Lecture – 2A

Global Climate Change & Mitigation

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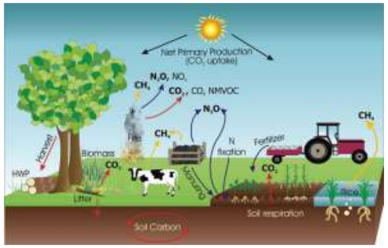
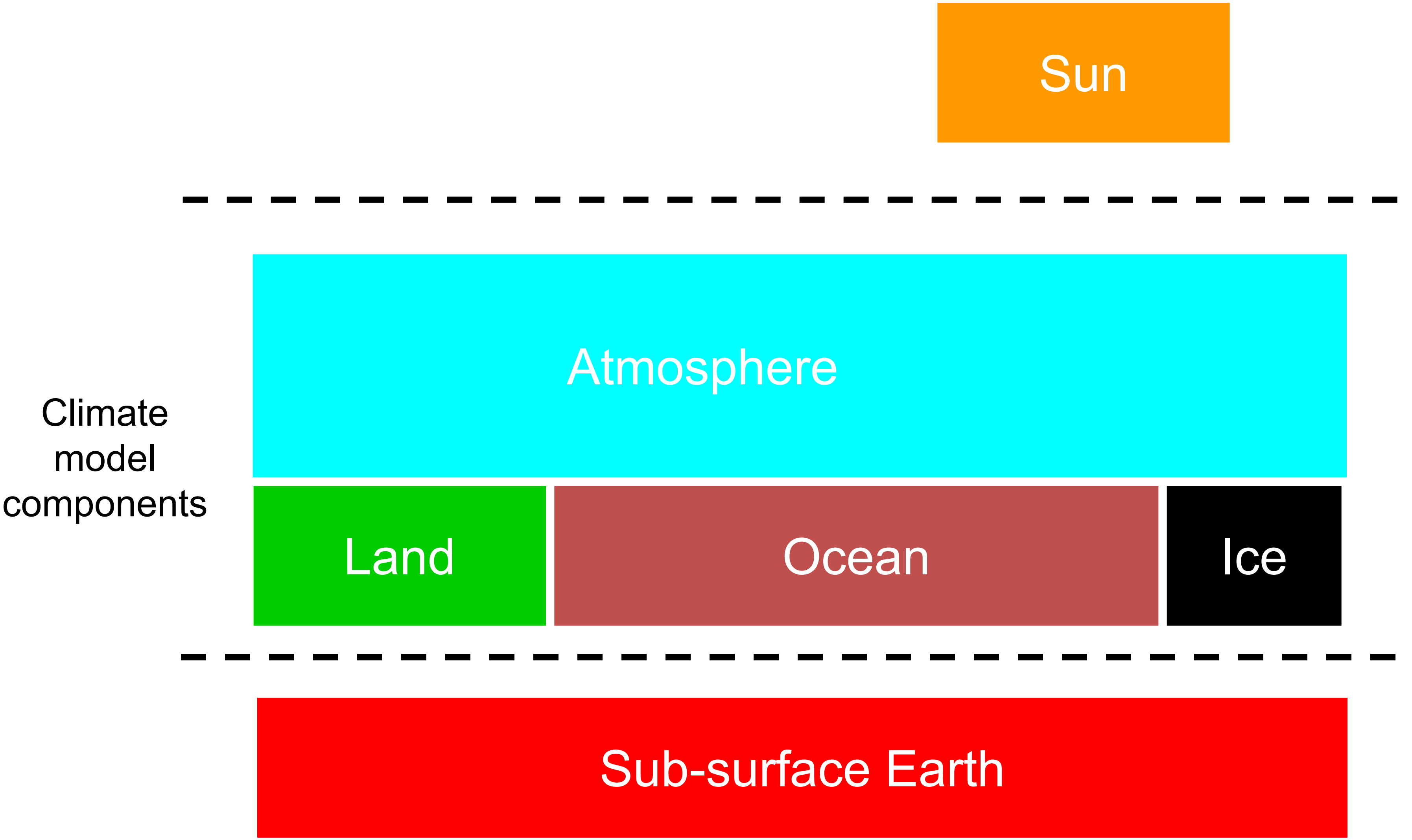
Outline

- Climate systems
- Are we change the atmosphere?
- How might that affect the climate?
- What is likely to happen in the future? . Risk & impacts
- Energy system design for climate change
- International commitment & Policy

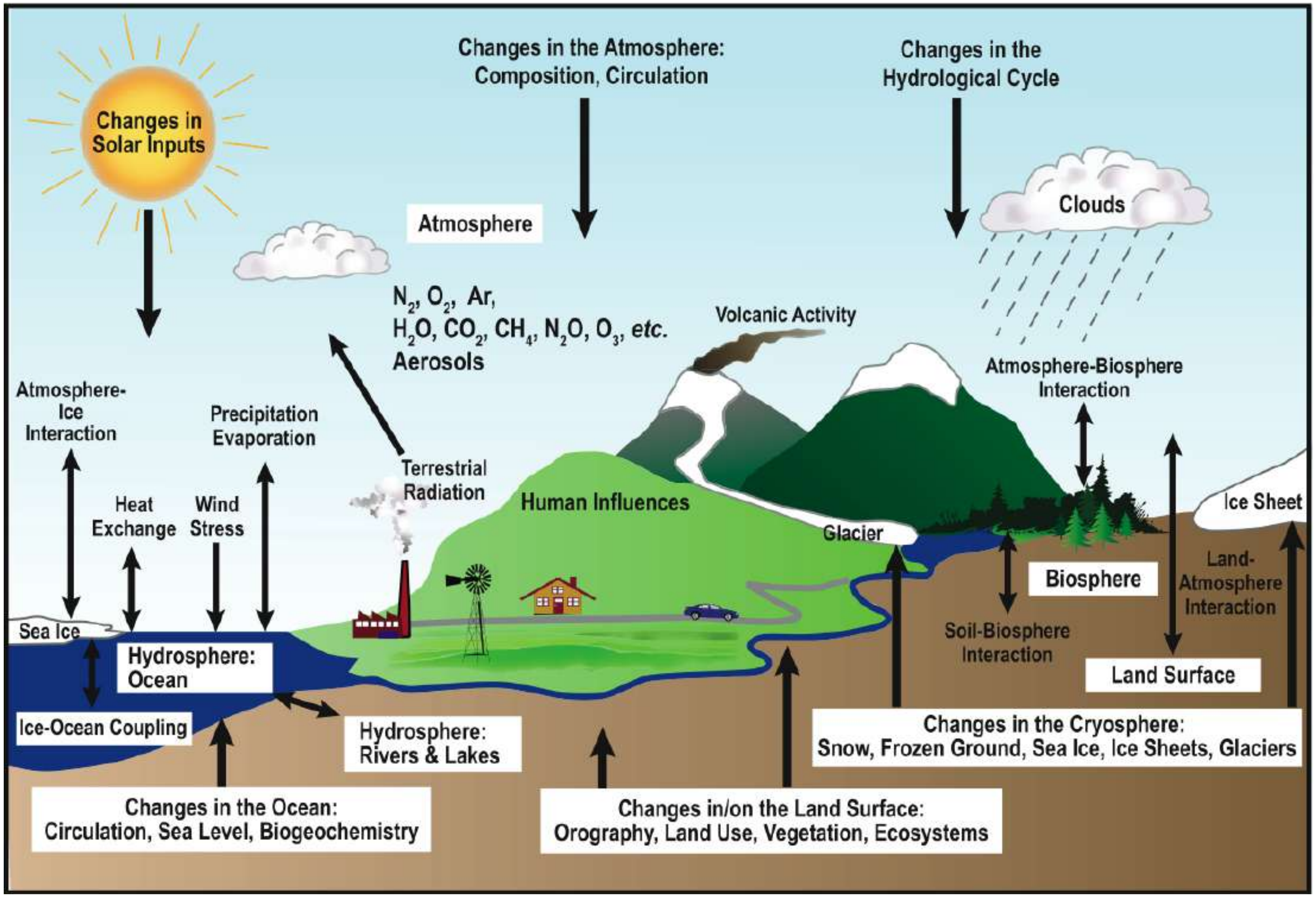
- Climate systems



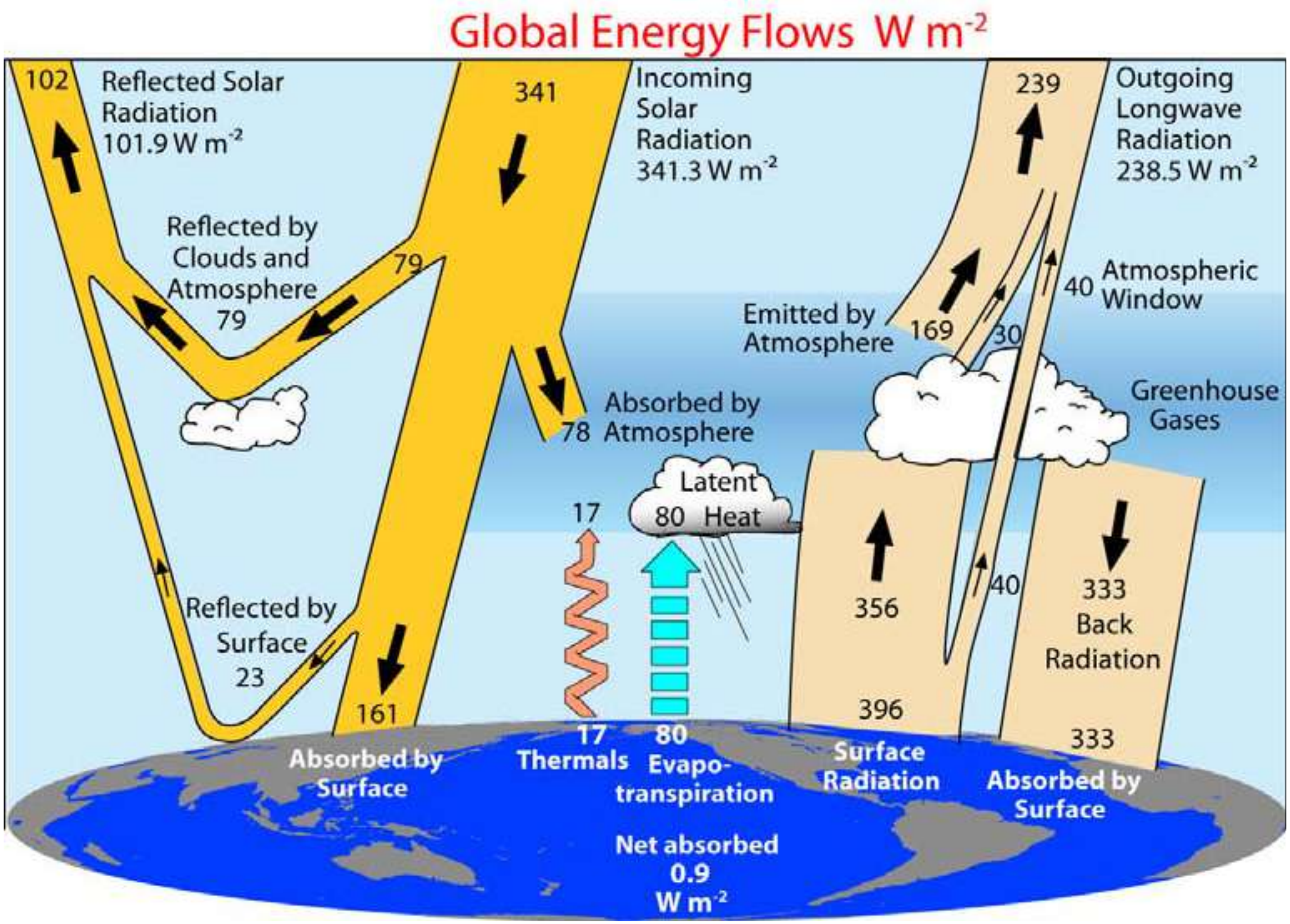
Earth’s Climate System



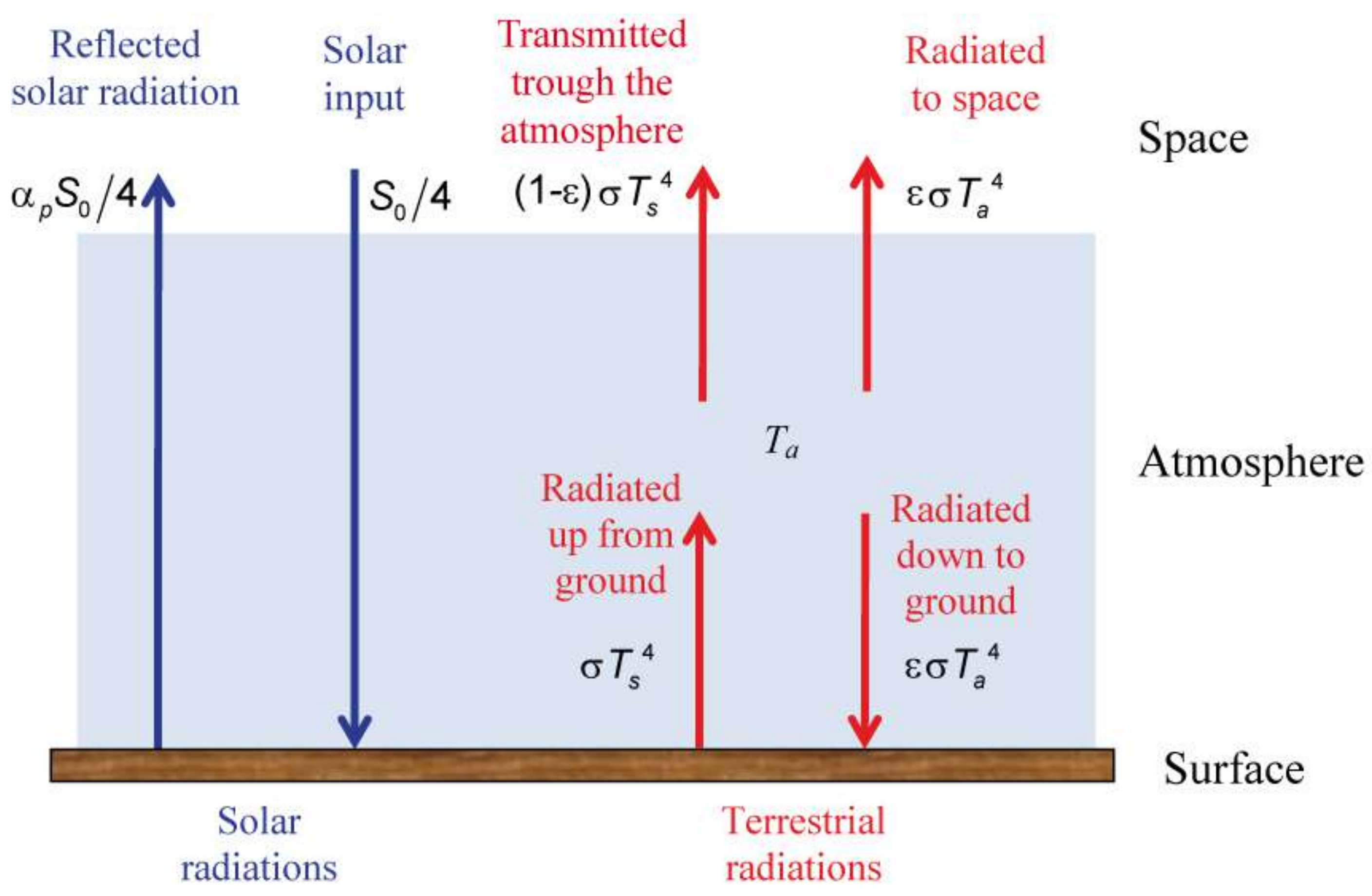
Factors driving climate



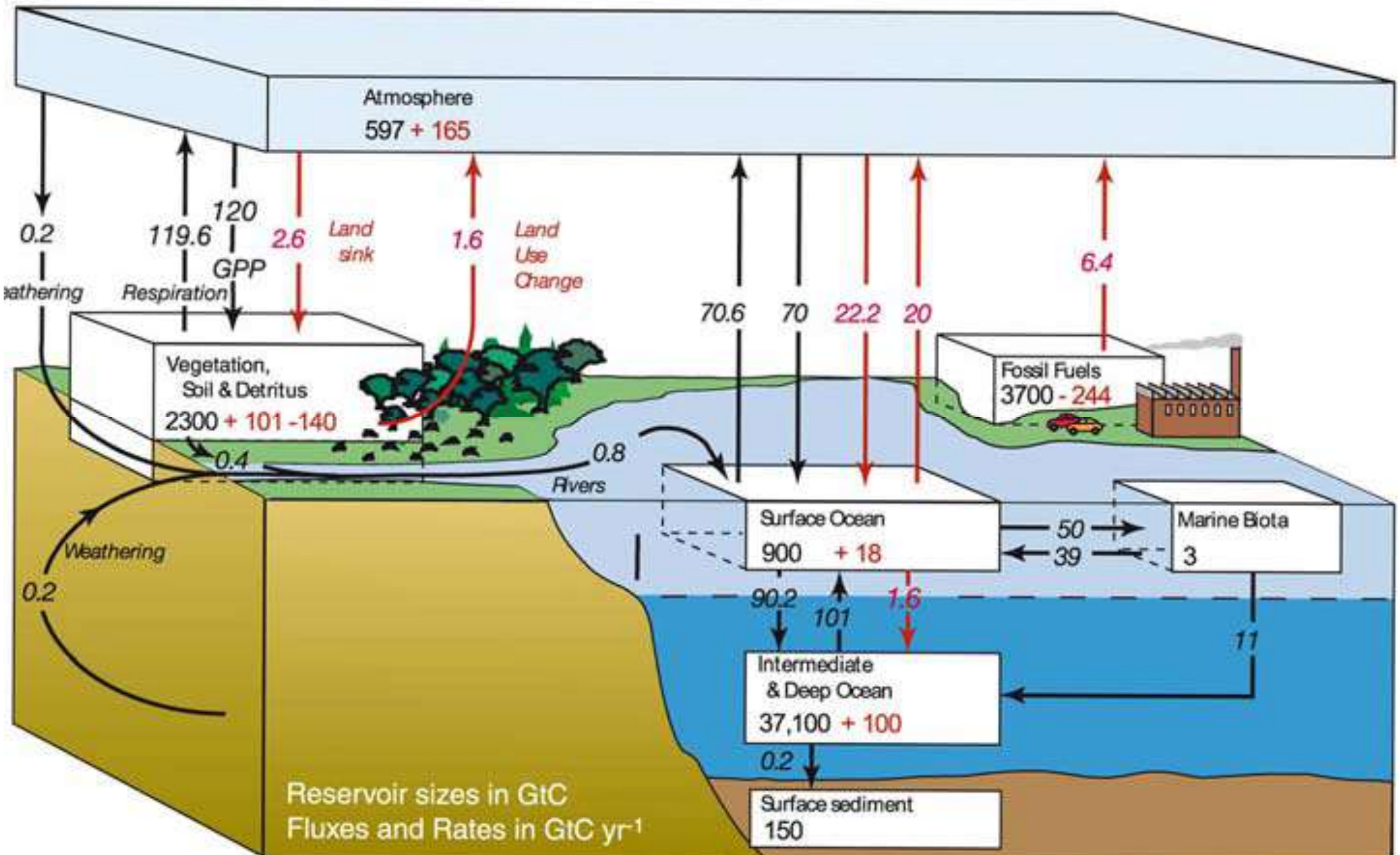
Earth’s annual and global energy balance



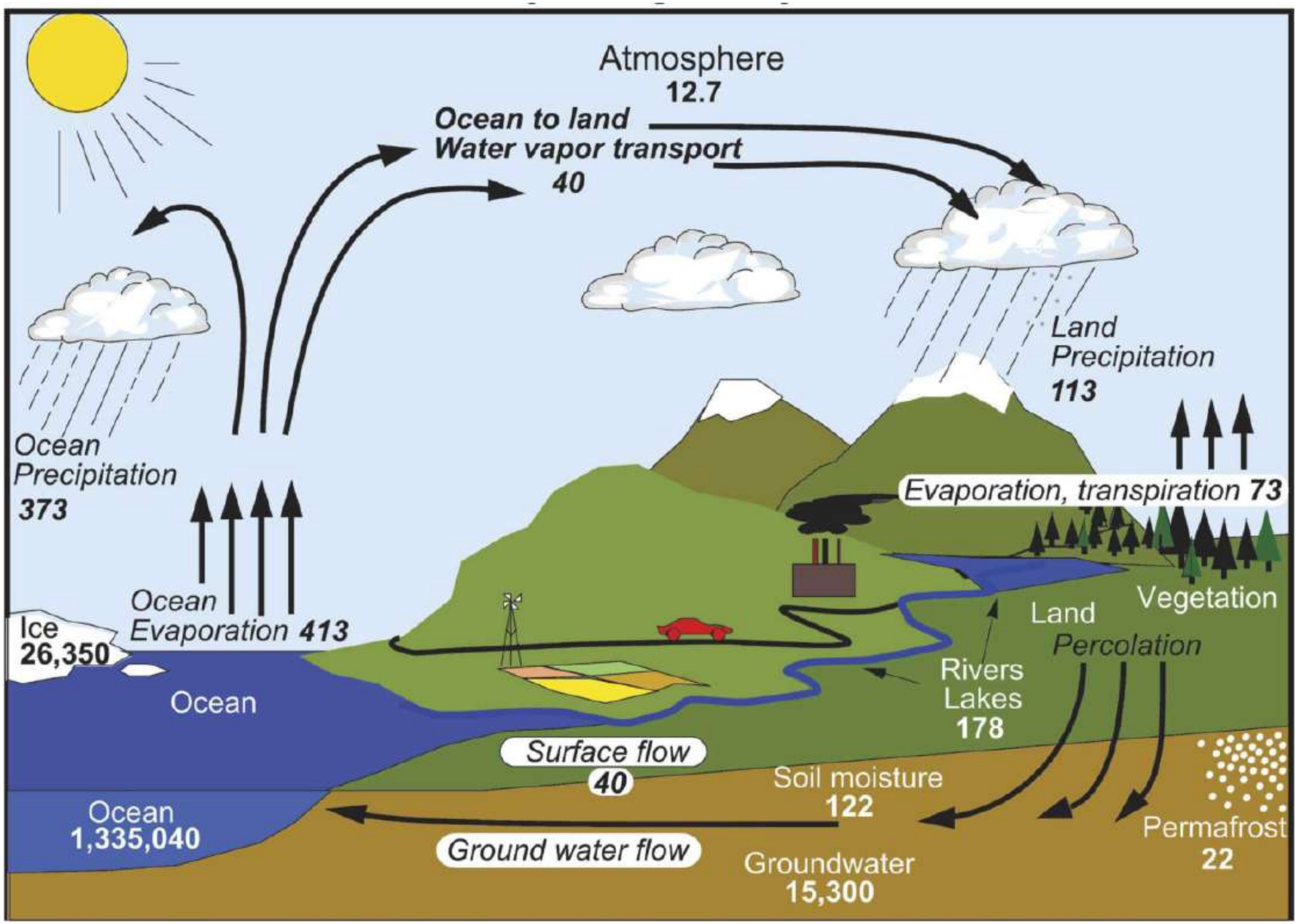
Energy balance of the earth with an atmosphere



