Mitigation of the Climate Change

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OUTLINE

1. Introduction to Mitigation
2. Mitigation Pathways
3. The Role Carbon Dioxide Removal
4. Energy end-use sectors
5. International and Subnational Policies and Institutions

Introduction

What is mitigation?

> *Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases.*

Mitigation has to be a global goal

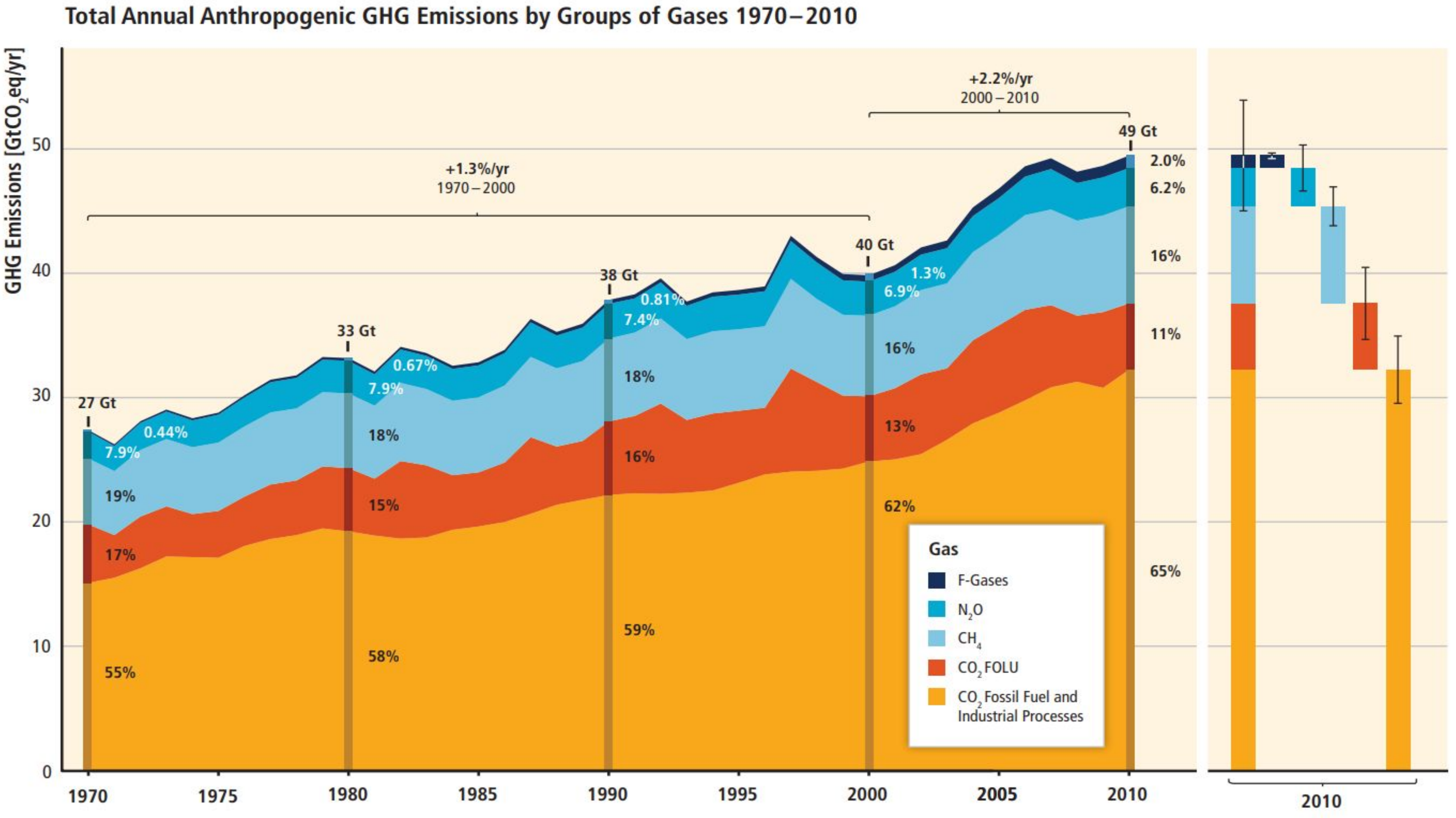
Effective mitigation will not be achieved if individual agents advance their own interests independently.

- GHG accumulate over time and mix globally
- Different agents possess different knowledge

Trends in GHG

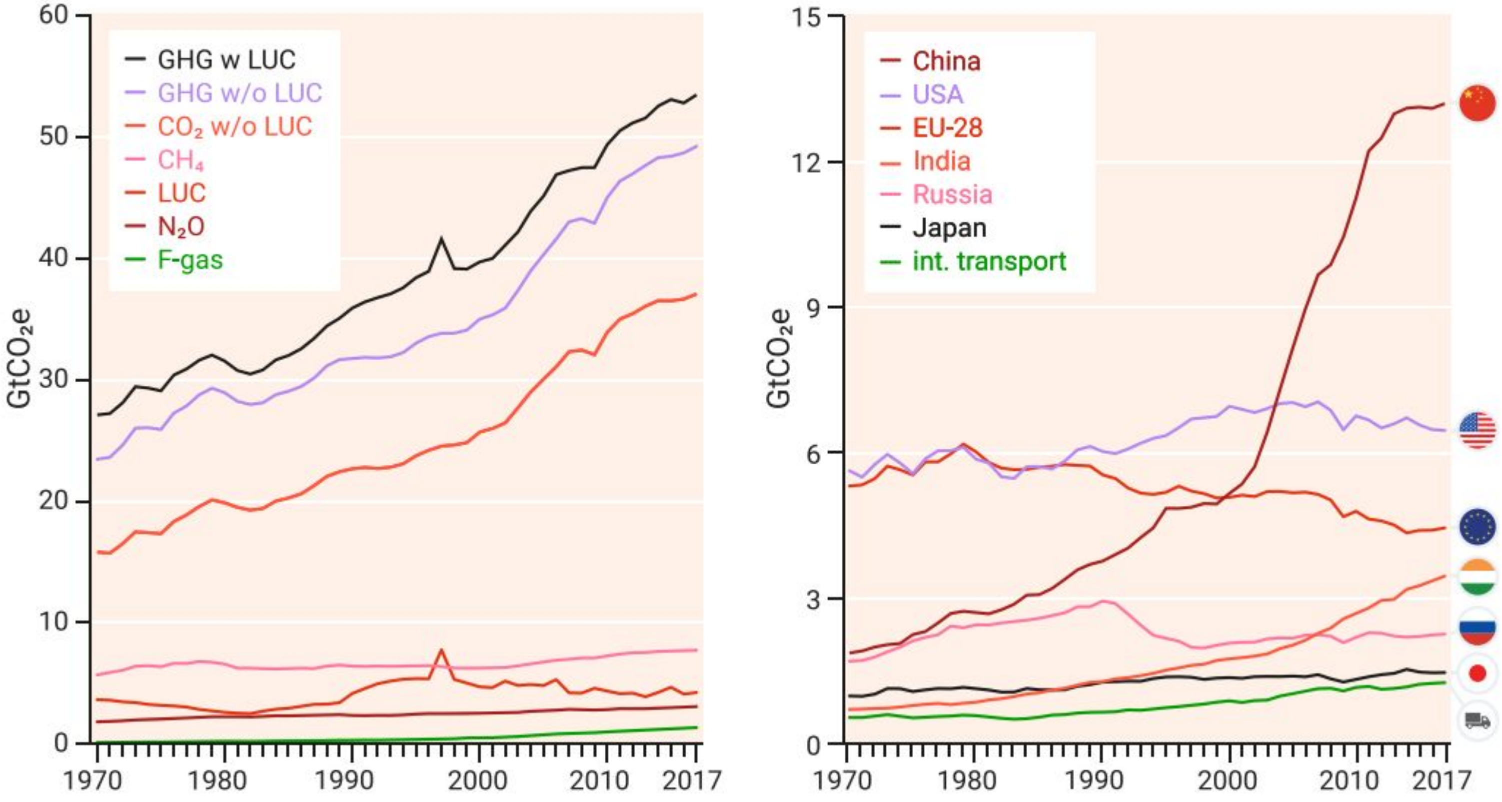
GHG emissions have continued to increase over 1970 to 2010 Despite a growing number of climate change mitigation policies.

