at the tropopause or top of atmosphere due to a change in an external driver of climate change, such as, for example, a change in the concentration of carbon dioxide ( $\text{CO}_2$ ), solar activity or sulfur dioxide ( $\text{SO}_2$ ).

# Radiative Forcing

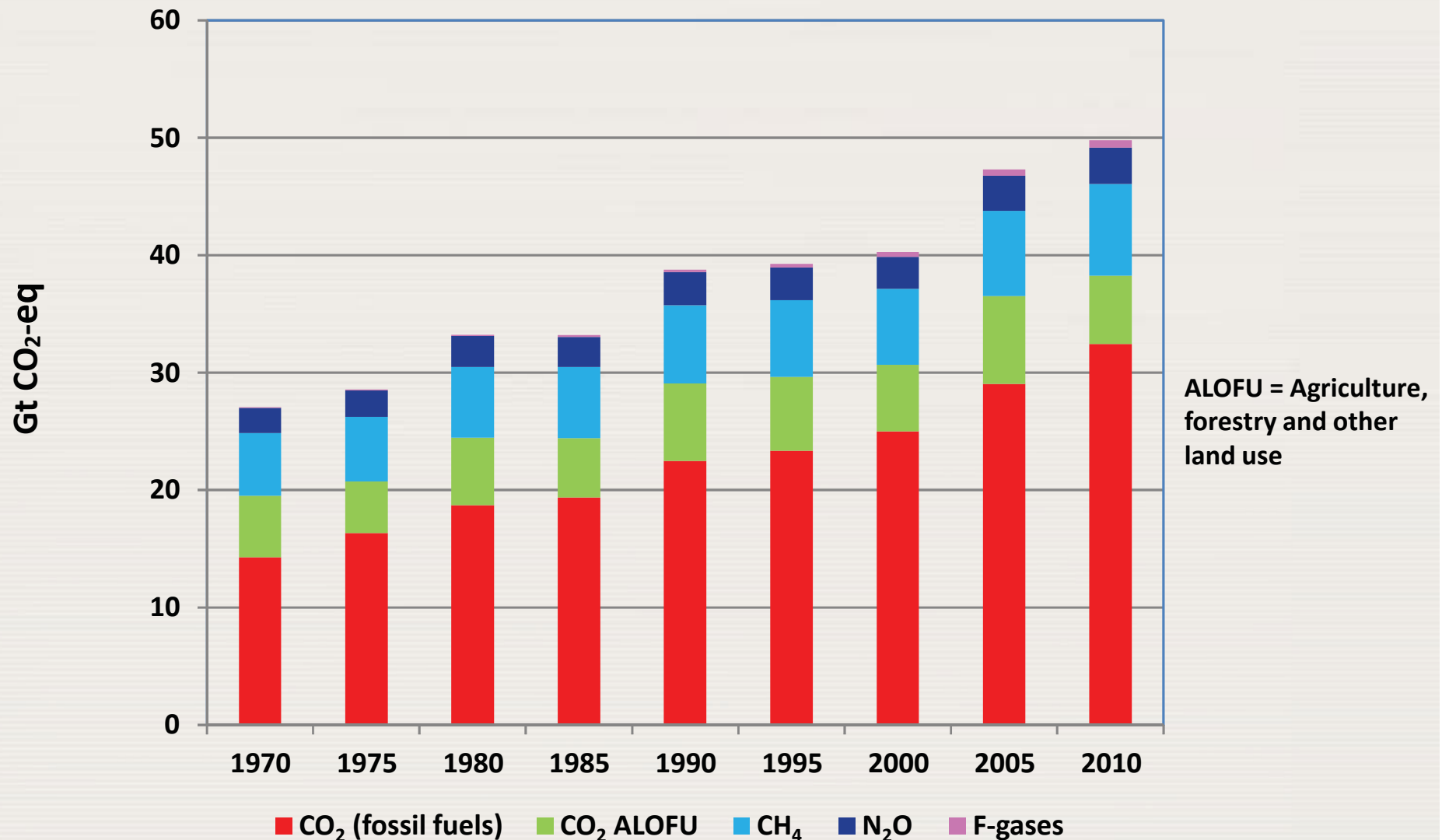
*The values represent the radiative forcings in 2005 relative to the start of the industrial era (about 1750). Human activities cause significant changes in long-lived gases, ozone, water vapour, surface albedo, aerosols and contrails. The only increase in natural forcing of any significance between 1750 and 2005 occurred in solar irradiance. Positive forcings lead to warming of climate and negative forcings lead to a cooling. The thin black line attached to each coloured bar represents the range of uncertainty for the respective value*

Source: IPCC AR4



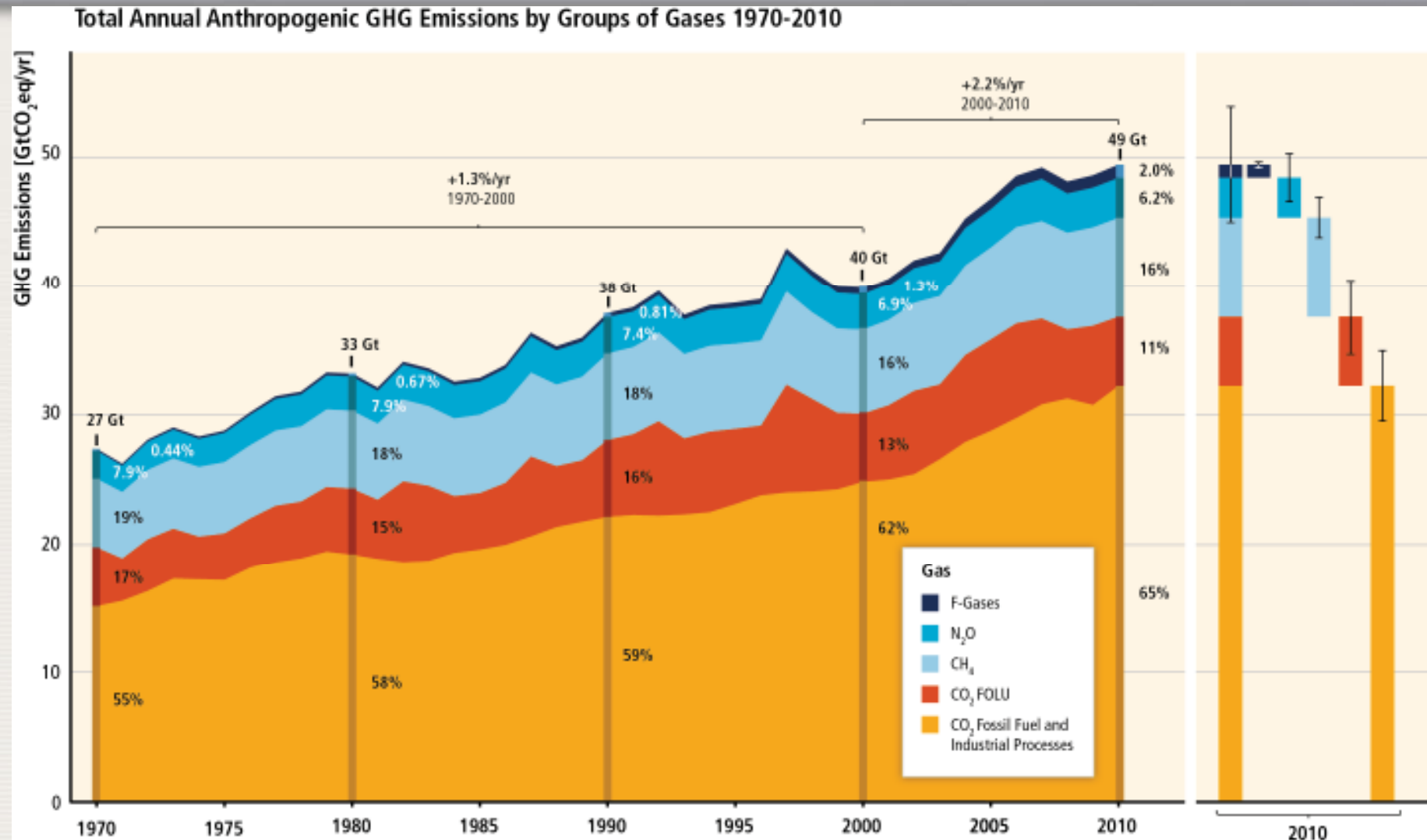


# Anthropogenic GHG emissions (Kyoto gases)



Source: IPCC AR5

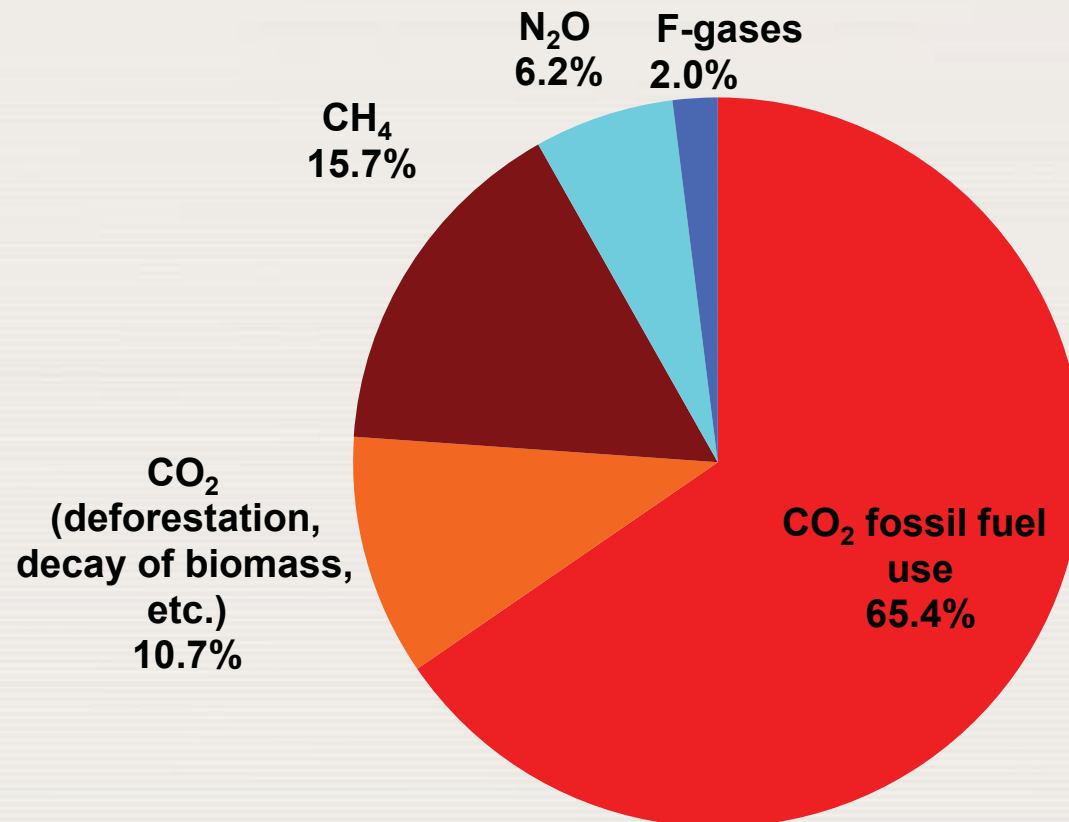
# Anthropogenic GHG emissions (Kyoto gases)



GHG emissions accelerate despite reduction efforts. Most emission growth is CO<sub>2</sub> from fossil fuel combustion and industrial processes.

