climate change 3/12/2020

Emission Scenarios

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Introduction

What are emission scenarios?

Possible **pathways** that society might take in the **emission of greenhouse gases in the future.**

IPCC released first emission scenarios in 1992, which were considered pathbreaking.

Consecutive versions of scenarios have been released and the following were introduced: **SRES (Special Report on Emissions Scenarios), RCPs (Representative Concentration Pathways), SSPs (Shared Socioeconomic Pathways).**

Driving forces of scenarios:

- Population growth
- Energy use changes
- Economic development
- Technological development and
- Land use change

Why do we need scenarios?

Different assumptions in various places of the world make it hard to compare and validate models.

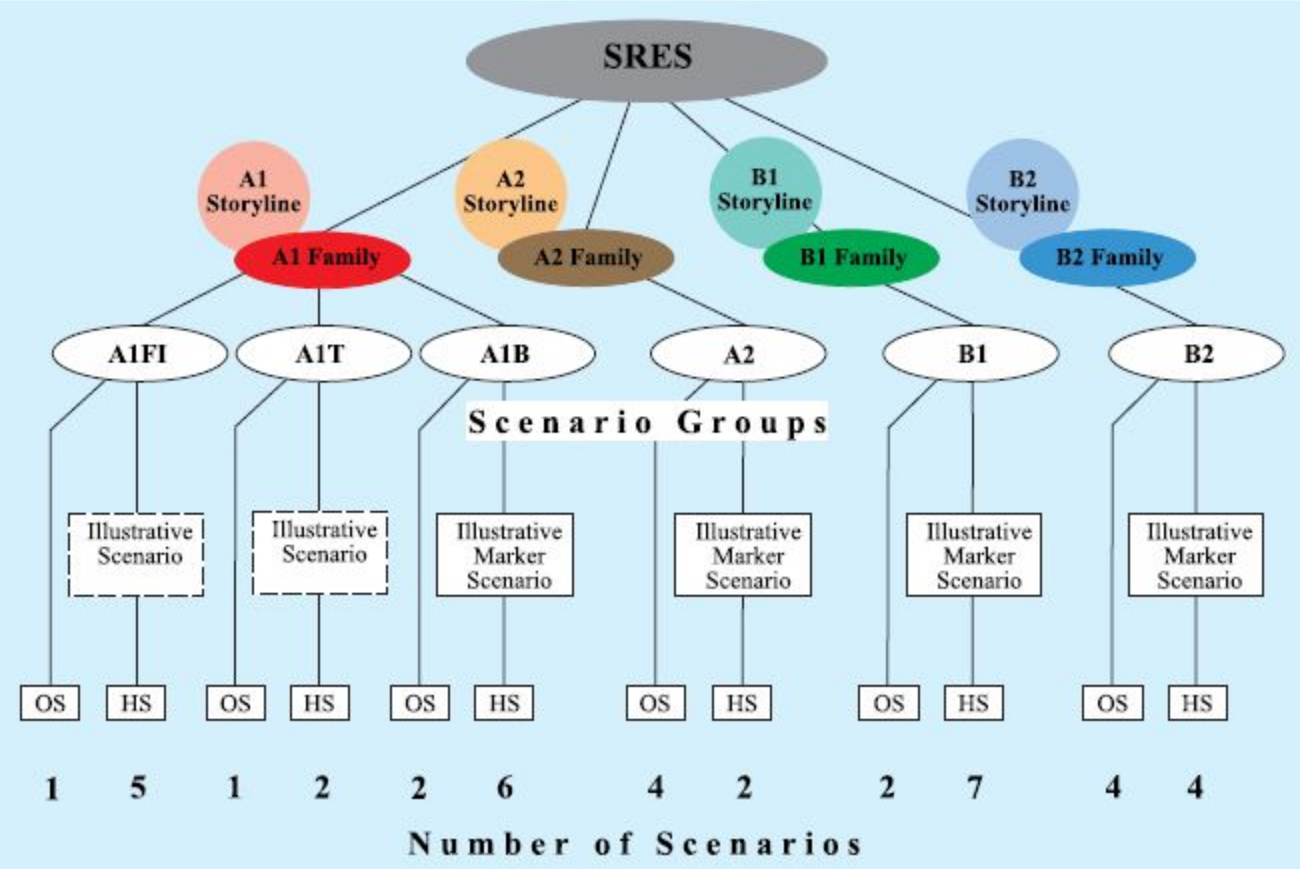
State of the world depends mainly on the amount of emissions that we are **about to produce** between 2000 and 2100, not on the previous data used in regular climate models.

Great amount of computer power needed for conventional models.

Scenarios help to define and interpret the infinite number of possibilities to describe future emissions.