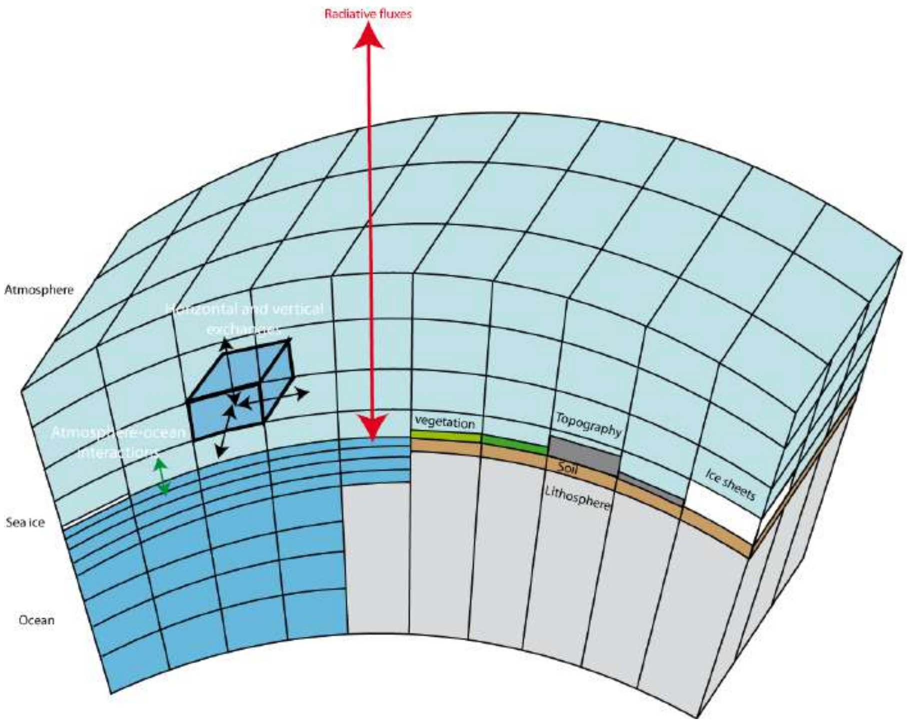
Global carbon cycle

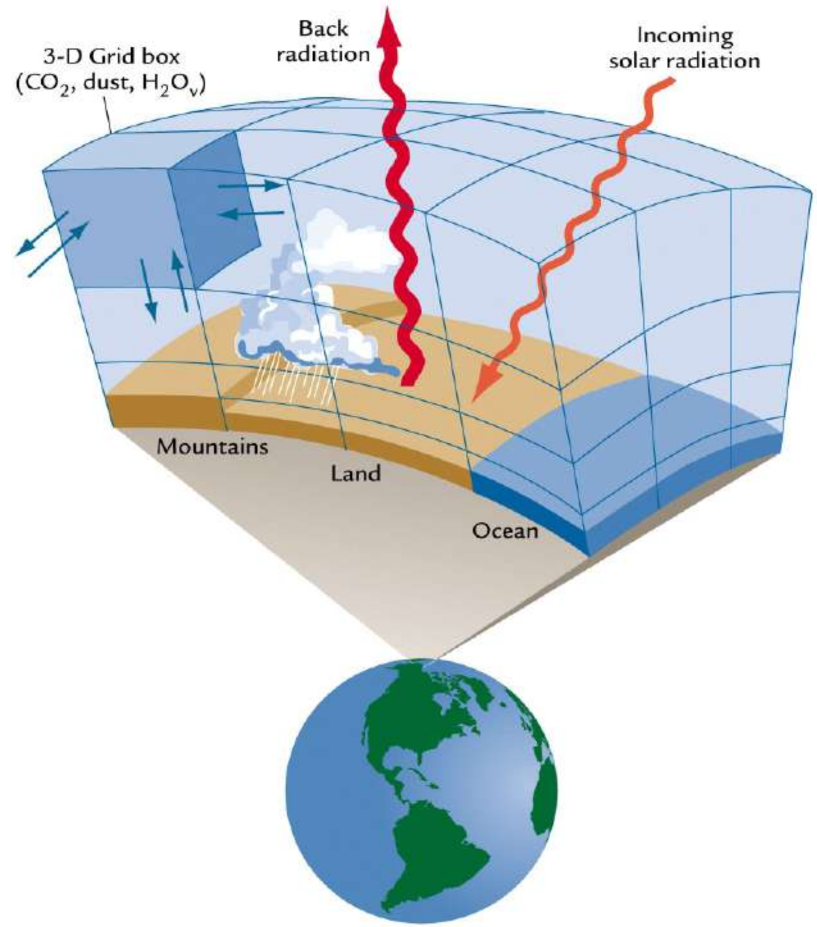


Global hydrological cycle

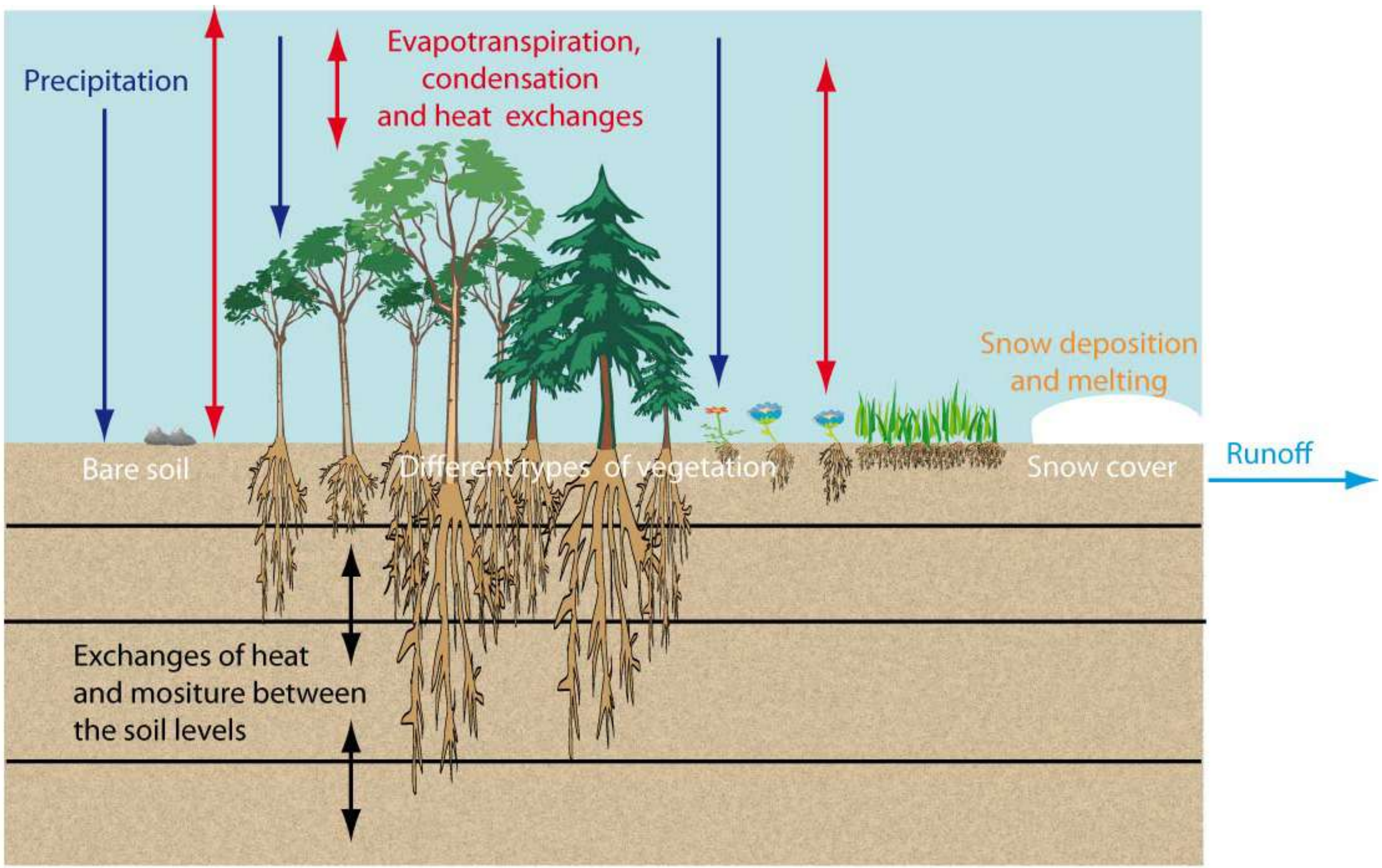


General circulation model

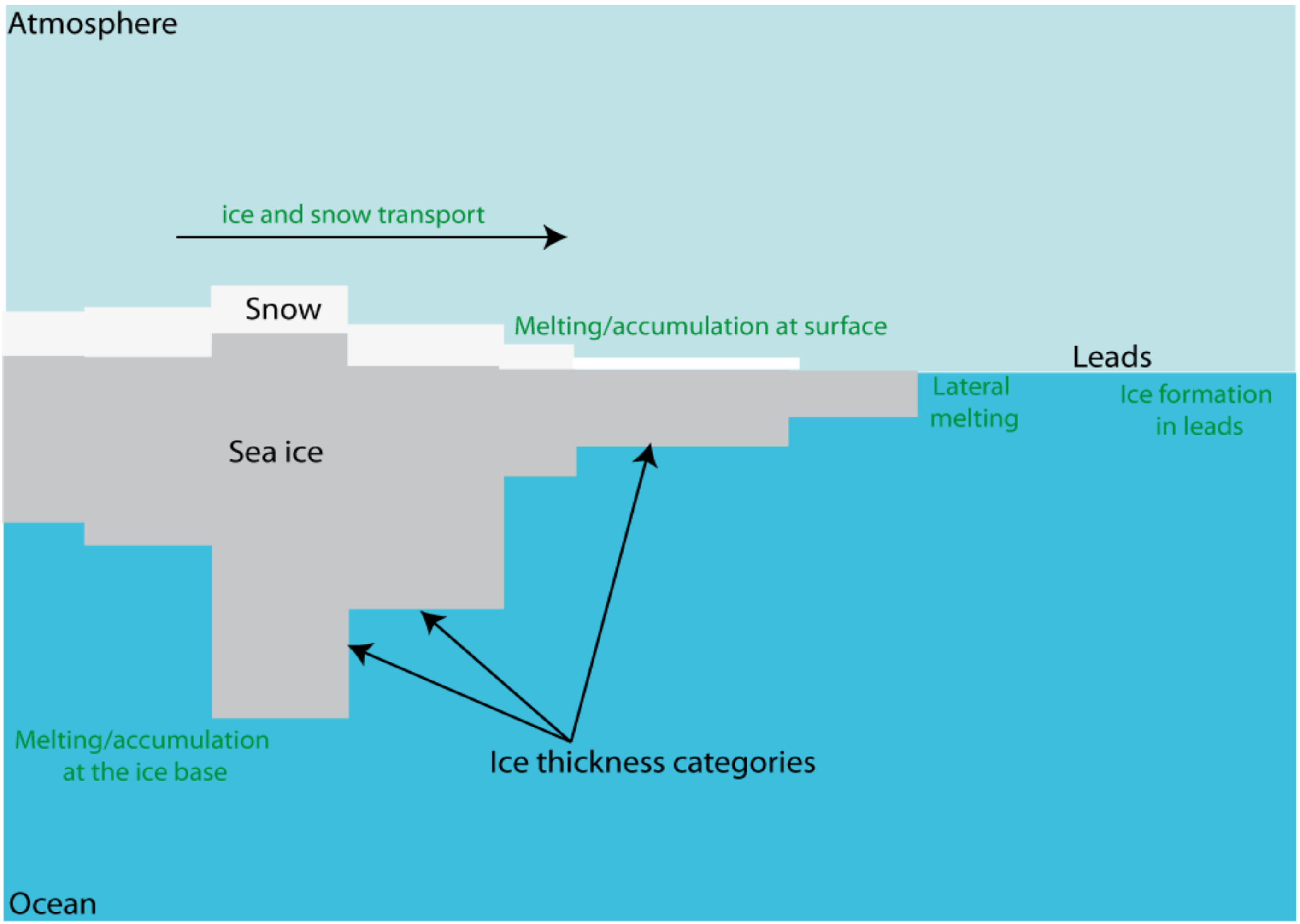




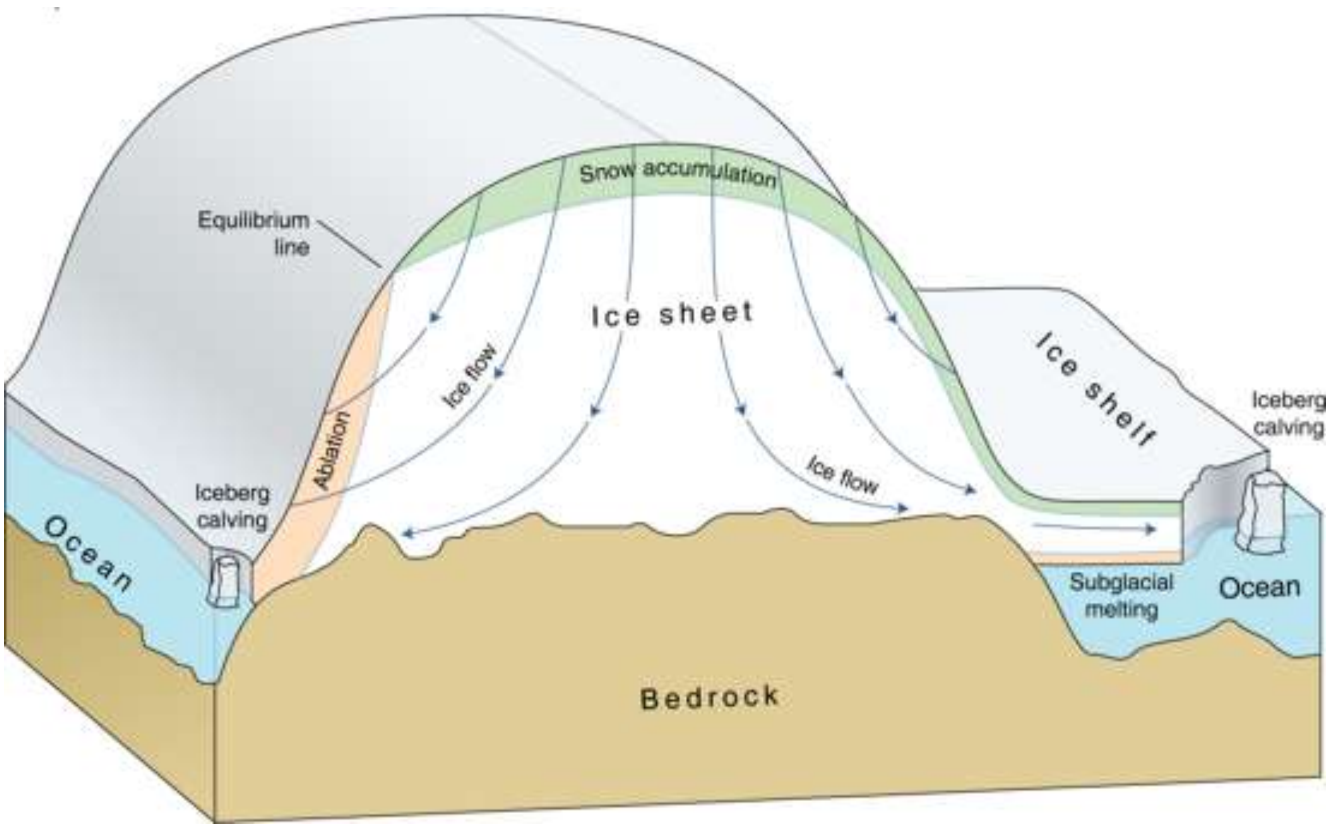
Land surface model



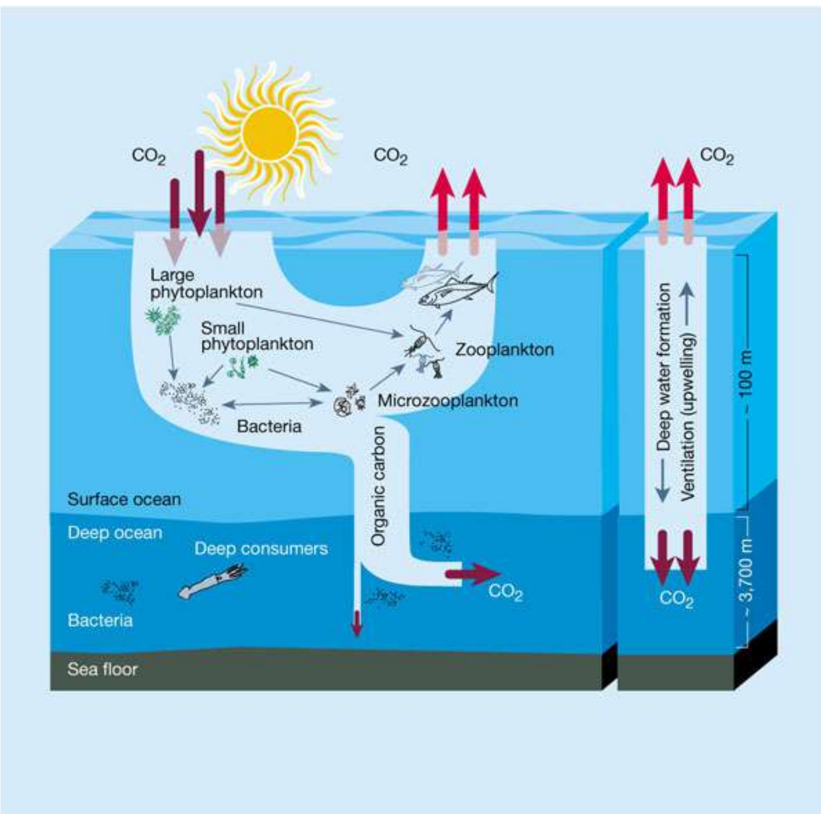
Sea-Ice models

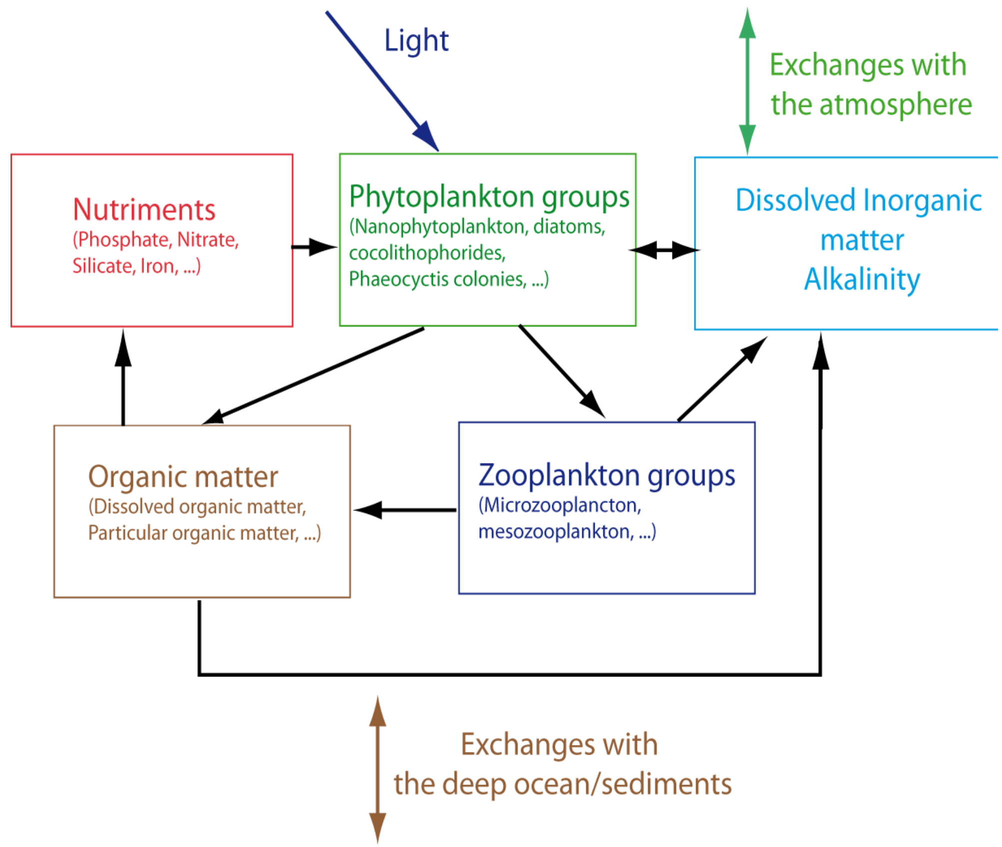


An ice sheet model

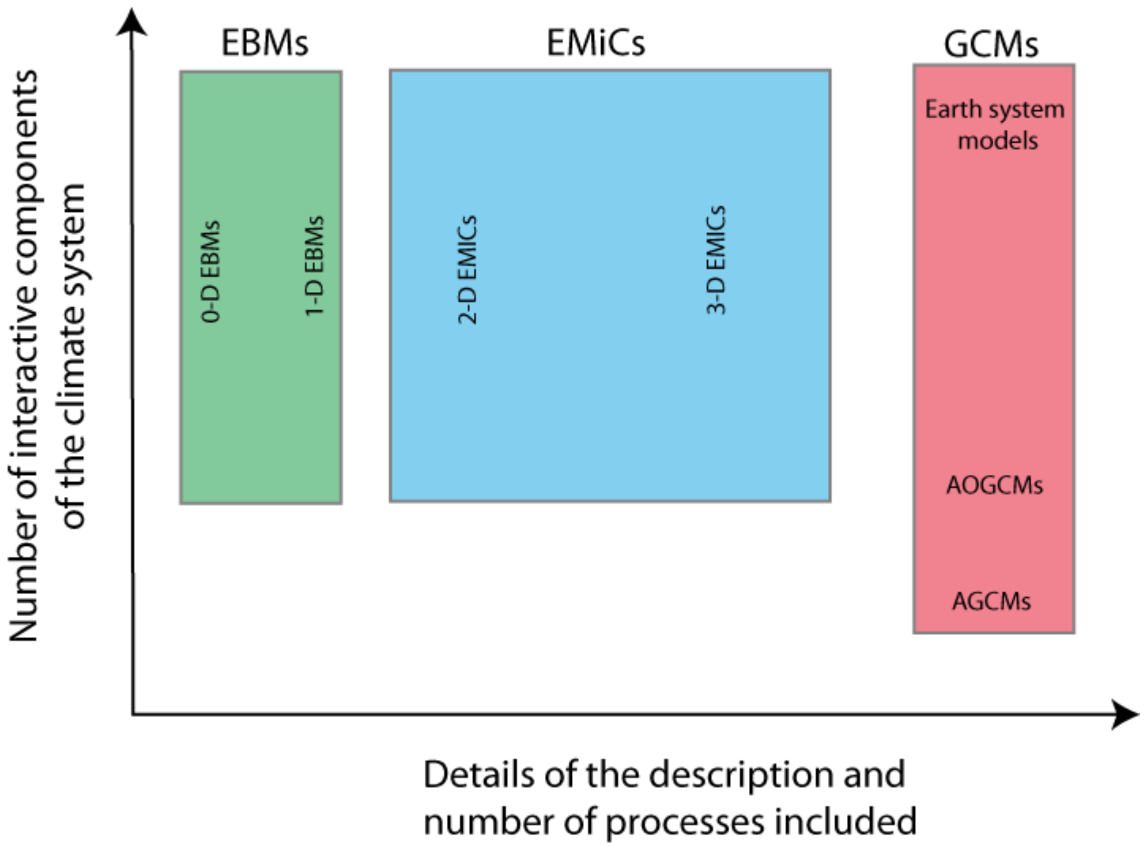


Biogeochemical model





Types of climate models

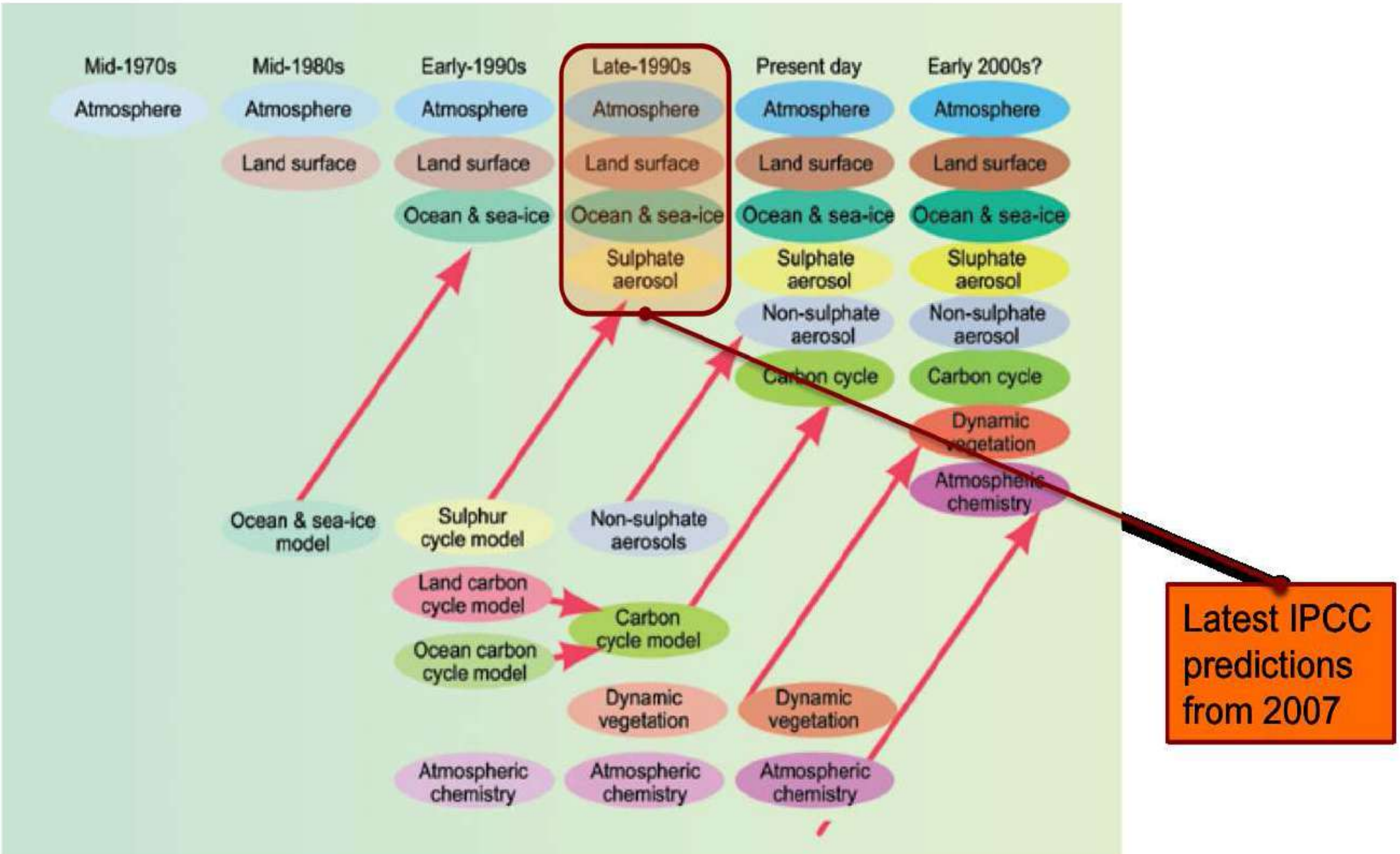


GCMs only included a representation of the atmosphere, the land surface, sometimes the ocean circulation, and a very simplified version of the sea ice. Nowadays, GCMs take more and more components into account, and many new models

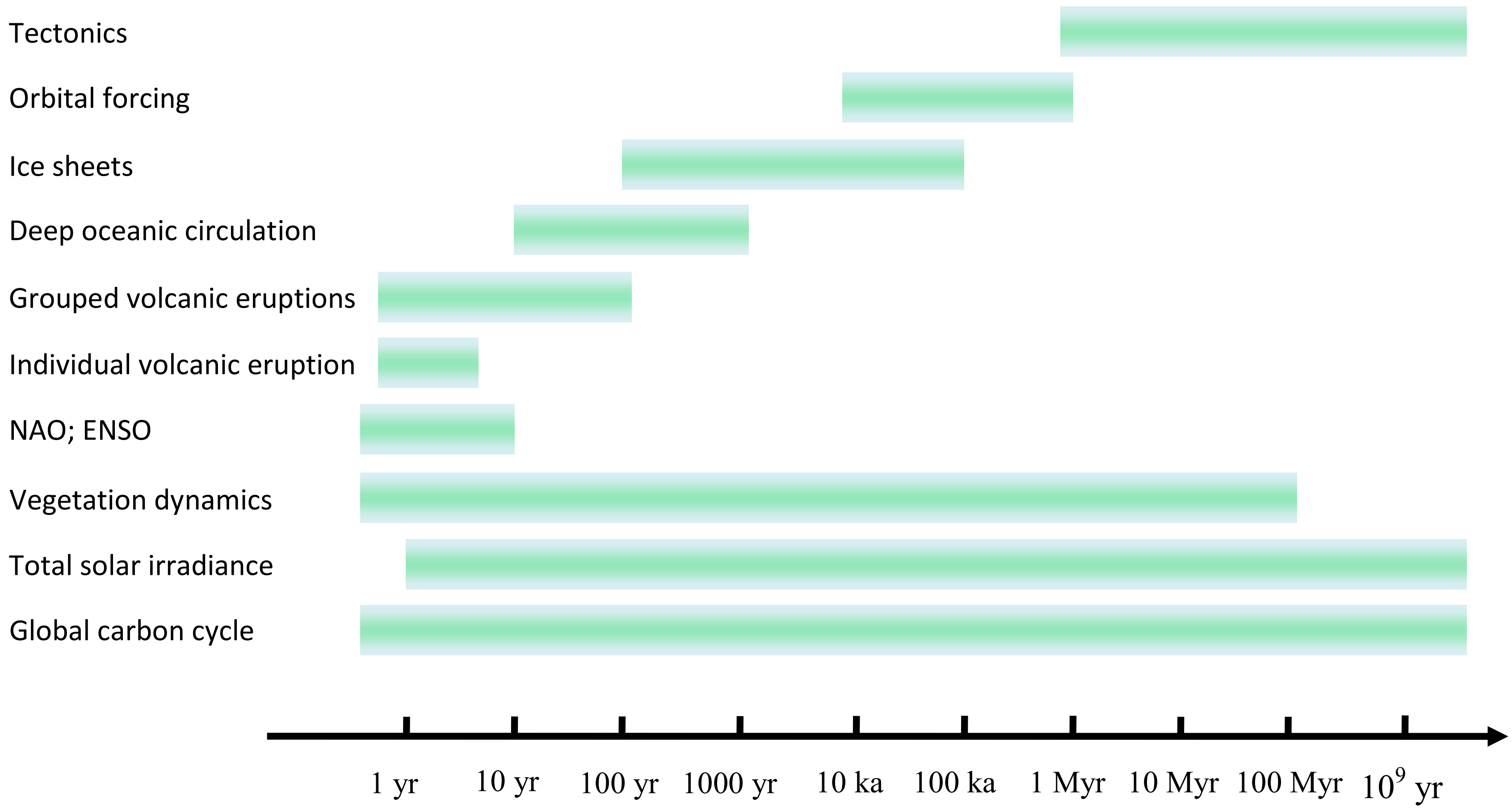
General Circulation Models (GCMs)
Atmospheric General Circulation Models (AGCMs)
Ocean General Circulation Models (OGCMs)
Atmosphere Ocean General Circulation Model(AOGCM)

Energy Balance Models (EBMs)
Earth Models of Intermediate Complexity (EMICs)

Development of climate models



Time scales of model



Is this rise surprising?

- Every gram of fossil fuel used produces 3 grams of CO_2
  - it's straight chemistry: to get the energy out via combustion, the carbon from the hydrocarbon gets attached to oxygen and off it goes
- How much should we expect?
  - global energy budget is 4×10^{20} J; pretend all from fossil fuels
  - average 10 Cal/gram $\rightarrow$ ~40,000 J/gram $\rightarrow$ 10^{16} g/yr F.F.
  - so 3×10^{16} g/yr CO_2 $\rightarrow$ 3×10^{13} kg/yr CO_2
  - atmosphere has mass = 5.3×10^{18} kg $\rightarrow$ CO_2 adds 5.7 ppm/yr by mass
  - about 3.7 ppm/yr by volume (CO_2 is 44 g/mol vs. 29 for air)
  - if half goes into ocean, half into atmosphere (as studies show), atmospheric rise is 1.85 ppm/yr, by volume
  - this is darned close to what we see on the "Keeling curve" graph

Total CO_2 rise

- We can do the same thing for the entire fossil fuel history
  - have gone through 1 trillion barrels of oil $\rightarrow$ 140 Gtoe
    - Gtoe is gigaton (10^9 ton) oil equivalent (by energy)
  - used about 160 Gtoe coal worldwide
    - using 40 Gtoe U.S. times four, since U.S. uses 25% of world energy
  - used 1037 tcf natural gas in U.S. $\rightarrow$ 27 Gtoe, so guess 100 Gtoe worldwide
  - 400 Gtoe of fossil fuels $\rightarrow$ 1.2×10^{15} kg of CO_2 ($3\times$ FF mass)
  - 228 ppm of atmosphere by mass; 150 ppm by volume
  - half into atmosphere $\rightarrow$ 75 ppm increase
  - see 100 ppm increase (280 ppm pre-industrial to 380 ppm)
- So the CO_2 increase is absolutely expected!

Expected Temperature Rise

- If you add to the blanket, expect to get warmer
- How much warmer?
  - Historically we have a 7°C effect from CO_2
  - Have gone from 280 to 400 ppm (10/7 times as much, or 3/7 increase)
  - This should translate into $7° \times 3/7 = 3°C$ change
    - but takes some time because oceans are slow to respond, having *enormous* heat capacity
- Should be NO SURPRISE that burning loads of fossil fuels makes us warmer
  - not actually hard to understand!

History of Sea Level

- Over the past four cycles, each lasting about 100,000 years, sea level rose and fell by about 400 feet, with ice ages having lower sea level and warm interglacial periods having higher sea level.
- During the warmest part of the last interglacial period (about 130,000 years ago), global average temperature was 2–3 °F warmer than today and global sea level was 13–20 feet higher.
- During the Middle Pliocene (3 million years ago), global temperature was 3.5–5.5 °F warmer than today and sea level was 80–115 feet higher.
- If emissions of man-made greenhouse gases continue without abatement, the earth could warm by 5.5 °F (3 °C) within the next century.

from http://www.pewclimate.org/global-warming-basics/slr.cfm

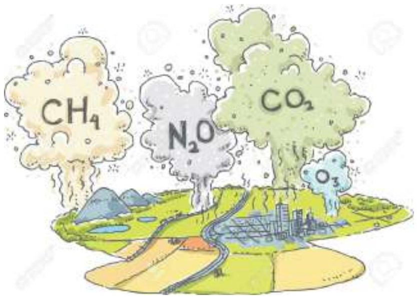
Predicted Temperature Changes

- The IPCC predicts an increase of 1.1ºC to 6.4ºC from 1990 to 2100 depending on scenario
- Earth can be slow to respond, due to thermal sink of oceans, and this lag means the temperature will continue to rise *even if we ceased burning fossil fuels today*!
- CO_2 hangs around long enough that we would likely not see the end of changes until ~2300
  - this is under scenario that we STOP fossil fuels tomorrow (not going to happen!)
  - sea-level rise is the gift that keeps on giving

Sea-level rise

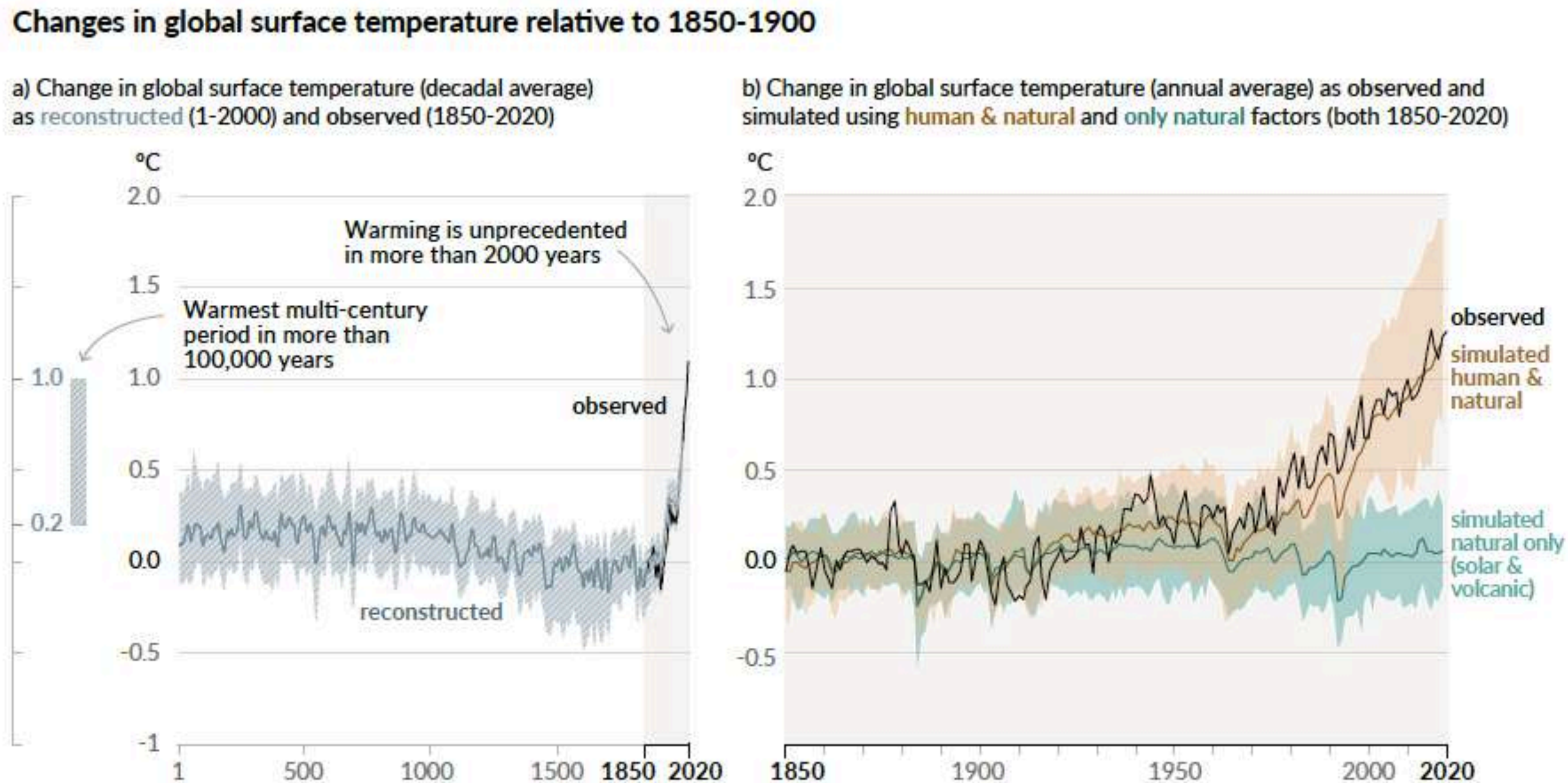
- Thermal expansion of water plus glacial and polar ice-cap melting raise the sea level
- The oceans are predicted to rise something like half-a-meter by 2100, maybe as much as 1 meter
  - goodbye to much of Bangladesh, much of the Nile valley, Louisiana
- Doesn't stop there: it won't stabilize until maybe 2300, by which time the rise could be several meters
  - this is even if we stop the CO_2 production *today*

- *Are we change the atmosphere?*



SPM 1.1 Observed changes in the climate system

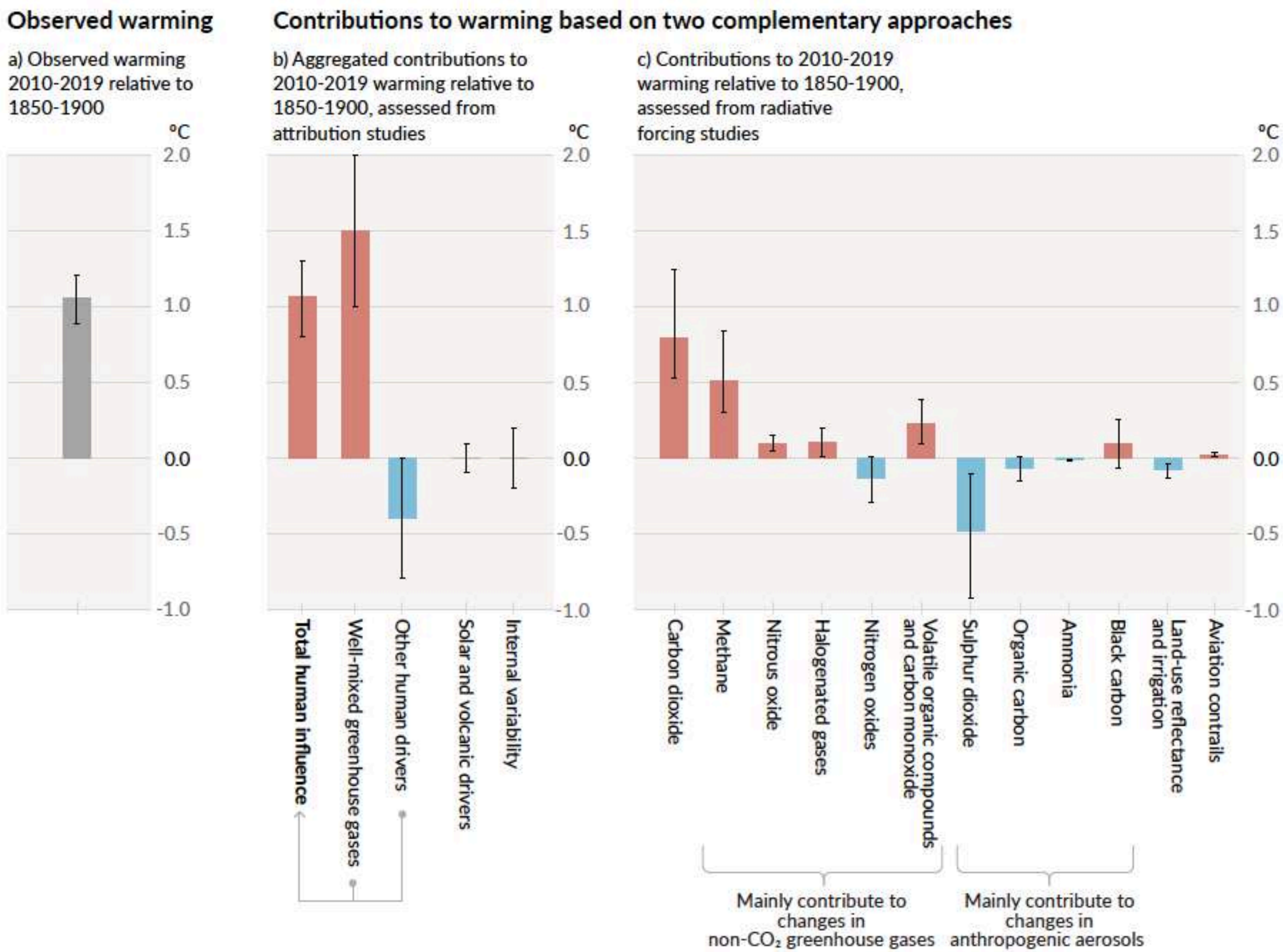
Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, and sea level has risen. *{1.1}*



Changes in global surface temperature relative to 1850-1900
a) Change in global surface temperature (decadal average) as reconstructed (1-2000) and observed (1850-2020)
°C
2.0
1.5
1.0
0.5
0.0
-0.5
-1
1.0
0.2
Warming is unprecedented in more than 2000 years
Warmest multi-century period in more than 100,000 years
observed
reconstructed
1
500
1000
1500
1850
2020
b) Change in global surface temperature (annual average) as observed and simulated using human & natural and only natural factors (both 1850-2020)
°C
2.0
1.5
1.0
0.5
0.0
-0.5
observed
simulated human & natural
simulated natural only (solar & volcanic)
1850
1900
1950
2000
2020

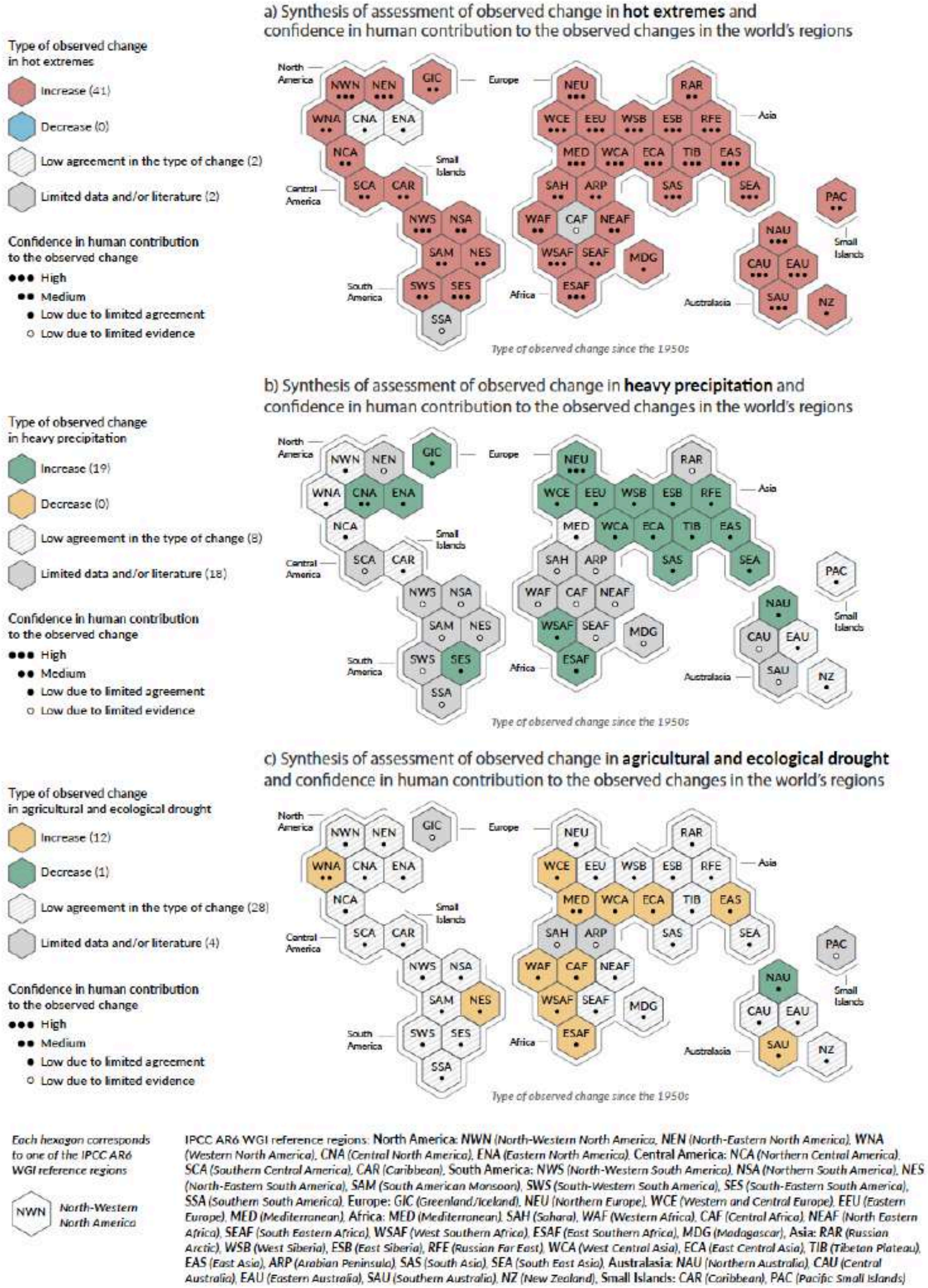
Source: IPCC

Observed warming is driven by emissions from human activities, with greenhouse gas warming partly masked by aerosol cooling



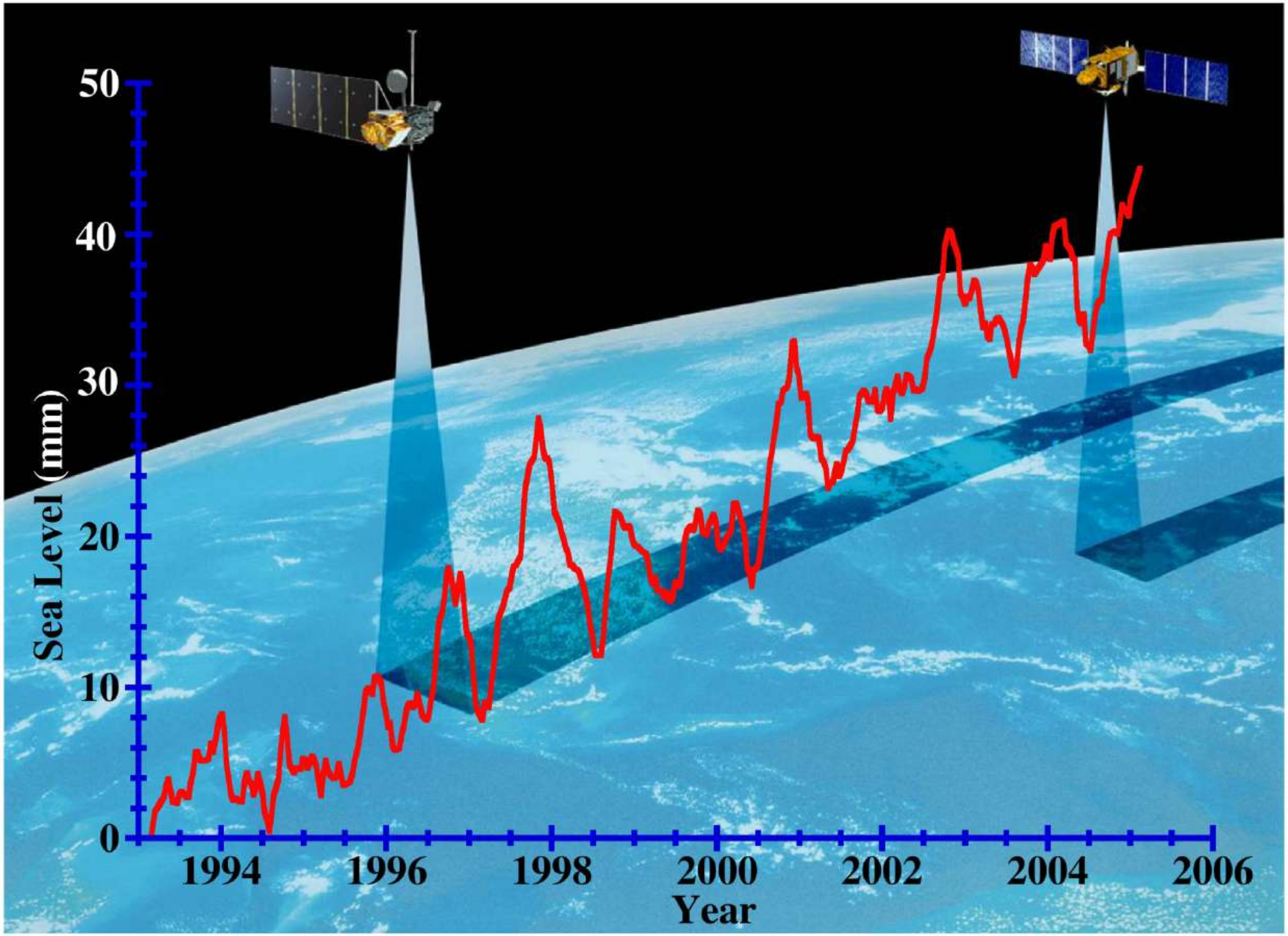
Source: IPCC

Climate change is already affecting every inhabited region across the globe with human influence contributing to many observed changes in weather and climate extremes