# Anthropogenic GHG emissions in 2010 by GHG

Total GHG emissions: 49.5 GtCO<sub>2</sub>eq

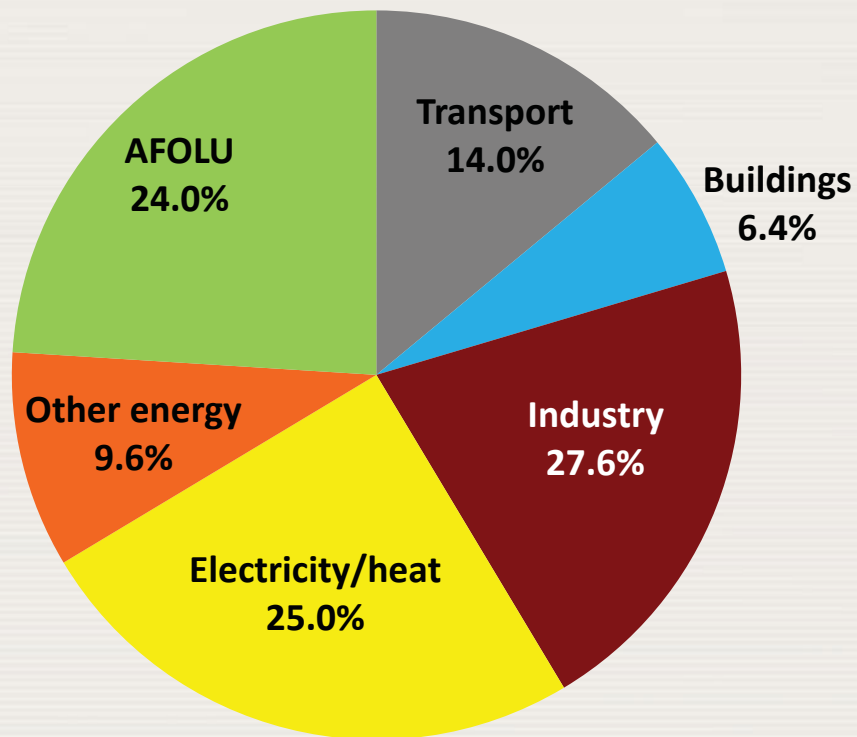


F-gases: Perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF<sub>6</sub>)