- ❑ Increase of 1.3% per year from 1970 to 2000
- ❑ Increase of 2.2% per year from 2000 to 2008
- ❑ Increase of 1.6% per year from 2008 to 2017



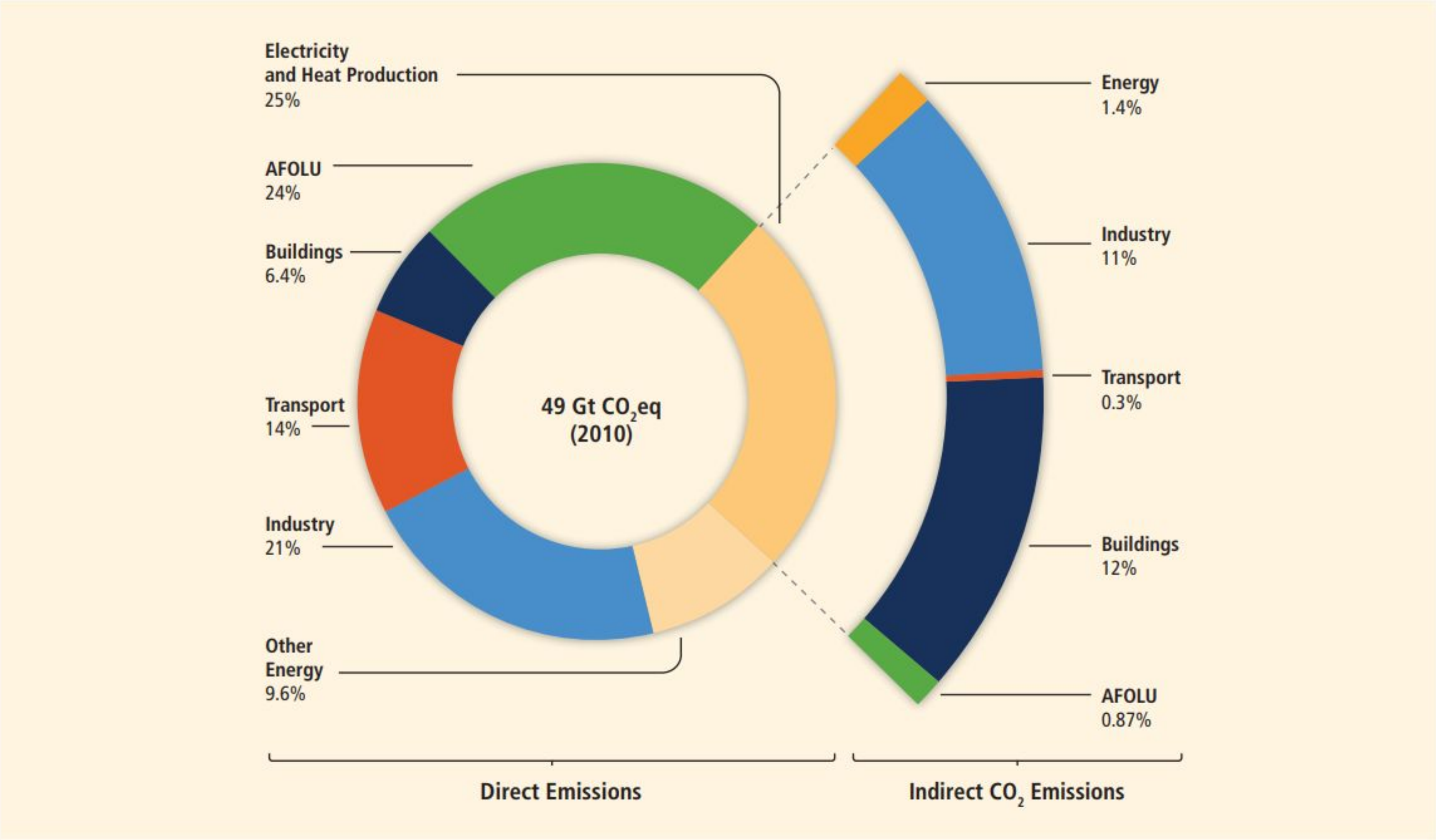
Total Annual Anthropogenic GHG Emissions by Groups of Gases 1970–2010
GHG Emissions [GtCO2eq/yr]
+1.3%/yr
1970 – 2000
+2.2%/yr
2000 – 2010
27 Gt
33 Gt
38 Gt
40 Gt
49 Gt
0.44%
7.9%
19%
17%
55%
0.67%
7.9%
18%
15%
58%
0.81%
7.4%
18%
16%
59%
1.3%
6.9%
16%
13%
62%
2.0%
6.2%
16%
11%
65%
Gas
F-Gases
N2O
CH4
CO2 FOLU
CO2 Fossil Fuel and Industrial Processes
0
10
20
30
40
50
1970
1975
1980
1985
1990
1995
2000
2005
2010
2010

Figure 3 — Global greenhouse gas emissions per type of gas (left) and Top greenhouse gas emitters, excluding land-use change emissions due to lack of reliable data (right)



Source: UNEP (2018), Figure 2.3.

Greenhouse Gas Emissions by Economic Sectors



Without additional efforts to reduce GHG emissions, emissions growth is expected to persist driven by growth in global population and economic activities.

- Expected 3.7 to 4.8 ℃ average temperature increase in 2100 without additional mitigation
- Some models predict up to 7.8 ℃ increase compared to the preindustrial temperatures

The UN's Emission Gap Report from 2019 shows that we are on the brink of missing the 1.5℃ target.

- We are projected to reach 56 GT CO2 emission in 2030 which is over twice that we need to achieve!
- However, it is still possible to make it if we collectively deliver a 7.6% reduction in emissions every year

Mitigation Pathways

Mitigation Pathways

"The world's societies will need to both mitigate and adapt to climate change if it is to effectively avoid harmful climate impacts " - AR5.

- Mitigation pathways are typically designed to reach a predefined climate target. They incorporate a range of different scenarios and describe the clear temporal evolution of specific scenario aspects or goal-oriented scenarios.
- The mitigation costs, co-benefits and geophysical uncertainties regarding the pathways will be discussed.

Characteristics of Mitigation Pathways

- Mitigation pathways can be distinguished from one another by a range of outcomes or requirements.
- Mitigation scenarios point to a range of technological and behavioral measures that could allow the world's societies to follow GHG emission pathways consistent with a range of different levels of mitigation.
- The scenarios are generated by large scale computer models (IAMs). **They provide global information about emissions pathways, energy and land use transitions, and aggregate economic costs of mitigation.**

➔ As part of this assessment, about 900 mitigation and 300 baseline scenarios have been collected from integrated modelling research groups around the world. - AR5

Table TS.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.[1,2] [Table 6.3]

CO_2eq Concentrations in 2100 [ppm CO_2eq] Category label (concentration range)[9]	Subcategories	Relative position of the RCPs[5]	Cumulative CO_2 emissions[3] [$GtCO_2$]		Change in CO_2eq emissions compared to 2010 in [%][4]		Temperature change (relative to 1850–1900)[5,6]				
			2011–2050	2011–2100	2050	2100	2100 Temperature change [°C][7]	Likelihood of staying below temperature level over the 21st century[8]: 1.5 °C	2.0 °C	3.0 °C	4.0 °C
< 430	Only a limited number of individual model studies have explored levels below 430 ppm CO_2eq										
450 (430–480)	Total range[1,10]	RCP2.6	550–1300	630–1180	−72 to −41	−118 to −78	1.5–1.7 (1.0–2.8)	*More unlikely than likely*	*Likely*	*Likely*	*Likely*
500 (480–530)	No overshoot of 530 ppm CO_2eq		860–1180	960–1430	−57 to −42	−107 to −73	1.7–1.9 (1.2–2.9)	*Unlikely*	*More likely than not*		
	Overshoot of 530 ppm CO_2eq		1130–1530	990–1550	−55 to −25	−114 to −90	1.8–2.0 (1.2–3.3)		*About as likely as not*		
550 (530–580)	No overshoot of 580 ppm CO_2eq		1070–1460	1240–2240	−47 to −19	−81 to −59	2.0–2.2 (1.4–3.6)		*More unlikely than likely*[12]		
	Overshoot of 580 ppm CO_2eq		1420–1750	1170–2100	−16 to 7	−183 to −86	2.1–2.3 (1.4–3.6)				
(580–650)	Total range	RCP4.5	1260–1640	1870–2440	−38 to 24	−134 to −50	2.3–2.6 (1.5–4.2)				
(650–720)	Total range		1310–1750	2570–3340	−11 to 17	−54 to −21	2.6–2.9 (1.8–4.5)		*Unlikely*	*More likely than not*	
(720–1000)[2]	Total range	RCP6.0	1570–1940	3620–4990	18 to 54	−7 to 72	3.1–3.7 (2.1–5.8)	*Unlikely*[11]		*More unlikely than likely*	
>1000[2]	Total range	RCP8.5	1840–2310	5350–7010	52 to 95	74 to 178	4.1–4.8 (2.8–7.8)		*Unlikely*[11]	*Unlikely*	*More unlikely than likely*

★ Delaying mitigation efforts beyond those in place today through 2030 will increase the challenges of, and reduce the options for, limiting atmospheric concentration levels to about 450-500 ppm CO2eq by the end of the century – IPCC AR5