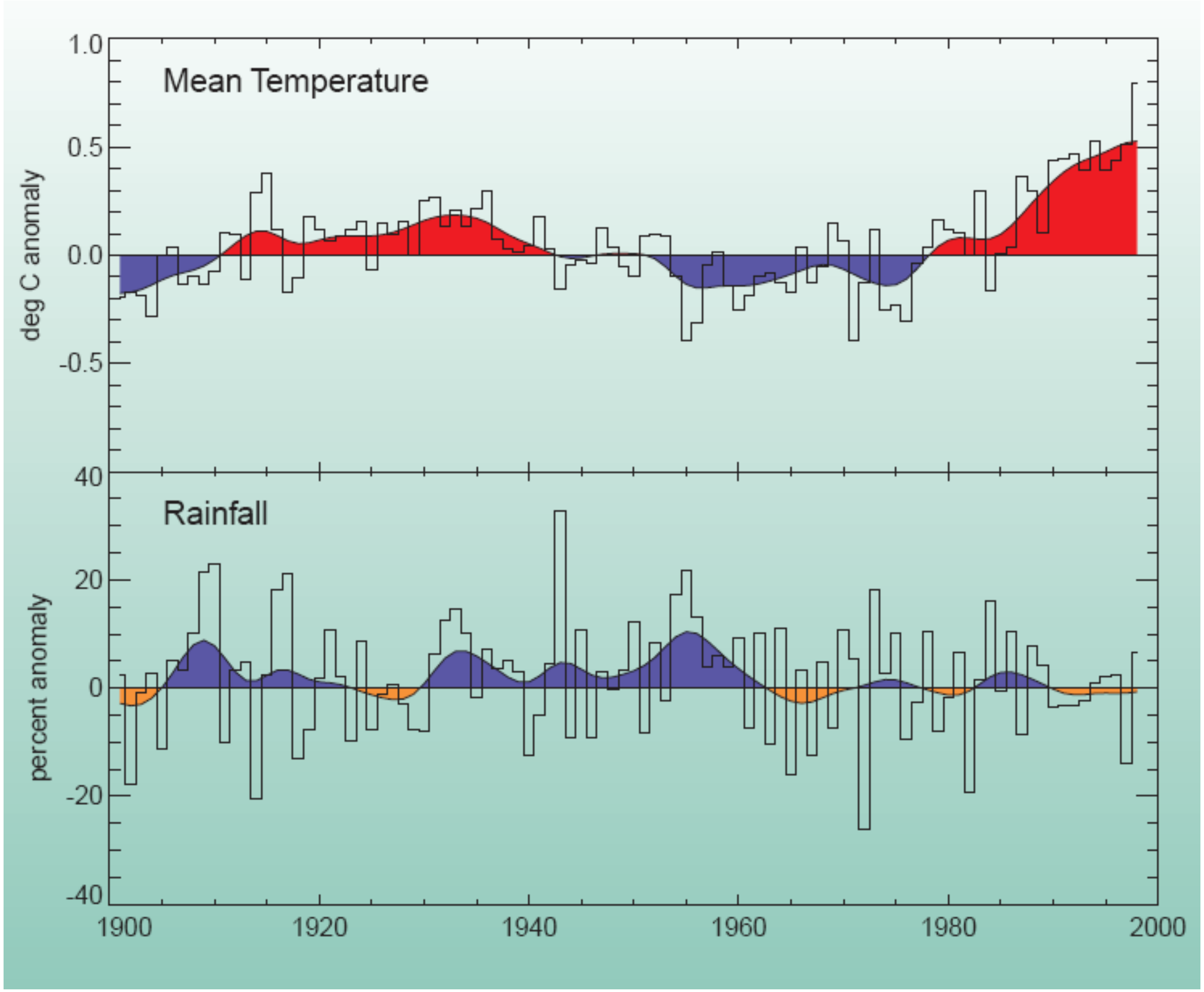


Source: IPCC

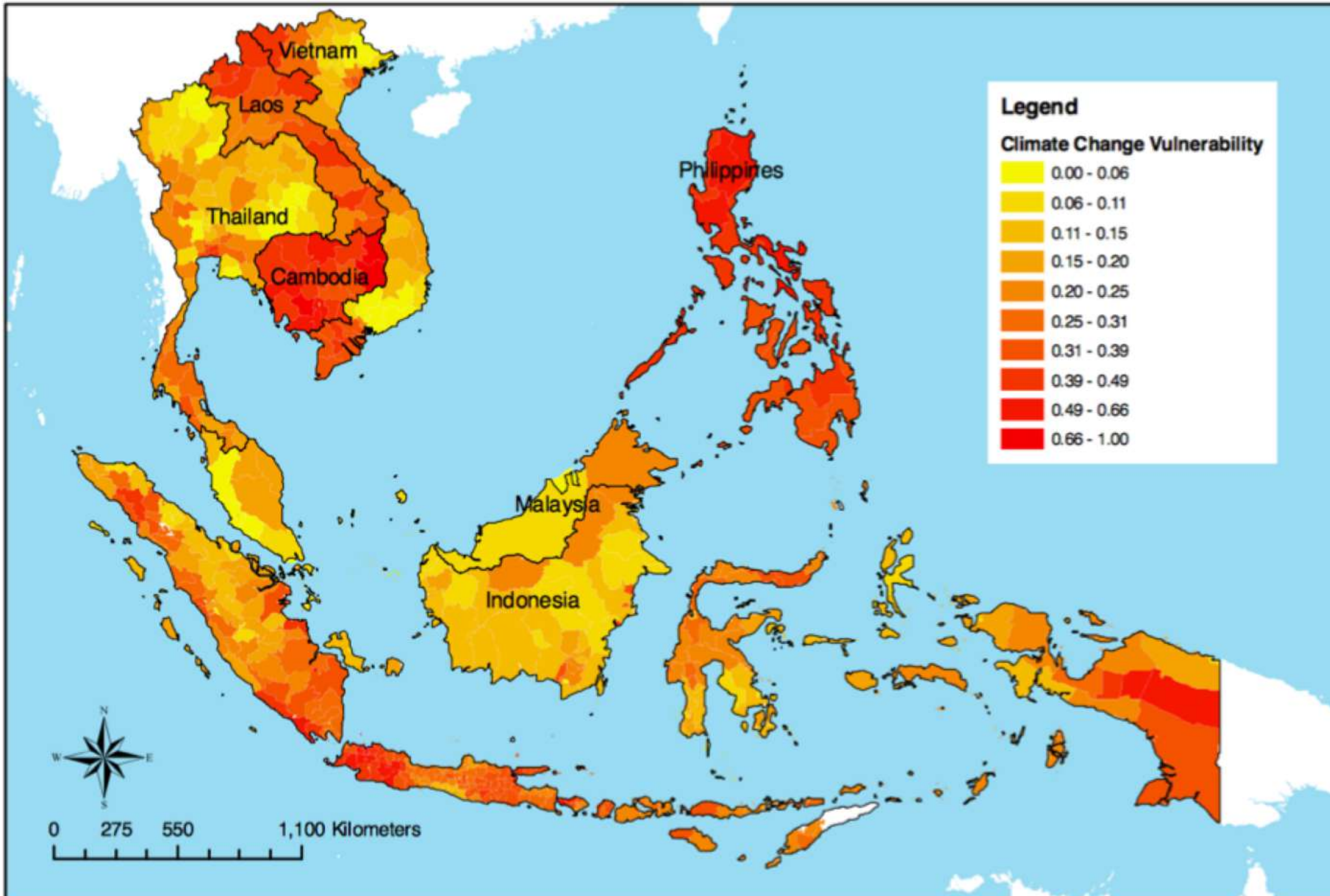
Sea-level from satellites: 4 cm rise in last 10 years



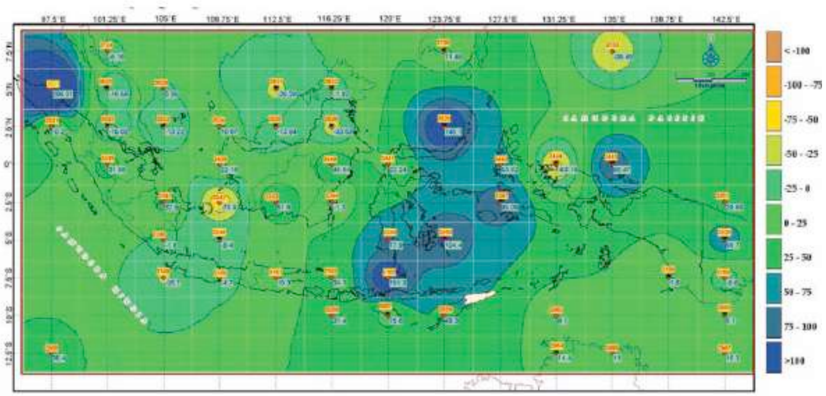
Changes in annual temperature and rainfall across Indonesia

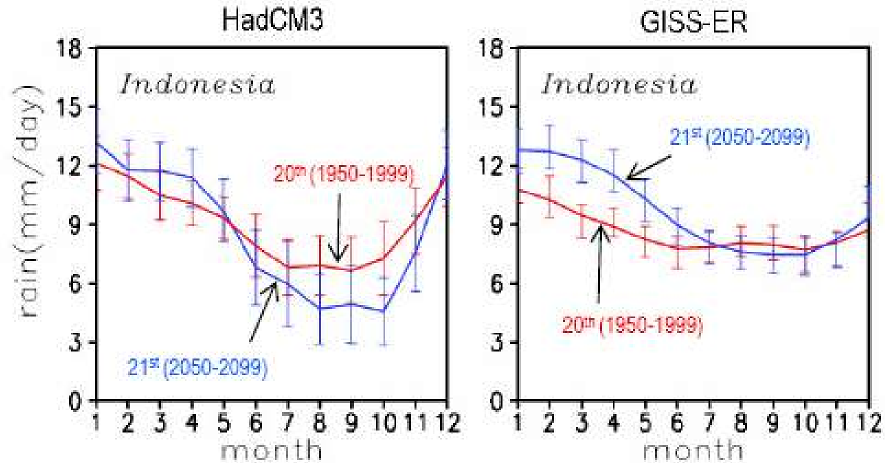


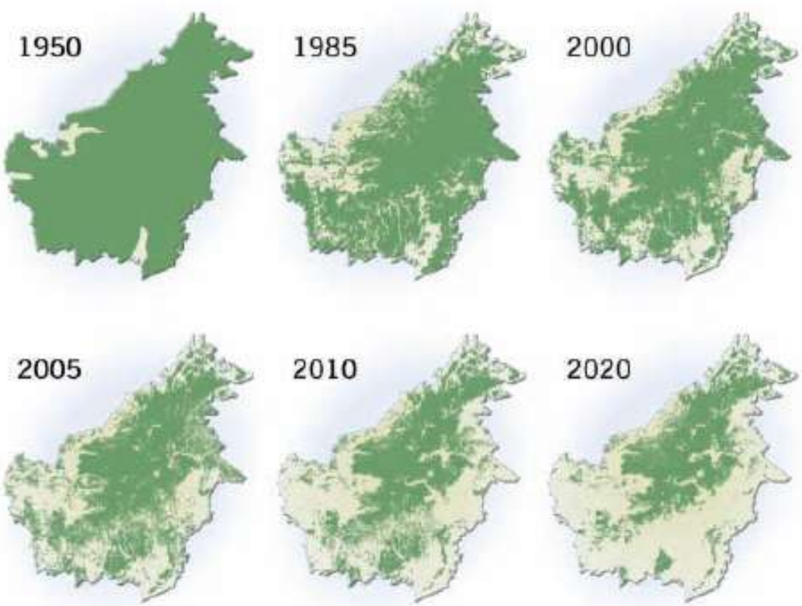
Source:
WWF

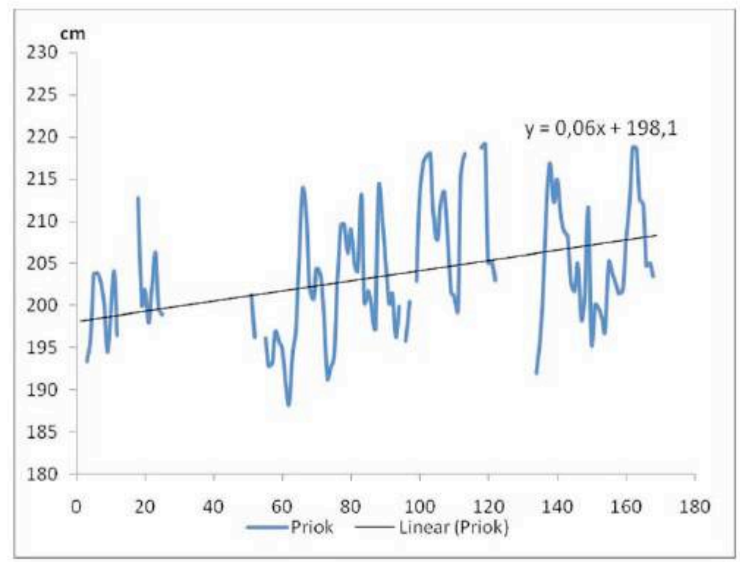


Vietnam
Laos
Thailand
Cambodia
Philippines
Malaysia
Indonesia
Legend
Climate Change Vulnerability
0.00 - 0.06
0.06 - 0.11
0.11 - 0.15
0.15 - 0.20
0.20 - 0.25
0.25 - 0.31
0.31 - 0.39
0.39 - 0.49
0.49 - 0.66
0.66 - 1.00
N
W
E
S
0
275
550
1,100 Kilometers









Trend of Mean Sea Level Rise in Tanjung Priok (Supangat, 2007)

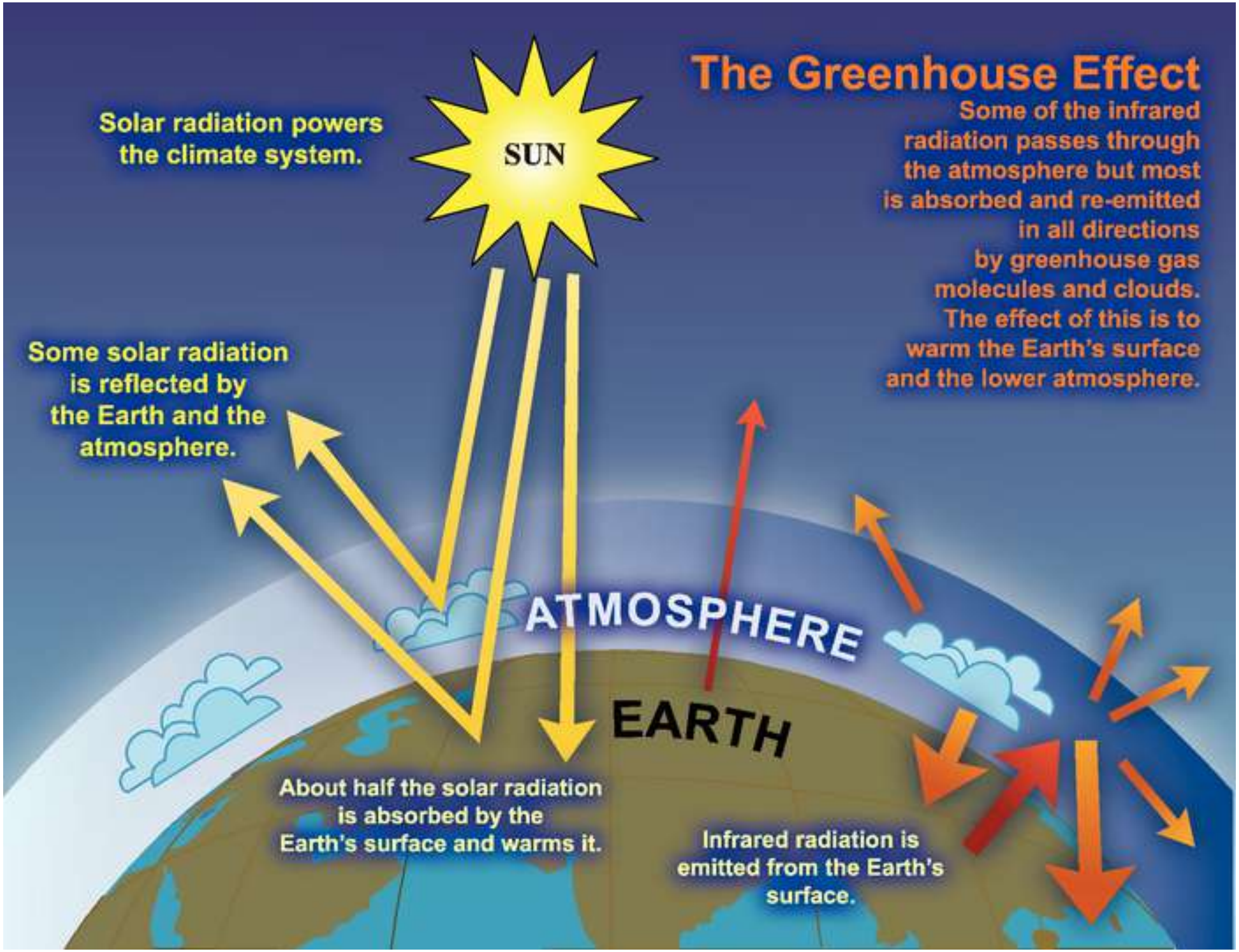
- How might that affect the climate?

SPM 1.2 Causes of climate change

Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are *extremely likely* to have been the dominant cause of the observed warming since the mid-20th century. *{1.2, 1.3.1}*

SPM 1.3 Impacts of climate change

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Impacts are due to observed climate change, irrespective of its cause, indicating the sensitivity of natural and human systems to changing climate. *{1.3.2}*


The Greenhouse Effect
Some of the infrared radiation passes through the atmosphere but most is absorbed and re-emitted in all directions by greenhouse gas molecules and clouds. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation powers the climate system.
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
ATMOSPHERE
EARTH
About half the solar radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

What is GHG

- These greenhouse gases include those listed in the Kyoto Protocol – methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) – and those listed under the Montreal Protocol and its Amendments – the chlorofluorocarbons (CFCs), the hydrochlorofluorocarbons (HCFCs), and the halons.

- A major focus of this assessment is the change in tropospheric ozone (O_3). Stratospheric water vapour (H_2O) is also treated here, but troposphericH_2O, which is part of the hydrological cycle and calculated within climate models, is not discussed.

- This also treats the reactive gases carbon monoxide (CO), volatile organic compounds (VOC), and nitrogen oxides (NO_x = $NO+NO_2$), termed indirect greenhouse gases. These pollutants are not significant direct greenhouse gases, but through atmospheric chemistry they control the abundances of direct greenhouse gases.

What is the greenhouse effect?

- The enhanced greenhouse effect is an increase in the amount of energy trapped by the atmosphere, largely due to increased concentrations of greenhouse gases.
- What GHGs have been increased in the atmosphere due to human activities?
- CO_2, CH_4, N_2O, tropospheric O_3 (smog), and halocarbons (CFCs, HCFCs, HFCs, halons, and other)

Greenhouse gas and global warming potentials

Gas	GWP
CO_2	1
CH_4	21
Nitrous Oxide (N_2O)	310
Hydrofluorocarbon (HFC)-23	11,700
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140

Gas	GWP
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{10}	7,400
SF_6	23,900

Table 4.1(a): Chemically reactive greenhouse gases and their precursors: abundances, trends, budgets, lifetimes, and GWPs.

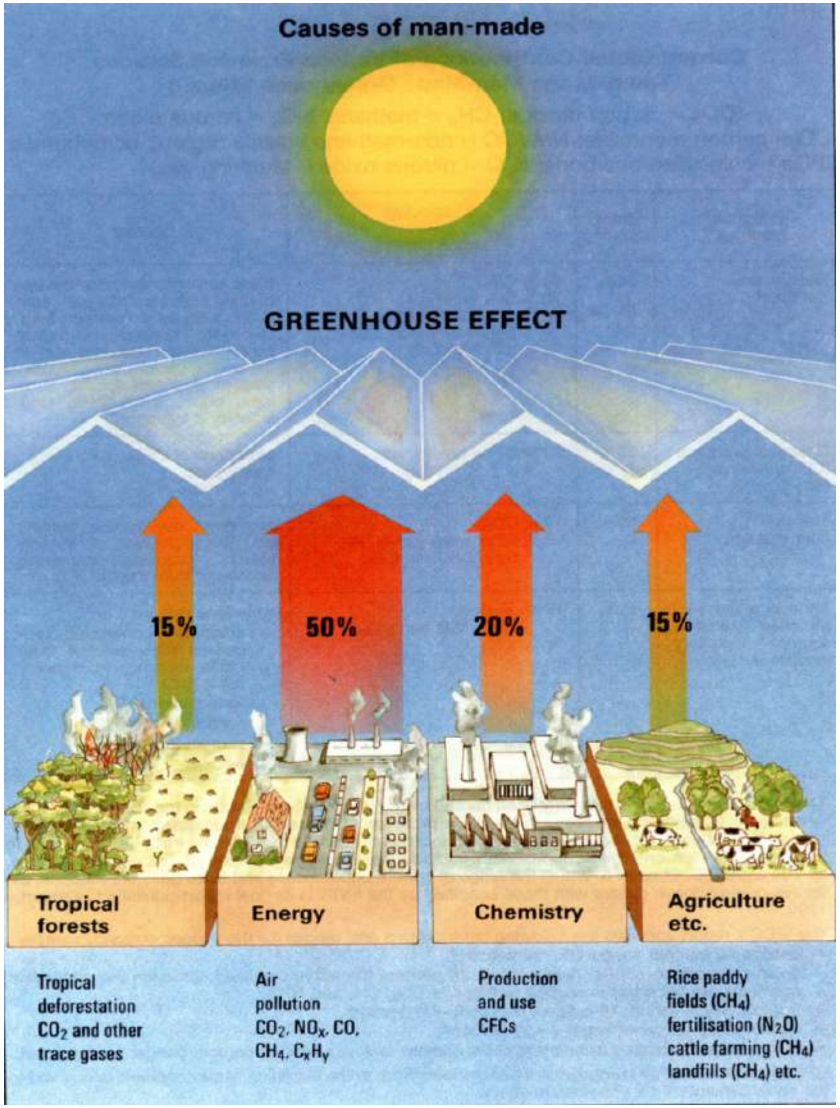
Chemical species	Formula	Abundance [a] ppt 1998	Abundance [a] ppt 1750	Trend ppt/yr [a] 1990s	Annual emission late 90s	Life-time (yr)	100-yr GWP [b]
Methane	CH_4 (ppb)	1745	700	7.0	600 Tg	8.4/12 [c]	23
Nitrous oxide	N_2O (ppb)	314	270	0.8	16.4 TgN	120/114 [c]	296
Perfluoromethane	CF_4	80	40	1.0	~15 Gg	>50000	5700
Perfluoroethane	C_2F_6	3.0	0	0.08	~2 Gg	10000	11900
Sulphur hexafluoride	SF_6	4.2	0	0.24	~6 Gg	3200	22200
HFC-23	CHF_3	14	0	0.55	~7 Gg	260	12000
HFC-134a	CF_3CH_2F	7.5	0	2.0	~25 Gg	13.8	1300
HFC-152a	CH_3CHF_2	0.5	0	0.1	~4 Gg	1.40	120
Important greenhouse halocarbons under Montreal Protocol and its Amendments							
CFC-11	$CFCl_3$	268	0	−1.4		45	4600
CFC-12	CF_2Cl_2	533	0	4.4		100	10600
CFC-13	CF_3Cl	4	0	0.1		640	14000
CFC-113	$CF_2ClCFCl_2$	84	0	0.0		85	6000
CFC-114	CF_2ClCF_2Cl	15	0	<0.5		300	9800
CFC-115	CF_3CF_2Cl	7	0	0.4		1700	7200
Carbon tetrachloride	CCl_4	102	0	−1.0		35	1800
Methyl chloroform	CH_3CCl_3	69	0	−14		4.8	140
HCFC-22	CHF_2Cl	132	0	5		11.9	1700
HCFC-141b	CH_3CFCl_2	10	0	2		9.3	700
HCFC-142b	CH_3CF_2Cl	11	0	1		19	2400
Halon-1211	CF_2ClBr	3.8	0	0.2		11	1300
Halon-1301	CF_3Br	2.5	0	0.1		65	6900
Halon-2402	CF_2BrCF_2Br	0.45	0	~ 0		<20	
Other chemically active gases dirctly or indirectly affecting radiative forcing							
Tropospheric ozone	O_3 (DU)	34	25	?	see text	0.01-0.05	–
Tropospheric NO_x	$NO + NO_2$	5-999	?	?	~52 TgN	<0.01-0.03	–
Carbon monoxide	CO (ppb) [d]	80	?	6	~2800 Tg	0.08 - 0.25	[d]
Stratospheric water	H_2O (ppm)	3-6	3-5	?	see text	1-6	–

Table 4.1(b): Additional synthetic greenhouse gases.

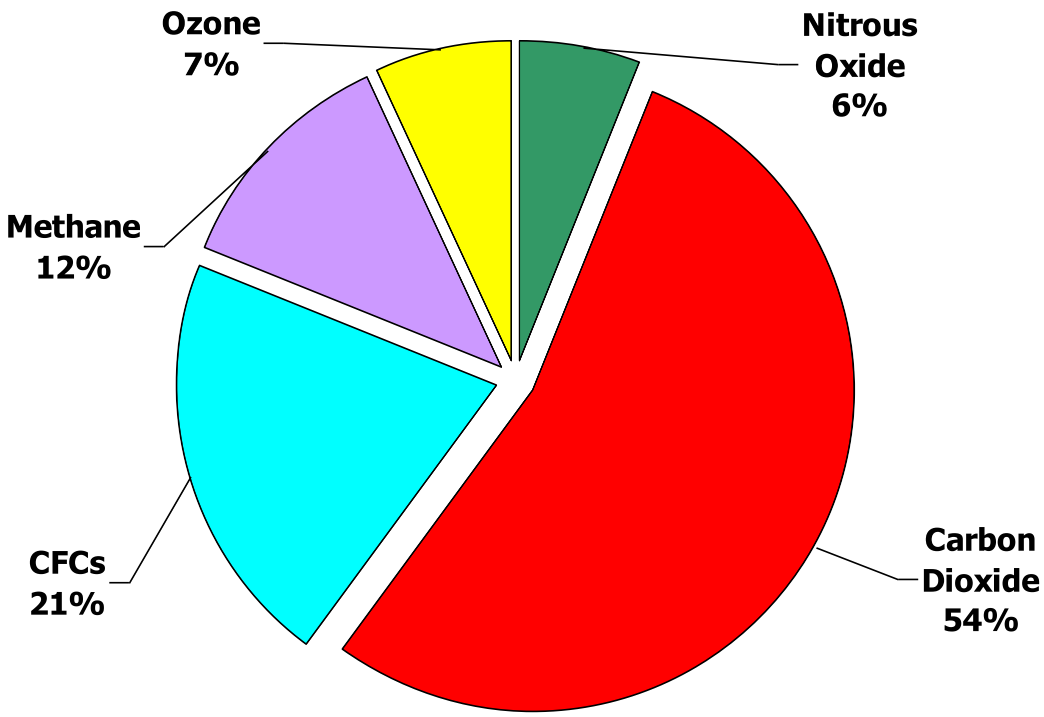
Chemical species	Formula	Lifetime (yr)	GWP[b]
Perfluoropropane	C_3F_8	2600	8600
Perfluorobutane	C_4F_{10}	2600	8600
Perfluorocyclobutane	C_4F_8	3200	10000
Perfluoropentane	C_5F_{12}	4100	8900
Perfluorohexane	C_6F_{14}	3200	9000
Trifluoromethyl-sulphur pentafluoride	SF_5CF_3	1000	17500
Nitrogen trifluoride	NF_3	>500	10800
Trifluoroiodomethane	CF_3I	<0.005	1
HFC-32	CH_2F_2	5.0	550
HFC-41	CH_3F	2.6	97
HFC-125	CHF_2CF_3	29	3400
HFC-134	CHF_2CHF_2	9.6	1100
HFC-143	CH_2FCHF_2	3.4	330
HFC-143a	CH_3CF_3	52	4300
HFC-152	CH_2FCH_2F	0.5	43
HFC-161	CH_3CH_2F	0.3	12
HFC-227ea	CF_3CHFCF_3	33	3500
HFC-236cb	$CF_3CF_2CH_2F$	13.2	1300
HFC-236ea	$CF_3CHFCHF_2$	10.0	1200
HFC-236fa	$CF_3CH_2CF_3$	220	9400
HFC-245ca	$CH_2FCF_2CHF_2$	5.9	640
HFC-245ea	$CHF_2CHFCHF_2$	4.0	
HFC-245eb	CF_3CHFCH_2F	4.2	
HFC-245fa	$CHF_2CH_2CF_3$	7.2	950
HFC-263fb	$CF_3CH_2CH_3$	1.6	
HFC-338pcc	$CHF_2CF_2CF_2CF_2H$	11.4	
HFC-356mcf	$CF_3CF_2CH_2CH_2F$	1.2	
HFC-356mff	$CF_3CH_2CH_2CF_3$	7.9	
HFC-365mfc	$CF_3CH_2CF_2CH_3$	9.9	890
HFC-43-10mee	$CF_3CHFCHFCF_2CF_3$	15	1500
HFC-458mfcf	$CF_3CH_2CF_2CH_2CF_3$	22	
HFC-55-10mcff	$CF_3CF_2CH_2CH_2CF_2CF_3$	7.7	
HFE-125	CF_3OCHF_2	150	14900
HFE-134	CF_2HOCF_2H	26	2400
HFE-143a	CF_3OCH_3	4.4	750
HFE-152a	CH_3OCHF_2	1.5	
HFE-245fa2	$CHF_2OCH_2CF_3$	4.6	570
HFE-356mff2	$CF_3CH_2OCH_2CF_3$	0.4	

Sources of greenhouse gases

- Carbon Dioxide (CO_2):
  100 years
- Methane:
  10 years
- Nitrous Oxide:
  150 years
- Chlorofluorocarbons:
  100 years



Contribution of greenhouse gases to climate change



Total annual anthropogenic GHG emissions by gases 1970–2010

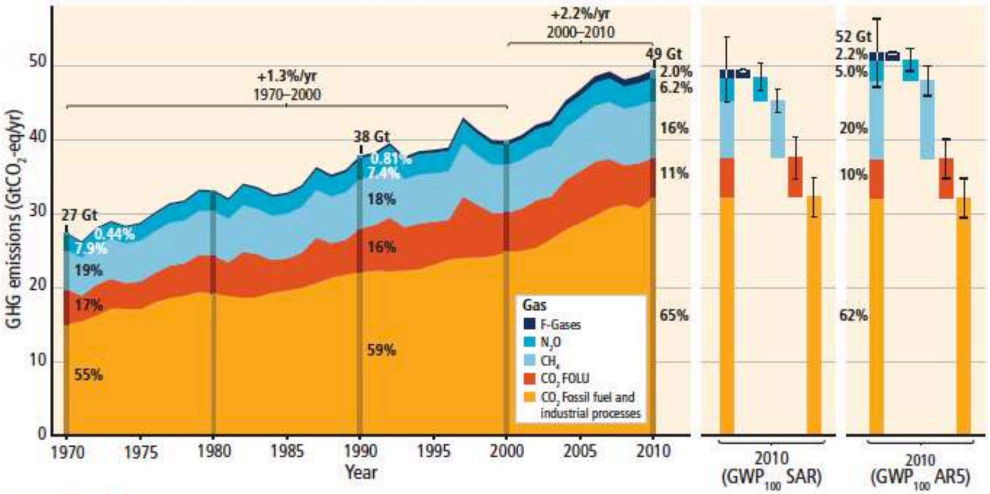
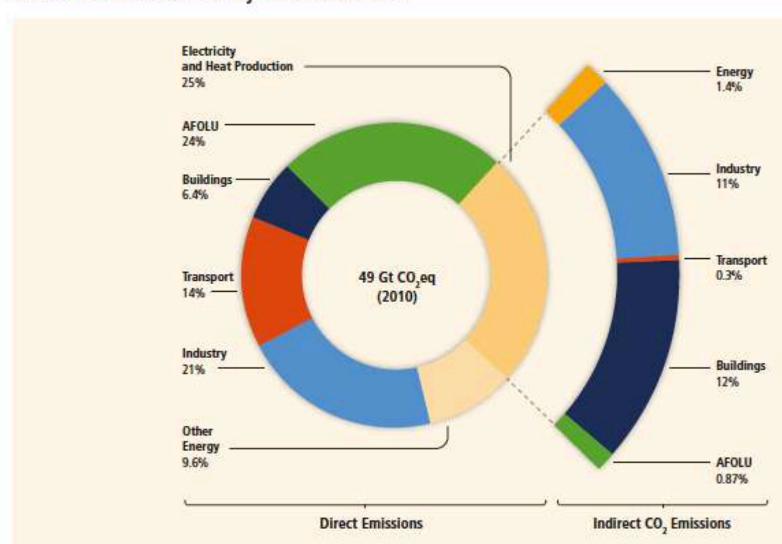


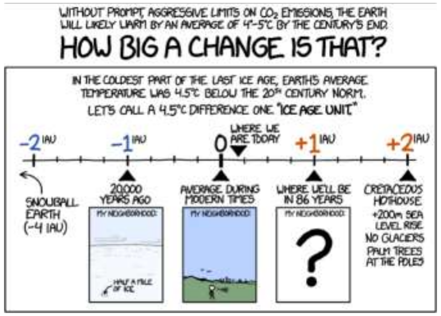
Figure SPM.2 | Total annual anthropogenic greenhouse gas (GHG) emissions (gigatonne of CO_2-equivalent per year, $GtCO_2$-eq/yr) for the period 1970 to 2010 by gases: CO_2 from fossil fuel combustion and industrial processes; CO_2 from Forestry and Other Land Use (FOLU); methane (CH_4); nitrous oxide (N_2O); fluorinated gases covered under the Kyoto Protocol (F-gases). Right hand side shows 2010 emissions, using alternatively CO_2-equivalent emission weightings based on IPCC Second Assessment Report (SAR) and AR5 values. Unless otherwise stated, CO_2-equivalent emissions in this report include the basket of Kyoto gases (CO_2, CH_4, N_2O as well as F-gases) calculated based on 100-year Global Warming Potential (GWP_{100}) values from the SAR (see Glossary). Using the most recent GWP_{100} values from the AR5 (right-hand bars) would result in higher total annual GHG emissions (52 $GtCO_2$-eq/yr) from an increased contribution of methane, but does not change the long-term trend significantly. *{Figure 1.6, Box 3.2}*

Greenhouse Gas Emissions by Economic Sectors



Source: IPCC

- What is likely to happen in the future. Risk & Impact



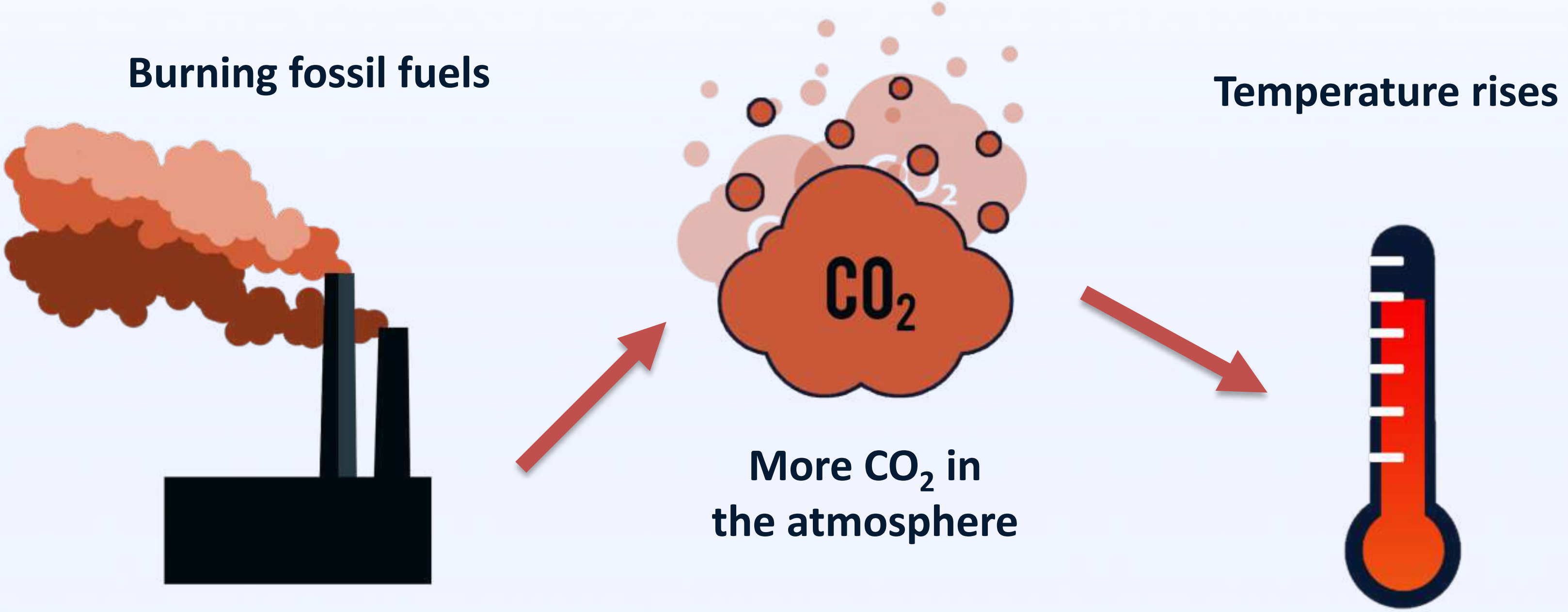
SPM 2. Future Climate Changes, Risks and Impacts

Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change would require substantial and sustained reductions in greenhouse gas emissions which, together with adaptation, can limit climate change risks. *{2}*