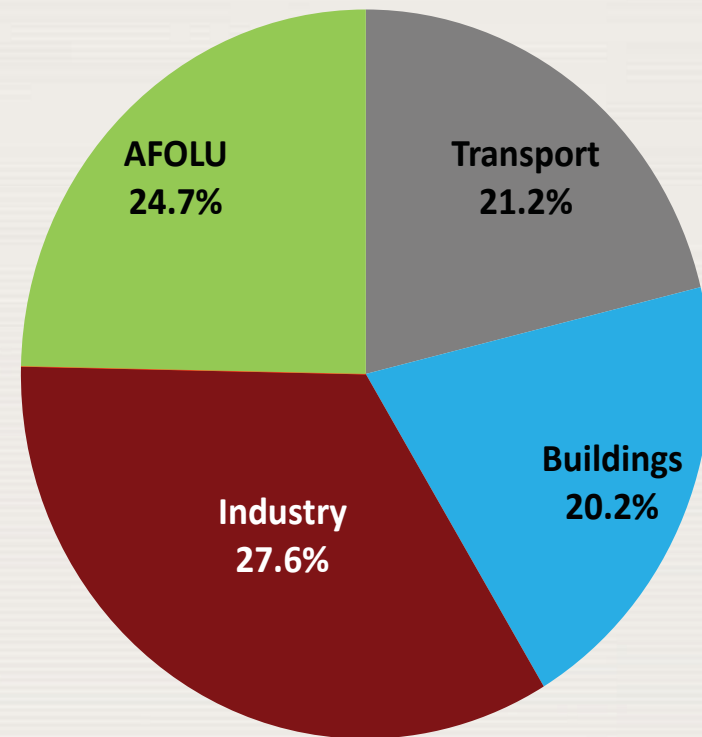
Source: IPCC AR5

# GHG emissions by sector in 2010

## Direct emissions



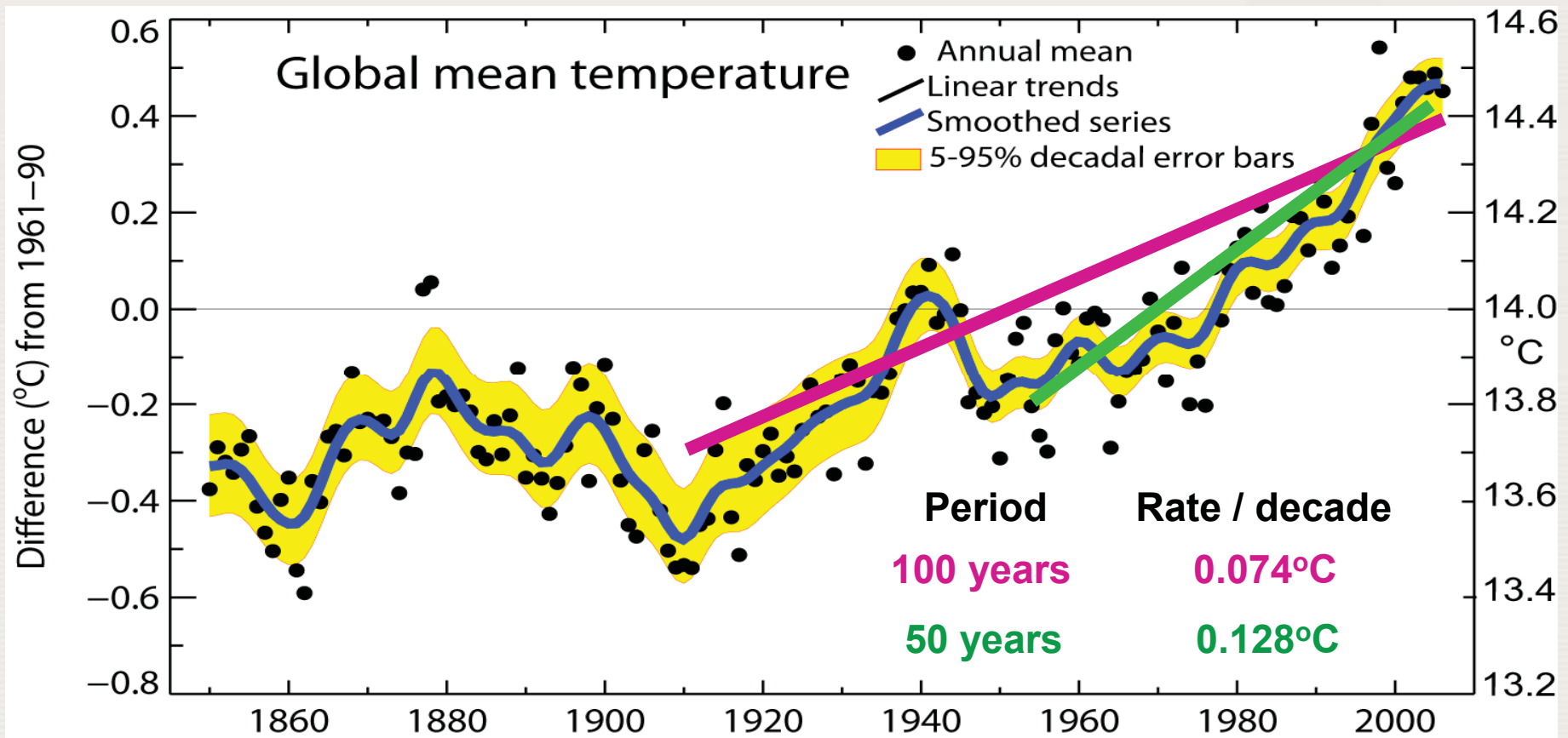
## Direct and indirect emissions



Total GHG emissions: 49.5 GtCO<sub>2</sub>eq

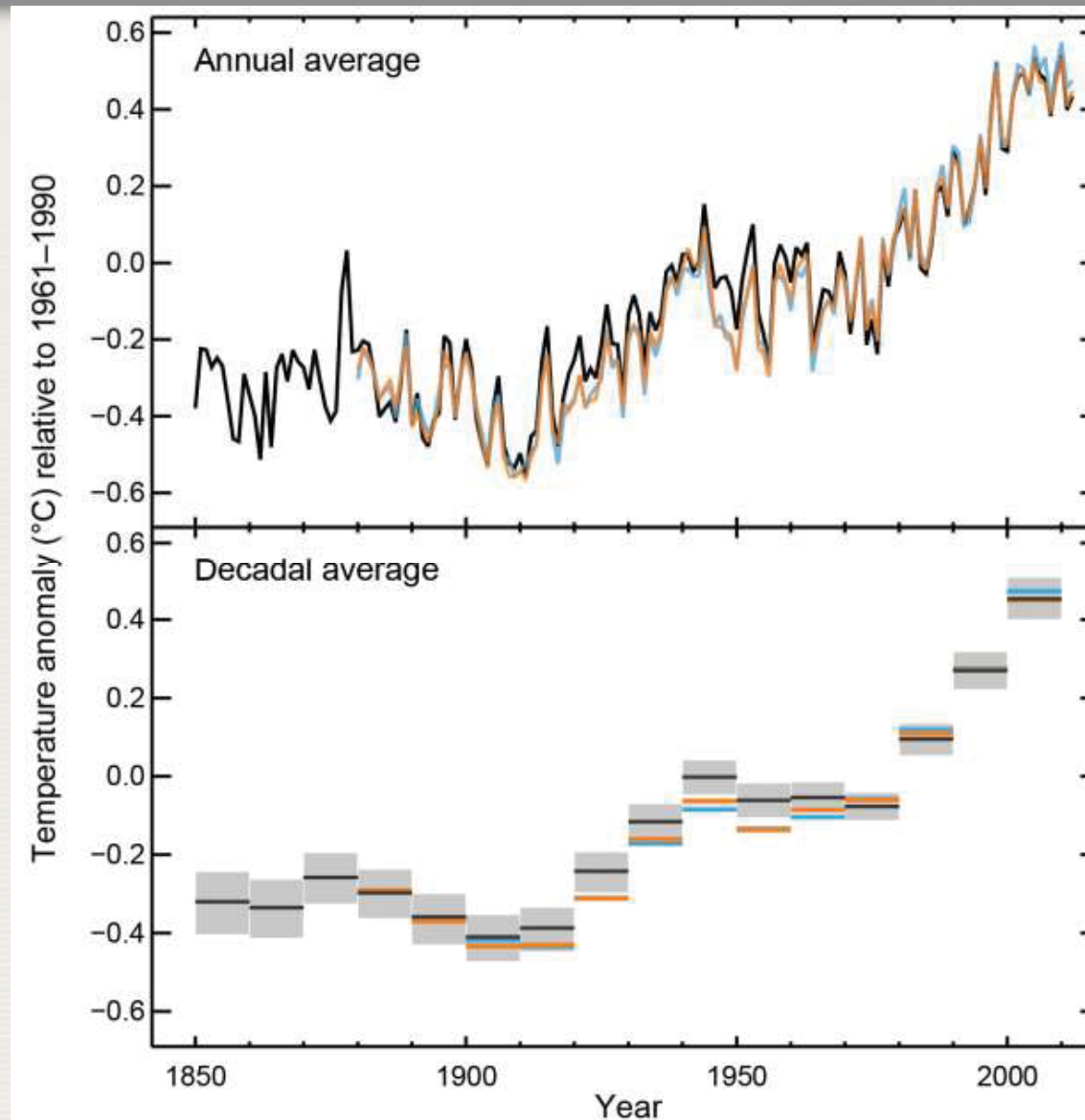


# Changes in global average surface temperature



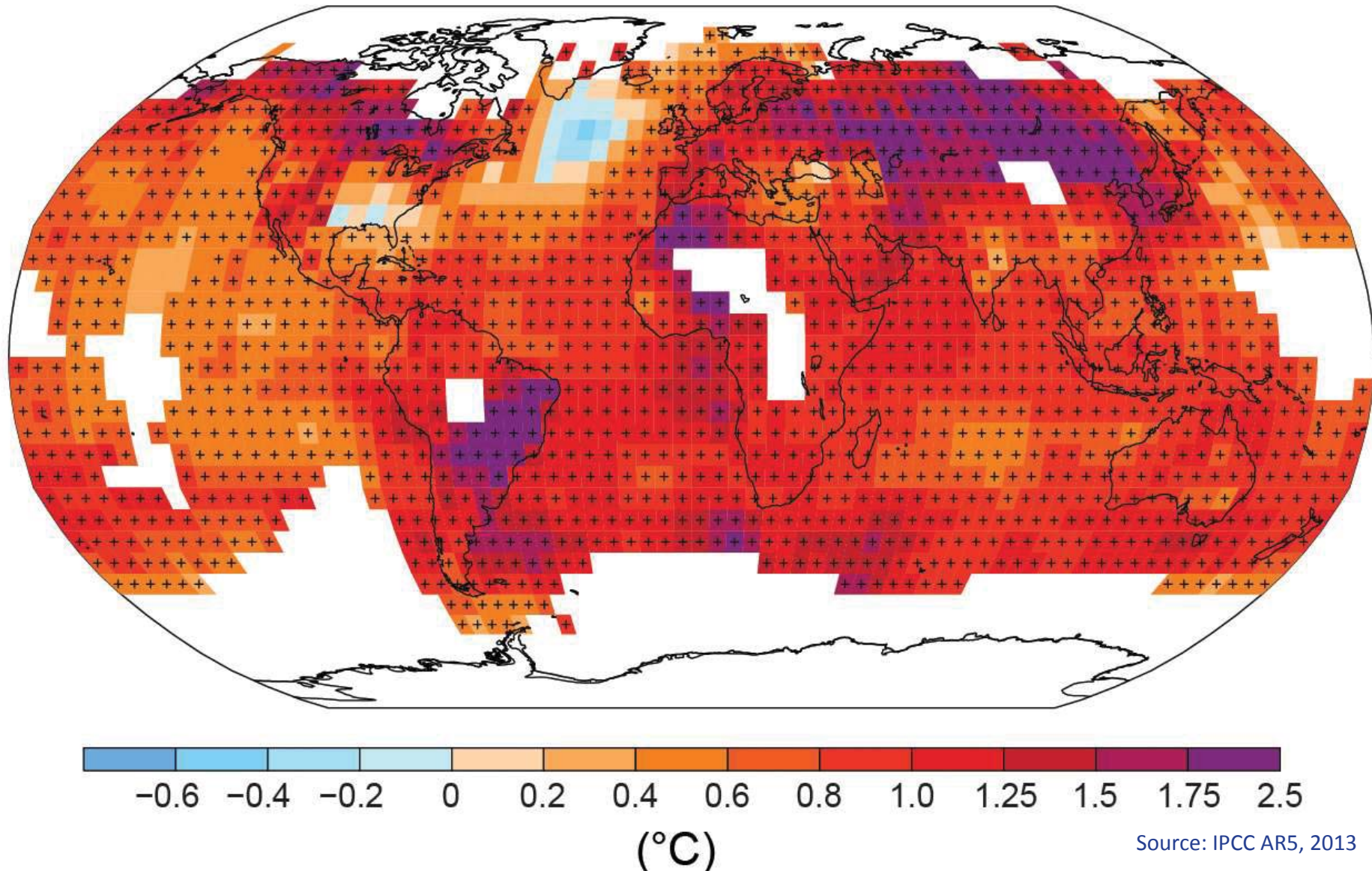
Eleven of the last twelve years rank among the twelve warmest years in the instrumental record of global surface temperature

# Observed globally averaged combined land and ocean surface temperature anomaly 1850-2012



Source: IPCC AR5, 2013

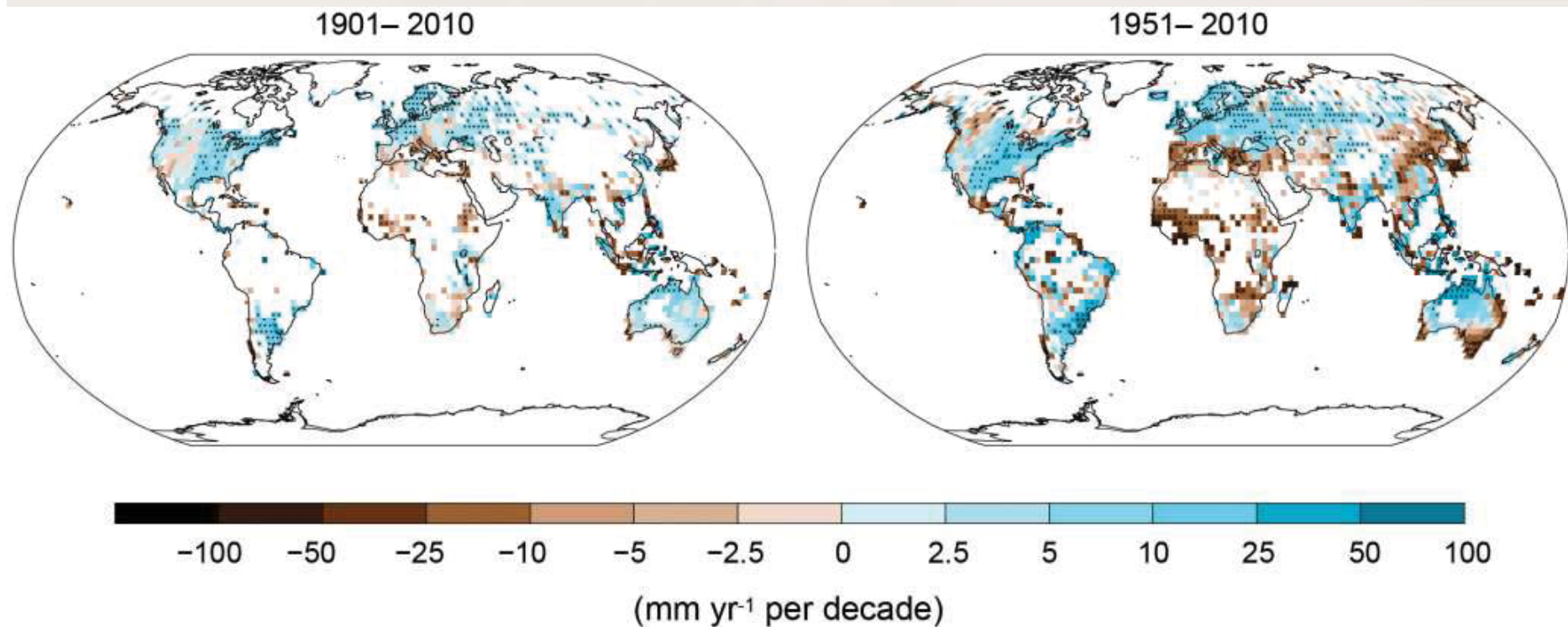
# Observed change in surface temperature 1901-2012



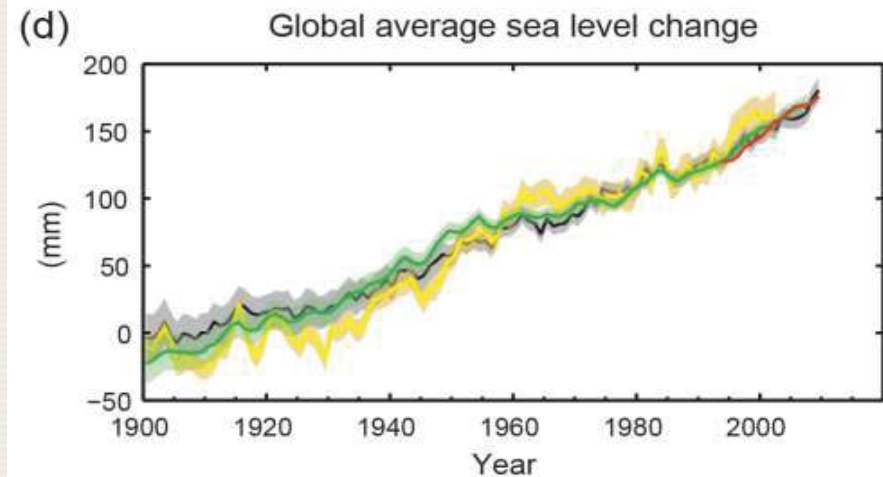
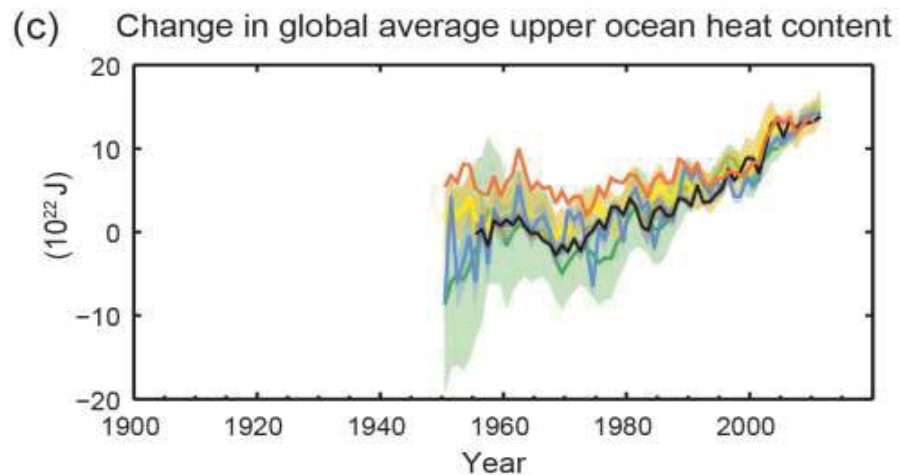
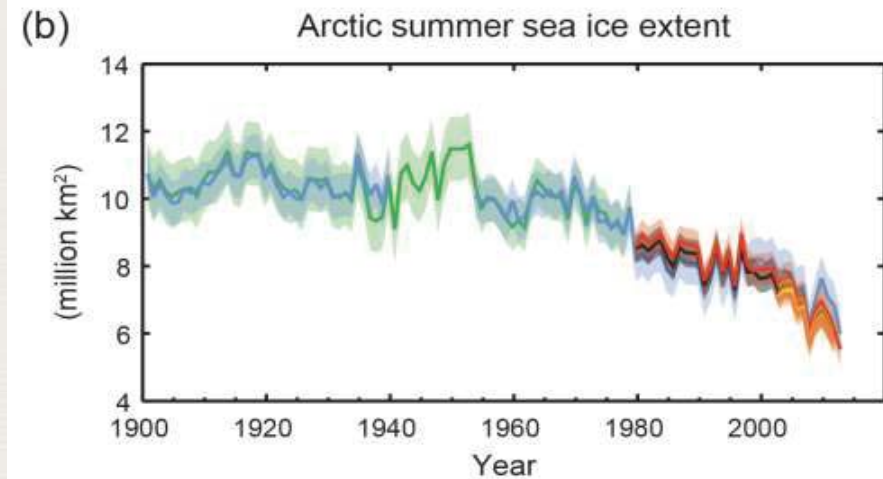
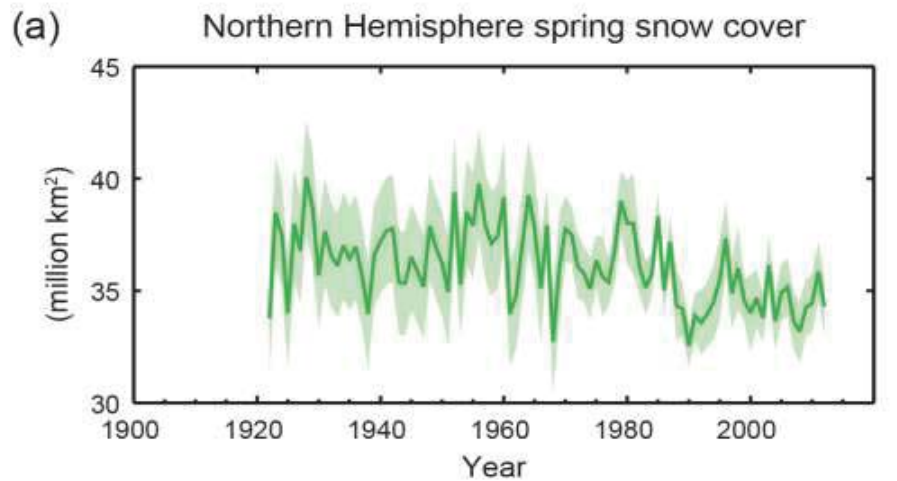
Source: IPCC AR5, 2013