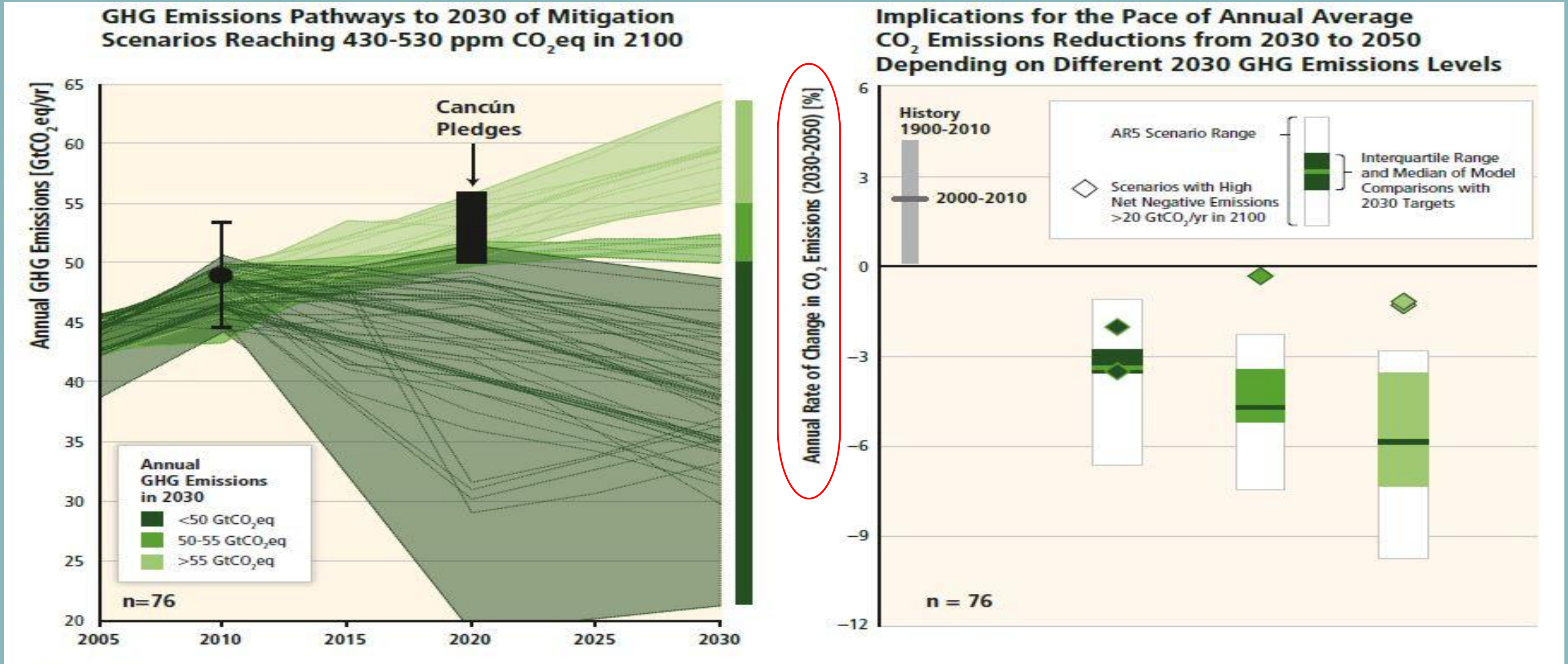


Figure TS.9 | The implications of different 2030 GHG emissions levels for the rate of CO_2 emissions reductions from 2030 to 2050 in mitigation scenarios reaching about 450 to about 500 (430–530) ppm CO_2eq concentrations by 2100. The scenarios are grouped according to different emissions levels by 2030 (coloured in different shades of green). The

- Mitigation scenarios also provide global information about emissions pathways, energy and land use transitions, and aggregate economic costs of mitigation.

Table TS.2 | Global mitigation costs in cost-effective scenarios[1] and estimated cost increases due to assumed limited availability of specific technologies and delayed additional mitigation. Cost estimates shown in this table do not consider the benefits of reduced climate change as well as co-benefits and adverse side-effects of mitigation. The yellow columns show consumption losses (Figure TS.12, right panel) and annualized consumption growth reductions in cost-effective scenarios relative to a baseline development without climate policy. The grey columns show the percentage increase in discounted costs[2] over the century, relative to cost-effective scenarios, in scenarios in which technology is constrained relative to default technology assumptions (Figure TS.13, left panel).[3] The orange columns show the increase in mitigation costs over the periods 2030–2050 and 2050–2100, relative to scenarios with immediate mitigation, due to delayed additional mitigation through 2030 (see Figure TS.13, right panel).[4] These scenarios with delayed additional mitigation are grouped by emission levels of less or more than 55 $GtCO_2eq$ in 2030, and two concentration ranges in 2100 (430–530 ppm CO_2eq and 530–650 ppm CO_2eq). In all figures, the median of the scenario set is shown without parentheses, the range between the 16th and 84th percentile of the scenario set is shown in the parentheses, and the number of scenarios in the set is shown in square brackets.[5] [Figures TS.12, TS.13, 6.21, 6.24, 6.25, Annex II.10]

	Consumption losses in cost-effective scenarios[1]						Increase in total discounted mitigation costs in scenarios with limited availability of technologies				Increase in medium- and long-term mitigation costs due to delayed additional mitigation until 2030			
	[% reduction in consumption relative to baseline]			[percentage point reduction in annualized consumption growth rate]			[% increase in total discounted mitigation costs (2015–2100) relative to default technology assumptions]				[% increase in mitigation costs relative to immediate mitigation]			
											≤55 $GtCO_2eq$		>55 $GtCO_2eq$	
Concentration in 2100 [ppm CO_2eq]	2030	2050	2100	2010–2030	2010–2050	2010–2100	No CCS	Nuclear phase out	Limited Solar/Wind	Limited Bioenergy	2030–2050	2050–2100	2030–2050	2050–2100
450 (430–480)	1.7 (1.0–3.7) [N: 14]	3.4 (2.1–6.2)	4.8 (2.9–11.4)	0.09 (0.06–0.2)	0.09 (0.06–0.17)	0.06 (0.04–0.14)	138 (29–297) [N: 4]	7 (4–18) [N: 8]	6 (2–29) [N: 8]	64 (44–78) [N: 8]	28 (14–50) [N: 34]	15 (5–59)	44 (2–78) [N: 29]	37 (16–82)
500 (480–530)	1.7 (0.6–2.1) [N: 32]	2.7 (1.5–4.2)	4.7 (2.4–10.6)	0.09 (0.03–0.12)	0.07 (0.04–0.12)	0.06 (0.03–0.13)	N/A	N/A	N/A	N/A				
550 (530–580)	0.6 (0.2–1.3) [N: 46]	1.7 (1.2–3.3)	3.8 (1.2–7.3)	0.03 (0.01–0.08)	0.05 (0.03–0.08)	0.04 (0.01–0.09)	39 (18–78) [N: 11]	13 (2–23) [N: 10]	8 (5–15) [N: 10]	18 (4–66) [N: 12]	3 (−5–16) [N: 14]	4 (−4–11)	15 (3–32) [N: 10]	16 (5–24)
580–650	0.3 (0–0.9) [N: 16]	1.3 (0.5–2.0)	2.3 (1.2–4.4)	0.02 (0–0.04)	0.03 (0.01–0.05)	0.03 (0.01–0.05)	N/A	N/A	N/A	N/A				

Mitigation costs; represent one component of the change in human welfare from climate change mitigation. Mitigation costs are expressed in monetary terms and generally are estimated against baseline scenarios**.**

Mitigation Pathways under IPCC Special Report on Global Warming of 1.5°C - 2018

- For each mitigation pathway, MAGICC and FAIR simulations were used to provide probabilistic estimates of atmospheric concentrations, radiative forcing and global temperature outcomes until 2100.

- The new scenarios explore 1.5°C-consistent pathways from multiple perspectives, examining sensitivity to assumptions regarding;

  - socio-economic drivers and developments including energy and food demand as, for example, characterized by the Shared Socio-Economic Pathways (SSPs)
  - near-term climate policies describing different levels of strengthening the NDCs
  - the use of bioenergy and the availability & desirability of carbon dioxide removal (CDR) technologies

- Geophysical uncertainties: non-CO2 forcing agents(CH2), earth and climate system feedback.

- The reduced complexity climate models employed in this assessment do not take into account permafrost or non-CO2 Earth system feedbacks.

Scenarios that are more likely than not to bring temperature change back to below 1.5 °C by 2100 relative to pre-industrial levels require; 1) immediate mitigation; (2) the rapid up-scaling of the full portfolio of mitigation technologies; and (3) development along a low-energy demand trajectory.

Table 2.1 | Classification of pathways that this chapter draws upon, along with the number of available pathways in each class. The definition of each class is based on probabilities derived from the MAGICC model in a setup identical to AR5 WGIII (Clarke et al., 2014), as detailed in Supplementary Material 2.SM.1.4.