Special Report on Emissions Scenarios (SRES)

The main characteristics of the four SRES storylines and scenario families



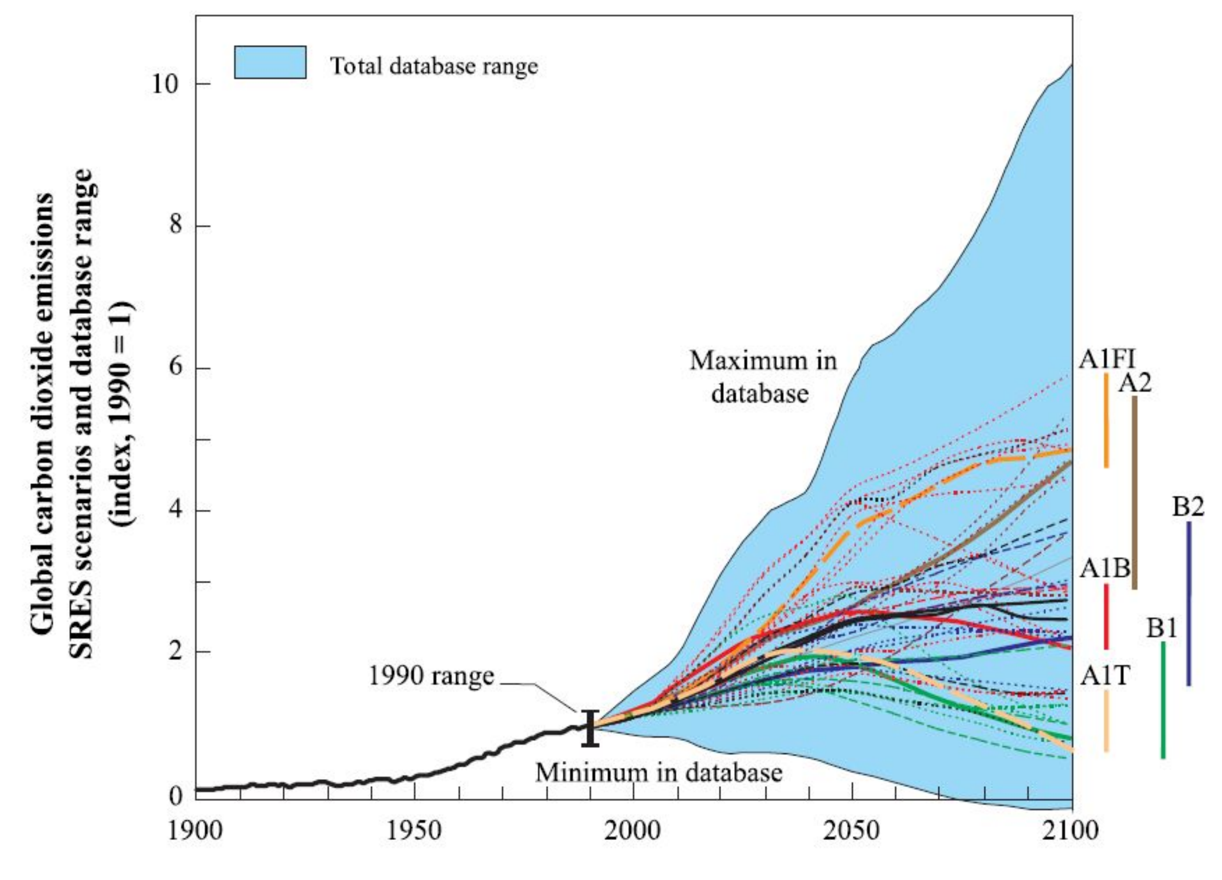
Overview of main primary driving forces

Family		A1			A2	B1	B2
Scenario group	**1990**	**A1FI**	**A1B**	**A1T**	**A2**	**B1**	**B2**
Population (billion)	5.3						
2020		**7.6** (7.4-7.6)	**7.5** (7.2-7.6)	**7.6** (7.4-7.6)	**8.2** (7.5-8.2)	**7.6** (7.4-7.6)	**7.6** (7.6-7.8)
2050		**8.7**	**8.7** (8.3-8.7)	**8.7**	**11.3** (9.7-11.3)	**8.7** (8.6-8.7)	**9.3** (9.3-9.8)
2100		**7.1** (7.0-7.1)	**7.1** (7.0-7.7)	**7.0**	**15.1** (12.0-15.1)	**7.0** (6.9-7.1)	**10.4** (10.3-10.4)
World GDP (10^{12} 1990US$/yr)	21						
2020		**53** (53-57)	**56** (48-61)	**57** (52-57)	**41** (38-45)	**53** (46-57)	**51** (41-51)
2050		**164** (163-187)	**181** (120-181)	**187** (177-187)	**82** (59-111)	**136** (110-166)	**110** (76-111)