SPM 2.1 Key drivers of future climate

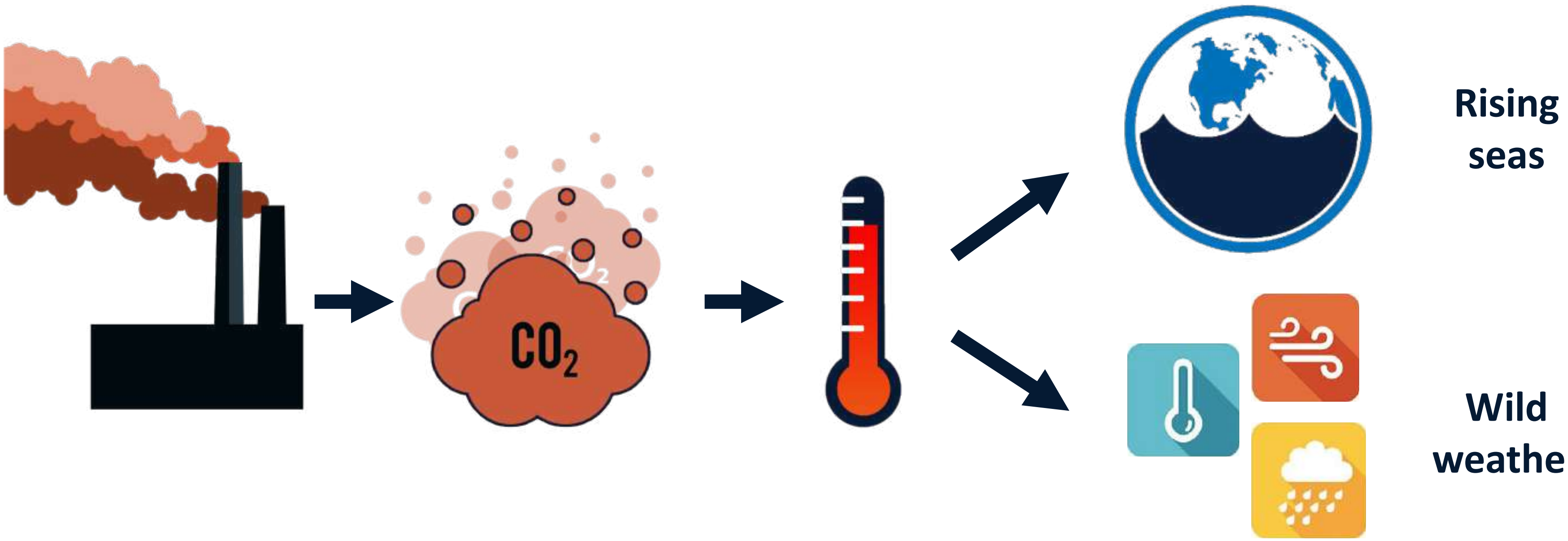
Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond. Projections of greenhouse gas emissions vary over a wide range, depending on both socio-economic development and climate policy. *{2.1}*

Simple



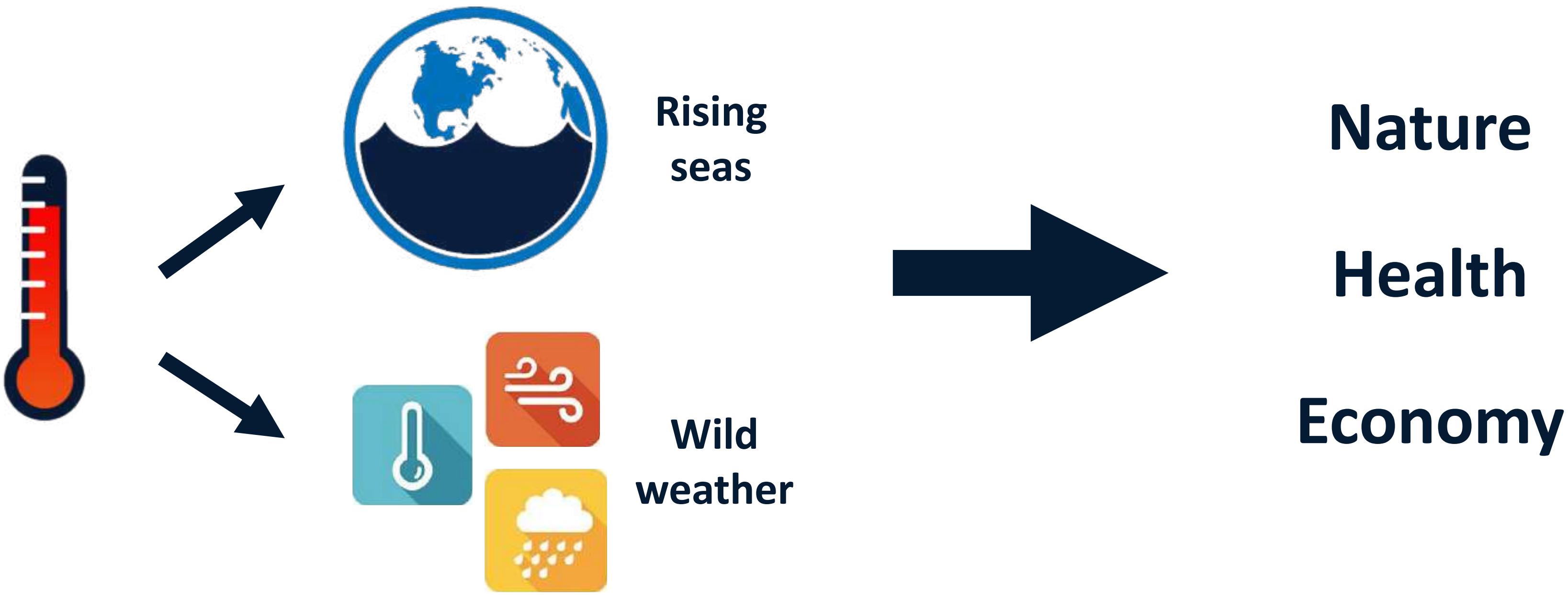
Source: Climate Central

Serious



Source: Climate Central

Serious



Source: Climate Central

Box SPM.1: Scenarios, Climate Models and Projections

Box SPM.1.1: This report assesses the climate response to five illustrative scenarios that cover the range of possible future development of anthropogenic drivers of climate change found in the literature. They start in 2015, and include scenarios[22] with high and very high GHG emissions (SSP3-7.0 and SSP5-8.5) and CO_2 emissions that roughly double from current levels by 2100 and 2050, respectively, scenarios with intermediate GHG emissions (SSP2-4.5) and CO_2 emissions remaining around current levels until the middle of the century, and scenarios with very low and low GHG emissions and CO_2 emissions declining to net zero around or after 2050, followed by varying levels of net negative CO_2 emissions[23] (SSP1-1.9 and SSP1-2.6) as illustrated in Figure SPM.4. Emissions vary between scenarios depending on socio-economic assumptions, levels of climate change mitigation and, for aerosols and non-methane ozone precursors, air pollution controls. Alternative assumptions may result in similar emissions and climate responses, but the socio-economic assumptions and the feasibility or likelihood of individual scenarios is not part of the assessment.
{TS.1.3, 1.6, Cross-Chapter Box 1.4} (Figure SPM.4)

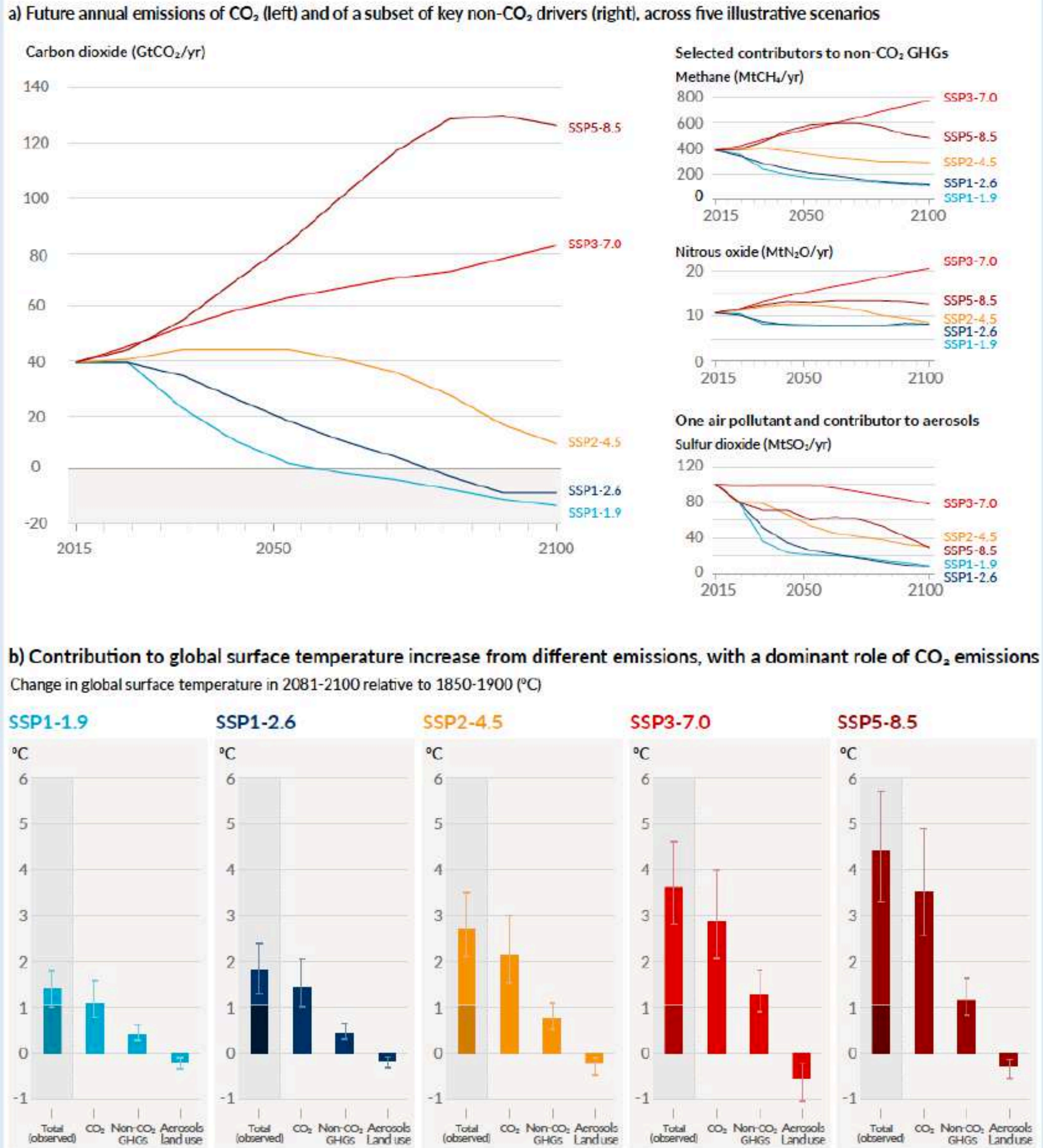
Box SPM.1.2: This report assesses results from climate models participating in the Coupled Model Intercomparison Project Phase 6 (CMIP6) of the World Climate Research Programme. These models include new and better representation of physical, chemical and biological processes, as well as higher resolution, compared to climate models considered in previous IPCC assessment reports. This has improved the simulation of the recent mean state of most large-scale indicators of climate change and many other aspects across the climate system. Some differences from observations remain, for example in regional precipitation patterns. The CMIP6 historical simulations assessed in this report have an ensemble mean global surface temperature change within 0.2°C of the observations over most of the historical period, and observed warming is within the *very likely* range of the CMIP6 ensemble. However, some CMIP6 models simulate a warming that is either above or below the assessed *very likely* range of observed warming.
{1.5, Cross-Chapter Box 2.2, 3.3, 3.8, TS.1.2, Cross-Section Box TS.1} (Figure SPM.1 b, Figure SPM.2)

Box SPM.1.3: The CMIP6 models considered in this Report have a wider range of climate sensitivity than in CMIP5 models and the AR6 assessed *very likely* range, which is based on multiple lines of evidence. These CMIP6 models also show a higher average climate sensitivity than CMIP5 and the AR6 assessed best estimate. The higher CMIP6 climate sensitivity values compared to CMIP5 can be traced to an amplifying cloud feedback that is larger in CMIP6 by about 20%.
{Box 7.1, 7.3, 7.4, 7.5, TS.3.2}

Box SPM.1.4: For the first time in an IPCC report, assessed future changes in global surface temperature, ocean warming and sea level are constructed by combining multi-model projections with observational constraints based on past simulated warming, as well as the AR6 assessment of climate sensitivity. For other quantities, such robust methods do not yet exist to constrain the projections. Nevertheless, robust projected

Source:IPCC

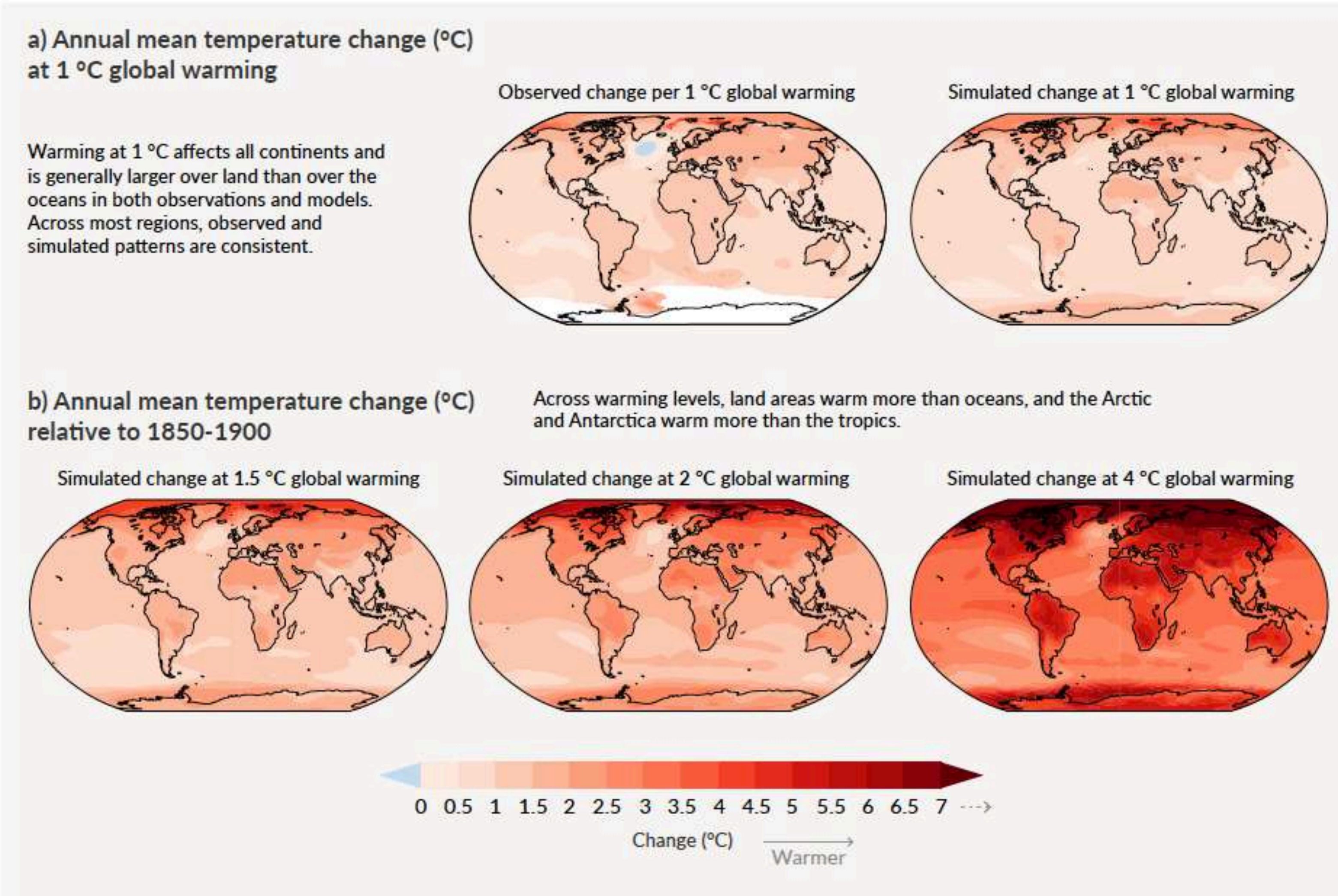
Future emissions cause future additional warming, with total warming dominated by past and future CO_2 emissions



Total warming (observed warming to date in darker shade), warming from CO_2, warming from non-CO_2 GHGs and cooling from changes in aerosols and land use

Source:IPCC

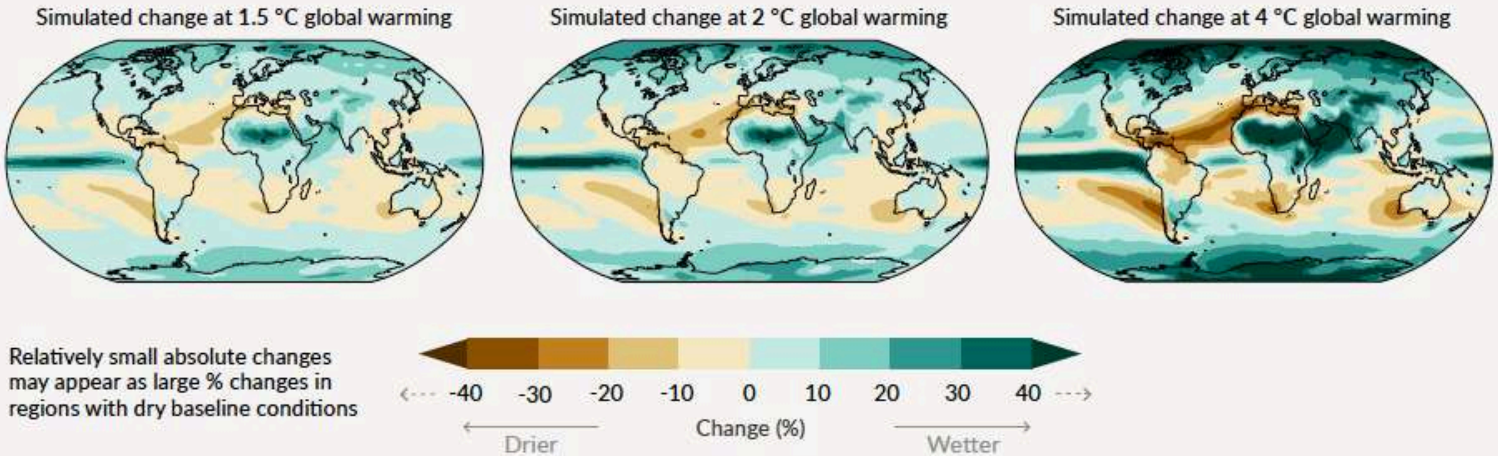
With every increment of global warming, changes get larger in regional mean temperature, precipitation and soil moisture



Source:IPCC

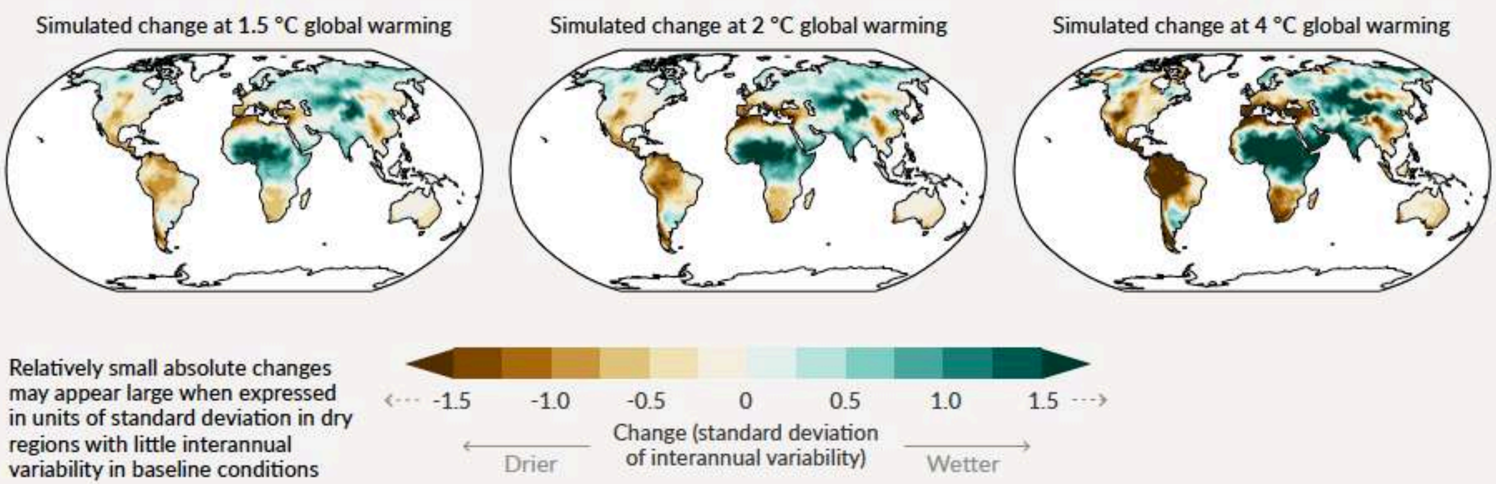
c) Annual mean precipitation change (%) relative to 1850-1900

Precipitation is projected to increase over high latitudes, the equatorial Pacific and parts of the monsoon regions, but decrease over parts of the subtropics and in limited areas of the tropics.



d) Annual mean total column soil moisture change (standard deviation)

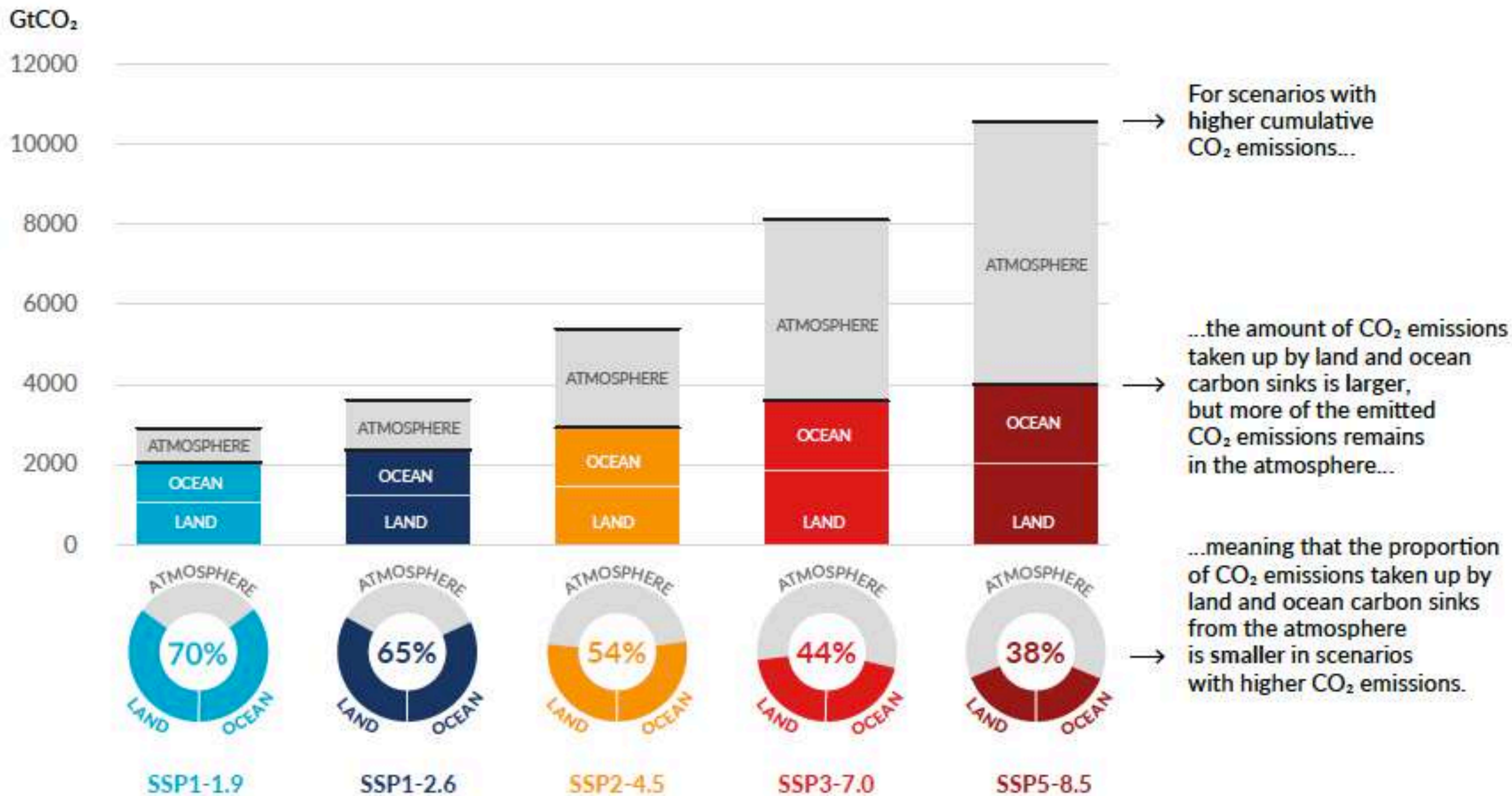
Across warming levels, changes in soil moisture largely follow changes in precipitation but also show some differences due to the influence of evapotranspiration.



Source:IPCC

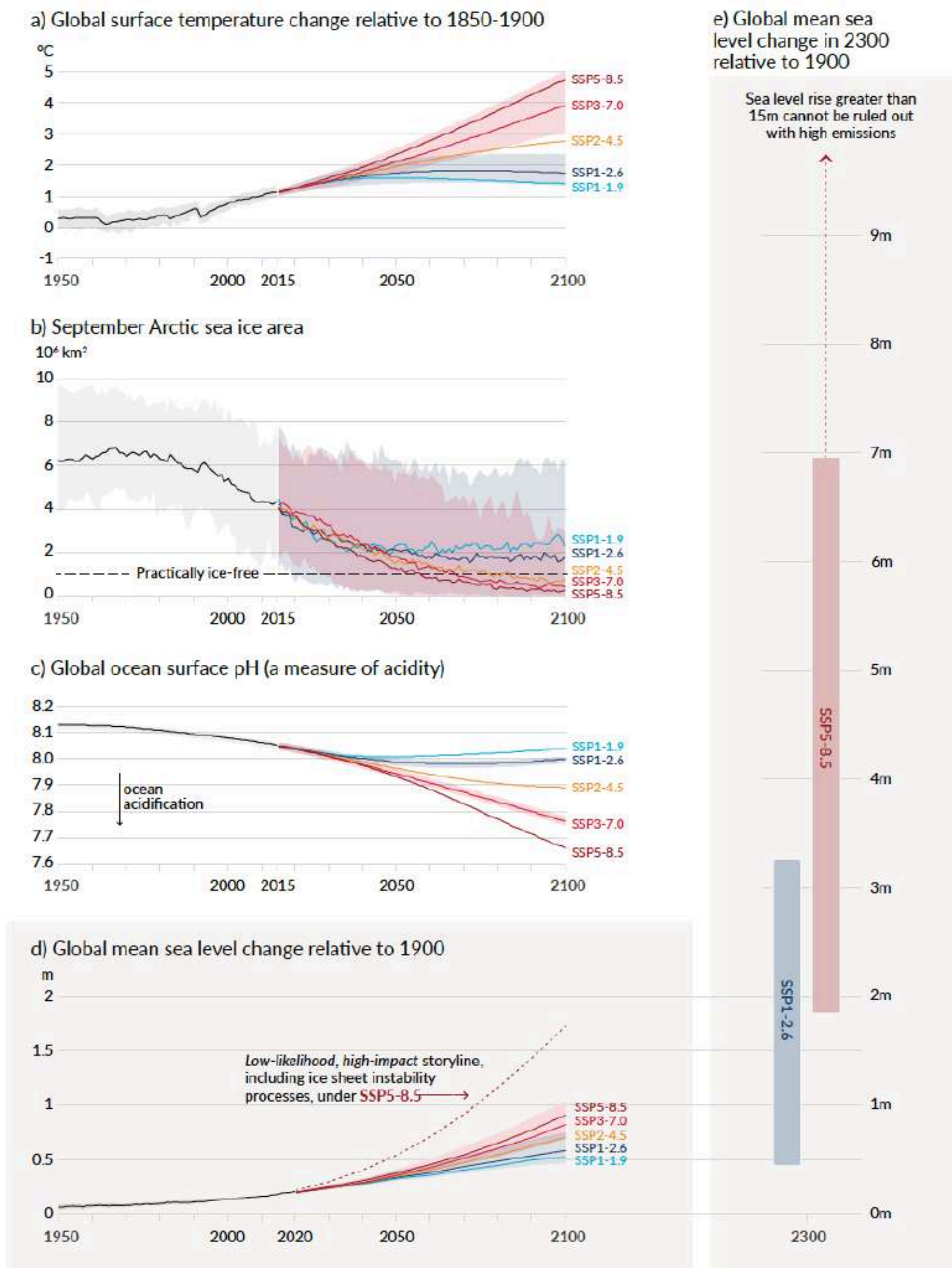
The proportion of CO_2 emissions taken up by land and ocean carbon sinks is smaller in scenarios with higher cumulative CO_2 emissions

Total cumulative CO_2 emissions **taken up by land and oceans** (colours) and remaining in the atmosphere (grey) under the five illustrative scenarios from 1850 to 2100

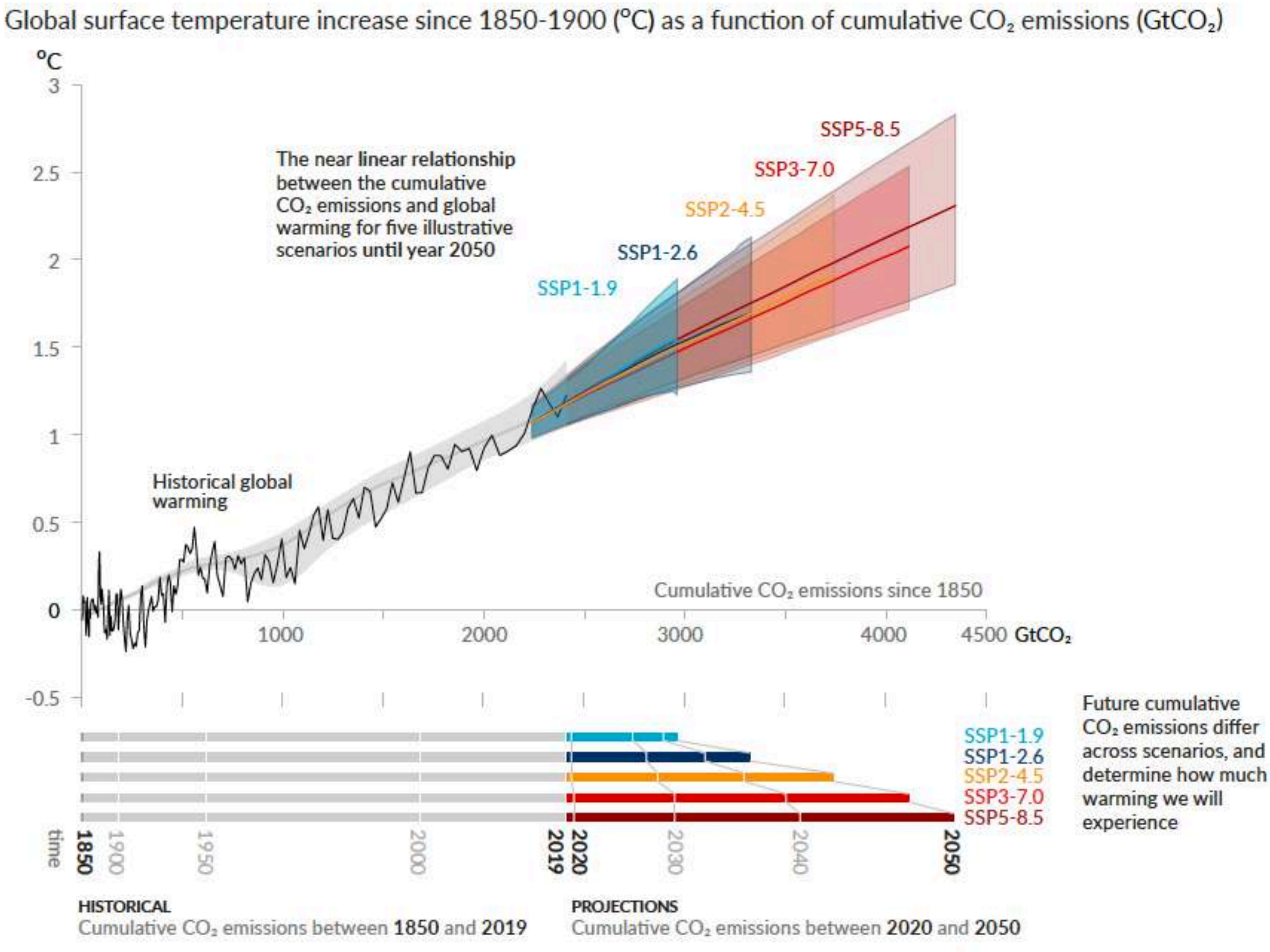


Source:IPCC

Human activities affect all the major climate system components, with some responding over decades and others over centuries



Source:IPCC

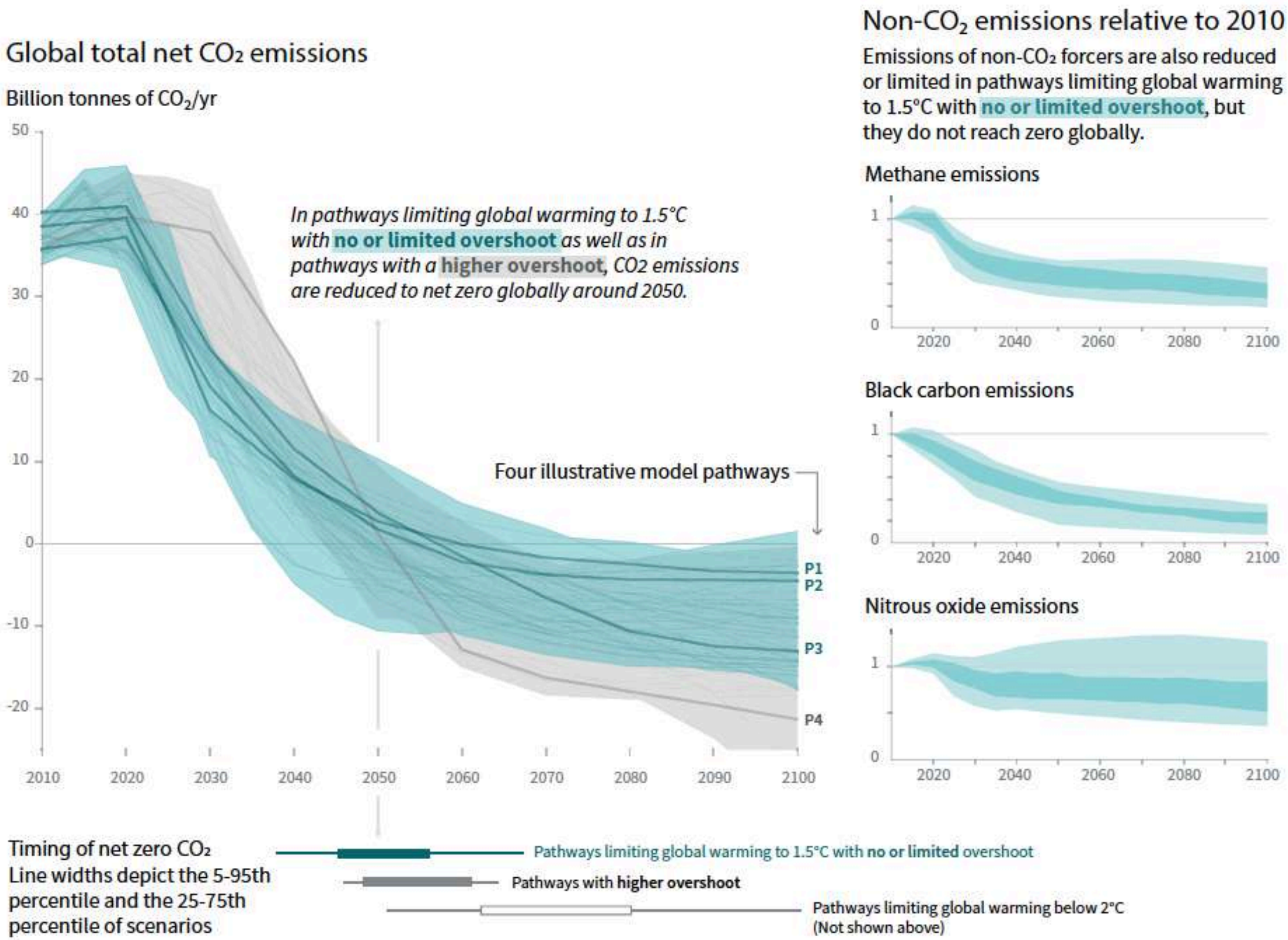

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)
°C
3
2.5
2
1.5
1
0.5
0
-0.5
The near linear relationship between the cumulative CO_2 emissions and global warming for five illustrative scenarios until year 2050
SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9
Historical global warming
Cumulative CO_2 emissions since 1850
1000
2000
3000
4000
4500 $GtCO_2$
Future cumulative CO_2 emissions differ across scenarios, and determine how much warming we will experience
SSP1-1.9
SSP1-2.6
SSP2-4.5
SSP3-7.0
SSP5-8.5
time
1850
1900
1950
2000
2019
2020
2030
2040
2050
HISTORICAL
Cumulative CO_2 emissions between 1850 and 2019
PROJECTIONS
Cumulative CO_2 emissions between 2020 and 2050

Source: IPCC

1.5°C (2.7°F)	VS	2°C (3.6°F)
8.5-30 inches of sea level rise by 2100	**Sea Level Rise**	Additional 4 inches of sea level rise and 10.4 million more people exposed
Loss of **70-90%** of coral reefs	**Ecosystems**	Loss of **99%** of coral reefs
350 million people in urban areas exposed to severe drought	**Extreme Weather**	**410 million people** in urban areas exposed to severe drought
At least one sea-ice-free Arctic summer **after 100 yrs**	**Arctic Ice**	At least one sea-ice-free Arctic summer **after 10 yrs**