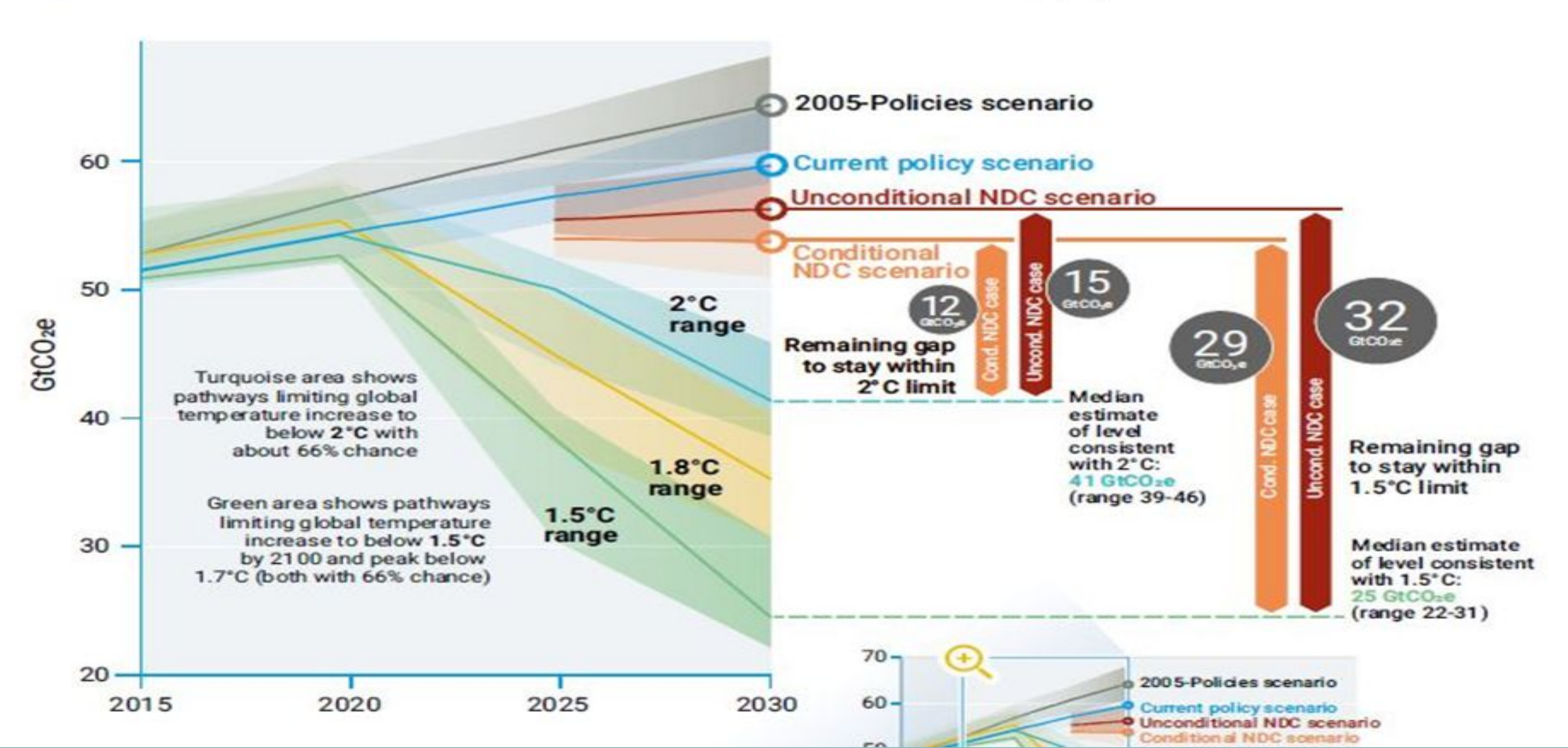
Pathway group	Pathway Class	Pathway Selection Criteria and Description	Number of Scenarios	Number of Scenarios
1.5°C or 1.5°C-consistent**	Below-1.5°C	Pathways limiting peak warming to below 1.5°C during the entire 21st century with 50–66% likelihood*	9	90
	1.5°C-low-OS	Pathways limiting median warming to below 1.5°C in 2100 and with a 50–67% probability of temporarily overshooting that level earlier, generally implying less than 0.1°C higher peak warming than Below-1.5°C pathways	44	
	1.5°C-high-OS	Pathways limiting median warming to below 1.5°C in 2100 and with a greater than 67% probability of temporarily overshooting that level earlier, generally implying 0.1–0.4°C higher peak warming than Below-1.5°C pathways	37	
2°C or 2°C-consistent	Lower-2°C	Pathways limiting peak warming to below 2°C during the entire 21st century with greater than 66% likelihood	74	132
	Higher-2°C	Pathways assessed to keep peak warming to below 2°C during the entire 21st century with 50–66% likelihood	58	

* No pathways were available that achieve a greater than 66% probability of limiting warming below 1.5°C during the entire 21st century based on the MAGICC model projections.

** This chapter uses the term 1.5°C-consistent pathways to refer to pathways with no overshoot, with limited (low) overshoot, and with high overshoot. However, the Summary for Policymakers focusses on pathways with no or limited (low) overshoot.

★ The importance of strengthening the NDCs - Emissions Gap Report 2019

Figure ES.4. Global GHG emissions under different scenarios and the emissions gap by 2030



LED, SSP1 and SSP2 are consistent with achieving 1.5C by 2100. – Special Report 2018