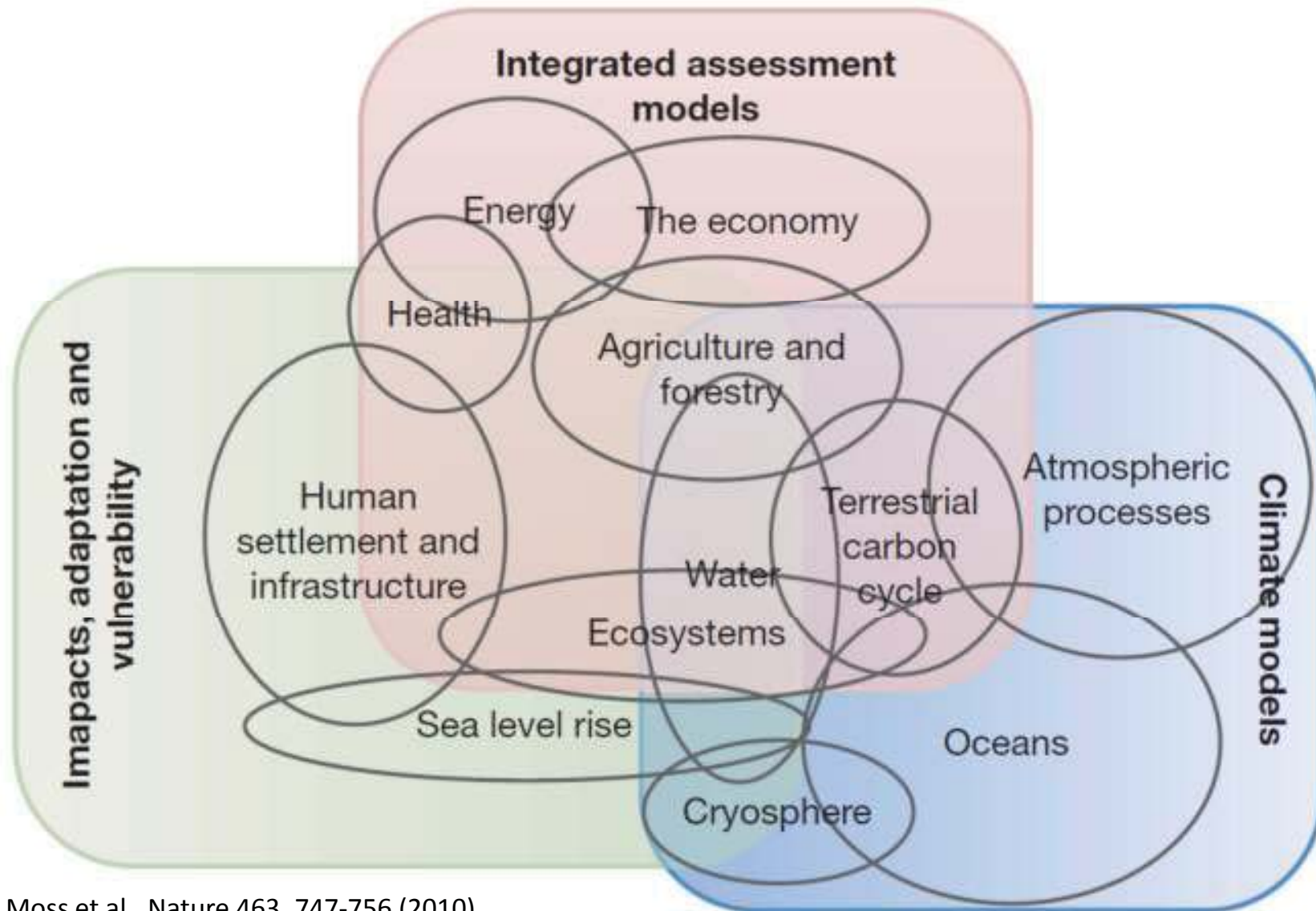
# Observed change in annual precipitation over land