SERIOUS

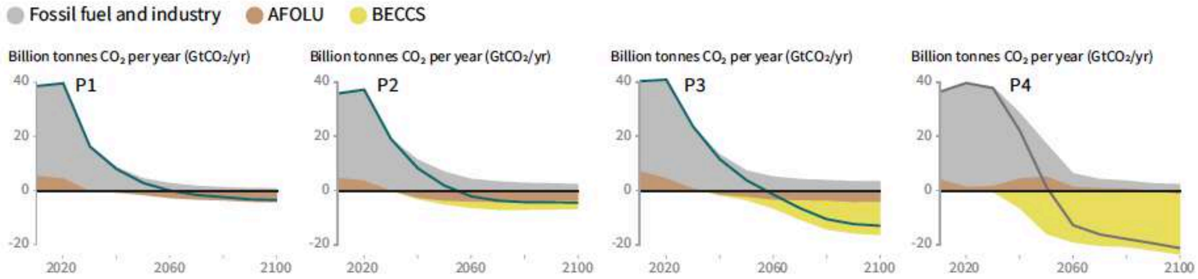
Source: Climate Central



Global total net CO₂ emissions
Billion tonnes of CO₂/yr
50
40
30
20
10
0
-10
-20
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
In pathways limiting global warming to 1.5°C with no or limited overshoot as well as in pathways with a higher overshoot, CO2 emissions are reduced to net zero globally around 2050.
Four illustrative model pathways
P1
P2
P3
P4
Non-CO₂ emissions relative to 2010
Emissions of non-CO₂ forcers are also reduced or limited in pathways limiting global warming to 1.5°C with no or limited overshoot, but they do not reach zero globally.
Methane emissions
Black carbon emissions
Nitrous oxide emissions
1
0
2020
2040
2060
2080
2100
Timing of net zero CO₂
Line widths depict the 5-95th percentile and the 25-75th percentile of scenarios
Pathways limiting global warming to 1.5°C with no or limited overshoot
Pathways with higher overshoot
Pathways limiting global warming below 2°C
(Not shown above)

Source: IPCC

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

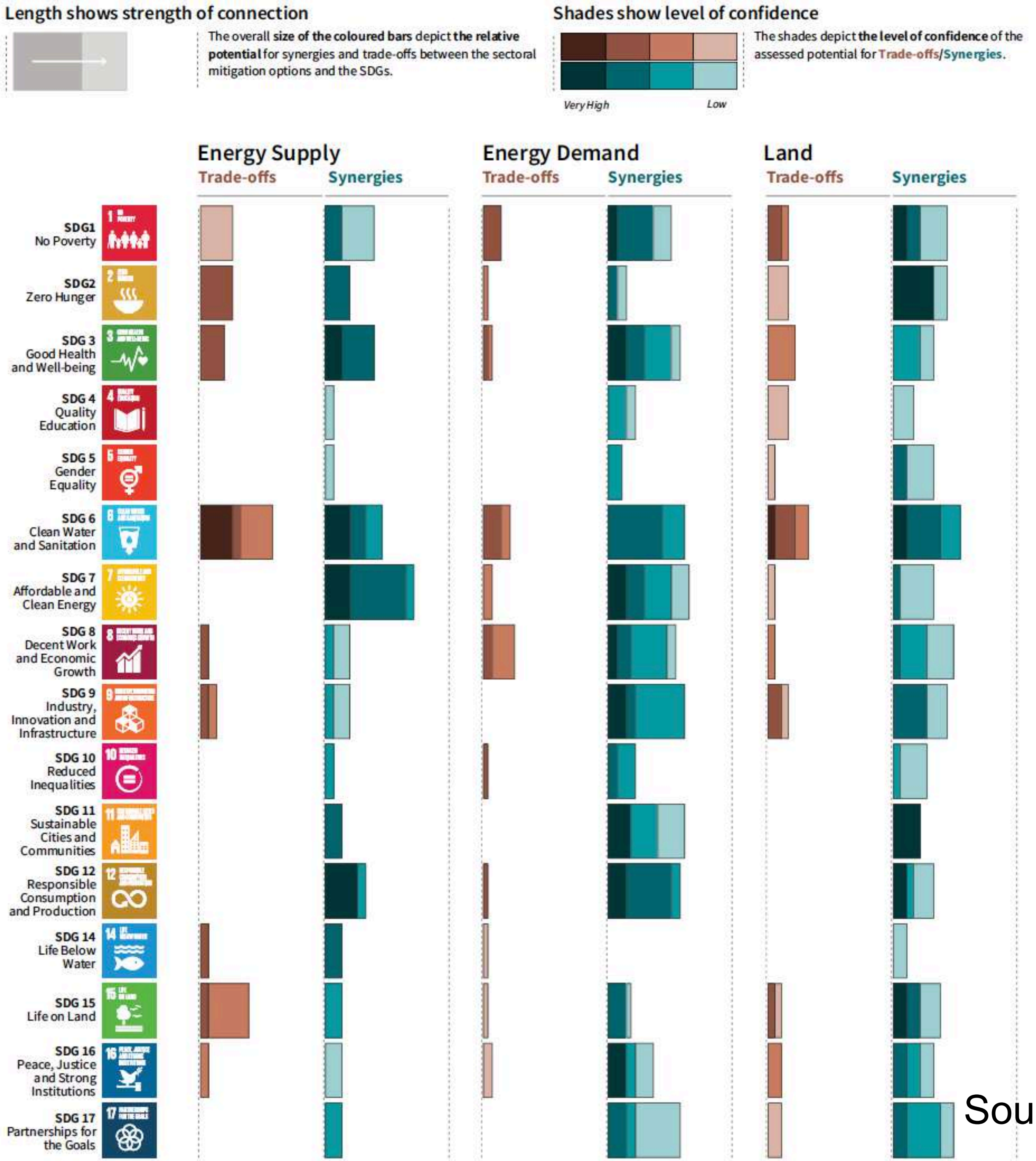
P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Global indicators	P1	P2	P3	P4	**Interquartile range**
Pathway classification	No or limited overshoot	No or limited overshoot	No or limited overshoot	Higher overshoot	No or limited overshoot
CO_2 emission change in 2030 (% rel to 2010)	-58	-47	-41	4	(-58,-40)
└ in 2050 (% rel to 2010)	-93	-95	-91	-97	(-107,-94)
Kyoto-GHG emissions in 2030 (% rel to 2010)*	-50	-49	-35	-2	(-51,-39)
└ in 2050 (% rel to 2010)	-82	-89	-78	-80	(-93,-81)
*Final energy demand** in 2030 (% rel to 2010)*	-15	-5	17	39	(-12,7)
└ in 2050 (% rel to 2010)	-32	2	21	44	(-11,22)
Renewable share in electricity in 2030 (%)	60	58	48	25	(47,65)
└ in 2050 (%)	77	81	63	70	(69,86)
Primary energy from coal in 2030 (% rel to 2010)	-78	-61	-75	-59	(-78, -59)
└ in 2050 (% rel to 2010)	-97	-77	-73	-97	(-95, -74)
from oil in 2030 (% rel to 2010)	-37	-13	-3	86	(-34,3)
└ in 2050 (% rel to 2010)	-87	-50	-81	-32	(-78,-31)
from gas in 2030 (% rel to 2010)	-25	-20	33	37	(-26,21)
└ in 2050 (% rel to 2010)	-74	-53	21	-48	(-56,6)
from nuclear in 2030 (% rel to 2010)	59	83	98	106	(44,102)
└ in 2050 (% rel to 2010)	150	98	501	468	(91,190)
from biomass in 2030 (% rel to 2010)	-11	0	36	-1	(29,80)
└ in 2050 (% rel to 2010)	-16	49	121	418	(123,261)
from non-biomass renewables in 2030 (% rel to 2010)	430	470	315	110	(245,436)
└ in 2050 (% rel to 2010)	833	1327	878	1137	(576,1299)
Cumulative CCS until 2100 ($GtCO_2$)	0	348	687	1218	(550,1017)
└ of which BECCS ($GtCO_2$)	0	151	414	1191	(364,662)
Land area of bioenergy crops in 2050 (million km^2)	0.2	0.9	2.8	7.2	(1.5,3.2)
Agricultural CH_4 emissions in 2030 (% rel to 2010)	-24	-48	1	14	(-30,-11)
in 2050 (% rel to 2010)	-33	-69	-23	2	(-47,-24)
Agricultural N_2O emissions in 2030 (% rel to 2010)	5	-26	15	3	(-21,3)
in 2050 (% rel to 2010)	6	-26	0	39	(-26,1)

NOTE: Indicators have been selected to show global trends identified by the Chapter 2 assessment. National and sectoral characteristics can differ substantially from the global trends shown above.

** Kyoto-gas emissions are based on IPCC Second Assessment Report GWP-100*
*** Changes in energy demand are associated with improvements in energy efficiency and behaviour change*

Source: IPCC


Length shows strength of connection
The overall size of the coloured bars depict the relative potential for synergies and trade-offs between the sectoral mitigation options and the SDGs.
Shades show level of confidence
The shades depict the level of confidence of the assessed potential for Trade-offs/Synergies.
Very High
Low
Energy Supply
Trade-offs
Synergies
Energy Demand
Trade-offs
Synergies
Land
Trade-offs
Synergies
SDG1 No Poverty
SDG2 Zero Hunger
SDG 3 Good Health and Well-being
SDG 4 Quality Education
SDG 5 Gender Equality
SDG 6 Clean Water and Sanitation
SDG 7 Affordable and Clean Energy
SDG 8 Decent Work and Economic Growth
SDG 9 Industry, Innovation and Infrastructure
SDG 10 Reduced Inequalities
SDG 11 Sustainable Cities and Communities
SDG 12 Responsible Consumption and Production
SDG 14 Life Below Water
SDG 15 Life on Land
SDG 16 Peace, Justice and Strong Institutions
SDG 17 Partnerships for the Goals

Source: IPCC

- What is future pathways for adaptation and mitigation

SPM 3.2 Climate change risks reduced by mitigation and adaptation

Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, widespread and irreversible impacts globally (*high confidence*). Mitigation involves some level of co-benefits and of risks due to adverse side effects, but these risks do not involve the same possibility of severe, widespread and irreversible impacts as risks from climate change, increasing the benefits from near-term mitigation efforts. *{3.2, 3.4}*

Adaptation & Mitigation

Many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself. Effective implementation depends on policies and cooperation at all scales and can be enhanced through integrated responses that link mitigation and adaptation with other societal objectives.

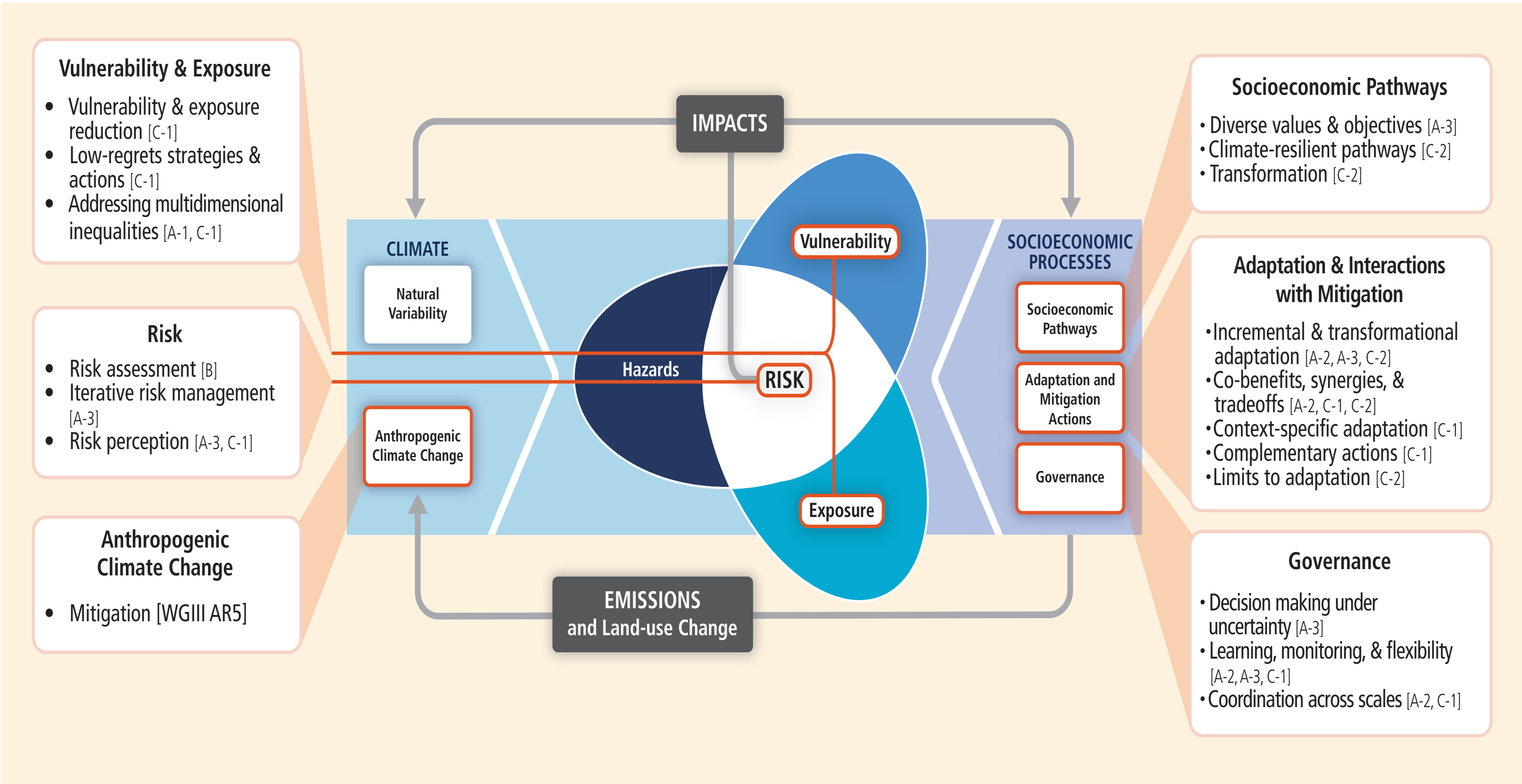


Table SPM.1 | Key characteristics of the scenarios collected and assessed for WGIII AR5. For all parameters the 10th to 90th percentile of the scenarios is shown[a]. *[Table 3.1]*

<table>
<tr><th rowspan="2">CO_2-eq Concentrations in 2100 (ppm CO_2-eq)[f]

Category label (conc. range)</th><th rowspan="2">Subcategories</th><th rowspan="2">Relative position of the RCPs[d]</th><th colspan="2">Change in CO_2-eq emissions compared to 2010 (in %)[c]</th><th colspan="4">Likelihood of staying below a specific temperature level over the 21st century (relative to 1850–1900)[d, e]</th></tr>
<tr><th>2050</th><th>2100</th><th>1.5°C</th><th>2°C</th><th>3°C</th><th>4°C</th></tr>
<tr><td><430</td><td colspan="8">Only a limited number of individual model studies have explored levels below 430 ppm CO_2-eq[j]</td></tr>
<tr><td>450
(430 to 480)</td><td>Total range[a, g]</td><td>RCP2.6</td><td>−72 to −41</td><td>−118 to −78</td><td>More unlikely than likely</td><td>Likely</td><td rowspan="6">Likely</td><td rowspan="8">Likely</td></tr>
<tr><td rowspan="2">500
(480 to 530)</td><td>No overshoot of 530 ppm CO_2-eq</td><td></td><td>−57 to −42</td><td>−107 to −73</td><td rowspan="6">Unlikely</td><td>More likely than not</td></tr>
<tr><td>Overshoot of 530 ppm CO_2-eq</td><td></td><td>−55 to −25</td><td>−114 to −90</td><td>About as likely as not</td></tr>
<tr><td rowspan="2">550
(530 to 580)</td><td>No overshoot of 580 ppm CO_2-eq</td><td></td><td>−47 to −19</td><td>−81 to −59</td><td rowspan="3">More unlikely than likely[i]</td></tr>
<tr><td>Overshoot of 580 ppm CO_2-eq</td><td></td><td>−16 to 7</td><td>−183 to −86</td></tr>
<tr><td>(580 to 650)</td><td>Total range</td><td rowspan="2">RCP4.5</td><td>−38 to 24</td><td>−134 to −50</td></tr>
<tr><td>(650 to 720)</td><td>Total range</td><td>−11 to 17</td><td>−54 to −21</td><td rowspan="2">Unlikely</td><td>More likely than not</td></tr>
<tr><td>(720 to 1000)[b]</td><td>Total range</td><td>RCP6.0</td><td>18 to 54</td><td>−7 to 72</td><td rowspan="2">Unlikely[h]</td><td>More unlikely than likely</td></tr>
<tr><td>>1000[b]</td><td>Total range</td><td>RCP8.5</td><td>52 to 95</td><td>74 to 178</td><td>Unlikely[h]</td><td>Unlikely</td><td>More unlikely than likely</td></tr>
</table>

Notes:

[a] The 'total range' for the 430 to 480 ppm CO_2-eq concentrations scenarios corresponds to the range of the 10th to 90th percentile of the subcategory of these scenarios shown in Table 6.3 of the Working Group III Report.

[b] Baseline scenarios fall into the >1000 and 720 to 1000 ppm CO_2-eq categories. The latter category also includes mitigation scenarios. The baseline scenarios in the latter category reach a temperature change of 2.5°C to 5.8°C above the average for 1850–1900 in 2100. Together with the baseline scenarios in the >1000 ppm CO_2-eq category, this leads to an overall 2100 temperature range of 2.5°C to 7.8°C (range based on median climate response: 3.7°C to 4.8°C) for baseline scenarios across both concentration categories.

[c] The global 2010 emissions are 31% above the 1990 emissions (consistent with the historic greenhouse gas emission estimates presented in this report). CO_2-eq emissions include the basket of Kyoto gases (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) as well as fluorinated gases).

[d] The assessment here involves a large number of scenarios published in the scientific literature and is thus not limited to the Representative Concentration Pathways (RCPs). To evaluate the CO_2-eq concentration and climate implications of these scenarios, the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) was used in a probabilistic mode. For a comparison between MAGICC model results and the outcomes of the models used in WGI, see WGI 12.4.1.2, 12.4.8 and WGIII 6.3.2.6.

[e] The assessment in this table is based on the probabilities calculated for the full ensemble of scenarios in WGIII AR5 using MAGICC and the assessment in WGI of the uncertainty of the temperature projections not covered by climate models. The statements are therefore consistent with the statements in WGI, which are based on the Coupled Model Intercomparison Project Phase 5 (CMIP5) runs of the RCPs and the assessed uncertainties. Hence, the likelihood statements reflect different lines of evidence from both WGs. This WGI method was also applied for scenarios with intermediate concentration levels where no CMIP5 runs are available. The likelihood statements are indicative only *[WGIII 6.3]* and follow broadly the terms used by the WGI SPM for temperature projections: likely 66–100%, more likely than not >50–100%, about as likely as not 33–66%, and unlikely 0–33%. In addition the term more unlikely than likely 0–<50% is used.

[f] The CO_2-equivalent concentration (see Glossary) is calculated on the basis of the total forcing from a simple carbon cycle/climate model, MAGICC. The CO_2-equivalent concentration in 2011 is estimated to be 430 ppm (uncertainty range 340 to 520 ppm). This is based on the assessment of total anthropogenic radiative forcing for 2011 relative to 1750 in WGI, i.e., 2.3 W/m², uncertainty range 1.1 to 3.3 W/m².

[g] The vast majority of scenarios in this category overshoot the category boundary of 480 ppm CO_2-eq concentration.

[h] For scenarios in this category, no CMIP5 run or MAGICC realization stays below the respective temperature level. Still, an *unlikely* assignment is given to reflect uncertainties that may not be reflected by the current climate models.

[i] Scenarios in the 580 to 650 ppm CO_2-eq category include both overshoot scenarios and scenarios that do not exceed the concentration level at the high end of the category (e.g., RCP4.5). The latter type of scenarios, in general, have an assessed probability of *more unlikely than likely* to stay below the 2°C temperature level, while the former are mostly assessed to have an *unlikely* probability of staying below this level.

[j] In these scenarios, global CO_2-eq emissions in 2050 are between 70 to 95% below 2010 emissions, and they are between 110 to 120% below 2010 emissions in 2100.

Global warming between 1850–1900 and 2010–2019 *(°C)*	Historical cumulative CO_2 emissions from 1850 to 2019 *(GtCO₂)*
1.07 (0.8–1.3; *likely* range)	2390 (± 240; *likely* range)

<table>
<tr><th rowspan="2">Approximate global warming relative to 1850–1900 until temperature limit (°C)*(1)</th><th rowspan="2">Additional global warming relative to 2010–2019 until temperature limit (°C)</th><th colspan="5">Estimated remaining carbon budgets from the beginning of 2020 (GtCO2)

Likelihood of limiting global warming to temperature limit*(2)</th><th rowspan="2">Variations in reductions in non-CO_2 emissions*(3)</th></tr>
<tr><th>17%</th><th>33%</th><th>50%</th><th>67%</th><th>83%</th></tr>
<tr><td>1.5</td><td>0.43</td><td>900</td><td>650</td><td>500</td><td>400</td><td>300</td><td rowspan="3">Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more</td></tr>
<tr><td>1.7</td><td>0.63</td><td>1450</td><td>1050</td><td>850</td><td>700</td><td>550</td></tr>
<tr><td>2.0</td><td>0.93</td><td>2300</td><td>1700</td><td>1350</td><td>1150</td><td>900</td></tr>
</table>

*(1) Values at each 0.1°C increment of warming are available in Tables TS.3 and 5.8.
*(2) This likelihood is based on the uncertainty in transient climate response to cumulative CO_2 emissions (TCRE) and additional Earth system feedbacks, and provides the probability that global warming will not exceed the temperature levels provided in the two left columns. Uncertainties related to historical warming (±550 $GtCO_2$) and non-CO_2 forcing and response (±220 $GtCO_2$) are partially addressed by the assessed uncertainty in TCRE, but uncertainties in recent emissions since 2015 (±20 $GtCO_2$) and the climate response after net zero CO_2 emissions are reached (±420 $GtCO_2$) are separate.
*(3) Remaining carbon budget estimates consider the warming from non-CO_2 drivers as implied by the scenarios assessed in SR1.5. The Working Group III Contribution to AR6 will assess mitigation of non-CO_2 emissions.

Source: IPCC

The water–energy–food nexus for both adaptation and mitigation strategies

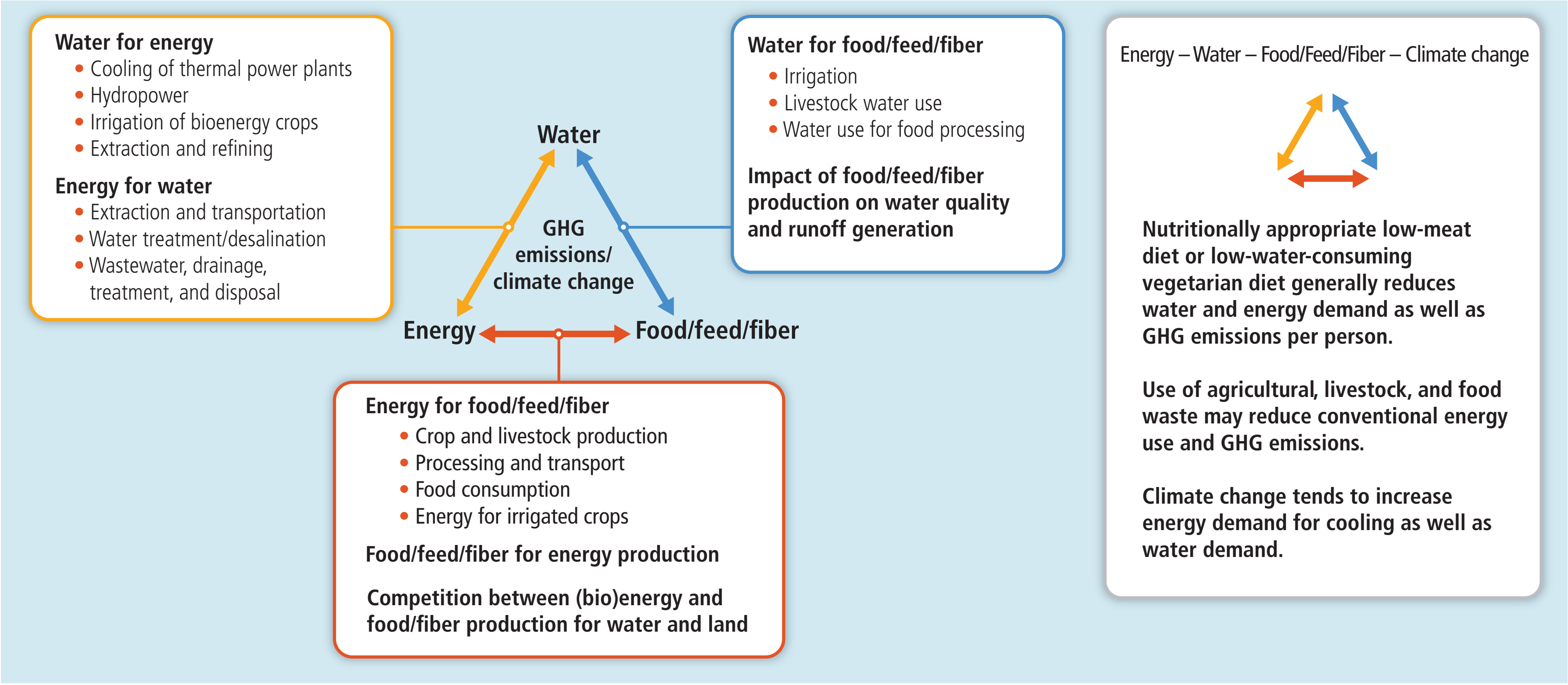
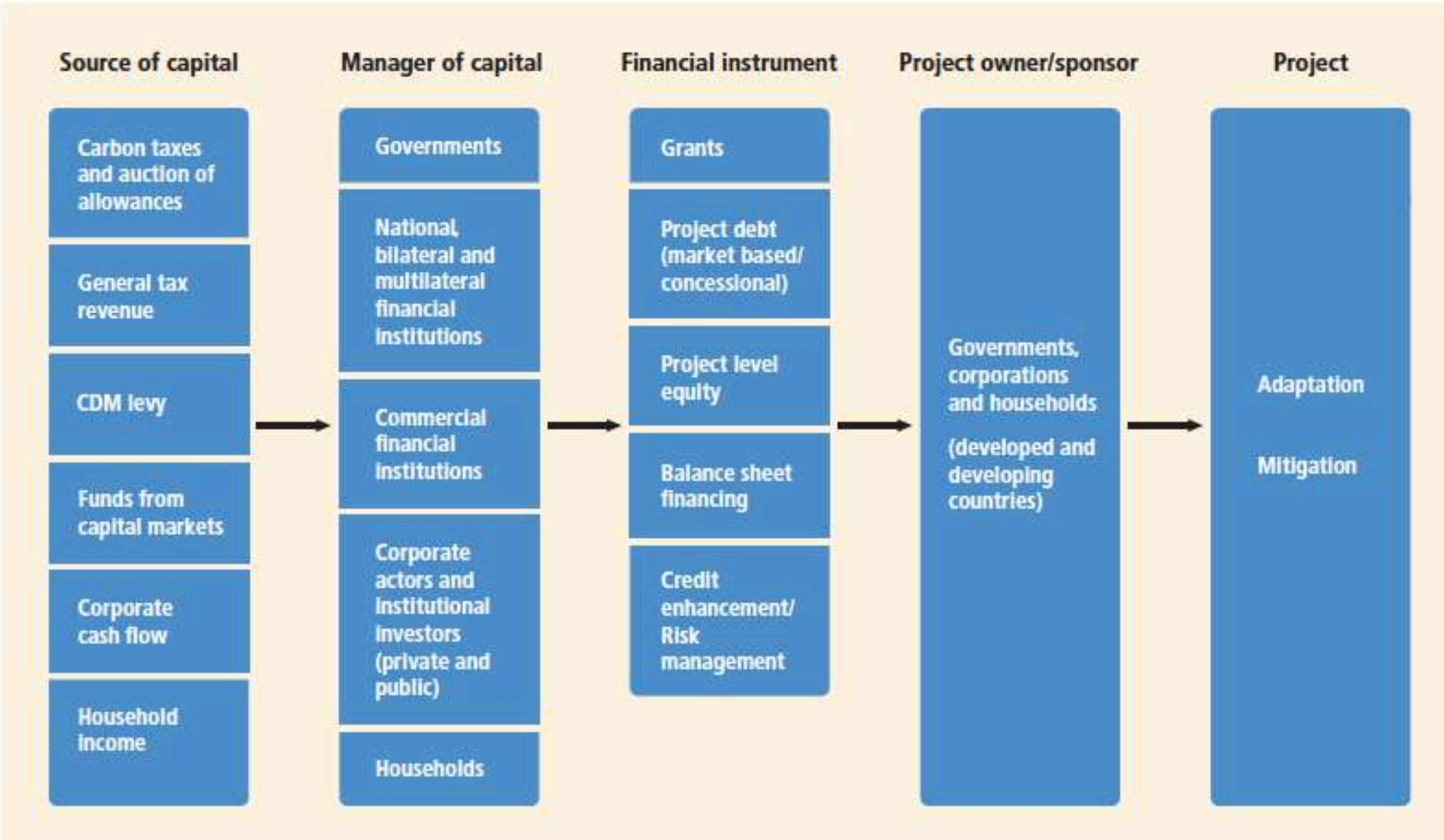


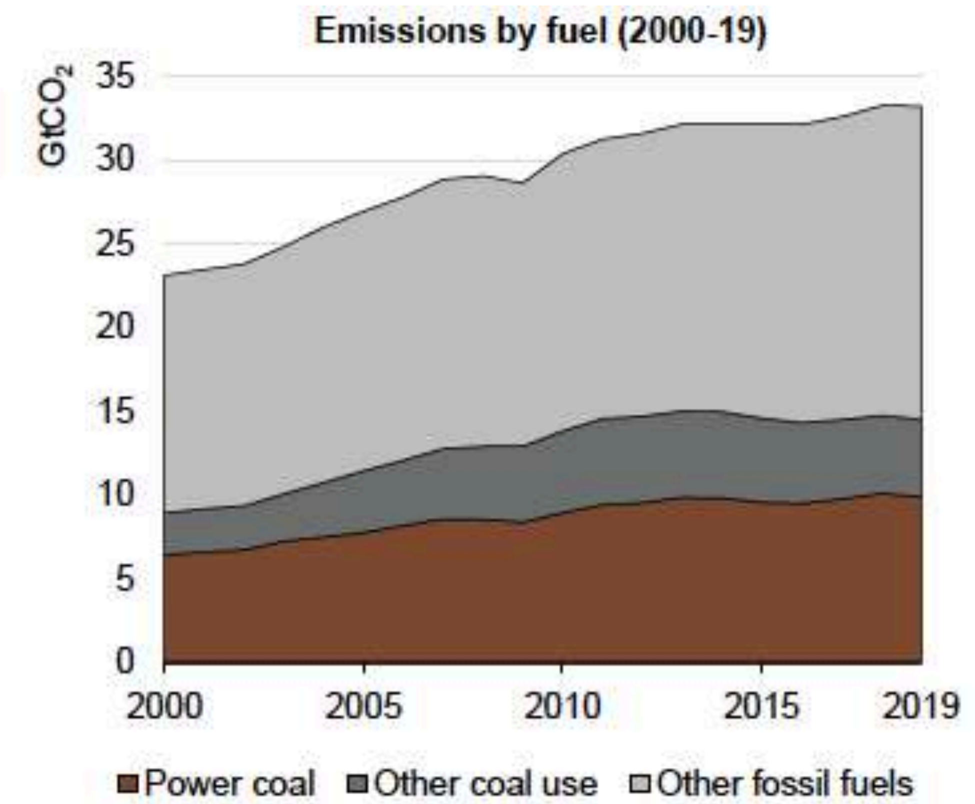
Table 4.7 | Sectoral Policy Instruments. *{WGIII Table 15.2}*

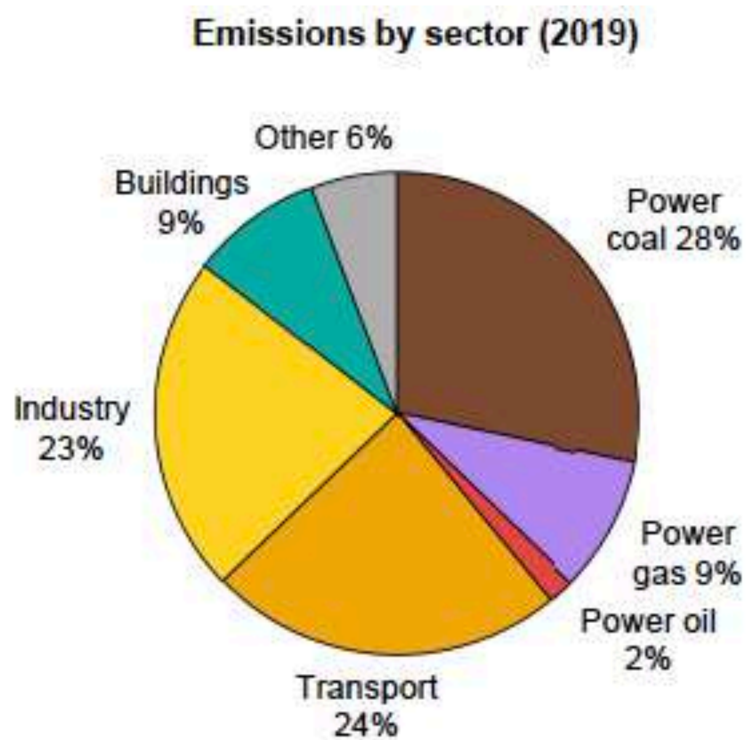
Policy Instruments	Energy	Transport	Buildings	Industry	AFOLU	Human Settlements and Infrastructure
Economic Instruments – Taxes (carbon taxes may be economy-wide)	- Carbon tax (e.g., applied to electricity or fuels)	- Fuel taxes - Congestion charges, vehicle registration fees, road tolls - Vehicle taxes	- Carbon and/or energy taxes (either sectoral or economy-wide)	- Carbon tax or energy tax - Waste disposal taxes or charges	- Fertilizer or nitrogen taxes to reduce nitrous oxide (N_2O)	- Sprawl taxes, Impact fees, exactions, split-rate property taxes, tax increment finance, betterment taxes, congestion charges
Economic Instruments – Tradable Allowances (may be economy-wide)	- Emission trading - Emission credits under the Clean Development Mechanism (CDM) - Tradable Green Certificates	- Fuel and vehicle standards	- Tradable certificates for energy efficiency improvements (white certificates)	- Emission trading - Emission credits under CDM - Tradable Green Certificates	- Emission credits under CDM - Compliance schemes outside Kyoto protocol (national schemes) - Voluntary carbon markets	- Urban-scale cap and trade
Economic Instruments – Subsidies	- Fossil fuel subsidy removal - Feed in tariffs (FITs) for renewable energy	- Biofuel subsidies - Vehicle purchase subsidies - Feebates	- Subsidies or tax exemptions for investment in efficient buildings, retrofits and products - Subsidized loans	- Subsidies (e.g., for energy audits) - Fiscal incentives (e.g., for fuel switching)	- Credit lines for low-carbon agriculture, sustainable forestry	- Special Improvement or Redevelopment Districts
Regulatory Approaches	- Efficiency or environmental performance standards - Renewable Portfolio Standards (RPS) for renewable energy (RE) - Equitable access to electricity grid - Legal status of long-term CO_2 storage	- Fuel economy performance standards - Fuel quality standards - Greenhouse gas (GHG) emission performance standards - Regulatory restrictions to encourage modal shifts (road to rail) - Restriction on use of vehicles in certain areas - Environmental capacity constraints on airports - Urban planning and zoning restrictions	- Building codes and standards - Equipment and appliance standards - Mandates for energy retailers to assist customers invest in energy efficiency	- Energy efficiency standards for equipment - Energy management systems (also voluntary) - Voluntary agreements (where bound by regulation) - Labelling and public procurement regulations	- National policies to support REDD+ including monitoring, reporting and verification - Forest laws to reduce deforestation - Air and water pollution control GHG precursors - Land use planning and governance	- Mixed use zoning - Development restrictions - Affordable housing mandates - Site access controls - Transfer development rights - Design codes - Building codes - Street codes - Design standards
Information Programmes		- Fuel labelling - Vehicle efficiency labelling	- Energy audits - Labelling programmes - Energy advice programmes	- Energy audits - Benchmarking - Brokerage for industrial cooperation	- Certification schemes for sustainable forest practices - Information policies to support REDD+ including monitoring, reporting and verification	
Government Provision of Public Goods or Services	- Research and development - Infrastructure expansion (district heating/cooling or common carrier)	- Investment in transit and human powered transport - Investment in alternative fuel infrastructure - Low-emission vehicle procurement	- Public procurement of efficient buildings and appliances	- Training and education - Brokerage for industrial cooperation	- Protection of national, state, and local forests. - Investment in improvement and diffusion of innovative technologies in agriculture and forestry	- Provision of utility infrastructure, such as electricity distribution, district heating/cooling and wastewater connections, etc. - Park improvements - Trail improvements - Urban rail
Voluntary Actions			- Labelling programmes for efficient buildings - Product eco-labelling	- Voluntary agreements on energy targets, adoption of energy management systems, or resource efficiency	- Promotion of sustainability by developing standards and educational campaigns	