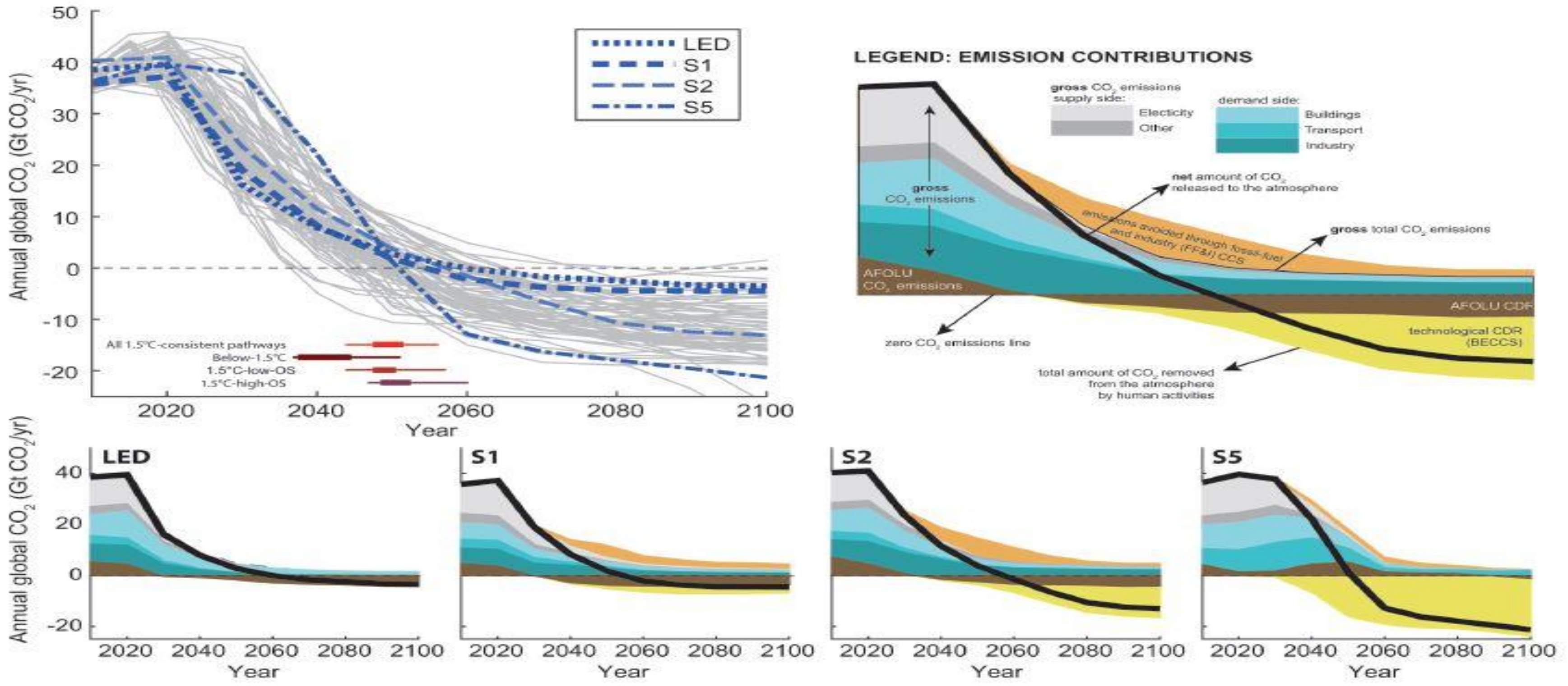
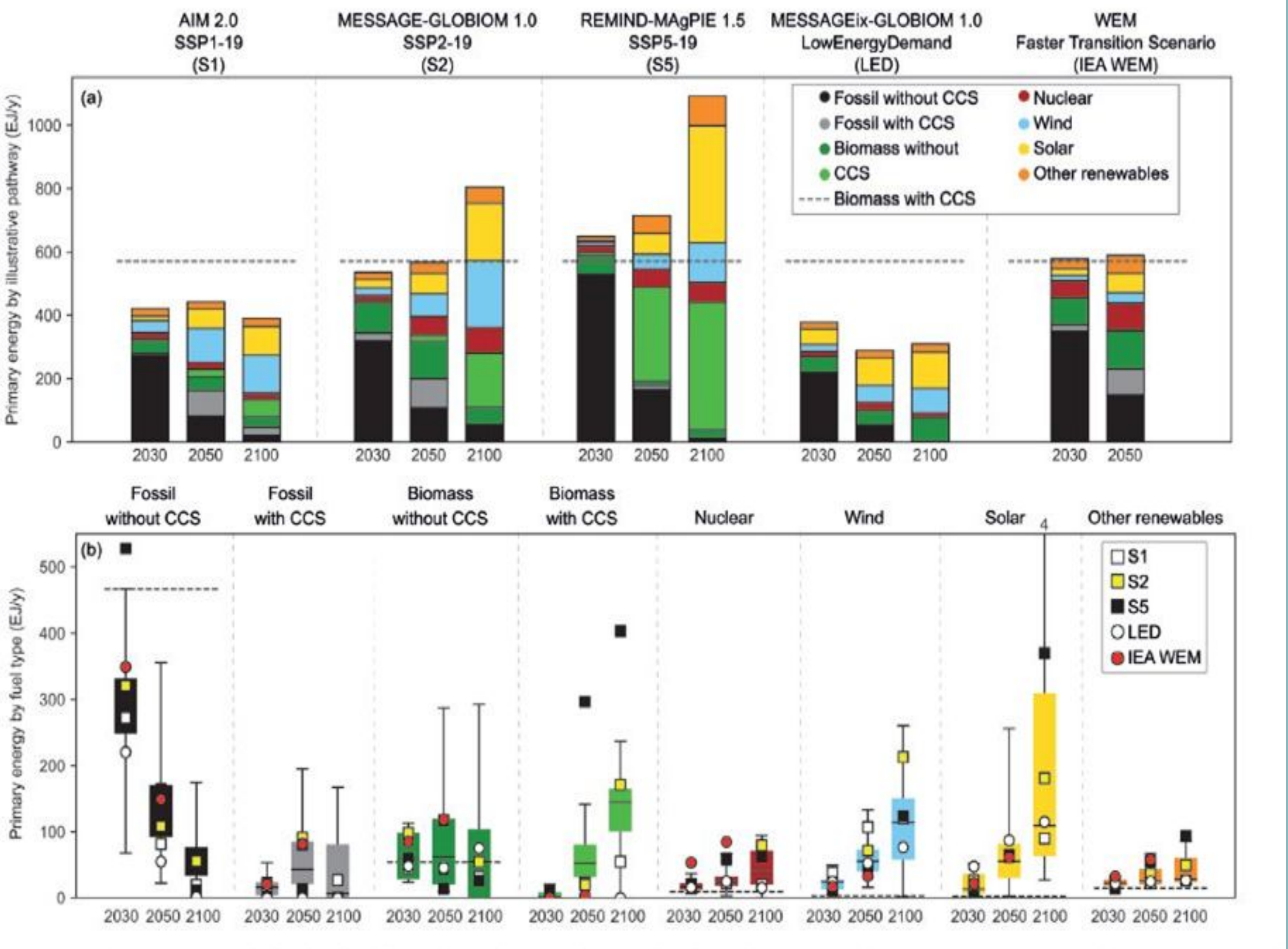


Figure 2.5 | Evolution and break down of global anthropogenic CO_2 emissions until 2100. The top-left panel shows global net CO_2 emissions in Below-1.5°C,

The transformations in primary energy sector;

- growth in the share of energy derived from low-carbon emitting and a decline in the overall share of fossil fuels without CCS
- rapid decline in the carbon intensity of electricity generation simultaneous with further electrification of energy end-use
- growth in the use of CCS applied to fossil and biomass carbon in most 1.5°C pathways.



ure 2.15 | Primary energy supply for the four illustrative pathway archetypes plus the IEA's Faster Transition Scenario (OECD/IEA and IRENA, 2017) (panel and their relative location in the ranges for pathways limiting warming to 1.5°C with no or limited overshoot (panel b). The category 'Other renewables'

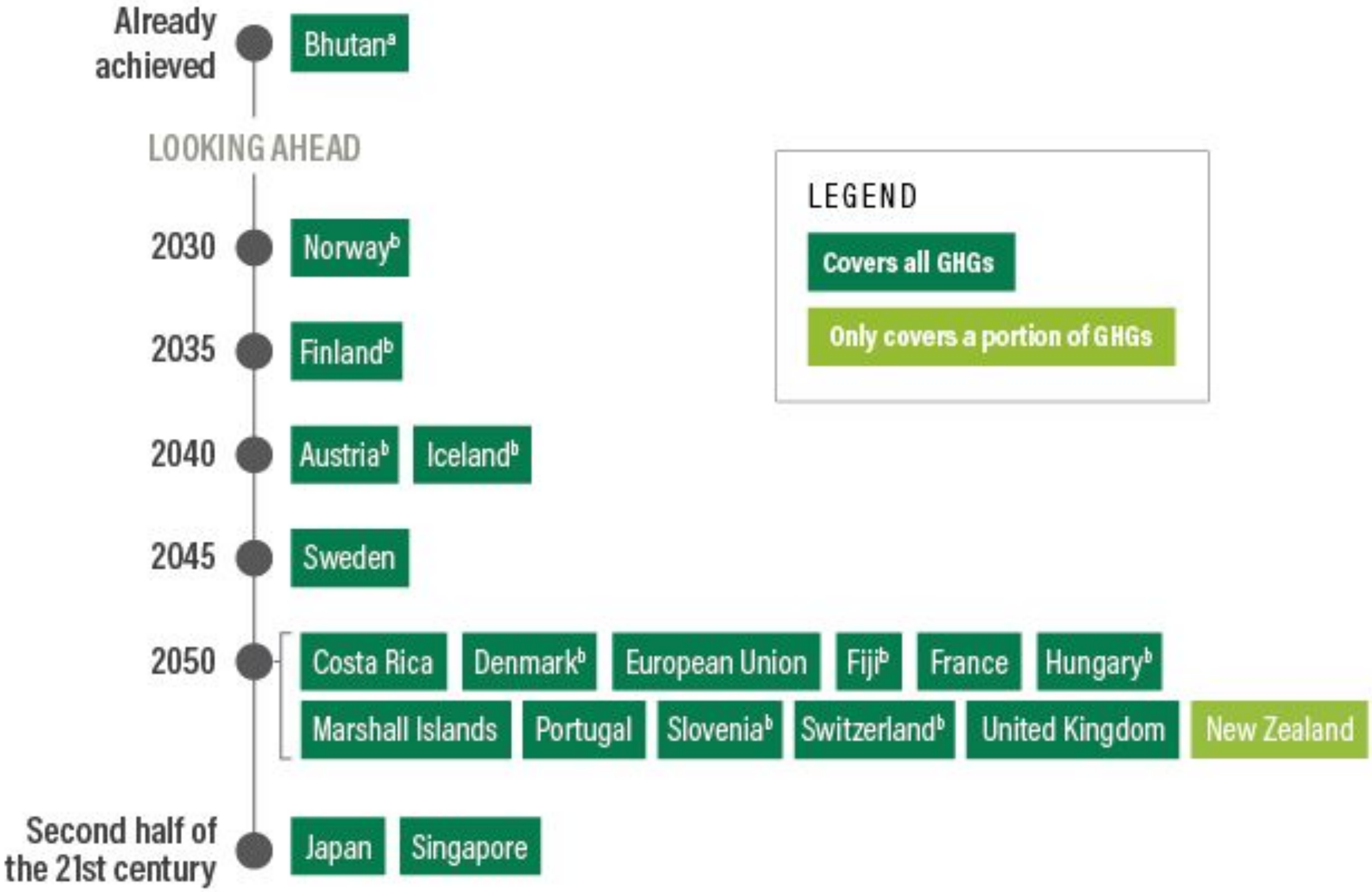
Net Zero Emissions and Carbon Dioxide Removal

What is Net-Zero Emission?