# Multiple observed indicators of a changing global climate

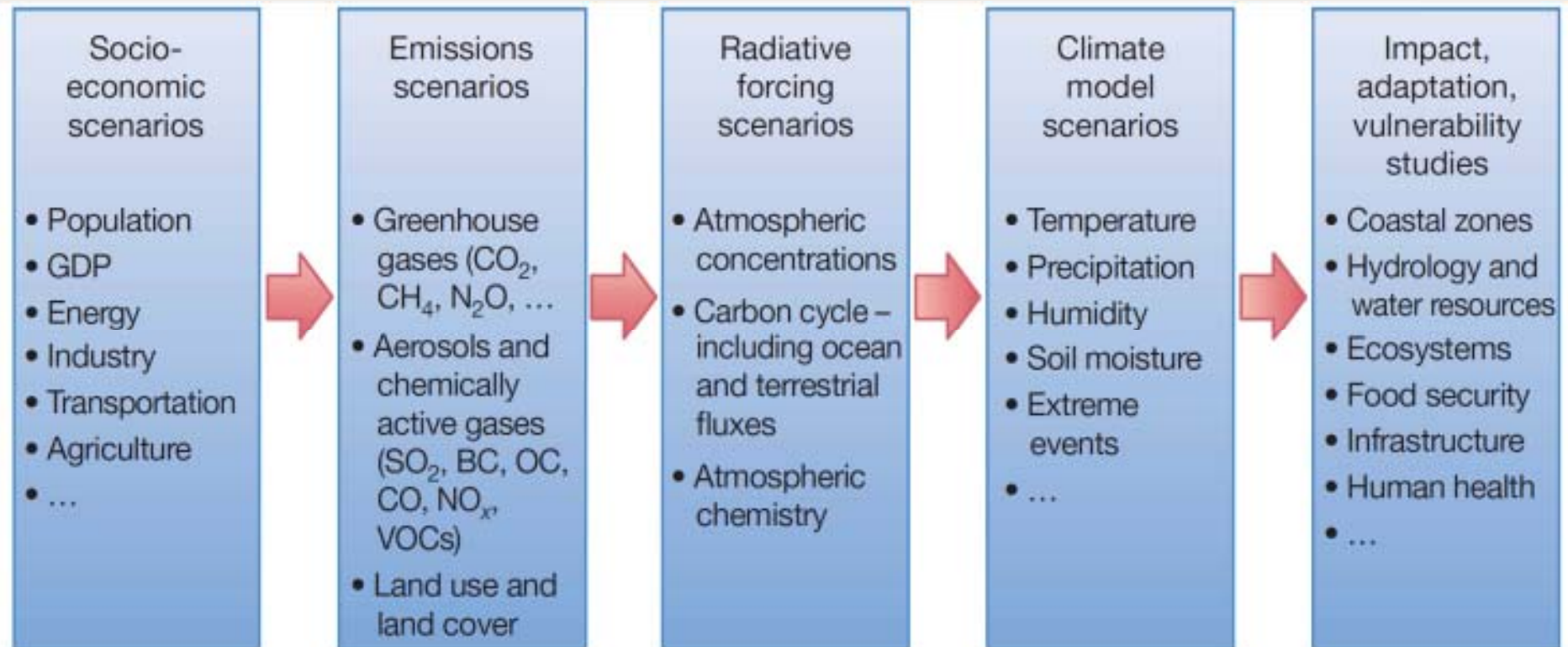


# Models, frameworks and scenarios



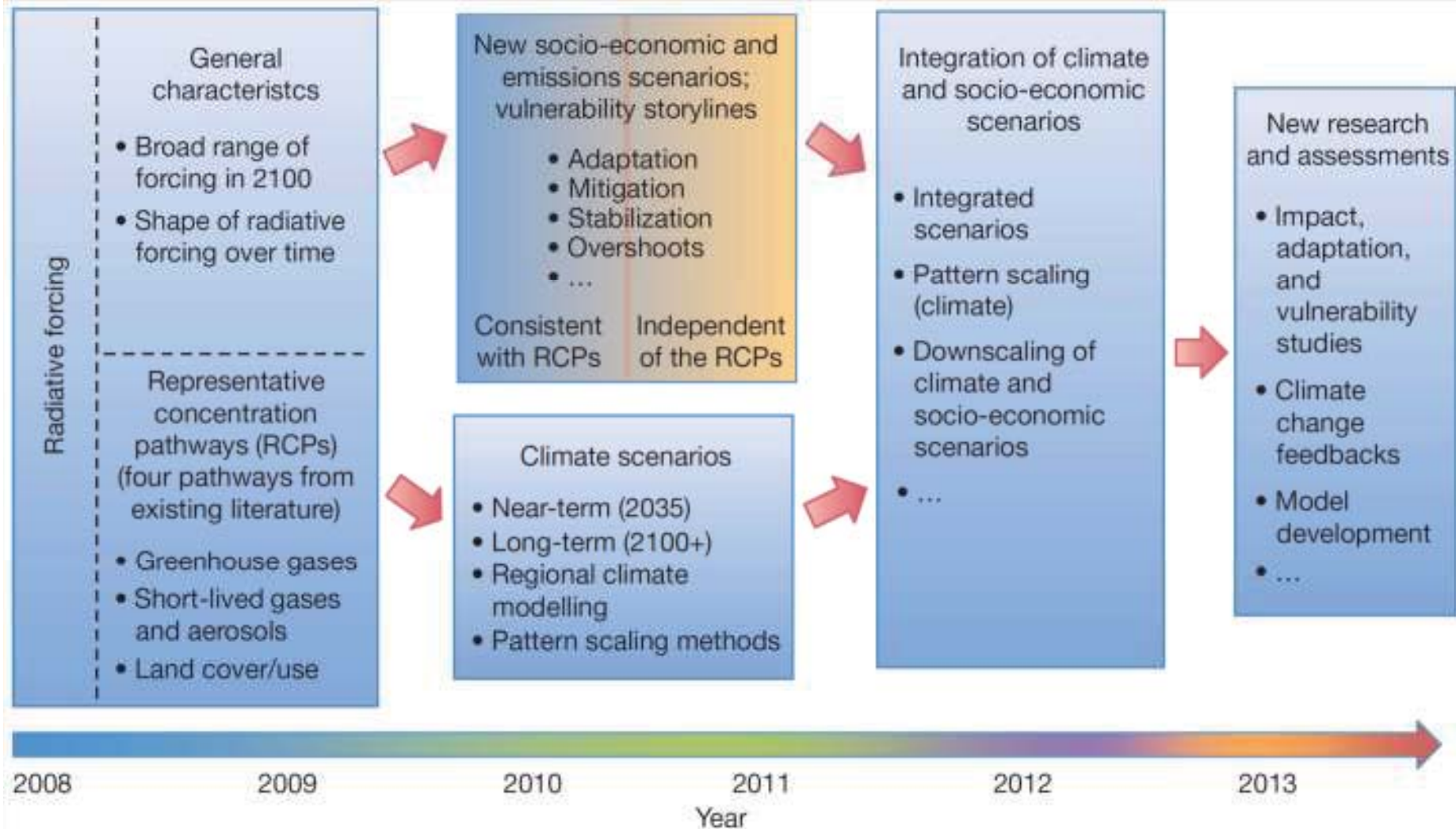
Source: Moss et al., Nature 463, 747-756 (2010)