Source of capital
Manager of capital
Financial instrument
Project owner/sponsor
Project
Carbon taxes and auction of allowances
General tax revenue
CDM levy
Funds from capital markets
Corporate cash flow
Household income
Governments
National, bilateral and multilateral financial institutions
Commercial financial institutions
Corporate actors and institutional investors (private and public)
Households
Grants
Project debt (market based/ concessional)
Project level equity
Balance sheet financing
Credit enhancement/ Risk management
Governments, corporations and households
(developed and developing countries)
Adaptation
Mitigation

- Energy system design for climate change

Global energy-related CO2 emissions by fuel (left) and sector (right), 2000-19





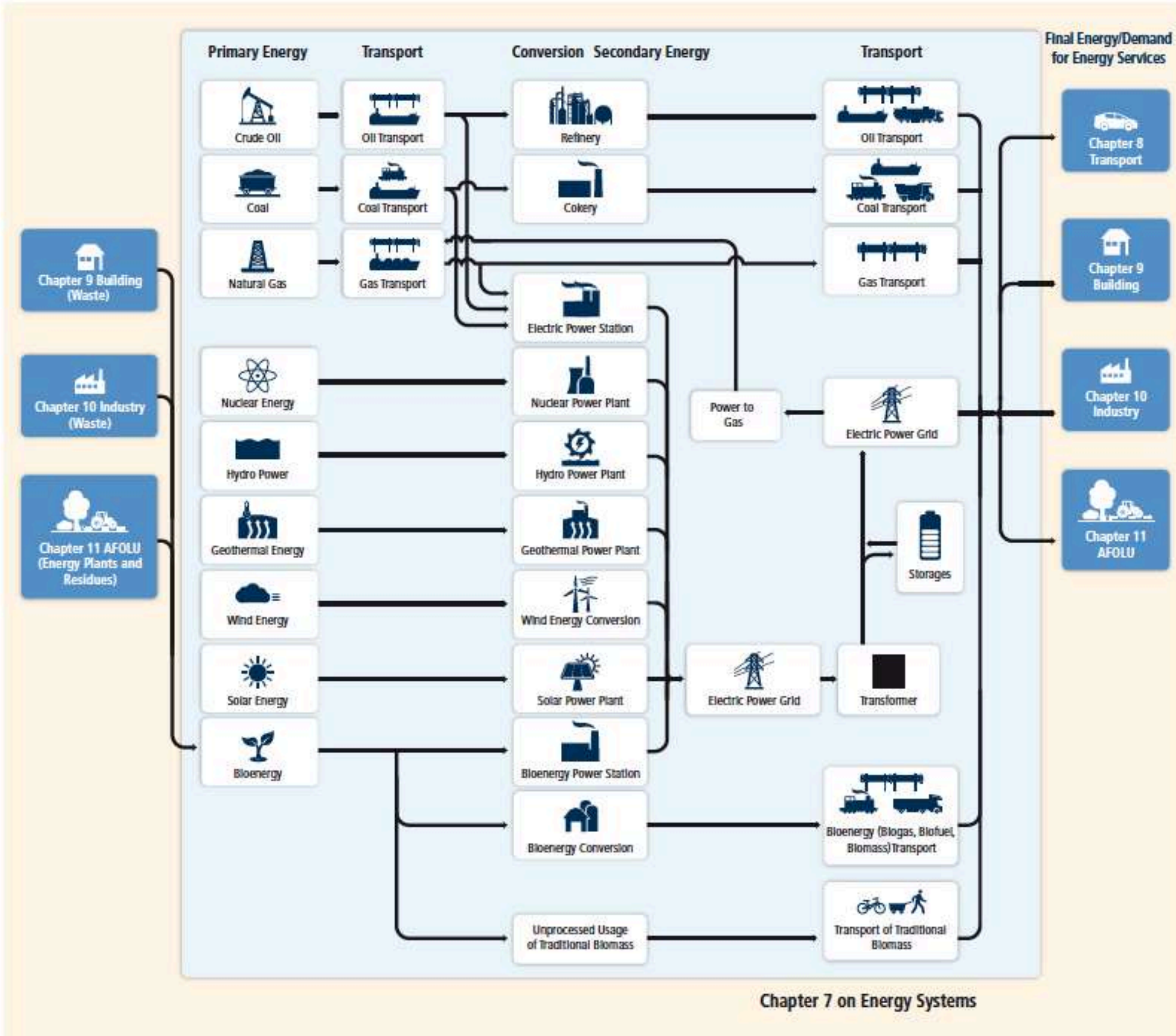
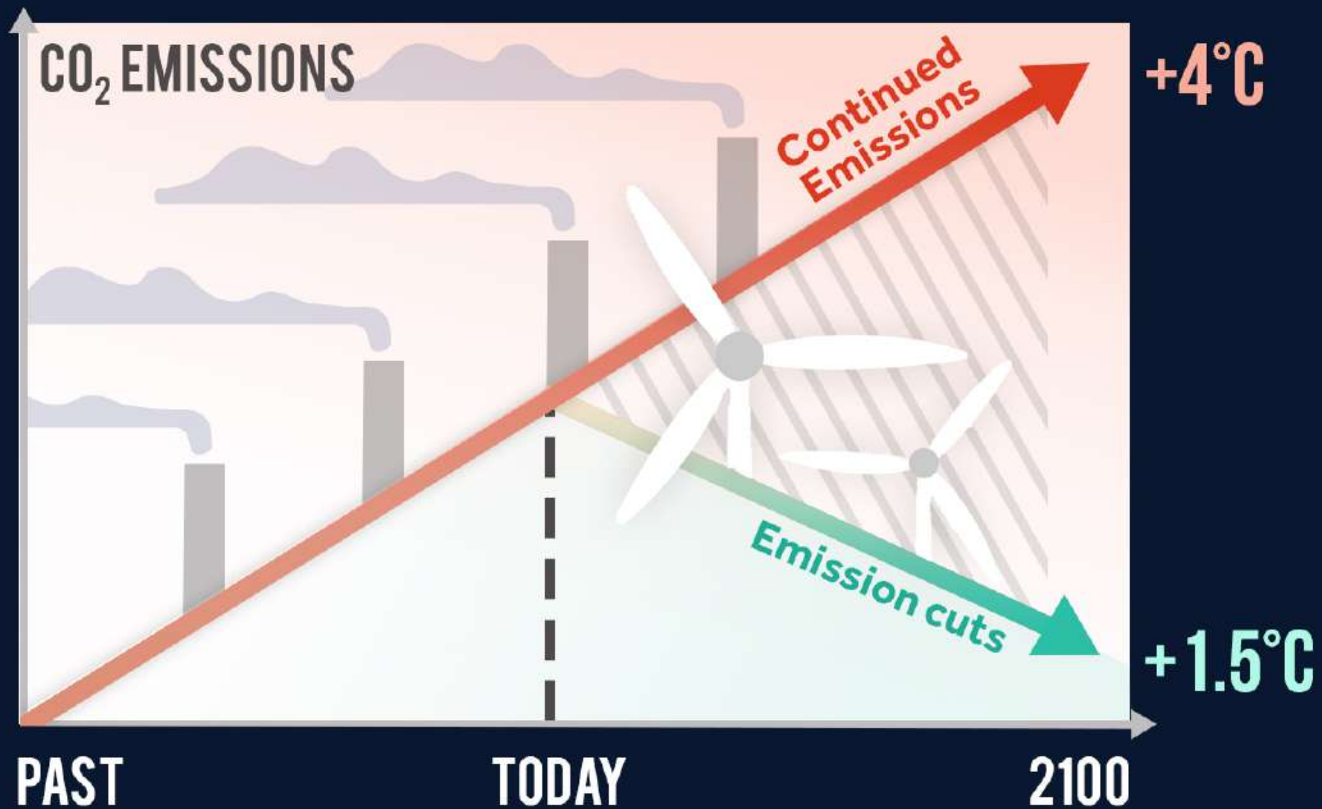


Figure 7.1 | Illustrative energy supply paths shown in order to illustrate the boundaries of the energy supply sector as defined in this report. The self-generation of heat and power in the end-use sectors (i.e., transport, buildings, industry, and Agriculture, Forestry, and Other Land Use (AFOLU)) is discussed in Chapters 8–11.

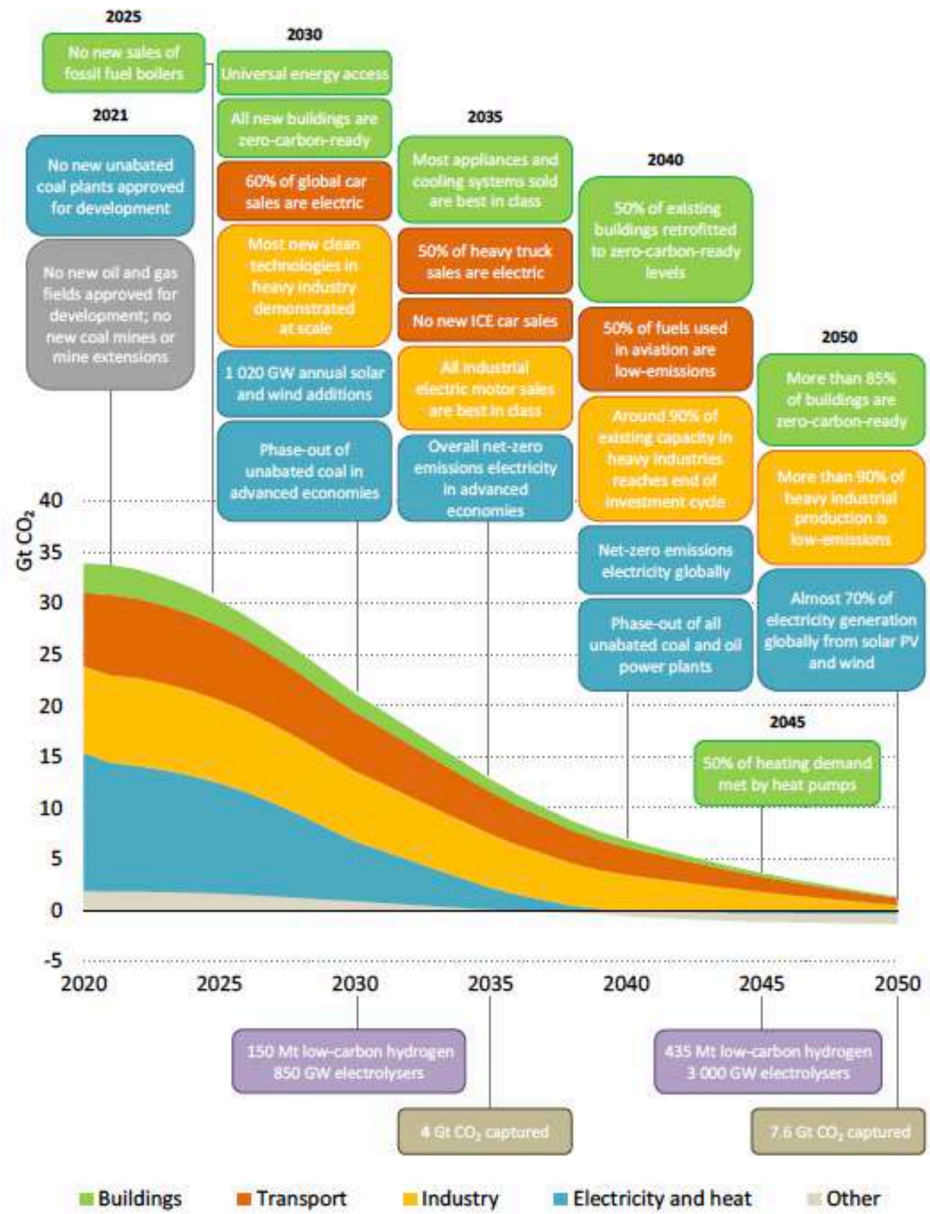
We Need to Make Big Cuts, Fast



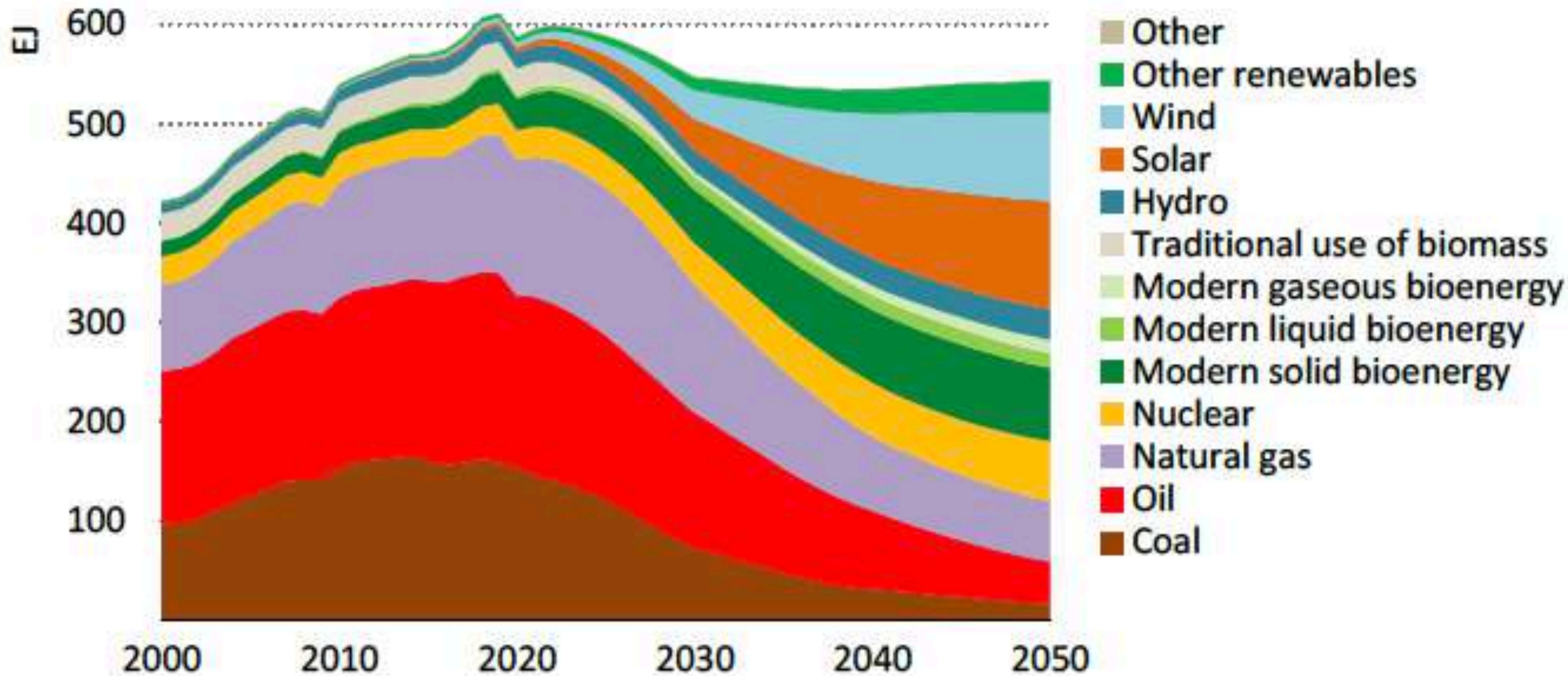
SERIOUS

Source: Climate Central

Key milestones in the pathway to net zero

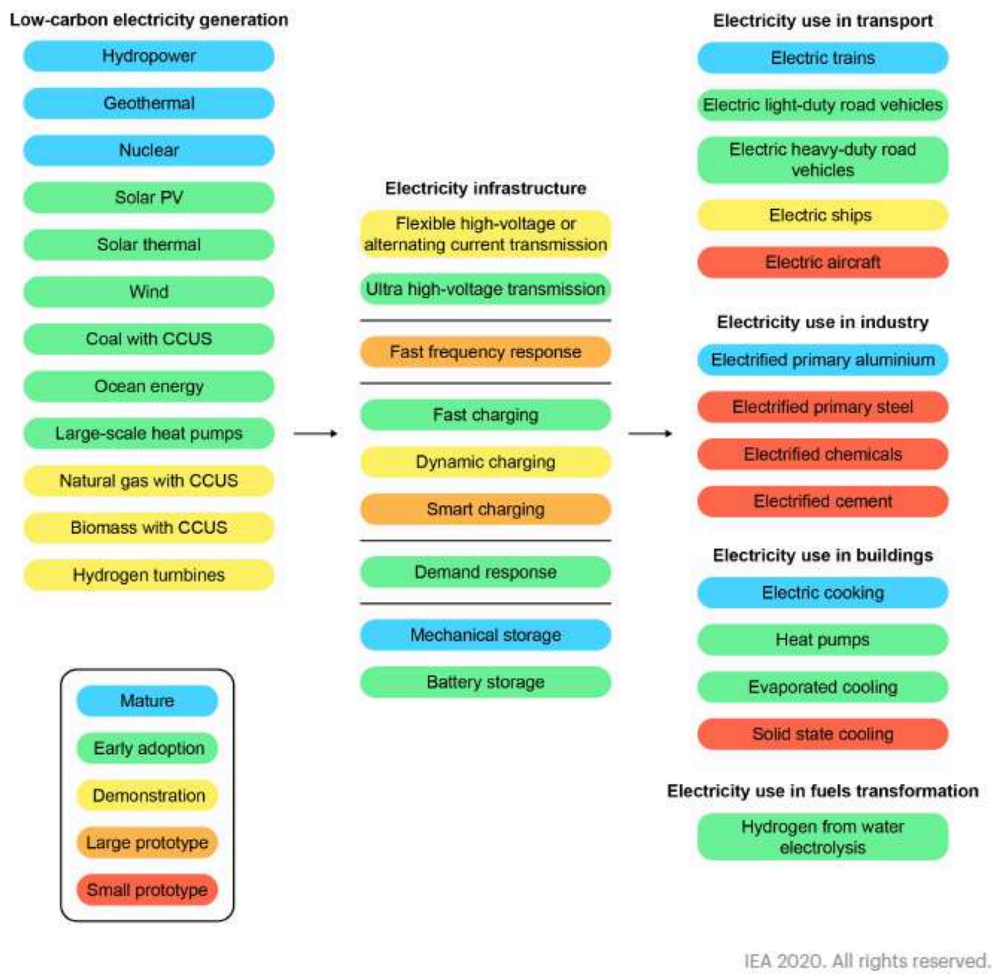


Total energy supply in the NZE



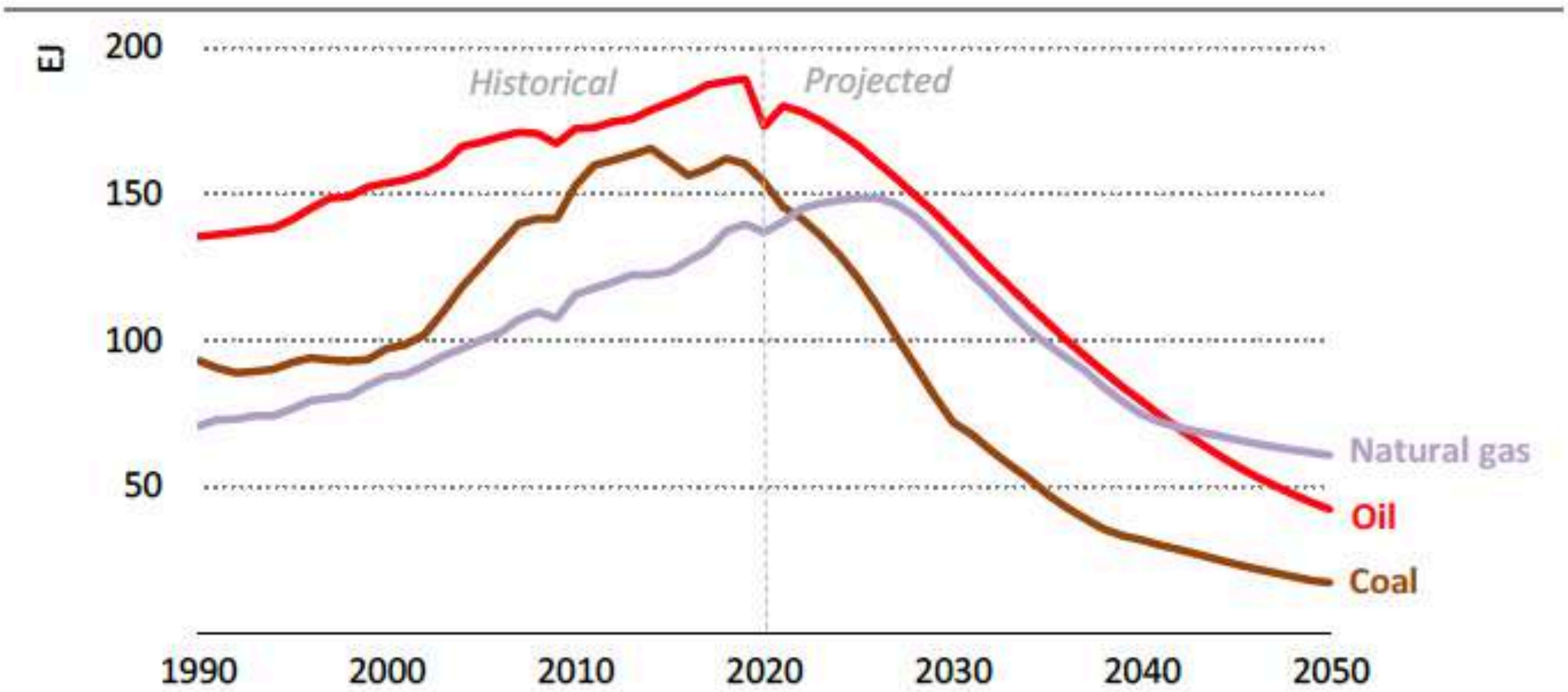
Renewables and nuclear power displace most fossil fuel use in the NZE, and the share of fossil fuels falls from 80% in 2020 to just over 20% in 2050

Technology readiness level of technologies along the low-carbon electricity value chain



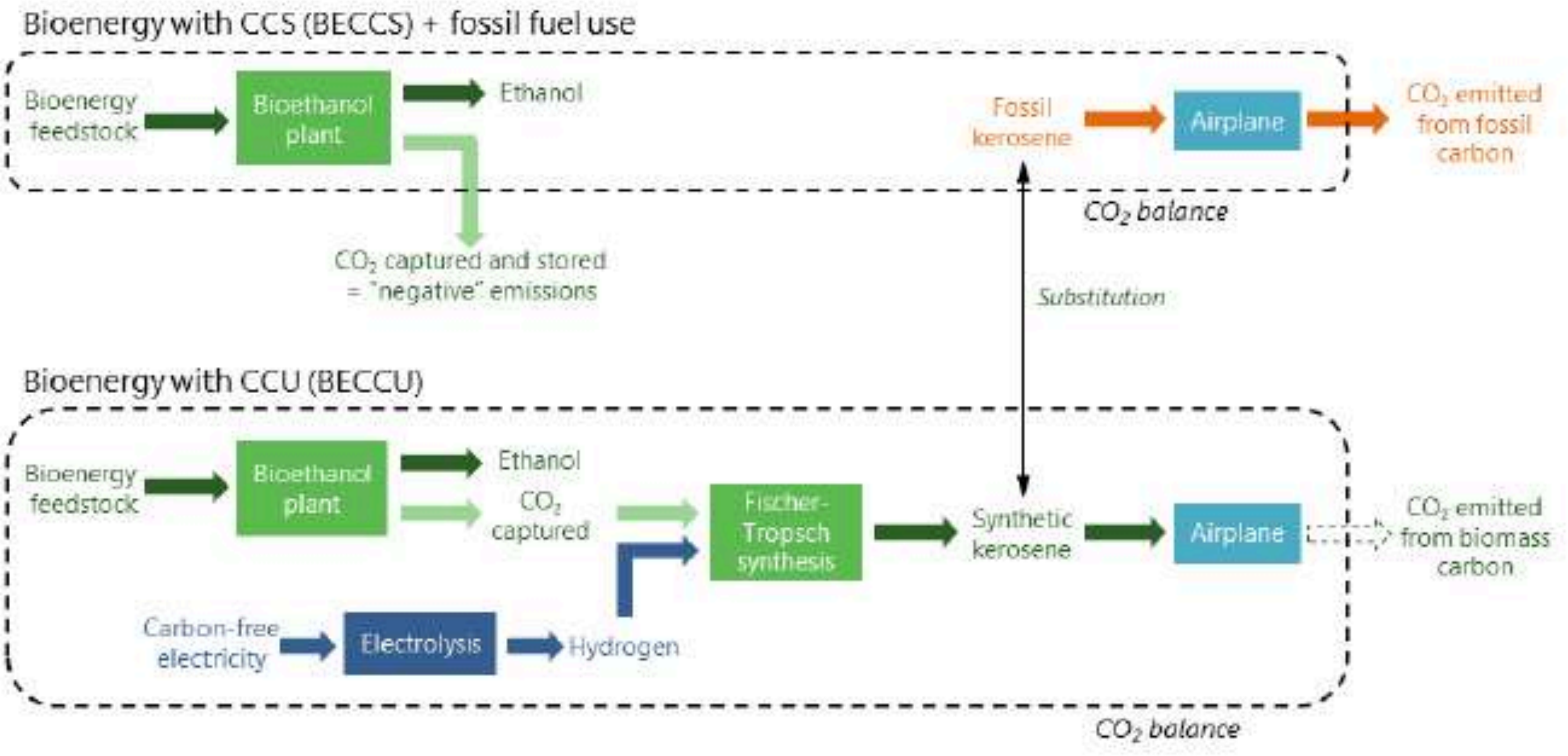
Source: IEA, 2020

Coal, oil and natural gas production in the NZE



Between 2020 and 2050, demand for coal falls by 90%, oil by 75%, and natural gas by 55%

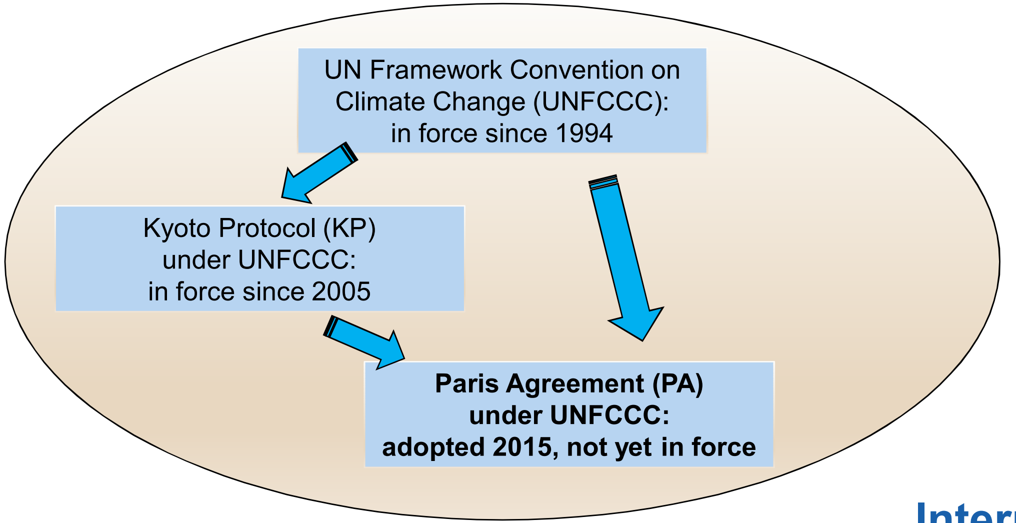
CCS&BECCS



BECCU can have an impact on CO_2 emissions similar to BECCS, as long as the produced hydrocarbon fuel can substitute for fossil fuels. A unique feature of BECCS is that it can create negative emissions.

- International commitment & Policy

International climate change regime: UNFCCC and its legal instruments



International climate change regime: evolution from Rio (1992) to Paris (2015)

UNFCCC (Climate Change Convention), with 196 "Parties":

- one of the three "Rio Conventions", adopted at "Rio Earth Summit" (1992); entered into force in 1994
- ultimate aim = preventing "dangerous" human interference with the climate system

Two major groups of Parties under the UNFCCC:

- Annex I Parties ("developed countries")
- Non-Annex I Parties ("developing countries")

Kyoto Protocol, with 192 Parties:

- a "Protocol" to the Convention, adopted in Kyoto, Japan, in 1997; entered into force in 2005
- introduced legally-binding targets/commitments to reduce/limit GHG emissions and more stringent reporting/review requirements
- these targets and rules apply only to Annex I countries

Paris Agreement (Paris, 2015):

- adopted in 2015, already signed by more than 180 countries
- not yet legally in force; conditions for entry into force to be fulfilled: ratification by 55 countries accounting for 55% of global emissions
- agreement for all Parties, with flexibility for developing countries

Source: UNFCC

International climate change regime: reporting / data requirements before Paris

Foundation: Articles 4 and 12 of the Convention

- Each Party, taking into account their common but differentiated responsibilities … to develop, periodically update, publish and communicate, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies… ”
- Each Party to communicate a “description of steps taken or envisaged to implement the Convention”
- Exact provisions are detailed in specific decisions/guidelines

Main reporting mechanisms:

- National communications, GHG inventories, biennial reports, biennial update reports…

GHGs to report on:

- Direct GHGs: CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3
- Indirect GHGs: CO, NO_x, NMVOCs, SO_x

Annex I / non-Annex I Parties have different requirements

- Different methodological basis (versions of IPCC guidelines)
- More extensive and frequent reporting for Annex I Parties
- Reporting by non-Annex I Parties is conditioned by funding
- Annex I Parties have a rigorous review process

Paris Agreement: COP-21, Paris, Dec.2015

Article 2.1. This Agreement, in enhancing the implementation of the Convention … aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the increase to 1.5°C above pre-industrial levels…

Article 4.1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of GHG emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter…, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the 2nd half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

Source: UNFCC

Paris Agreement COP 21

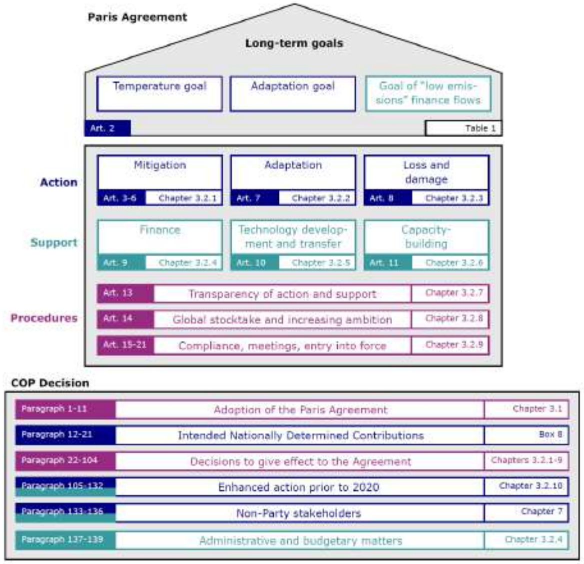
The Paris Agreement is a bridge between today's policies and climate-neutrality before the end of the century.

Mitigation: reducing emissions

Governments agreed

- a long-term goal of keeping the increase in global average temperature to **well below 2°C** above pre-industrial levels;
- to aim to limit the increase to **1.5°C**, since this would significantly reduce risks and the impacts of climate change;
- on the need for **global emissions to peak as soon as possible**, recognising that this will take longer for developing countries;
- to undertake **rapid reductions thereafter** in accordance with the best available science.

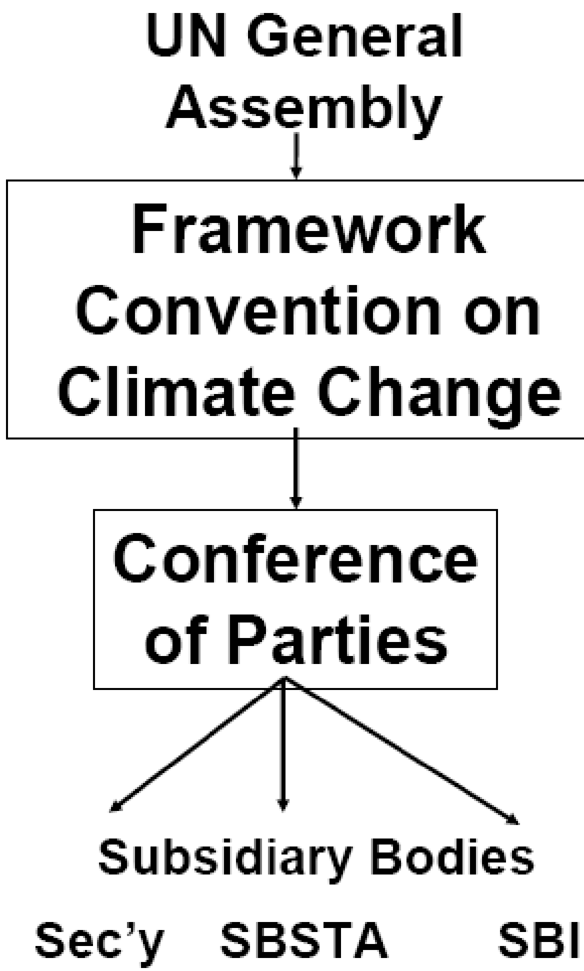
Before and during the Paris conference, countries submitted comprehensive **national climate action plans** ([INDCs]()). These are not yet enough to keep global warming below 2°C, but the agreement traces the way to achieving this target.