Net-Zero emission is reached when any remaining human-caused GHG emissions are balanced by carbon dioxide removal

- For the 1.5 ℃ goal we must reach NZE of CO_2 in 2050.
- For the 2 ℃ goal we must reach NZE of CO_2 by 2070

The Timing of Countries' Net-Zero Emissions Targets



Carbon Dioxide Removing

All scenarios are using CDR. Some show that we will need to remove billions of tons per year after 2050

- Move more rapidly towards the point of carbon neutrality and maintain it afterwards
- Produce net negative CO2 emissions to decline the global mean temperature after a peak

CO2 removal methods

- Afforestation
- Soil carbon enhancement
- Bio-energy with CCS
- Direct air capture
- Carbon mineralization
- Ocean-based concepts

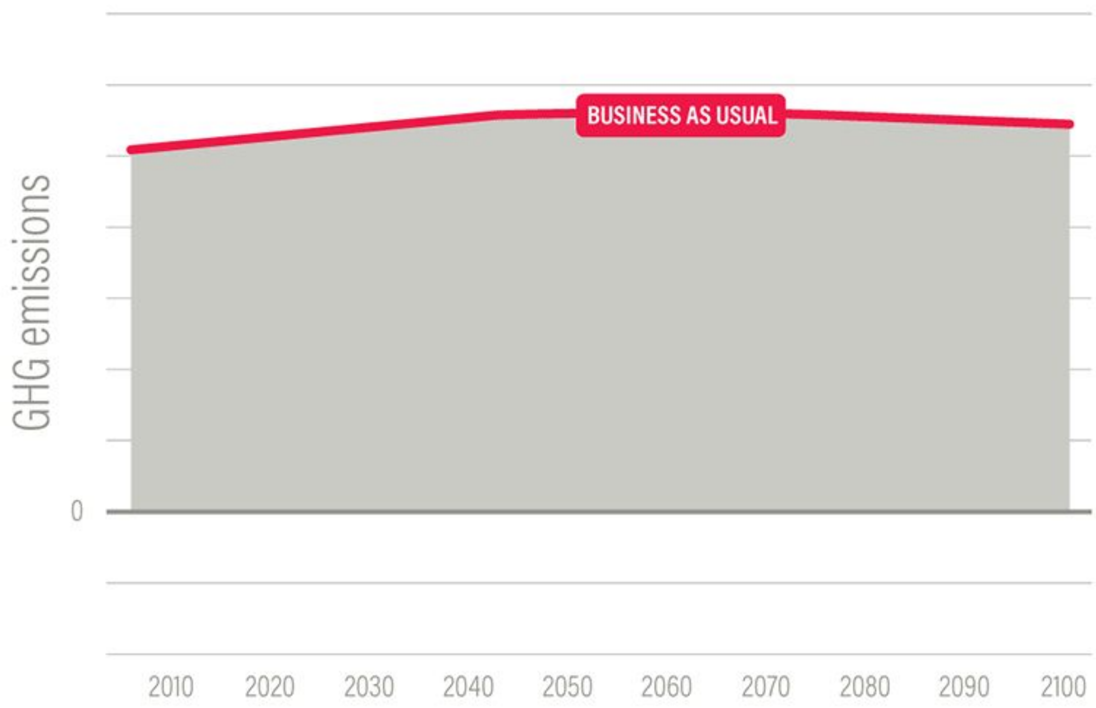
CDR is uncertain

The costs, potential and side effects of these measurements still possess large uncertainties

- In particular, the feasibility and the impact of large-scale deployment is unknown
- The most cost-efficient and lowest risk strategy would be to involve different variety of approaches together