# Sequential approach to scenario development



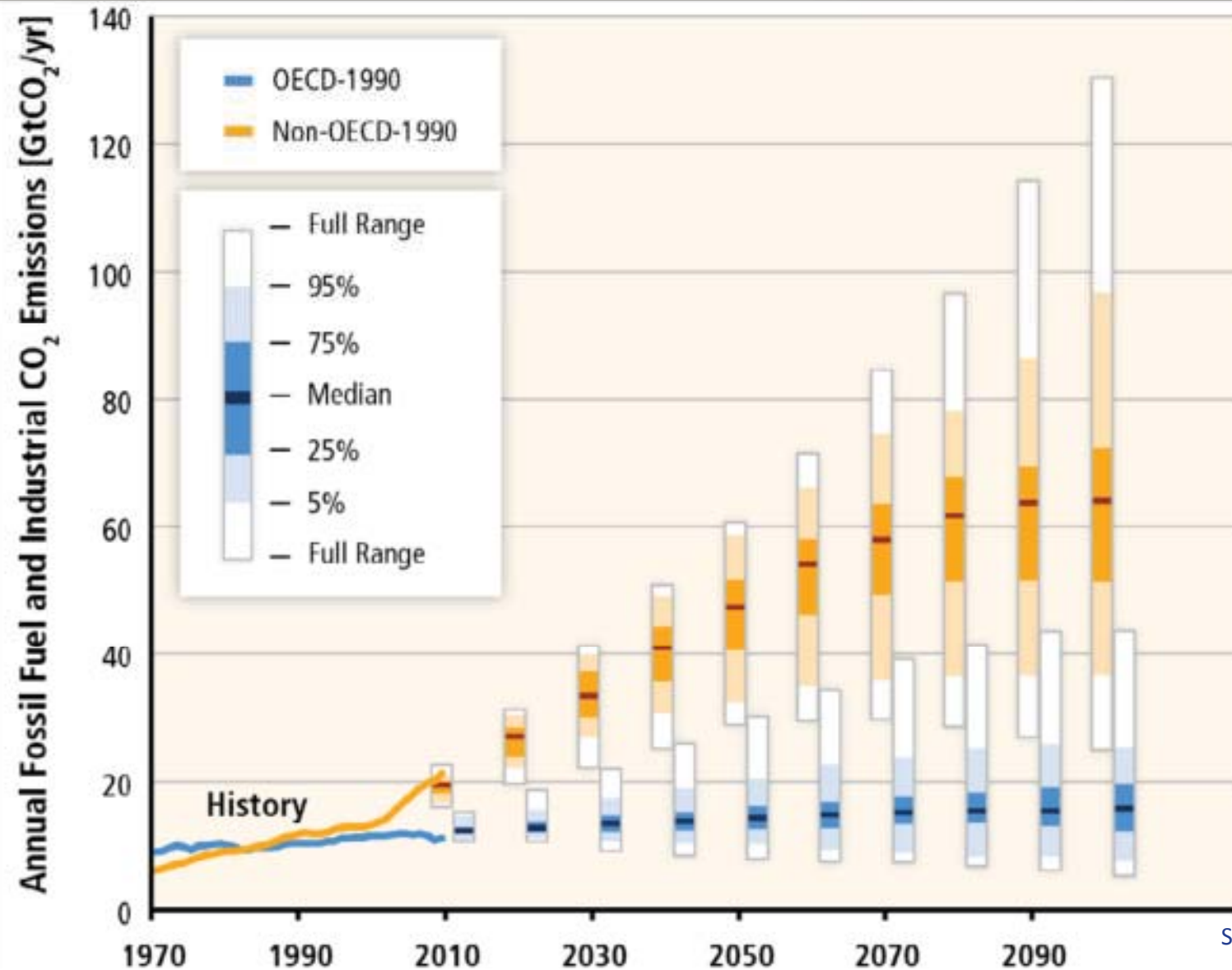


# The parallel process



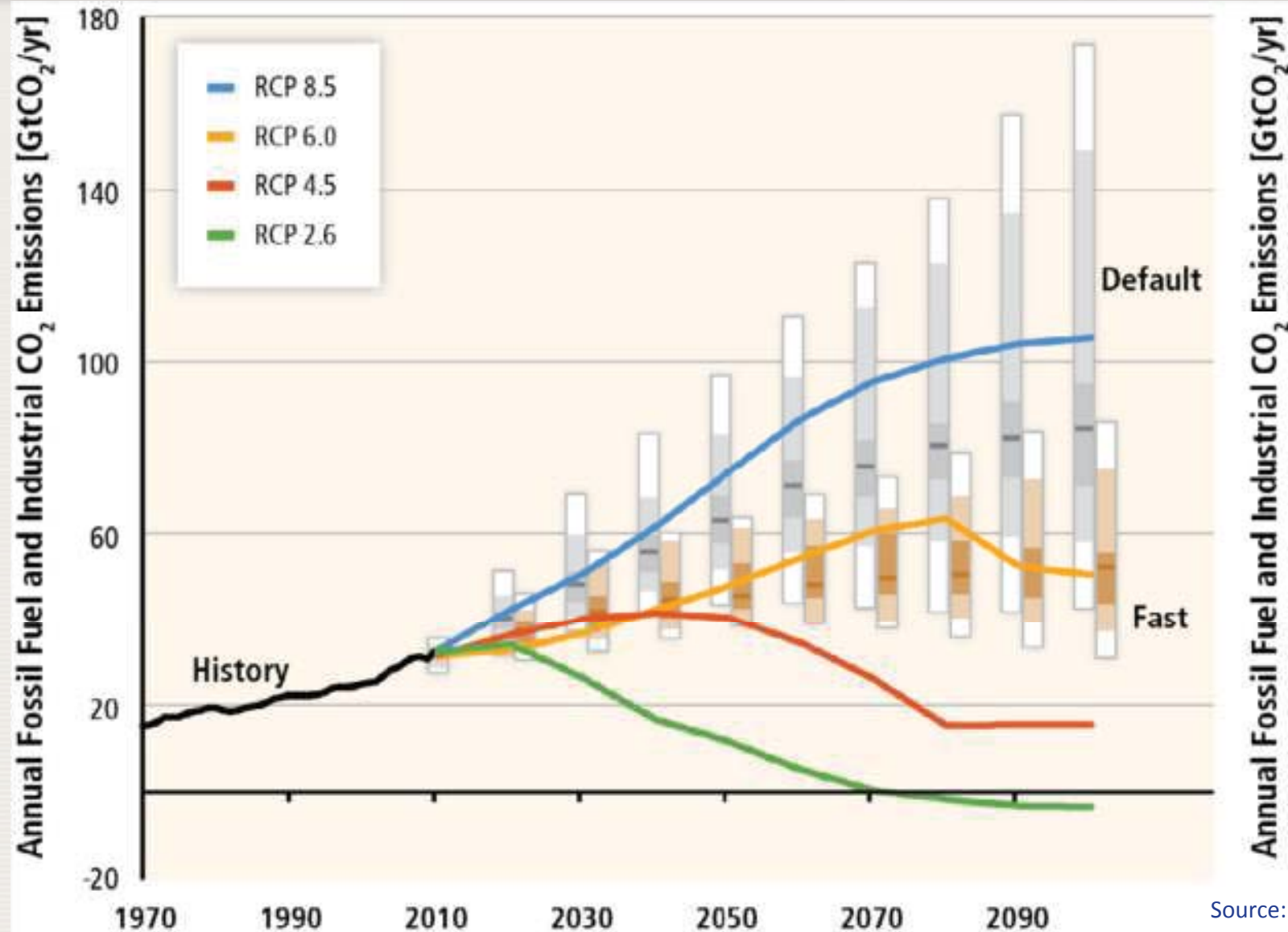


# Global CO<sub>2</sub> emissions in baseline scenarios



Source: IPCC AR5, 2014

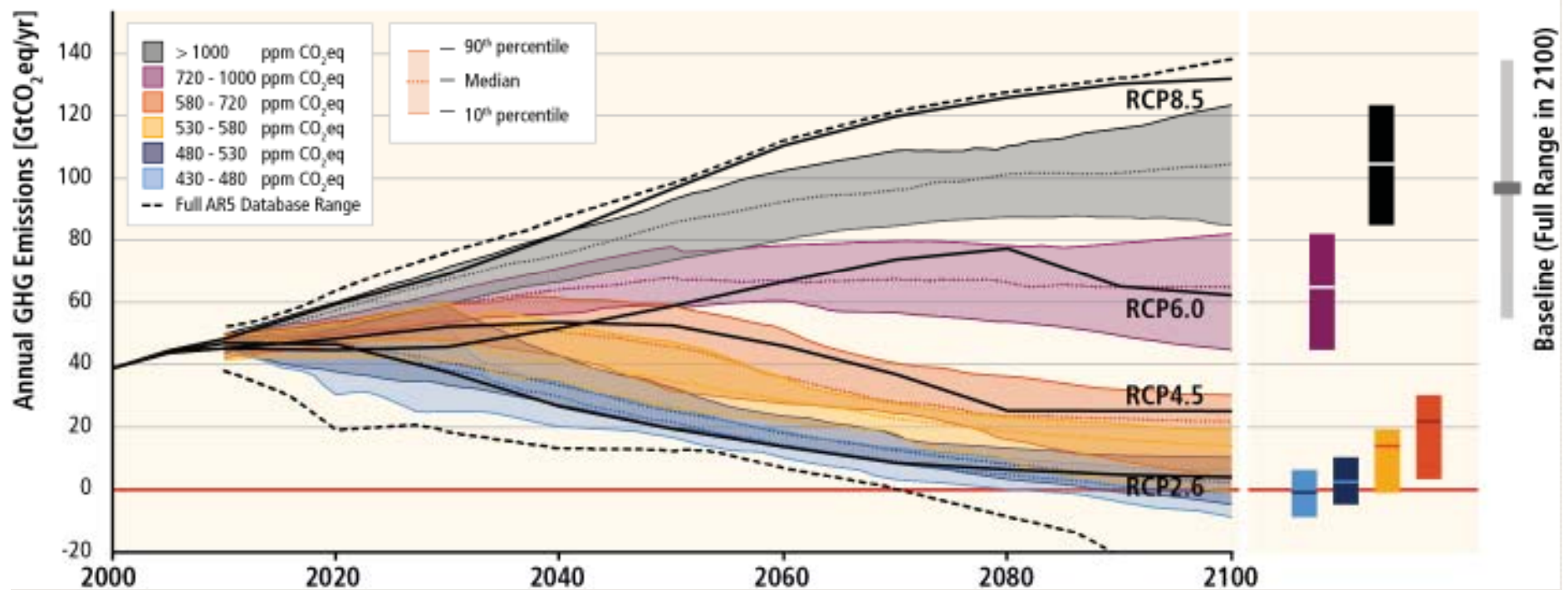
# Global CO<sub>2</sub> emissions in baseline scenarios



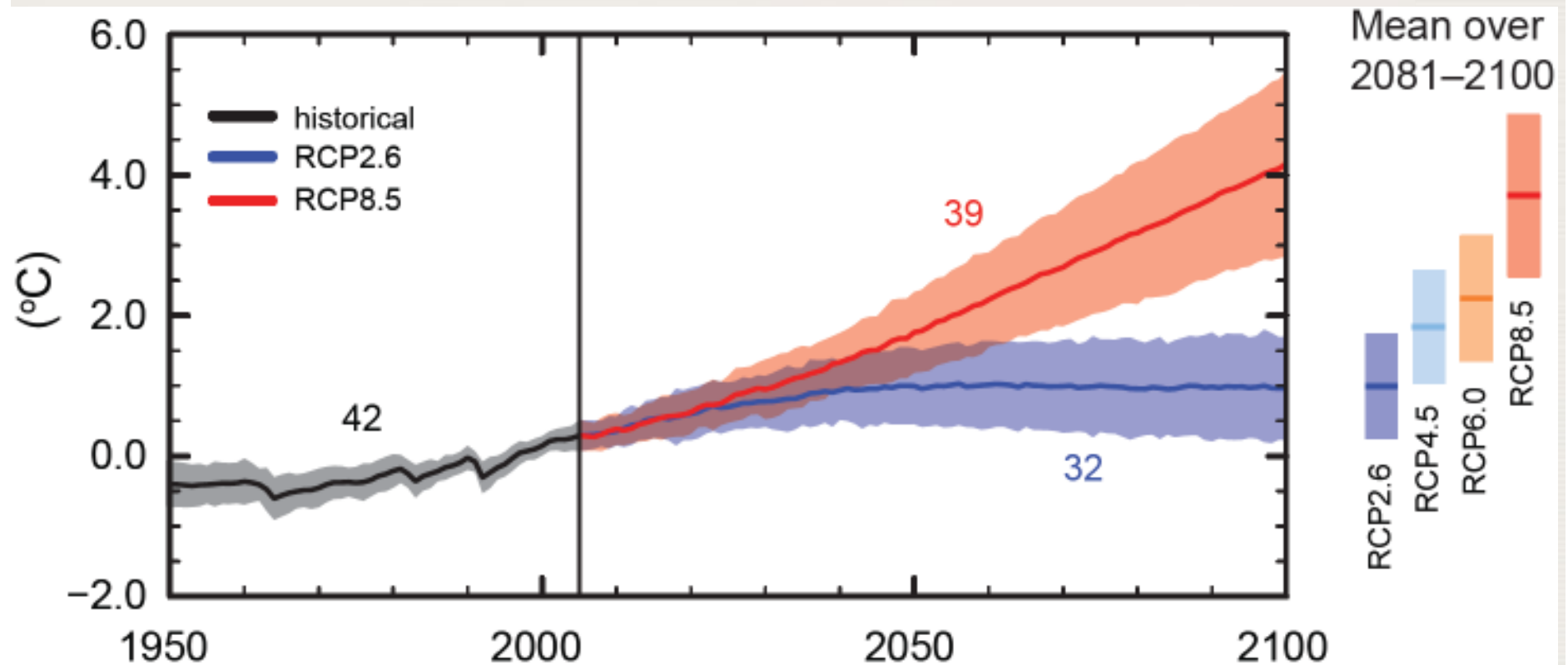
# Future GHG emission outlook

Without more mitigation, global mean surface temperature might increase by 3.7° to 4.8°C over the 21st century

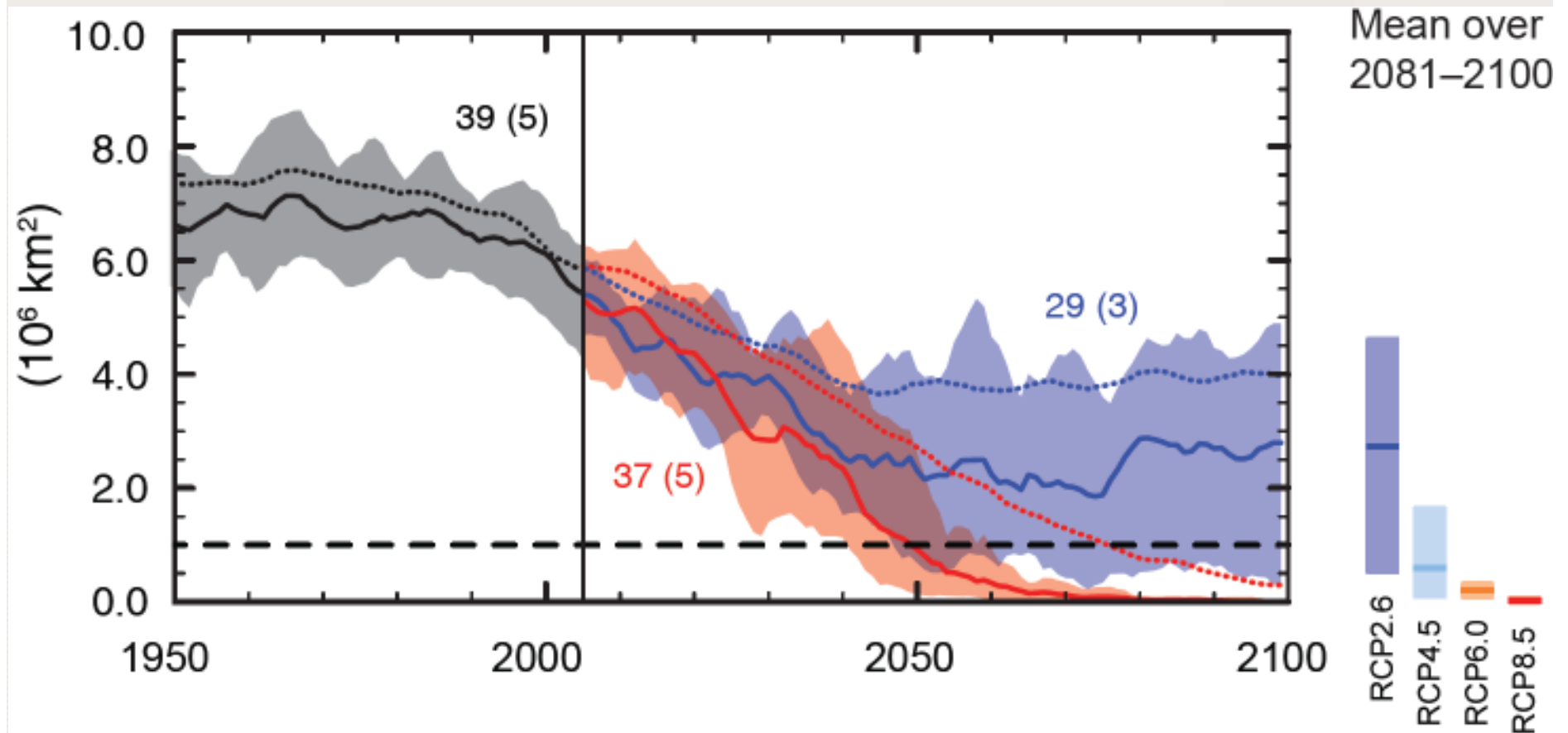
GHG Emission Pathways 2000-2100: All AR5 Scenarios