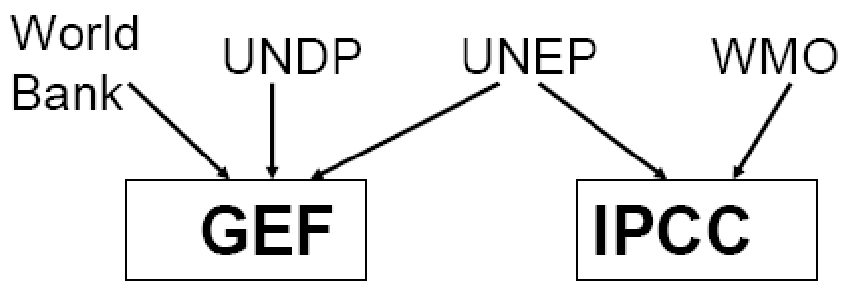


Acronyms: International Institutions

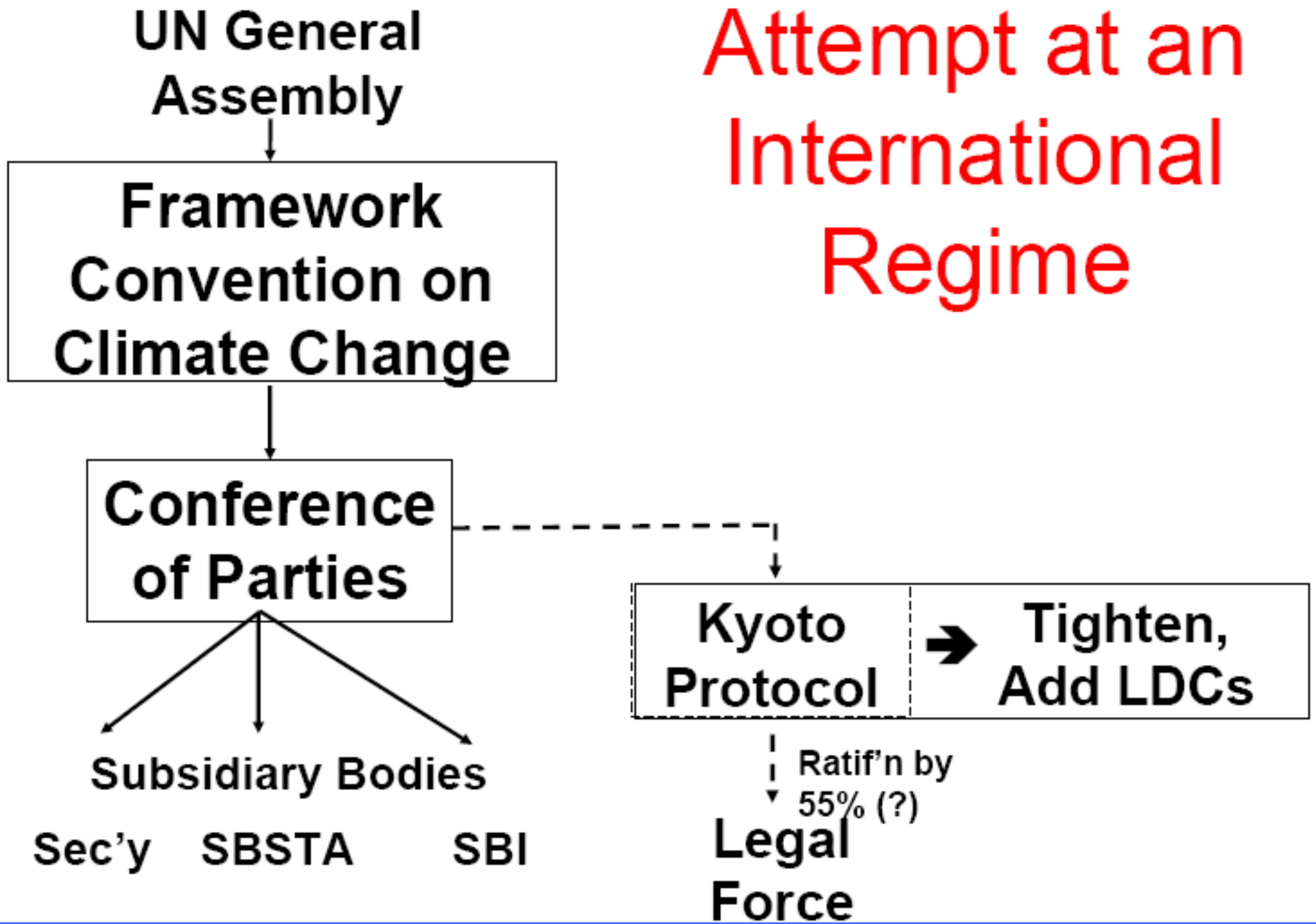
• FCCC	Framework Convention on Climate Change
• AGBM	Ad-Hoc Group on the Berlin Mandate
• SBSTA	Subsidiary Body on Scientific and Technical Advice (FCCC)
• SBI	Subsidiary Body on Implementation (FCCC)
• COP	Conference of the Parties (FCCC)
• MOP	Members of the (Kyoto) Protocol
• IPCC	Intergovernmental Panel on Climate Change
• GEF	Global Environmental Facility ($$)
• WMO	World Meteorological Organization
• UNEP	U.N. Environment Program

Structure of Institutions





Attempt at an International Regime



Acronyms: National Groupings

- Annex I = OECD + Economies in Transition
  - OECD = EU + USA, Canada, Australia, New Zealand, Scandinavia, Austria (rich nations)
  - EIT = Econ's in Transition (Russia, others of former Soviet Union, Eastern Europe)
- Annex B Slight variation on Annex I
- Annex II OECD, with special responsibilities
- Non-Annex I Developing Countries
- G-77 & China Coalition of developing nations
- EU "bubble" EU burden-sharing agreement
- Umbrella G'p Japan, US, Canada, Aus. & New Zealand

Acronyms: International Institutions

• FCCC	Framework Convention on Climate Change
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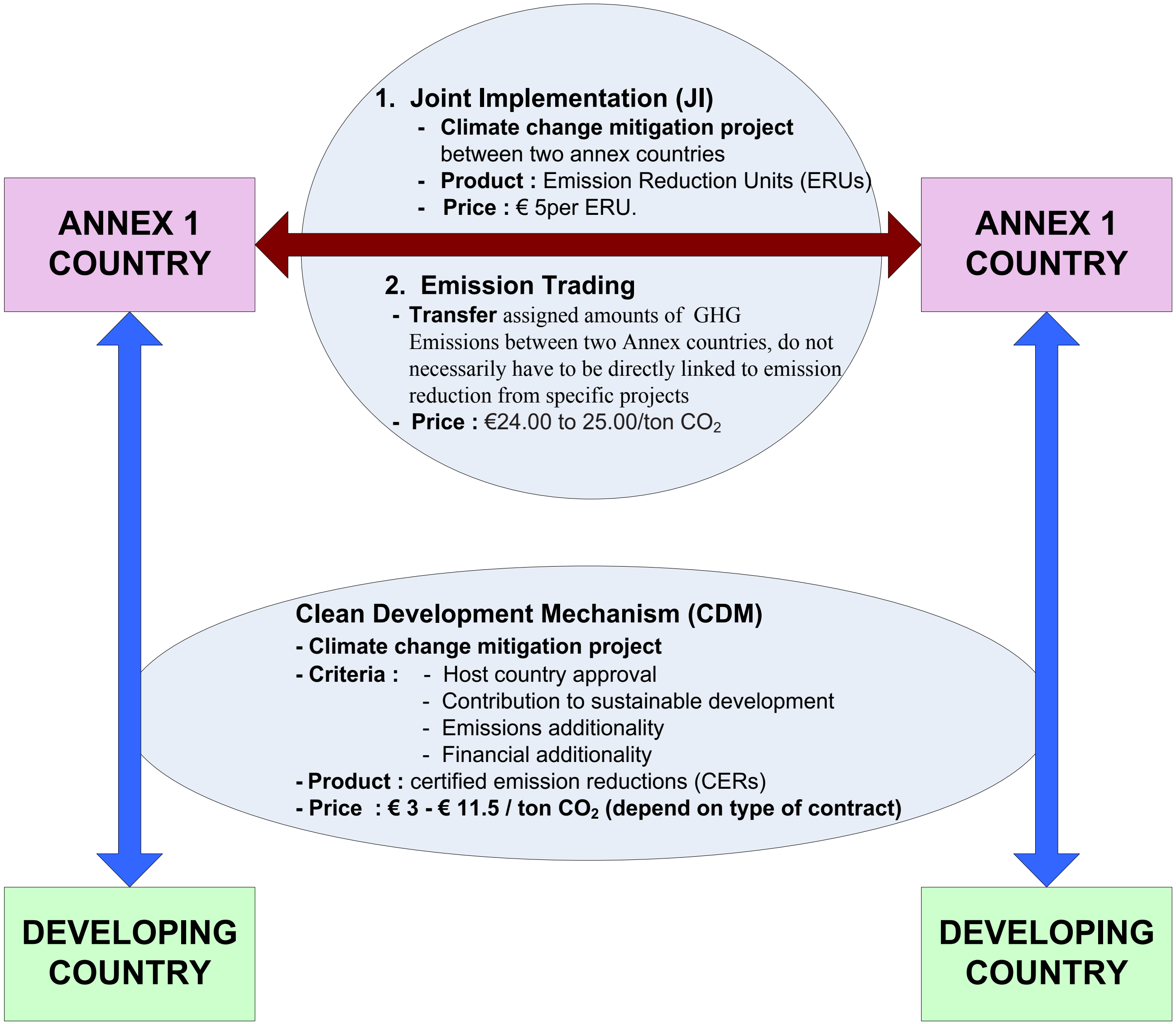
Carbon Trading



The Clean Development Mechanism (CDM)

Eligibility Criteria :

- Host country approval
- Contribution to sustainable development
- Emissions additionality
- Financial additionality

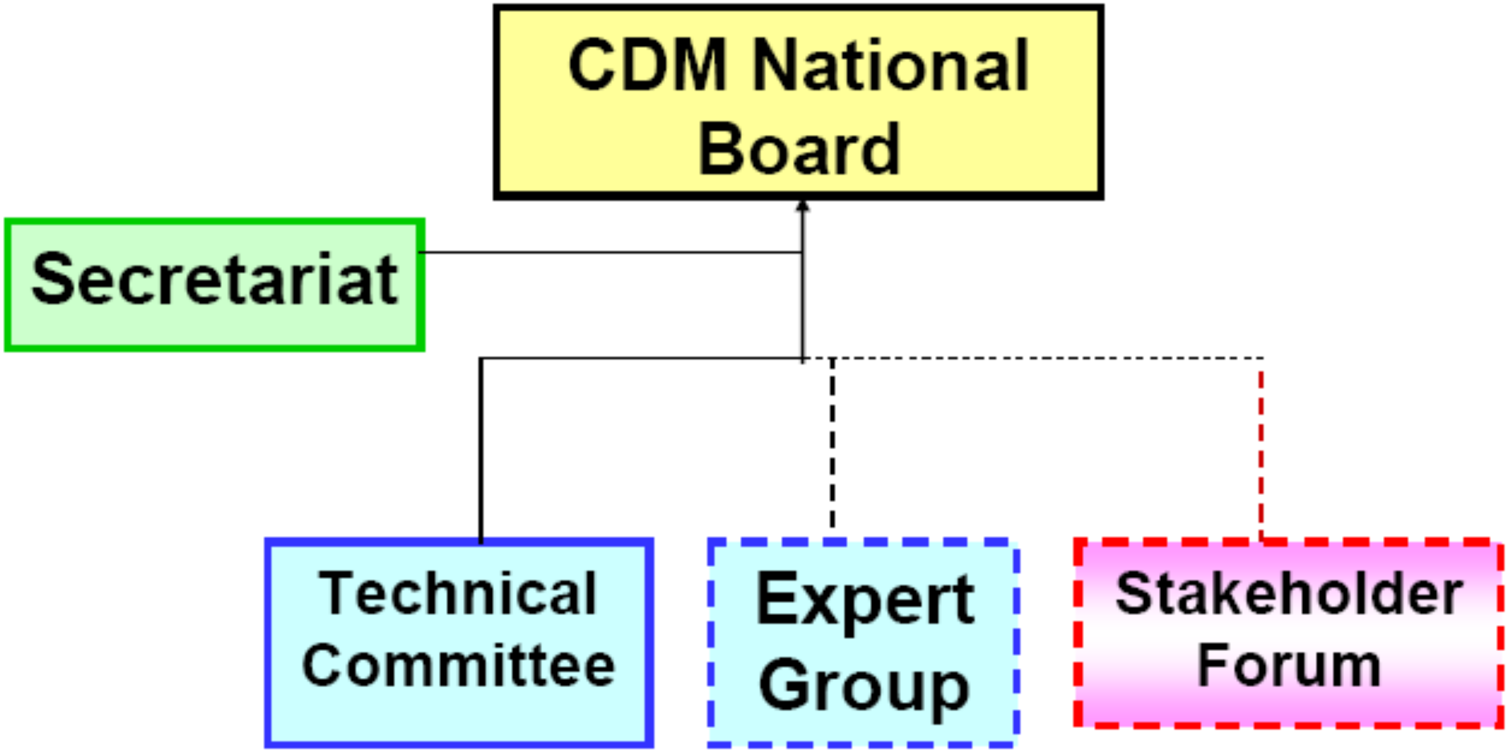
CDM-Indonesia

- Ratification of the UNFCCC (act no. 6/1994)
  - Indonesia committed to participate in the global climate change mitigation and adaptation programmes
- Ratification of the Kyoto Protocol (act no. 17/2004)
  - Opportunities for Indonesia to implement CDM

1. Indonesia's DNA on CDM

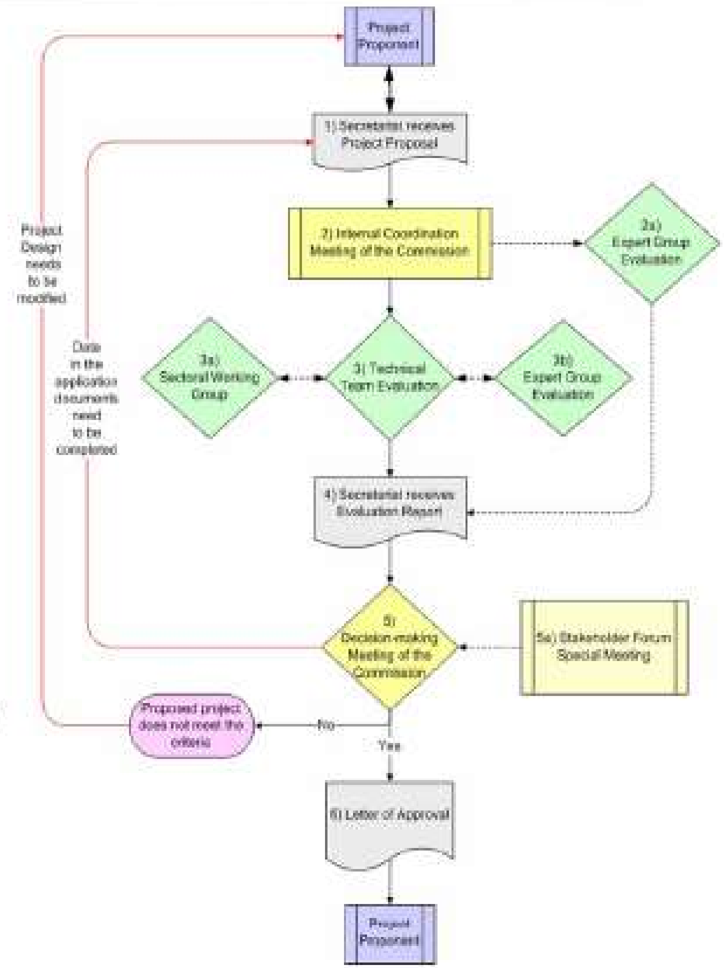
- *Komisi Nasional Mekanisme Pembangunan Bersih* (Nat'l Committee on CDM)
- Established in July 2005 by the Minister of Environment Devree no. 206/2005
- Tasks:
  - Provide approval → evaluate CDM project proposal according to criteria and indicators of sustainable development
  - Submit the result of tracking
  - Monitoring and evaluation

2. Ministry of Forestry Decree 14/2004 on A/R CDM


CDM National Board
Secretariat
Technical Committee
Expert Group
Stakeholder Forum

Procedure for CDM project approval

1. The Secretariat receives and checks that the application documents are complete
2. Internal Coordination Meeting between Members of the Commission to decide whether or not to assign Expert Advisors to perform an additional evaluation to the Project Proposal as second opinion.
3. The Commission assigns members of Technical Team to evaluate Project Proposals based on sustainable development criteria and indicators
4. Technical Team submits the Evaluation Report and Expert Advisors submit the Additional Evaluation Report to the Secretariat. Secretariat then passes both reports to the Members of the Commission
5. Members of the Commission make a decision whether the Project Proposal will be given Approval or Rejection in The National Commission Decision-making Meeting.
6. The Secretariat gives the Approval Letter from NCCDM to the Project Proponent

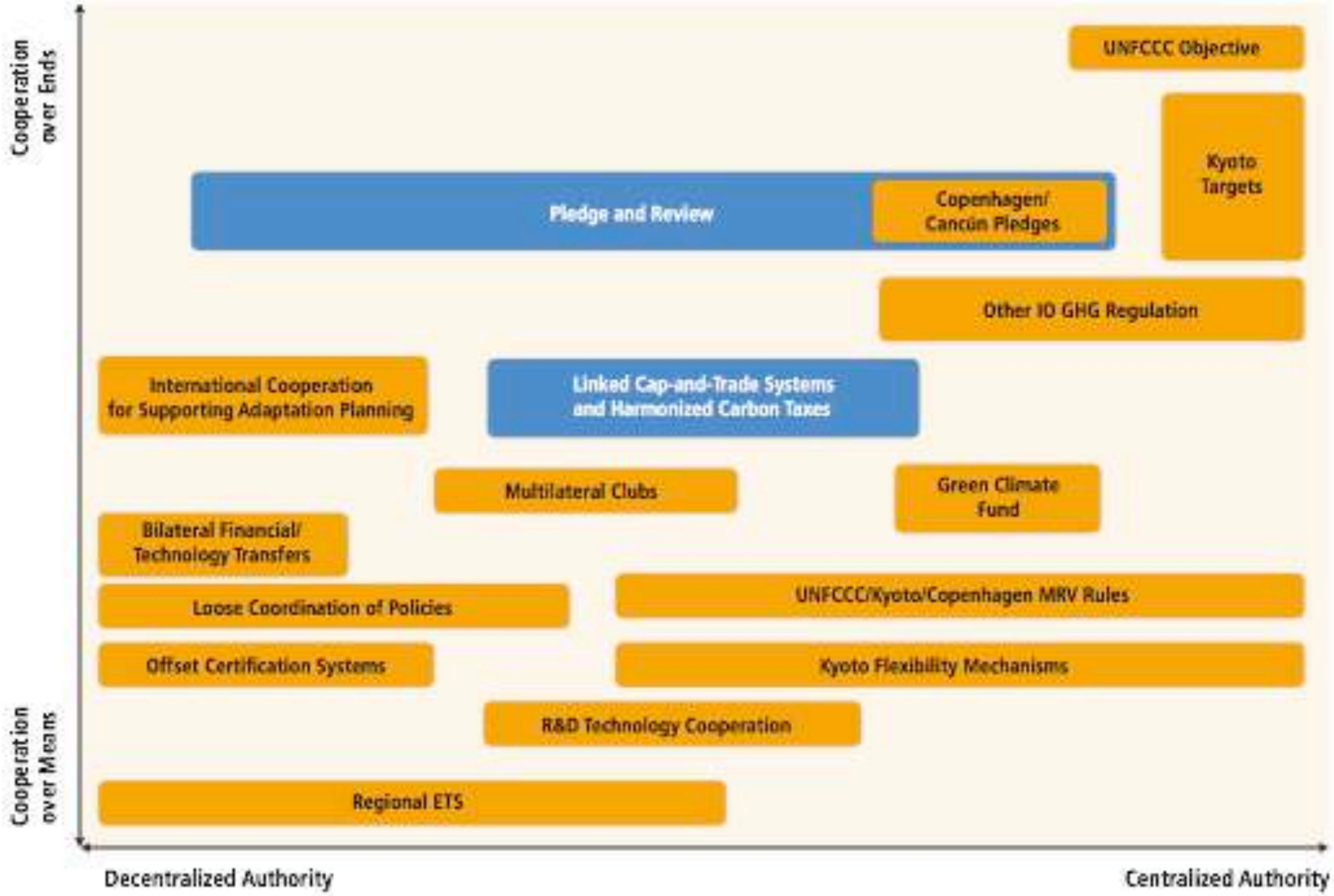


CER Price Categorisation

- The **”World Bank” contract:**
  - Few preconditions.
  - Average Prices: US$ 3.8 early 2004 to US$ 5.1 recently.
- The **standard off-take contract:**
  - Contract is only valid on a set of preconditions.
  - Average prices: US$ 5.1 early 2004 to US$ 8.2 recently.
- The **guaranteed delivery contract:**
  - Contract is only valid on a set of preconditions (including some warranties).
  - Average prices: US$ 5.1 early 2004 to US$ 12 recently.
- The **exchange contract:**
  - Non-delivery: seller pays EUA mark-to market/liquidated damages CERs or cash.
  - Average prices: US$ 8.2 early 2005 to US$ 14.6 recently.

CDM In Indonesia = US$ 1.83/Ton CO_2

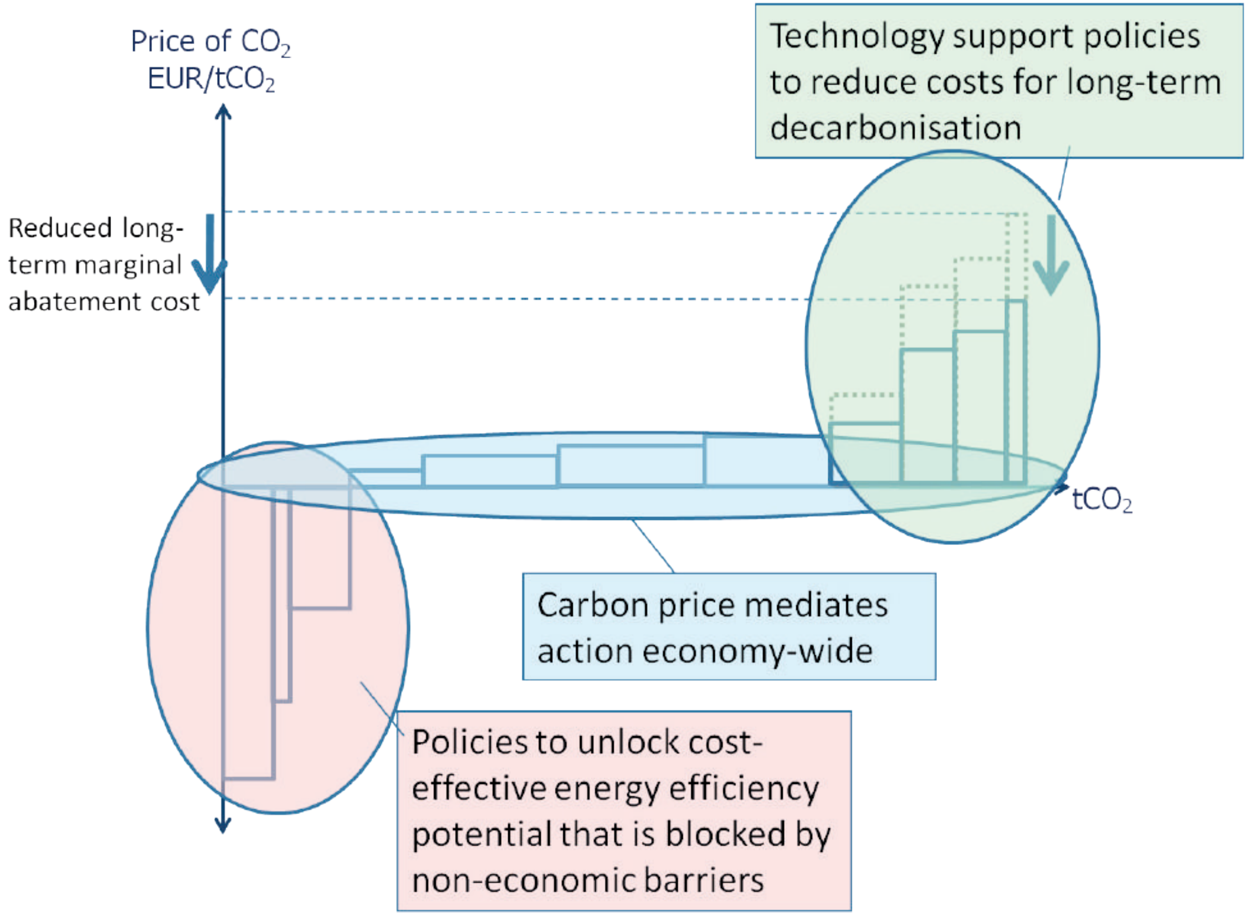
Alternative forms of international cooperation



Loose coordination of policies: examples include transnational city networks and Nationally Appropriate Mitigation Actions (NAMAs); R&D technology cooperation: examples include the Major Economies Forum on Energy and Climate (MEF), Global Methane Initiative (GMI), or Renewable Energy and Energy Efficiency Partnership (REEEP); Other international organization (IO) GHG regulation: examples include the Montreal Protocol, International Civil Aviation Organization (ICAO), International Maritime Organization (IMO).

Source: IPCC

The core policy mix: a carbon price, energy efficiency and technology policies



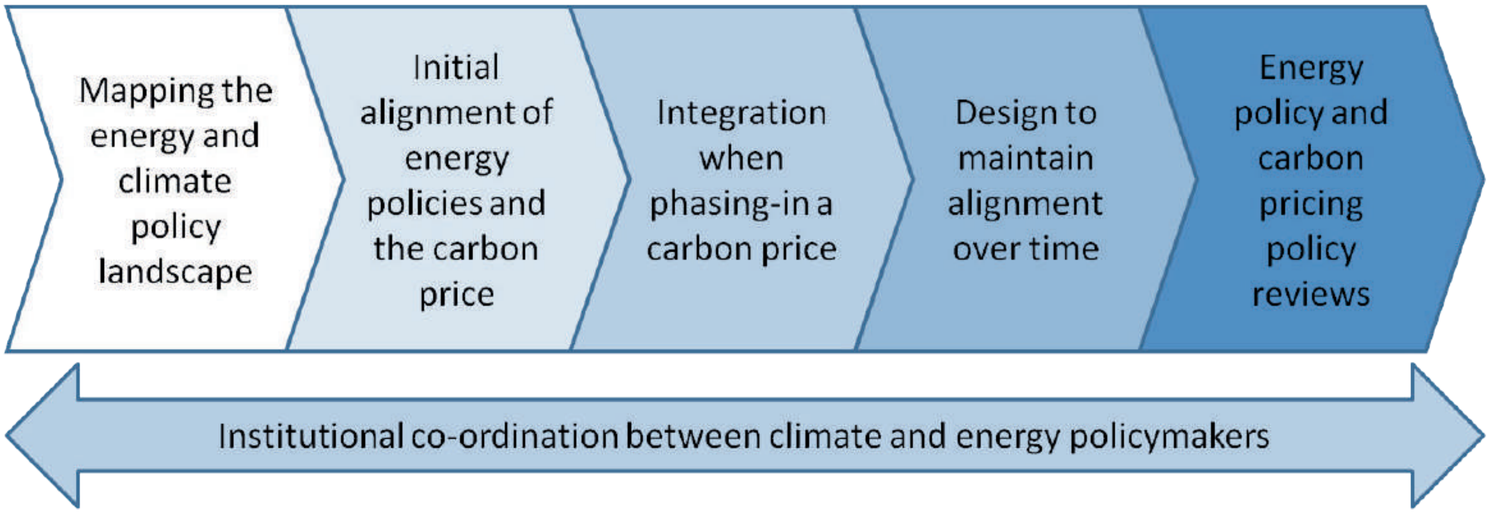
Source: Hood (2011)

Note: unless otherwise indicated, all material in figures and tables derives from IEA data and analysis.

Source: IEA

Integration energy and climate

Figure 8 • Steps for integration of energy and climate policies



Source: IEA

A wide range of energy and climate policies reduce GHGs

Policy Type	Policy options
Price-based instruments	Taxes on CO_2 directly Taxes/charges on inputs or outputs of process (*e.g.* fuel and vehicle taxes) Subsidies for emissions-reducing activities Emissions trading systems (cap and trade or baseline and credit)
Command and control regulations	Technology standards (*e.g.* biofuel blend mandate, minimum energy performance standards) Performance standards (*e.g.* fleet average CO_2 vehicle efficiency) Prohibition or mandating of certain products or practices Reporting requirements Requirements for operating certification (*e.g.* HFC handling certification) Land use planning, zoning
Technology support policies	Public and private RD&D funding Public procurement Green certificates (renewable portfolio standard or clean energy standard) Feed-in tariffs Public investment in underpinning infrastructure for new technologies Policies to remove financial barriers to acquiring green technology (loans, revolving funds)
Information and voluntary approaches	Rating and labelling programmes Public information campaigns Education and training Product certification and labelling Award schemes

Source: Hood (2011), based on de Serres, Murtin and Nicolleti (2010).

Source: IEA

Box 2 • Different purposes and design of carbon taxes in Norway, Switzerland, and Japan

Norway

Norway's CO_2 tax was introduced in 1991, to provide a cost-effective way to reduce emissions. It is applied to oil products, emissions from oil and gas production, and gas used for heating and transport. This was followed by introduction of a Norwegian ETS in 2005, and Norway joining the EU ETS in 2008. Sectors covered by the EU ETS were generally exempted from the carbon tax, with the exception of the offshore oil and gas sector – here the carbon tax level was reduced so that the combined incentive of carbon tax plus EU ETS price is equivalent to levels prior to the introduction of emissions trading. As this sector accounts for 25% of Norway's emissions, it was considered important not to reduce the incentive for emissions reductions in this sector when emissions trading began. From 2013 the tax level has been increased to offset the falling EU ETS allowance price. The CO_2 tax on offshore oil and gas production has been the key policy driver of carbon capture and storage at production facilities. (Hertzberg, 2013)

Switzerland

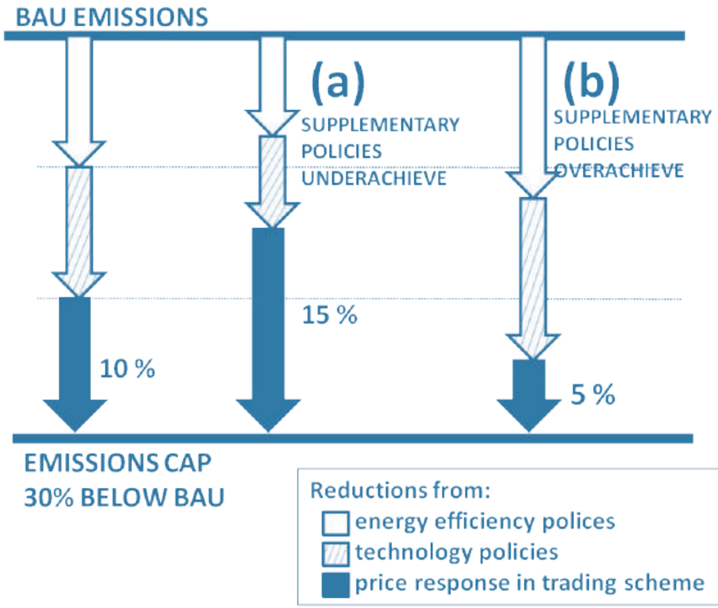
The Swiss CO_2 levy is intended as an incentive for energy efficiency and for shifting toward cleaner heating and process fuels, not to raise revenue. Revenue raised is redistributed to the population and economy. It has been in place since 2008, starting at a level of 12 CHF/tCO_2. The law governing the CO_2 levy provides for automatic increases in the levy level if predefined emissions reduction objectives are not met. As a result, the levy was raised to 36 CHF/tCO_2 in 2010, and further increases up to 120 CHF/tCO_2 are possible from 2014. (Mortier, 2013)

Japan

In October 2012 Japan introduced a new carbon tax, with the aim of raising revenue for energy efficiency and renewable energy programmes, not as a direct price incentive. This is in part because Japan already has high energy prices and efficient use of energy: the government's analysis found that use of revenue raised is more powerful in reducing emissions than response to the price itself. The tax starts at a level of JPY 289/tCO2, and will increase gradually over 3½ years. (Kihara, 2013)

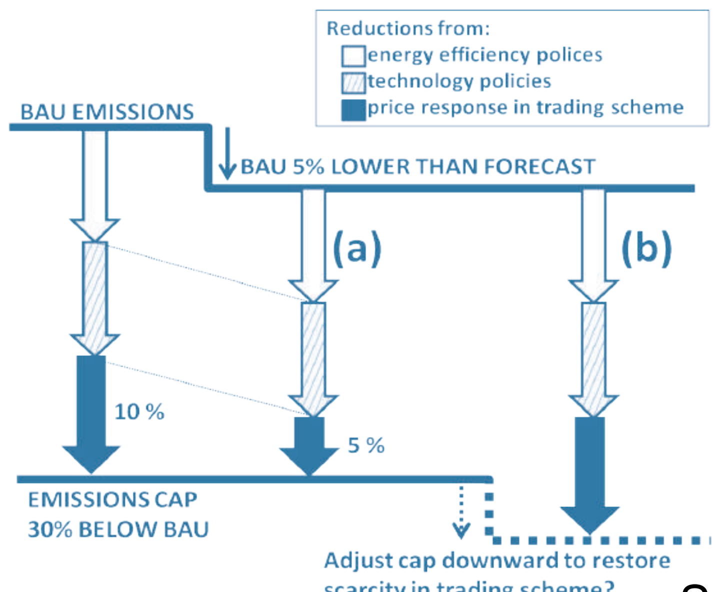
Source: IEA

Figure 6 • Policy interactions can significantly impact ETS prices



Source: Hood (2011)

Figure 7 • Energy policies can amplify the impact of changing economic conditions on ETS scarcity



Source: IEA

Source: Hood (2011)

Energy policy interactions with emissions trading systems

An emissions trading system (ETS) can interact strongly with other energy policies that also reduce emissions in the same sector and over the same timeframe, particularly energy efficiency and technology deployment policies. The precise details of this interaction will depend on the design of the ETS chosen: in particular whether there is an absolute cap on emissions, or whether the ETS has output-based obligations (*e.g.* for power generation, a requirement to surrender allowances for emissions above a target level of CO_2 per megawatt-hour [MWh]). Each of these two basic designs can be modified in a multitude of ways, for example by introduction of ceiling and floor prices to provide greater price certainty. This section will consider only the policy interaction characteristics of the two basic policies: modifications will be considered subsequently as part of the discussion on how to manage policy interactions.

ETS with a fixed emissions cap ("cap and trade")

Because energy efficiency and technology deployment policies reduce emissions, they deliver some of the emissions reductions required to meet the ETS cap. This reduces the quantity of emissions reductions that must be delivered by the ETS market, and so reduces demand for ETS allowances and hence their price. The energy policies do not deliver additional reductions on top of the ETS cap, rather they displace abatement that would otherwise have been be delivered by companies covered by obligations in the ETS market. There is a risk that if the energy policies deliver too much of the abatement required to meet the ETS cap, the ETS allowance price could be reduced to the point where it no longer provides a clear signal for clean investment. The challenge is to balance the desire to minimise short-term compliance costs for participants by keeping ETS allowance prices low, with keeping prices high enough to stimulate private investment in low-carbon assets, which in turn will reduce societal costs over the long term.

Any *uncertainty* in the emissions reductions that will be delivered by the energy policies can create uncertainty in ETS allowance prices, which could also undermine investment. In the example shown in Figure 6, an absolute emissions cap is set 30% below business as usual (BAU). Emissions reductions are delivered in part by targeted energy efficiency and technology deployment policies (for example a renewable energy feed-in tariff), with the remainder delivered by the ETS market. If the energy policies deliver less than expected, pressure on the ETS market increases, raising allowance prices. If they deliver more than expected, pressure on the ETS market reduces and allowance prices will fall. Such price uncertainties create an additional risk for investors, and this type of uncertainty has been shown to delay investment decisions (IEA, 2007).

---

[1] If energy efficiency policies are set using a shadow carbon price to reflect the social cost of carbon, then price changes that internalize these costs do not alter the cost-effective potential.

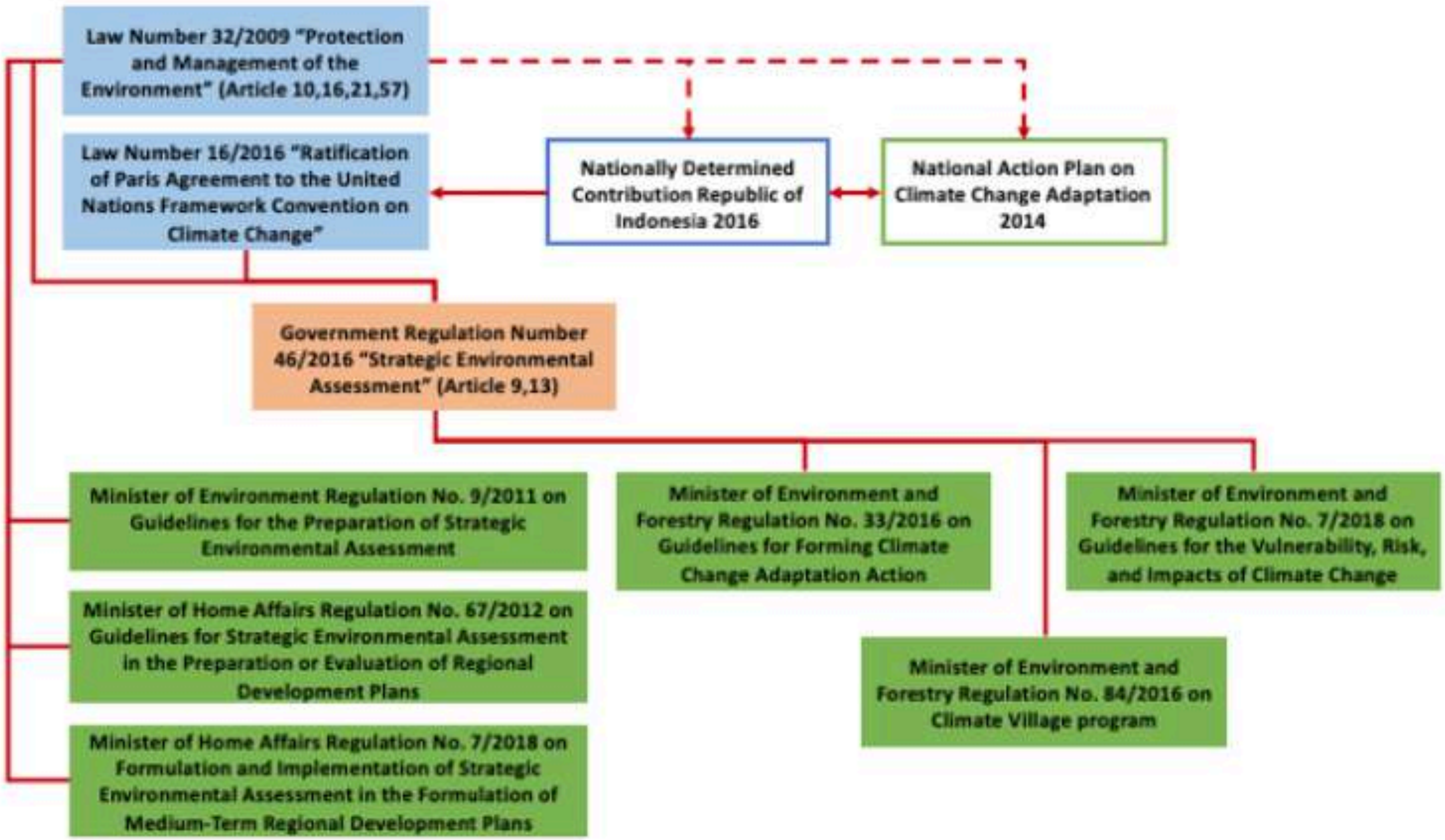
Source: IEA

- Indonesia

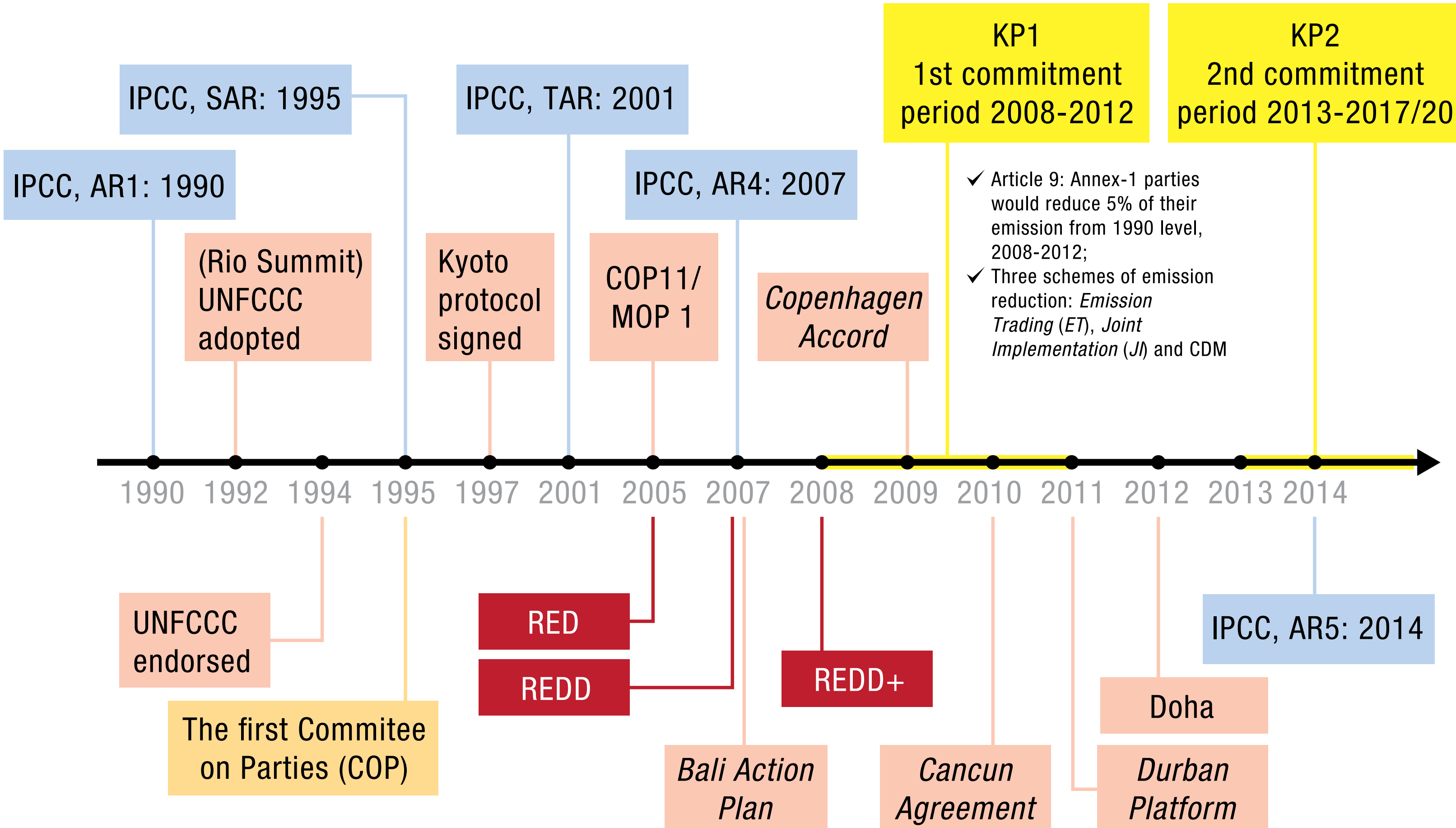
Perkembangan kebijakan nasional penanganan perubahan iklim