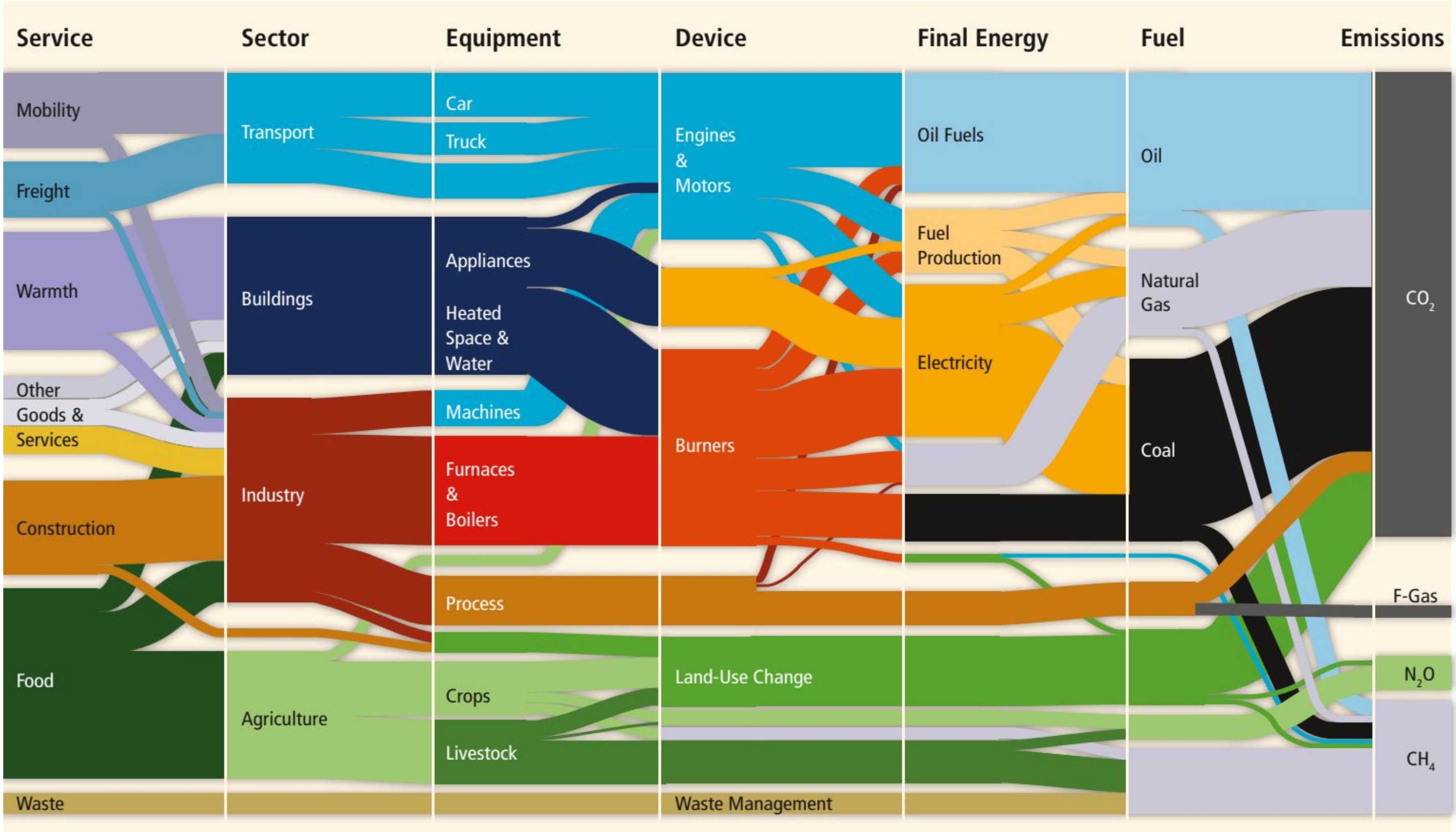
HOW TO GET TO NET-ZERO

Transition to a low-carbon economy

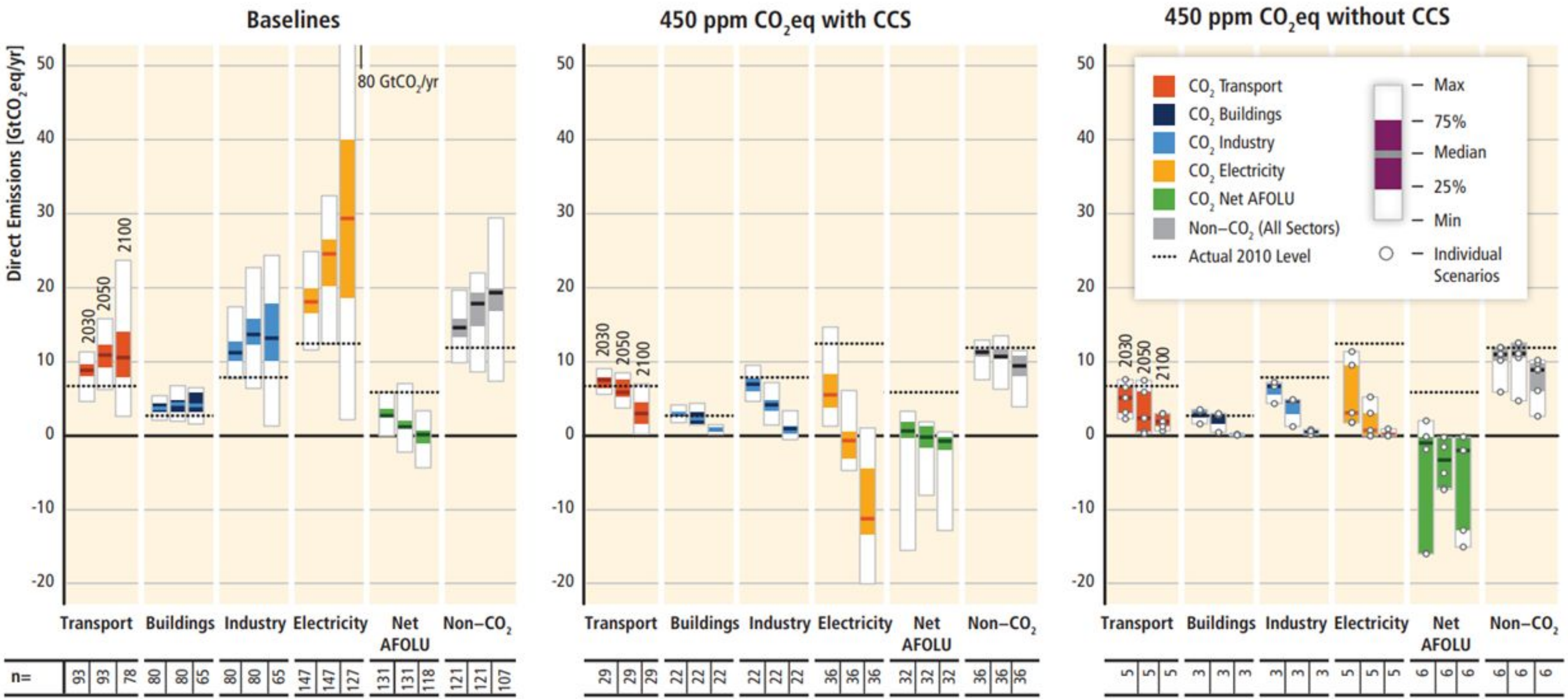


WORLD RESOURCES INSTITUTE

Energy end-use sectors


Service
Sector
Equipment
Device
Final Energy
Fuel
Emissions
Mobility
Freight
Warmth
Other
Goods &
Services
Construction
Food
Waste
Transport
Buildings
Industry
Agriculture
Car
Truck
Appliances
Heated
Space &
Water
Machines
Furnaces
&
Boilers
Process
Crops
Livestock
Engines
&
Motors
Burners
Land-Use Change
Waste Management
Oil Fuels
Fuel
Production
Electricity
Oil
Natural
Gas
Coal
CO_2
F-Gas
N_2O
CH_4

Direct Sectoral CO_2 and Non-CO_2 GHG Emissions in Baseline and Mitigation Scenarios with and without CCS



Transport

The transport sector accounted for 27% of final energy use and had produced 7.0 $GtCO_2eq$ of direct GHG emissions (including non-CO_2 gases) in 2010 and hence was responsible for approximately 23% of total energy-related CO_2 emissions (6.7 $GtCO_2$)

Greenhouse gas (GHG) emissions from the transport sector have more than doubled since 1970, and have increased at a faster rate than any other energy end-use sector.

Mitigation options in Transport sector

Options concerning passenger and freight transport:
•avoiding journeys where possible
•modal shift to lower-carbon transport systems
•lowering energy intensity (MJ/passenger km or MJ/tonne km)
•reducing carbon intensity of fuels (CO_2eq/MJ)

Technology options:
•improving internal combustion engines
•new propulsion systems include electric motors powered by batteries or fuel cells, turbines (particularly for rail), and various hybridized concepts
•reducing vehicle weight

In addition, indirect GHG emissions arise during the construction of infrastructure, manufacture of vehicles, and provision of fuels

Industry

In 2010, the industry sector accounted for around 28% of final energy use, and 13 $GtCO_2$ emissions, including direct and indirect emissions as well as process emissions, with emissions projected to increase by 50–150% by 2050

Mitigation options in Industry sector

•Innovations

•Information programmes promoting energy efficiency by economic instruments, regulatory approaches and voluntary actions

•Overall reductions in product demand

•Process optimization, refrigerant recovery, recycling and substitution

•Material use, recycling and re-use of materials and products

•Application of cross-cutting technologies and measures

•Waste reduction, followed by re-use, recycling and energy recovery

•New industrial processes, radical product innovations

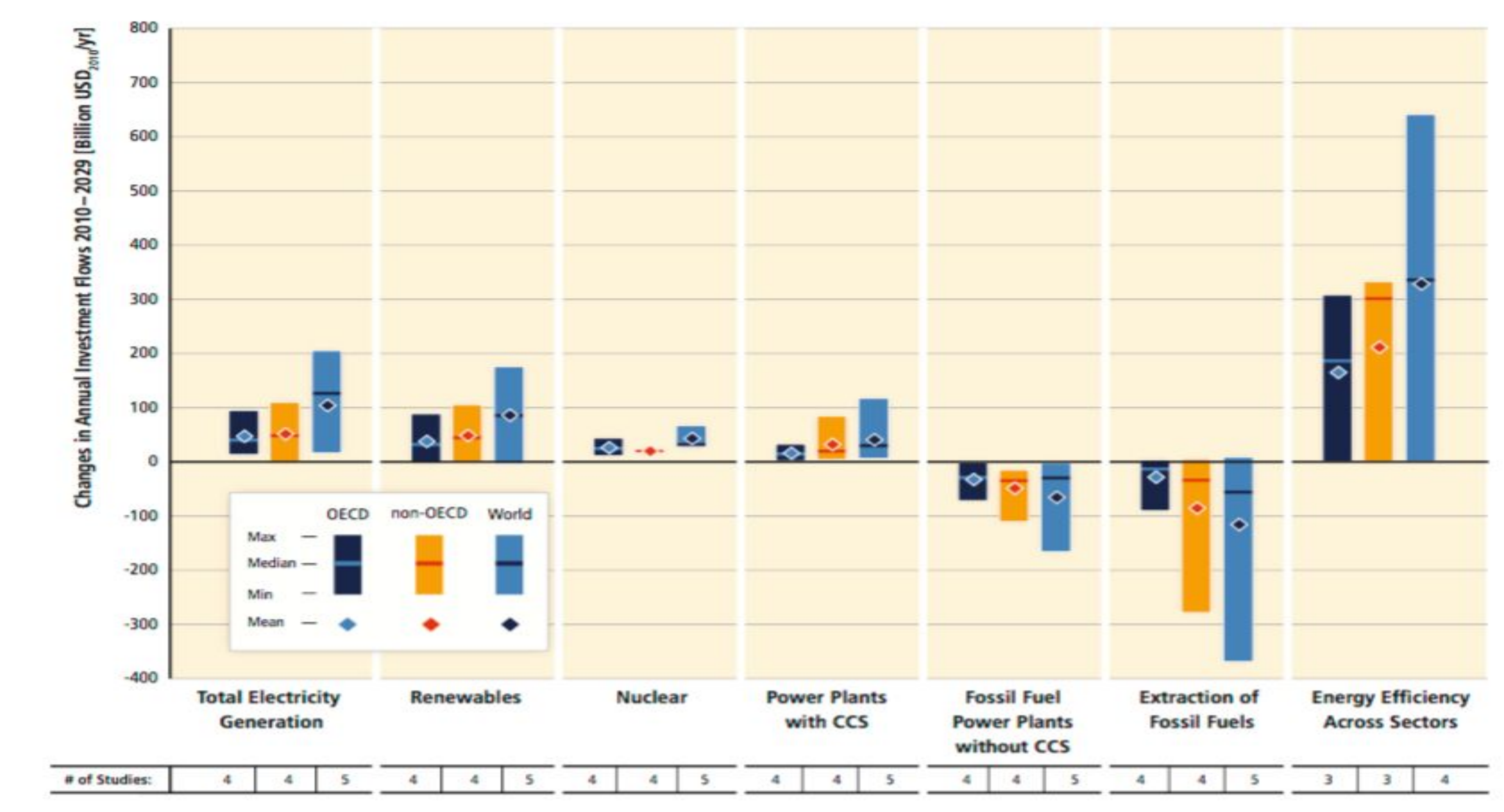
MITIGATION POLICIES AND INSTITUTIONS

1. SECTORAL AND NATIONAL POLICIES

- **Substantial reductions in emissions would require large changes in investment patterns.** Over the next two decades annual investment in conventional fossil fuel technologies associated with the electricity supply sector is projected to decline by about 30 billion USD while annual investment in low-carbon electricity supply (i. e., renewables, nuclear and electricIty generation with CCS) is projected to rise by about 147 (31–360) billion USD. Annual incremental energy efficiency investments in transport, buildings and industry is projected to increase by about 336 billion USD