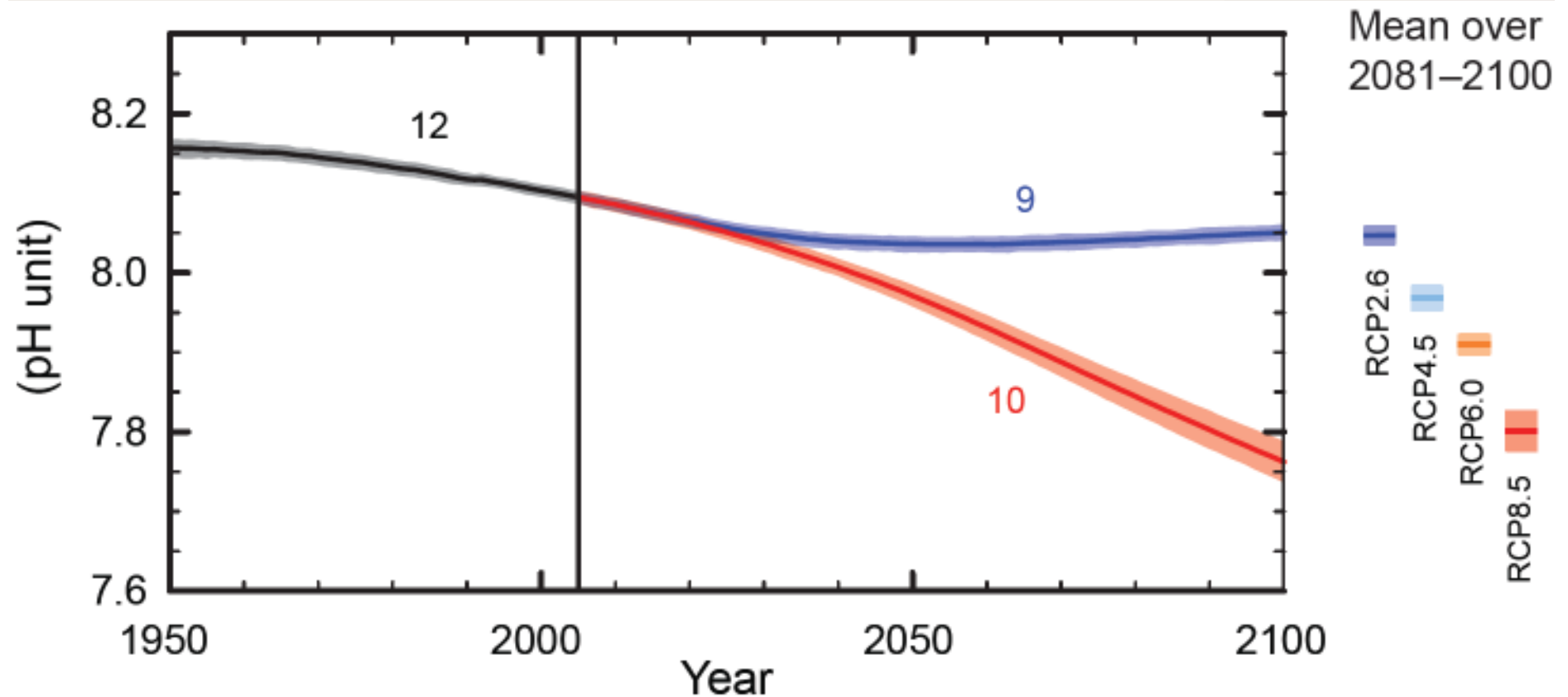
# Global average surface temperature



# Northern Hemisphere September sea ice extent

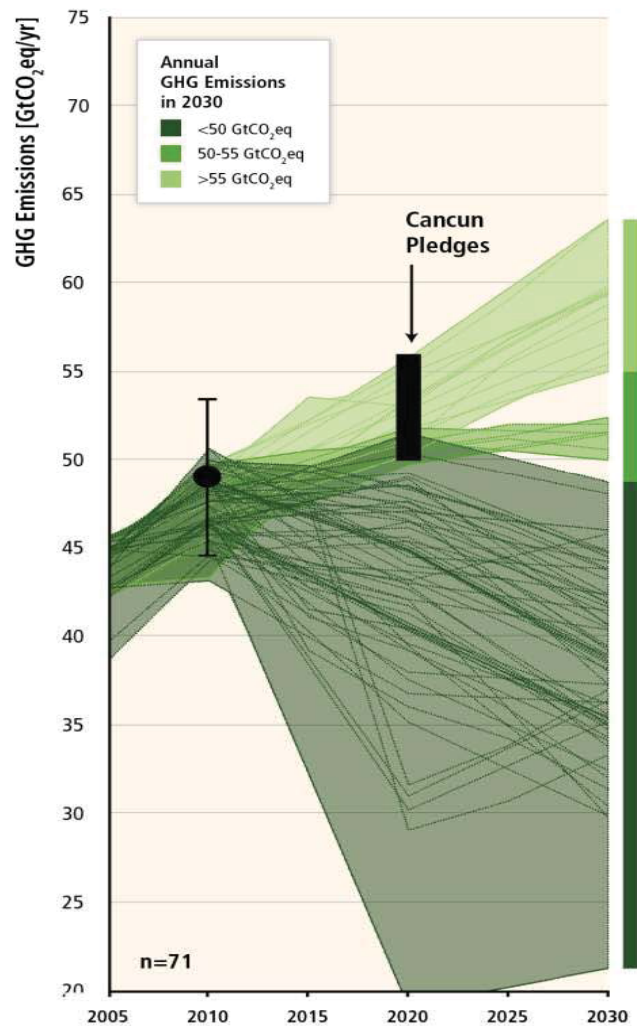


# Global ocean surface pH

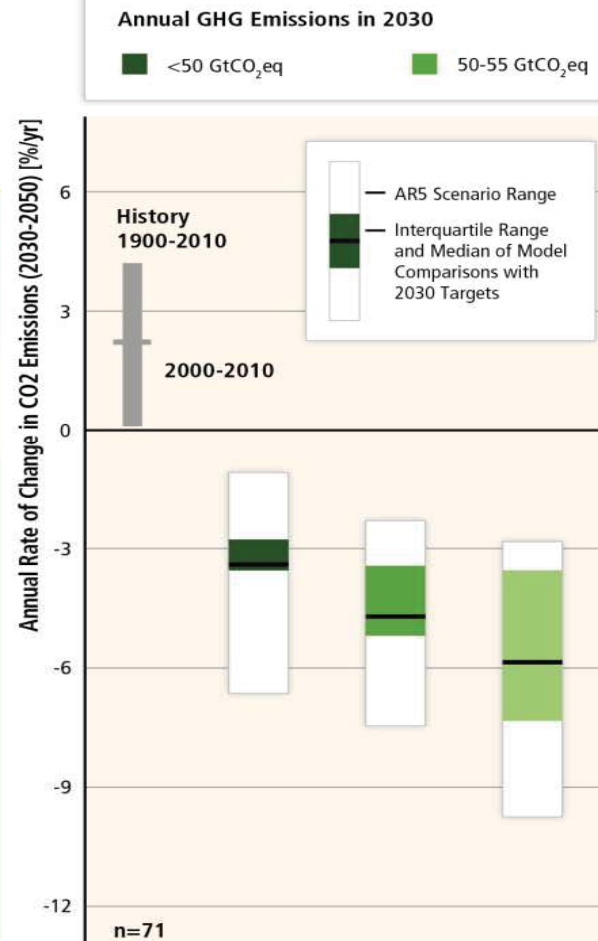


# Delaying mitigation is estimated to increase the difficulty and narrow the options for limiting warming to 2°C

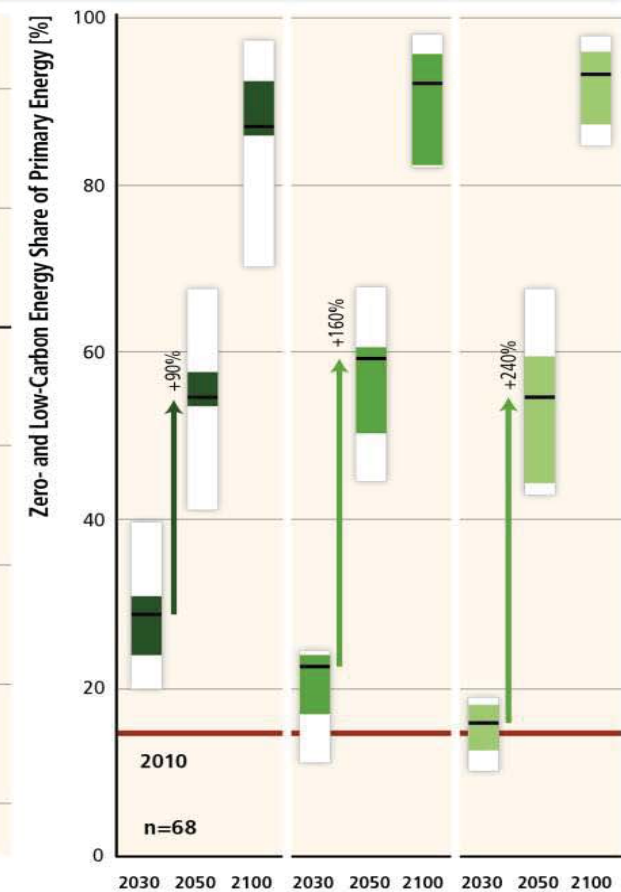
GHG Emissions Pathways to 2030



Implications of Different 2030 GHG Emissions Levels for the Rate of Annual Average CO<sub>2</sub> Emissions Reductions from 2030 to 2050



Implications of Different 2030 GHG Emissions Levels for Low-Carbon Energy Upscaling