Source: Bappenas, 2014

National policy and regulatory framework supporting climate change



RED, REDD, REDD+



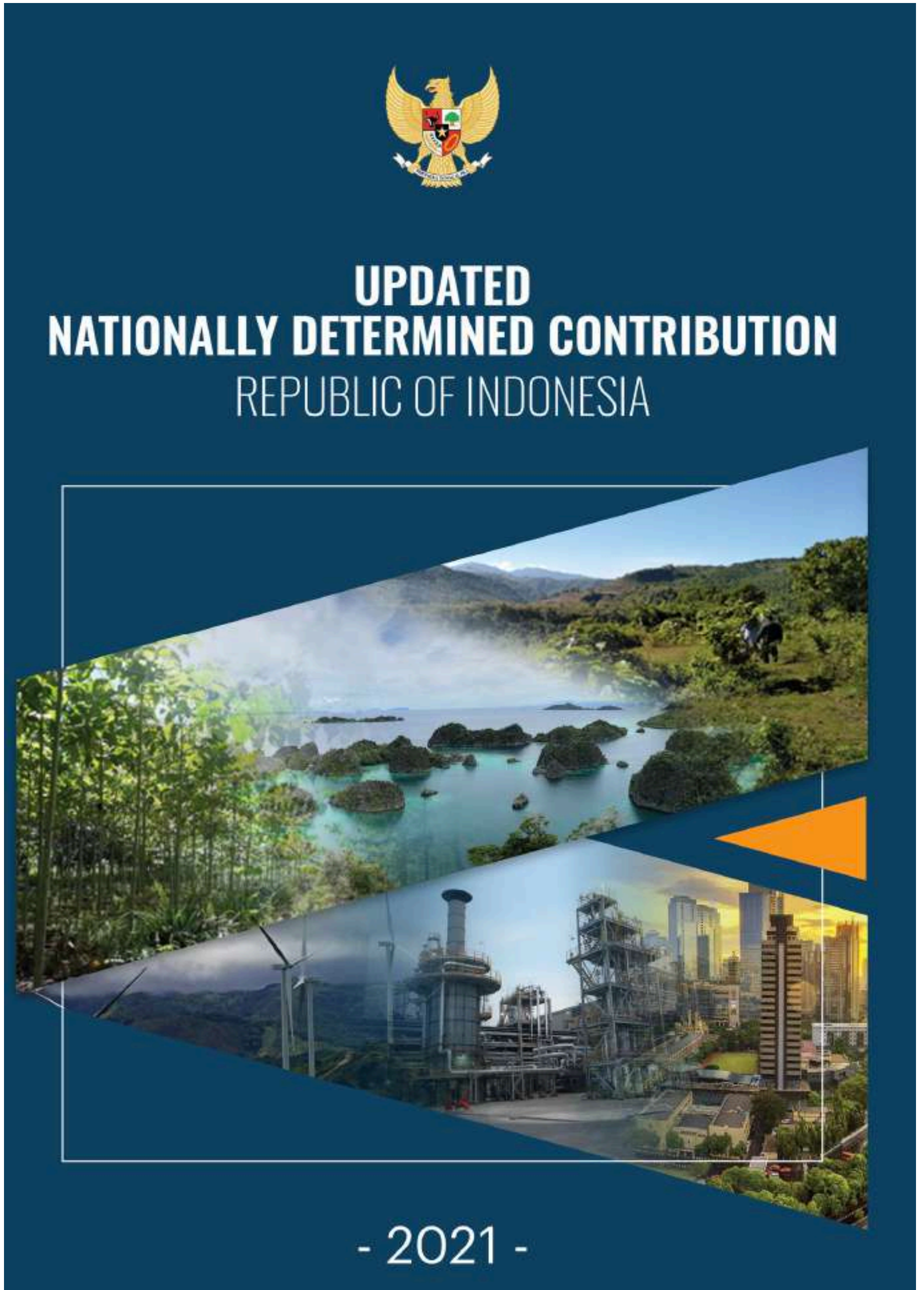
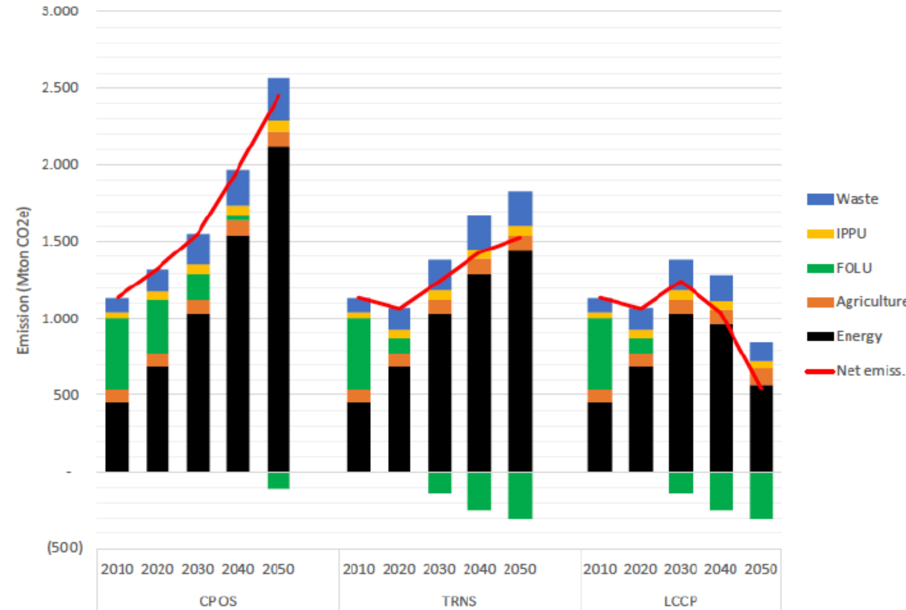


Table 1. Projected BAU and emission reduction from each sector category

Sector	GHG Emission Level 2010* (MTon CO_2e)	GHG Emission Level 2030			GHG Emission Reduction				Annual Average Growth BAU (2010-2030)	Average Growth 2000-2012
		MTon CO_2e			MTon CO_2e		% of Total BaU			
		BaU	CM1	CM2	CM1	CM2	CM1	CM2		
1. Energy*	453.2	1,669	1,355	1,407	314	441	11%	15.5%	6.7%	4.50%
2. Waste	88	296	285	270	11	26	0.38%	1.0%	6.3%	4.00%
3. IPPU	36	69.6	66.85	66.35	2.75	3.25	0.10%	0.11%	3.4%	0.10%
4. Agriculture	110.5	119.66	110.39	115.86	9	4	0.32%	0.13%	0.4%	1.30%
5. Forestry and Other Land Uses (FOLU)	647	714	217	68	497	692	17.2%	24.5%	0.5%	2.70%
TOTAL	**1,334**	**2,869**	**2,034**	**1,927**	**834**	**1,166**	**29%**	**41%**	**3.9%**	**3.20%**

*Including fugitive

Notes: **CM1**= Counter Measure 1 (*unconditional mitigation scenario*)
CM2= Counter Measure 2 (*conditional mitigation scenario*)



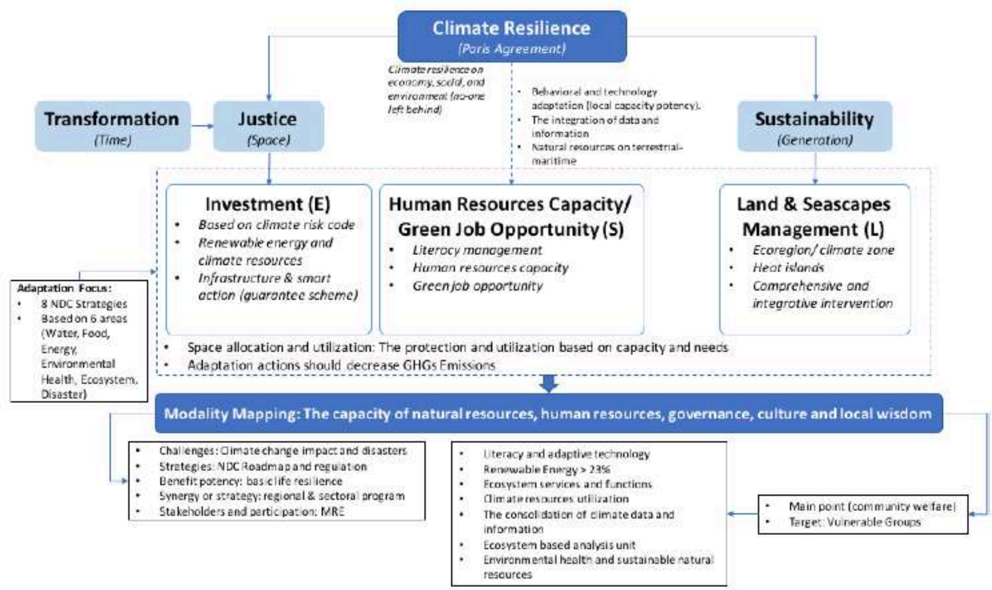
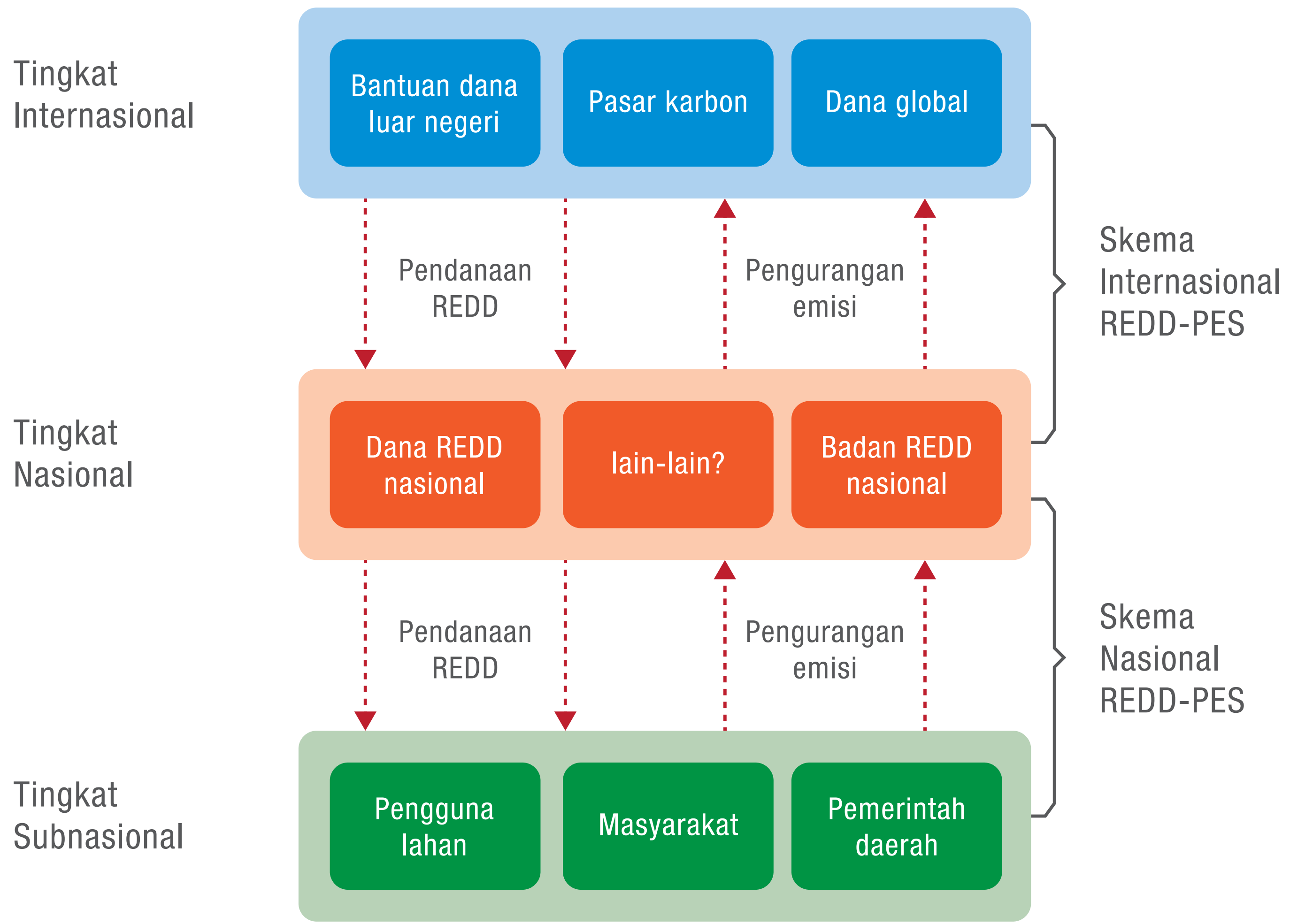


Figure 39. The scheme LTS-LCCR 2050 on adaptation

Konsep skema pembayaran jasa lingkungan bertingkat ganda untuk REDD+



Lima Pilar Strategi Nasional ReDD+ di Indonesia

1.

KELEMBAGAAN DAN PROSES:
1. Lembaga REDD+
2. Instrumen Pendanaan
3. Institusi MRV

2.

KERANGKA HUKUM DAN PERATURAN:
1. Meninjau hak-hak atas lahan dan mempercepat pelaksanaan tata ruang
2. Meningkatkan penegakan hukum dan mencegah korupsi
3. Menangguhkan izin baru untuk hutan dan lahan gambut selama 2 tahun
4. Memperbaiki data tutupan dan perizinan di hutan dan lahan gambut
5. Memberikan insentif untuk sektor swasta

3.

Program-Program Strategis

1. Konservasi dan Rehabilitasi
- ☐ Memantapkan fungsi kawasan lindung
- ☐ Mengendalikan konversi hutan dan lahan gambut
- ☐ Restorasi hutan rehabilitasi gambut

2. Pertanian, Kehutanan, dan Pertambangan yang berkelanjutan
- ☐ Meningkatkan produktivitas pertanian dan perkebunan
- ☐ Mengelola hutan secara lestari
- ☐ Mengendalikan dan mencegah kebakaran hutan dan lahan
- ☐ Mengendalikan Konversi lahan untuk tambang terbuka

4.

Perubahan Paradigma Strategis

- ☐ Penguatan Tata kelola Kehutanan dan Pemanfaatan lahan
- ☐ Pemberdayaan ekonomi lokal dengan prinsip berkelanjutan
- ☐ Kampanye nasional untuk aksi “Penyelamatan Hutan Indonesia”

5.

Pelibatan para Pihak

- ☐ Melakukan interaksi dengan berbagai kelompok (pemerintah regional, sektor swasta, organisasi non-pemerintah, masyarakat adat/lokal dan internasional
- ☐ Mengembangkan sistem pengaman (*safeguards*) sosial dan lingkungan
- ☐ Mengusahakan pembagian manfaat (*benefit sharing*) secara adil

1. Reduksi Emisi
2. Cadangan karbon hutan meningkat
3. Keanekaragaman hayati dan jasa lingkungan terpelihara
4. Pertumbuhan ekonomi

RAN-GRK

Tabel 1. Target Penurunan Emisi di 5 Sektor Utama pada tahun 2020 Berdasarkan RAN-GRK

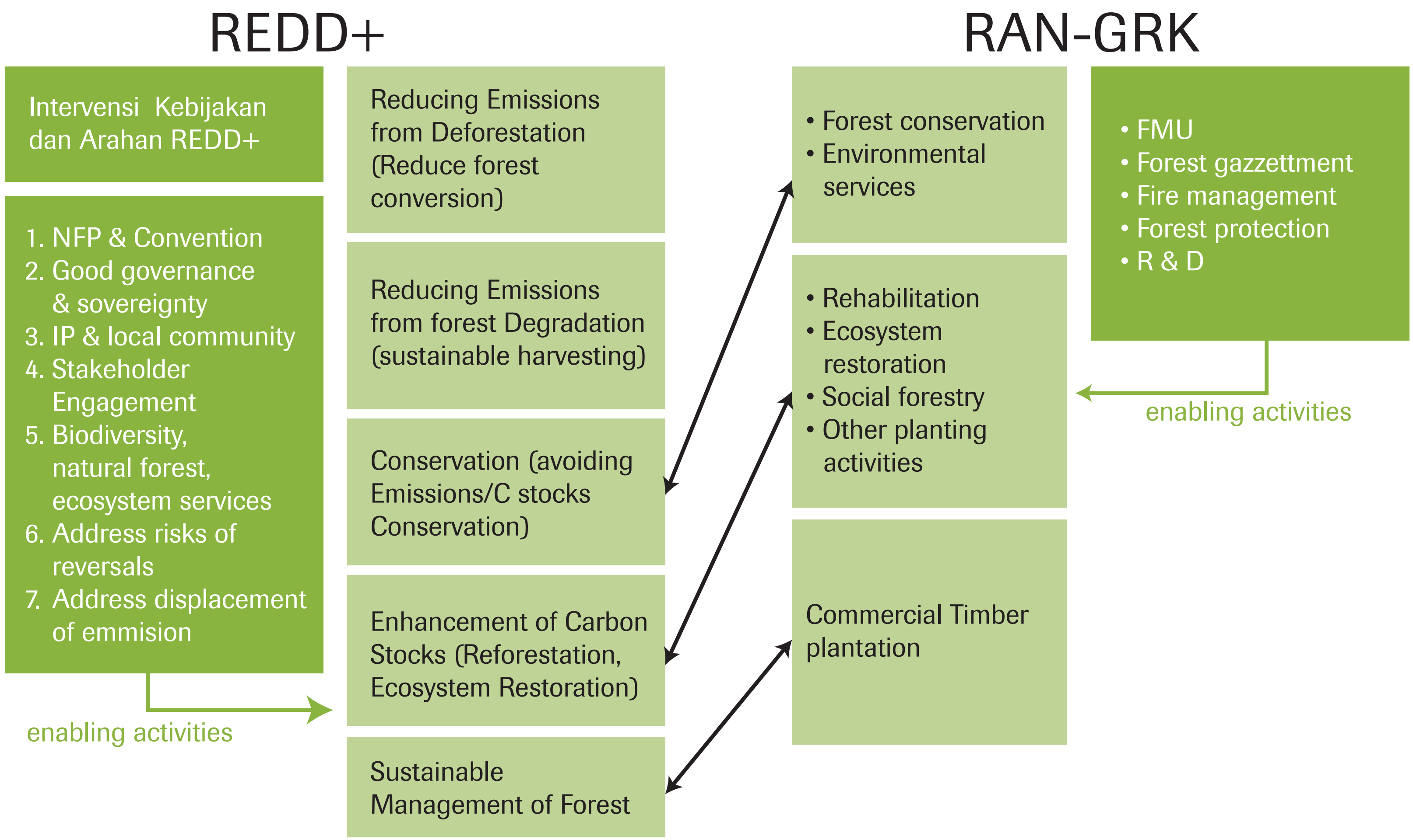
Sektor	Target Penurunan (juta ton CO2e)	
	26%	41%
Kehutanan dan lahan gambut	672	1.039
Pertanian	8	11
Energi dan transportasi	36	56
Industri	1	5
Pengelolaan limbah	48	78
Total	767	1.189

Tabel 2. Kegiatan Utama Dalam RAN GRK

# Sektor	Kegiatan Utama	
1. Kehutanan dan lahan gambut	o Pembangunan kesatuan pengelolaan hutan o Perencanaan pemanfaatan dan peningkatan usaha kawasan hutan o Pengembangan pemanfaatan jasa lingkungan o Pengukuhan kawasan hutan o Rehabilitasi dan reklamasi hutan dan lahan di DAS prioritas	o Pengembangan perhutanan sosial o Pengendalian kebakaran hutan o Penyidikan dan pengamanan hutan o Pengembangan kawasan konservasi, ekosistem esensial & pembinaan hutan lindung o Peningkatan usaha hutan tanaman
2. Pertanian	o Optimalisasi lahan o Penerapan Teknologi Budidaya Tanaman o Pemanfaatan pupuk organik dan biopestisida o Pengembangan areal perkebunan (sawit, karet, kakao) di lahan tidak berhutan/lahan terlantar/ lahan terdegradasi/ Areal Penggunaan Lain (APL)	o Pemanfaatan kotoran/urin ternak dan limbah pertanian untuk biogas o Pengelolaan lahan gambut untuk pertanian berkelanjutan o Pengembangan pengelolaan lahan pertanian di lahan gambut terlantar & terdegradasi untuk mendukung sub sektor perkebunan, peternakan dan hortikultura
3. Energi	o Program kemitraan konservasi energi o Penyediaan dan pengelolaan energi baru dan terbarukan o Pemanfaatan biogas o Penggunaan gas alam sebagai bahan bakar angkutan umum perkotaan	o Penggunaan sambungan rumah yang teraliri gas bumi melalui pipa o Reklamasi lahan pasca tambang, o Pemanfaatan biodiesel

# Sektor	Kegiatan Utama
4. Industri	o Penerapan modifikasi proses & teknologi pada industri semen o Konservasi dan audit energi untuk membentuk sistem manajemen industri pada 8 sektor industri; yaitu: industri semen, baja, pulp dan kertas, geras dan keramik, pupuk, petrokimia, makanan dan minuman, tekstil dan produk tekstil serta kimia dasar o Penghapusan bahan perusak ozon (BPO) pada sektor refrigeran font, chiller dan pemadam api
5. Pengelolaan limbah	o Pengelolaan sampah dengan TPS 3R & TPA sampah o Pengelolaan air limbah di perkotaan

Relationship REDD+ and RAN-GRK



Activities which can be measured in terms of emission reduction/emission avoidance/carbon stock enhancement

Climate Change Performance Index (CCPI)

Rank		Country	Score***	Categories
1.*		-	–	
2.		-	–	
3.		-	–	
4.	–	Sweden	75.77	
5.	▲	Denmark	71.14	
6.	▼	Morocco	70.63	
7.	▲	United Kingdom	69.80	
8.	▼	Lithuania	66.22	
9.	▲	India	66.02	
10.	▲	Finland	63.25	
11.		Chile	62.88	
12.	–	Norway	61.14	
13.	▲	Luxembourg	60.91	
14.	▼	Malta	60.76	
15.	▼	Latvia	60.75	
16.	▼	Switzerland	60.61	
17.**	▲	Ukraine	60.60	
18.	▲	France	57.90	
19.	▲	Egypt	57.53	
20.	▼	Croatia	56.97	
21.	▲	Brazil	55.82	
22.	▼	European Union (28)	55.82	
23.	▲	Germany	55.78	
24.	▼	Romania	54.85	
25.	▼	Portugal	54.10	
26.	▼	Italy	53.92	
27.	▼	Slovak Republic	52.69	
28.	▲	Greece	52.59	
29.	▼	Netherlands	50.89	
30.	▲	China	48.16	
31.	▲	Estonia	48.05	
32.	▼	Mexico	47.01	
33.	▲	Thailand	46.76	
34.	▲	Spain	46.03	
35.	▼	Belgium	45.73	
36.	▲	South Africa	45.67	
37.	▲	New Zealand	45.67	
38.	▼	Austria	44.74	
39.	▼	Indonesia	44.65	
40.	▼	Belarus	44.18	
41.	▲	Ireland	44.04	
42.	▼	Argentina	43.77	
43.	▼	Czech Republic	42.93	
44.	▼	Slovenia	41.91	
45.	▲	Cyprus	41.66	
46.	▲	Algeria	41.45	
47.	▼	Hungary	41.17	
48.	▲	Turkey	40.76	
49.	▼	Bulgaria	40.12	
50.	▼	Poland	39.98	
51.	▼	Japan	39.03	
52.	–	Russian Federation	37.85	
53.	▼	Malaysia	34.21	
54.	▼	Kazakhstan	33.39	
55.	▼	Canada	31.01	
56.	▼	Australia	30.75	
57.	▲	Islamic Republic of Iran	28.41	
58.	▼	Korea	26.75	
59.	▼	Chinese Taipei	23.33	
60.	–	Saudi Arabia	22.03	
61.	▼	United States	18.60	

Index Categories

- GHG Emissions (40% weighting)
- Renewable Energy (20% weighting)
- Energy Use (20% weighting)
- Climate Policy (20% weighting)

* None of the countries achieved positions one to three. No country is doing enough to prevent dangerous climate change.
** The position of Ukraine in the overall ranking is highly influenced by the effects of the ongoing conflict in the Donbas region on key CCPI indicators. For more information please refer to the country text on page 19.
***rounded

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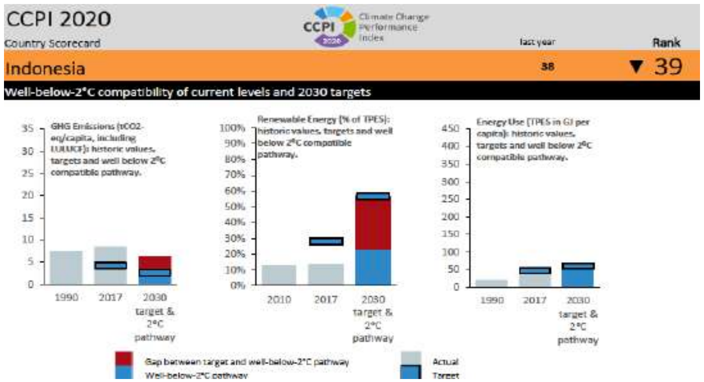
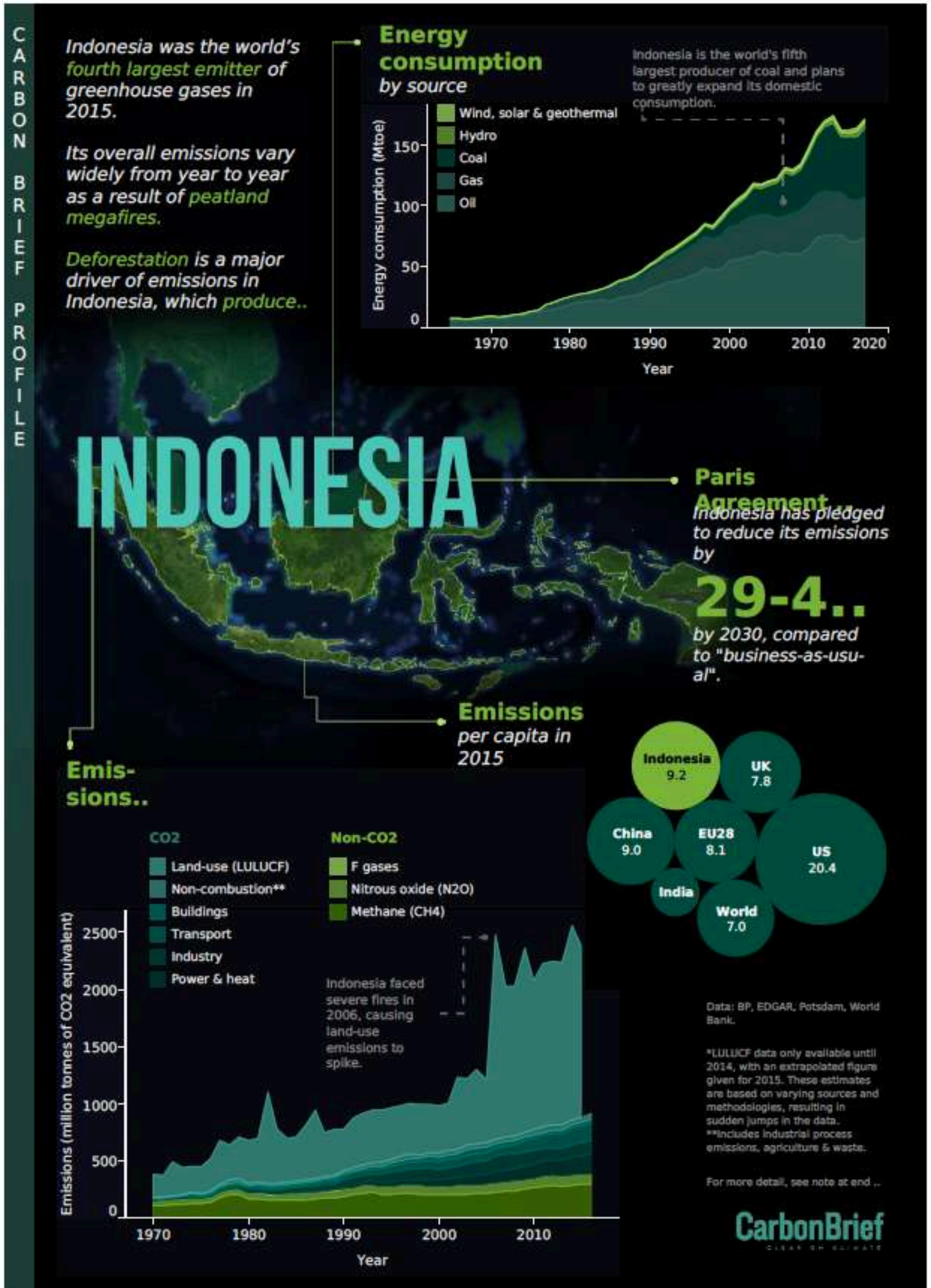
Indonesia

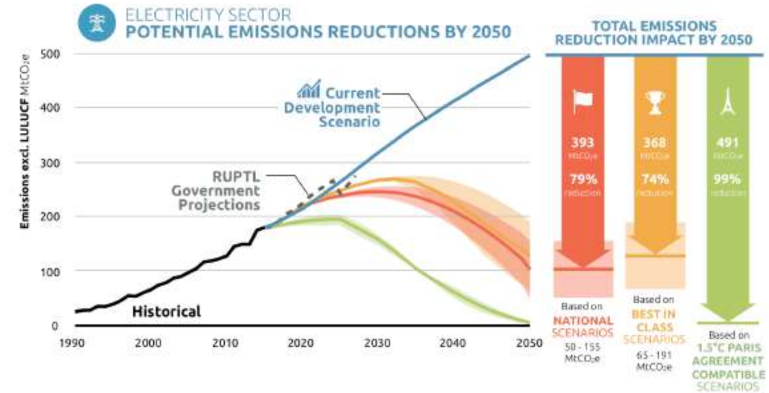
39 | 38 | ▼

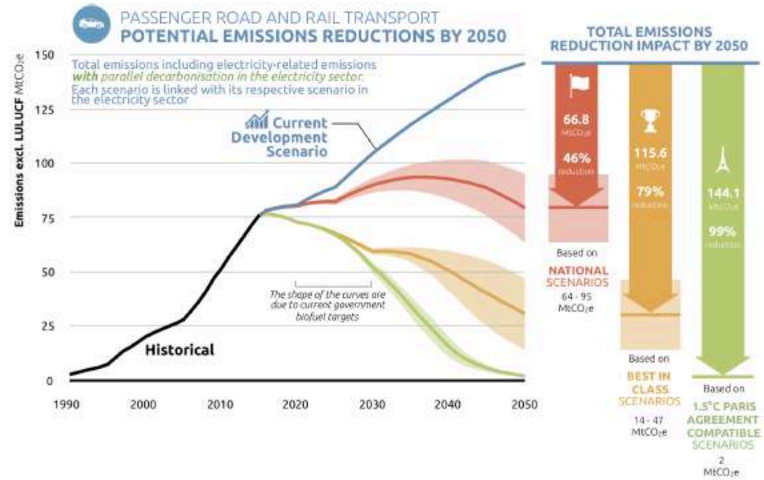
Ranked 39th, Indonesia remains in the list of *low* performers in the CCPI 2020. Compared to the CCPI 2019, the country was unable to maintain its *medium* rating in the GHG Emissions category, and instead now receives a *low* rating. However, Indonesia was able to improve its performance in the Energy Use category from a *medium* rating last year to a *high* rating with the current level of per capita energy use being in line with a well-below-2°C pathway. The country is rated *medium* in Renewable Energy, with experts criticising a limited renewable energy support scheme in the electricity sector. Further, national experts highlight that the country's NDC targets for emissions reduction, renewable energy and energy use are not well integrated into national policies and therefore lack proper implementation. This results in a *very low* rating for the country's national climate policy performance. With a *medium* performance for its international climate policy, Indonesia receives an overall *low* rating in the Climate Policy category.

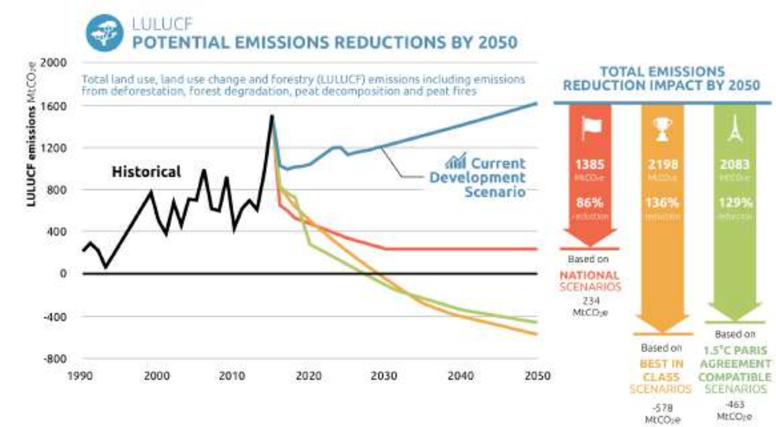


Source: CCPI, 2020


CARBON BRIEF PROFILE
Indonesia was the world's fourth largest emitter of greenhouse gases in 2015.
Its overall emissions vary widely from year to year as a result of peatland megafires.
Deforestation is a major driver of emissions in Indonesia, which produce..
Energy consumption by source
Indonesia is the world's fifth largest producer of coal and plans to greatly expand its domestic consumption.
Wind, solar & geothermal
Hydro
Coal
Gas
Oil
Energy consumption (Mtoe)
Year
INDONESIA
Paris Agreement..
Indonesia has pledged to reduce its emissions by
29-4..
by 2030, compared to "business-as-usual".
Emissions per capita in 2015
Indonesia 9.2
UK 7.8
China 9.0
EU28 8.1
US 20.4
India
World 7.0
Emissions..
CO2
Land-use (LULUCF)
Non-combustion**
Buildings
Transport
Industry
Power & heat
Non-CO2
F gases
Nitrous oxide (N2O)
Methane (CH4)
Indonesia faced severe fires in 2006, causing land-use emissions to spike.
Emissions (million tonnes of CO2 equivalent)
Year
Data: BP, EDGAR, Potsdam, World Bank.
*LULUCF data only available until 2014, with an extrapolated figure given for 2015. These estimates are based on varying sources and methodologies, resulting in sudden jumps in the data.
**Includes industrial process emissions, agriculture & waste.
For more detail, see note at end ..
CarbonBrief


ELECTRICITY SECTOR
POTENTIAL EMISSIONS REDUCTIONS BY 2050
Emissions excl. LULUCF MtCO2e
Current Development Scenario
RUPTL Government Projections
Historical
TOTAL EMISSIONS REDUCTION IMPACT BY 2050
393
79%
368
74%
491
99%
Based on NATIONAL SCENARIOS 50 - 155 MtCO2e
Based on BEST IN CLASS SCENARIOS 65 - 191 MtCO2e
Based on 1.5°C PARIS AGREEMENT COMPATIBLE SCENARIOS


PASSENGER ROAD AND RAIL TRANSPORT
POTENTIAL EMISSIONS REDUCTIONS BY 2050
Total emissions including electricity-related emissions with parallel decarbonisation in the electricity sector. Each scenario is linked with its respective scenario in the electricity sector
Emissions excl. LULUCF MtCO2e
Current Development Scenario
The shape of the curves are due to current government biofuel targets
Historical
TOTAL EMISSIONS REDUCTION IMPACT BY 2050
66.8
46%
115.6
79%
144.1
99%
Based on NATIONAL SCENARIOS 64 - 95 MtCO2e
Based on BEST IN CLASS SCENARIOS 14 - 47 MtCO2e
Based on 1.5°C PARIS AGREEMENT COMPATIBLE SCENARIOS 2 MtCO2e


LULUCF
POTENTIAL EMISSIONS REDUCTIONS BY 2050
Total land use, land use change and forestry (LULUCF) emissions including emissions from deforestation, forest degradation, peat decomposition and peat fires
LULUCF emissions MtCO2e
Historical
Current Development Scenario
TOTAL EMISSIONS REDUCTION IMPACT BY 2050
1385
86%
2198
136%
2083
129%
Based on NATIONAL SCENARIOS 234 MtCO2e
Based on BEST IN CLASS SCENARIOS -578 MtCO2e
Based on 1.5°C PARIS AGREEMENT COMPATIBLE SCENARIOS -463 MtCO2e

Source: CAT

Thank You