- **There is no widely agreed definition of what constitutes climate finance, but estimates of the financial flows associated with climate change mitigation and adaptation are available.**Published assessments of all current annual financial flows whose expected effect is to reduce net GHG emissions and/or to enhance resilience to climate change and climate variability show 343 to 385 billion USD per year globally

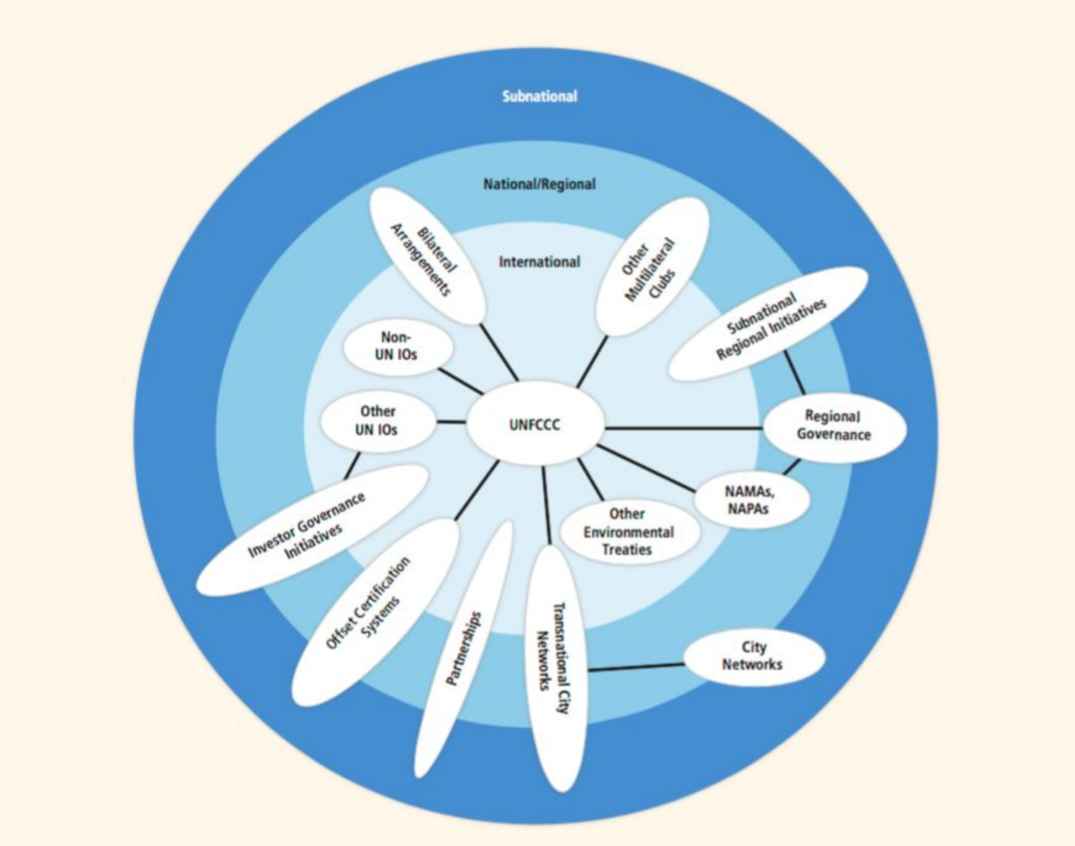
Change in annual investment flows from the average baseline level over the next two decades (2010–2029)



Source: IPCC report 2014

- Sector-specific policies have been more widely used than economy-wide policies
- Regulatory approaches and information measures are widely used, and are often environmentally effective
- In some countries, tax-based policies specifially aimed at reducing GHG emissions—alongside technology and other policies—have helped to weaken the link between GHG emissions and GDP
- The reduction of subsidies for GHG-related activities in various sectors can achieve emission reductions, depending on the social and economic context
- Interactions between or among mitigation policies may be synergistic or may have no additive effect on reducing emissions
- Some mitigation policies raise the prices for some energy services and could hamper the ability of societies to expand access to modern energy services to underserved populations. These potential adverse side-effects can be avoided with the adoption of complementary policies.
- Technology policy complements other mitigation policies
- In many countries, the private sector plays central roles in the processes that lead to emissions as well as to mitigation. Within appropriate enabling environments, the private sector, along with the public sector, can play an important role in financing mitigation

2. INTERNATIONAL COOPERATION

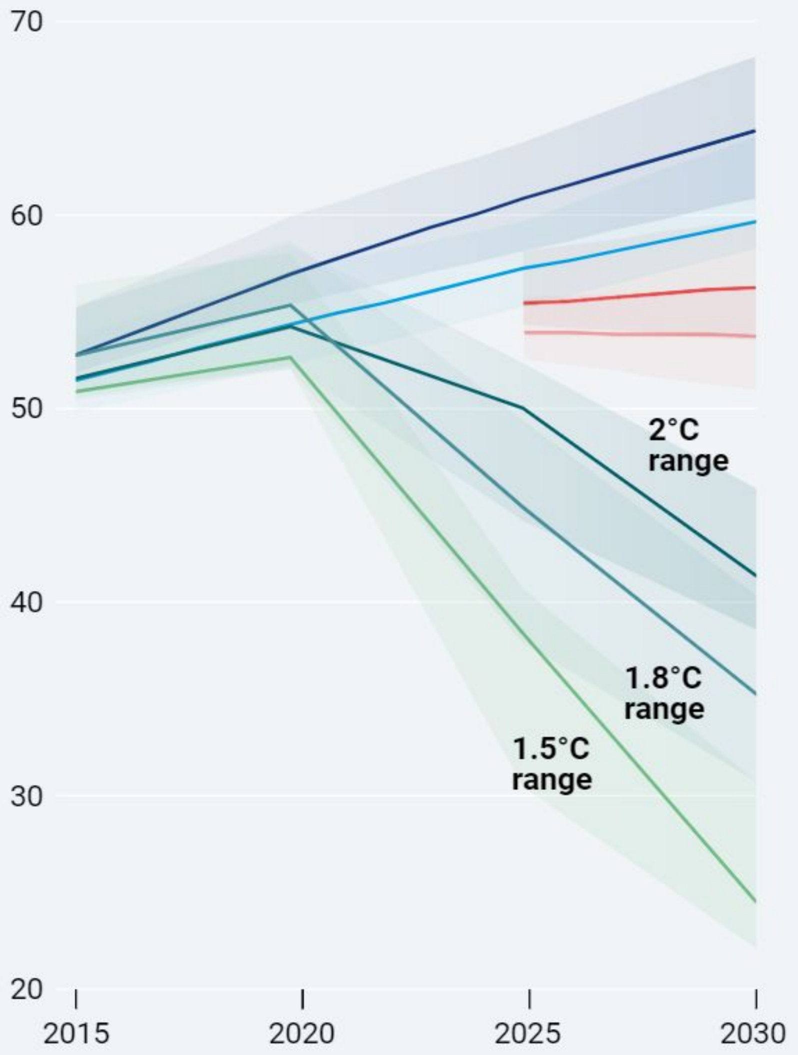


Source: IPCC report 2014

The landscape of agreements and institutions on climate change

UNFCCC	Kyoto Protocol, Clean Development Mechanism, International Emissions Trading
Other UN Intergovernmental organizations	Intergovernmental Panel on Climate Change, UN Development Programme, UN Environment Programme, UN Global Compact, International Civil Aviation Organization, International Maritime Organization, UN Fund for International Partnerships
Non-UN IOs	World Bank, World Trade Organization
Other environmental treaties	Montreal Protocol, UN Conference on the Law of the Sea, Environmental Modification Treaty, Convention on Biological Diversity
Other multilateral 'clubs'	Major Economies Forum on Energy and Climate, G20, REDD+ Partnerships
Bilateral arrangements	e.g., US-India, Norway-Indonesia
Partnerships	Global Methane Initiative, Renewable Energy and Energy Efficiency Partnership, Climate Group
Offset certification systems	e.g., Gold Standard, Voluntary Carbon Standard
Investor governance initiatives	Carbon Disclosure Project, Investor Network on Climate Risk
Regional governance	e.g., EU climate change policy
Subnational regional initiatives	Regional Greenhouse Gas Initiative, California emissions-trading system
City networks	US Mayors' Agreement, Transition Towns
Transnational city networks	C40, Cities for Climate Protection, Climate Alliance, Asian Cities Climate Change Resilience Network
NAMAs, NAPAs	Nationally Appropriate Mitigation Actions (NAMAs) of developing countries; National Adaptation Programmes of Action (NAPAs)

Source:IPCC report 2014


70
60
50
40
30
20
2015
2020
2025
2030
2°C
range
1.8°C
range
1.5°C
range

As for the future, your task is not to foresee it, but to enable it”

- Antoine de Saint Exupery

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