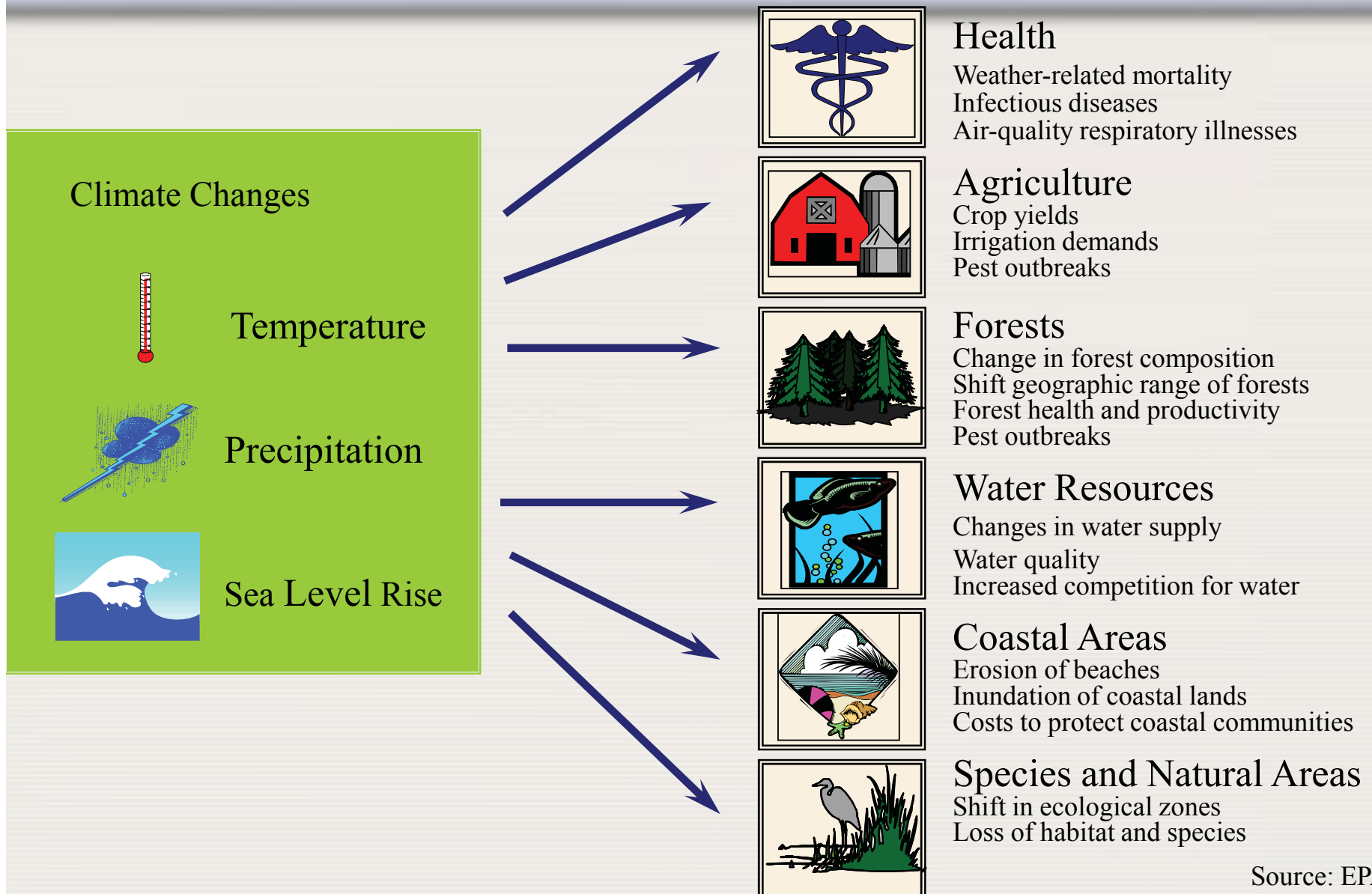


# Climate Change – IPCC statements

- FAR 1990: *little* observational evidence of a *detectable anthropogenic influence* on climate
- SAR 1995: “The balance of evidence suggests a *discernible human influence* on the climate of the 20th century.”
- TAR 2001: “There is new and stronger evidence that most of the warming observed over the last 50 years is *attributable to human activities*.”
- AR4 2007: “Warming of the climate system is *unequivocal*, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level”. (WGI SPM)
- AR5 2013: “Global surface temperature change for the end of the 21st century is likely to exceed 1.5°C relative to 1850 to 1900 for all RCP scenarios except RCP2.6. It is likely to exceed 2°C for RCP6.0 and RCP8.5, and more likely than not to exceed 2°C for RCP4.5. Warming will continue beyond 2100 under all RCP scenarios except RCP2.6. Warming will continue to exhibit interannual-to-decadal variability and will not be regionally uniform”. (WG I, SPM)



# Potential Climate Change Impacts



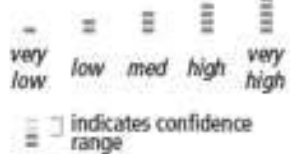
# Heavier precipitation, more intense and longer droughts....



(A)



Confidence in attribution to climate change



Observed impacts attributed to climate change for

Physical systems



Biological systems



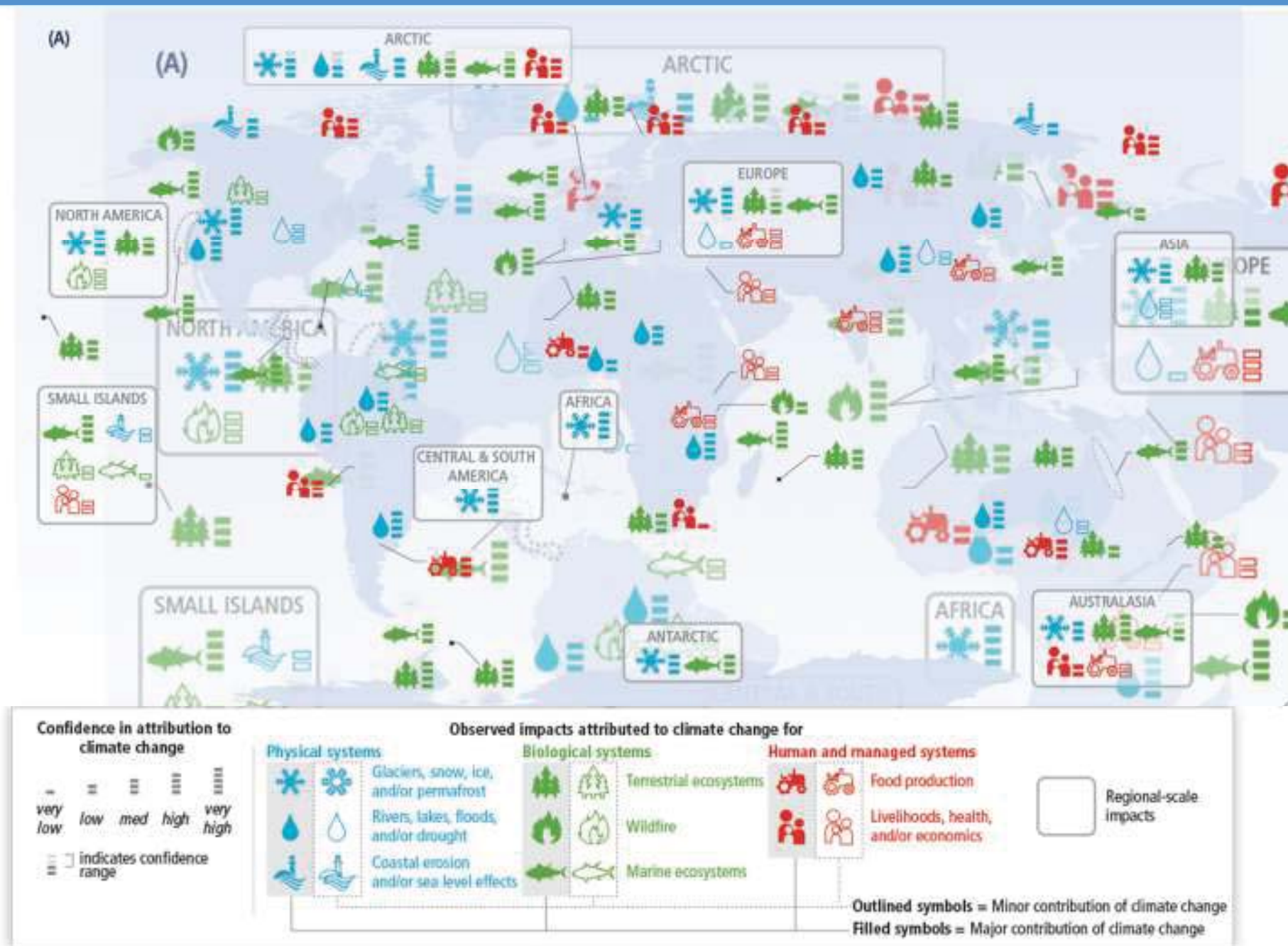
Human and managed systems

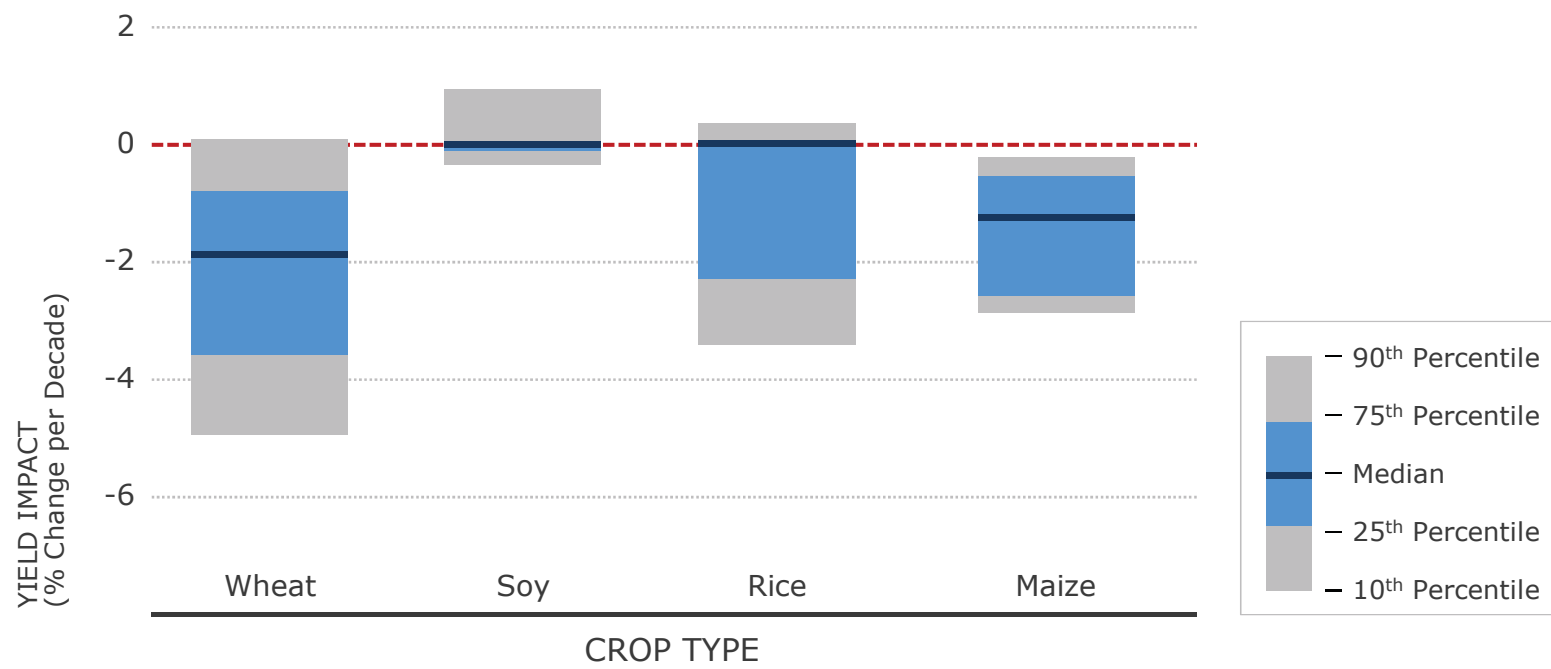


Regional-scale impacts

Outlined symbols = Minor contribution of climate change  
Filled symbols = Major contribution of climate change







# Adaptation is necessary but not sufficient....

- Adaptation to climate change is necessary to address impacts resulting from the warming which is already unavoidable due to past emissions
- However:
  - Adaptation alone cannot cope with all the projected impacts of climate change
  - The costs of adaptation and impacts will increase as global temperatures increase

Making development more sustainable can enhance both mitigative and adaptive capacity, and reduce emissions and vulnerability to climate change

# Mitigation urgently needed

- Continued GHG emissions at or above current rate would induce **larger climatic changes** than those observed in 20<sup>th</sup> century
- Emissions of GHGs covered by the Kyoto Protocol **increased by about 70%** from 1970–2004
- All credible scenario analyses project a **substantial** increase by 2030 of 25-90% (with recent projections closer to the higher end)

Mitigation needs to start in short term, even when benefits may only arise in a few decades

# Approach to climate change: mitigation

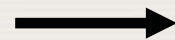
## Using the Kaya identity

CO<sub>2</sub> emissions =

population \* income per capita \* energy intensity \* carbon intensity

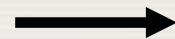
$$\text{CO}_2 = \text{CAP} * \text{GDP/CAP} * \text{ENE/GDP} * \text{CO}_2/\text{ENE}$$

Reduction in energy intensity



Reduced end use demand, economic restructuring, increased efficiency (technology change)

Reduction in carbon intensity



Reduced end use demand, economic restructuring, increased efficiency (tech change)



# GHG emissions rise with growth in GDP and population; long-standing trend of decarbonisation of energy reversed