2100		**525** (522-550)	**529** (340-536)	**550** (519-550)	**243** (197-249)	**328** (328-350)	**235** (199-255)
Per capita income ratio: developed countries and economies in transition (Annex-I) to developing countries (Non-Annex-I)	16.1						
2020		**7.5** (6.2-7.5)	**6.4** (5.2-9.2)	**6.2** (5.7-6.4)	**9.4** (9.0-12.3)	**8.4** (5.3-10.7)	**7.7** (7.5-12.1)
2050		**2.8**	**2.8** (2.4-4.0)	**2.8** (2.4-2.8)	**6.6** (5.2-8.2)	**3.6** (2.7-4.9)	**4.0** (3.7-7.5)
2100		**1.5** (1.5-1.6)	**1.6** (1.5-1.7)	**1.6** (1.6-1.7)	**4.2** (2.7-6.3)	**1.8** (1.4-1.9)	**3.0** (2.0-3.6)

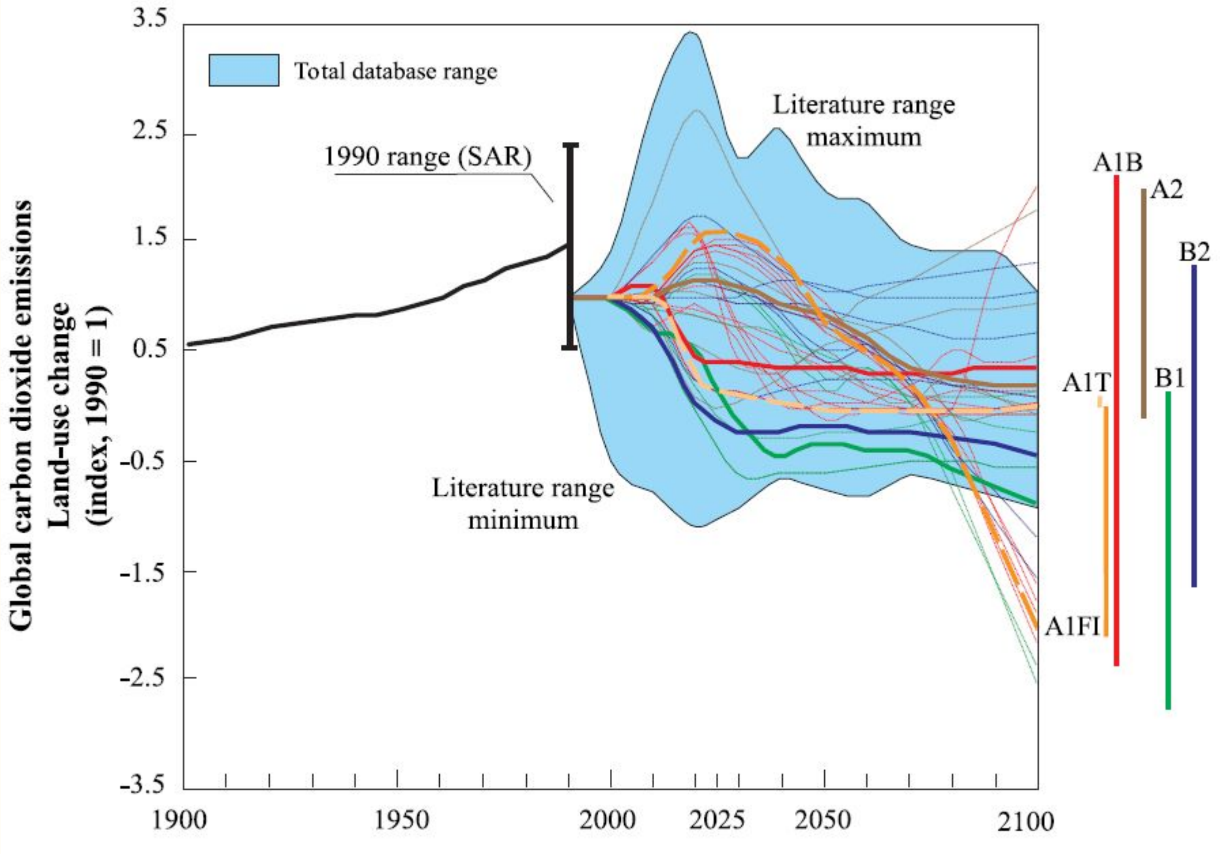
[a] For some driving forces, no range is indicated because all scenario runs have adopted exactly the same assumptions.

Technological change is not quantified in the table.

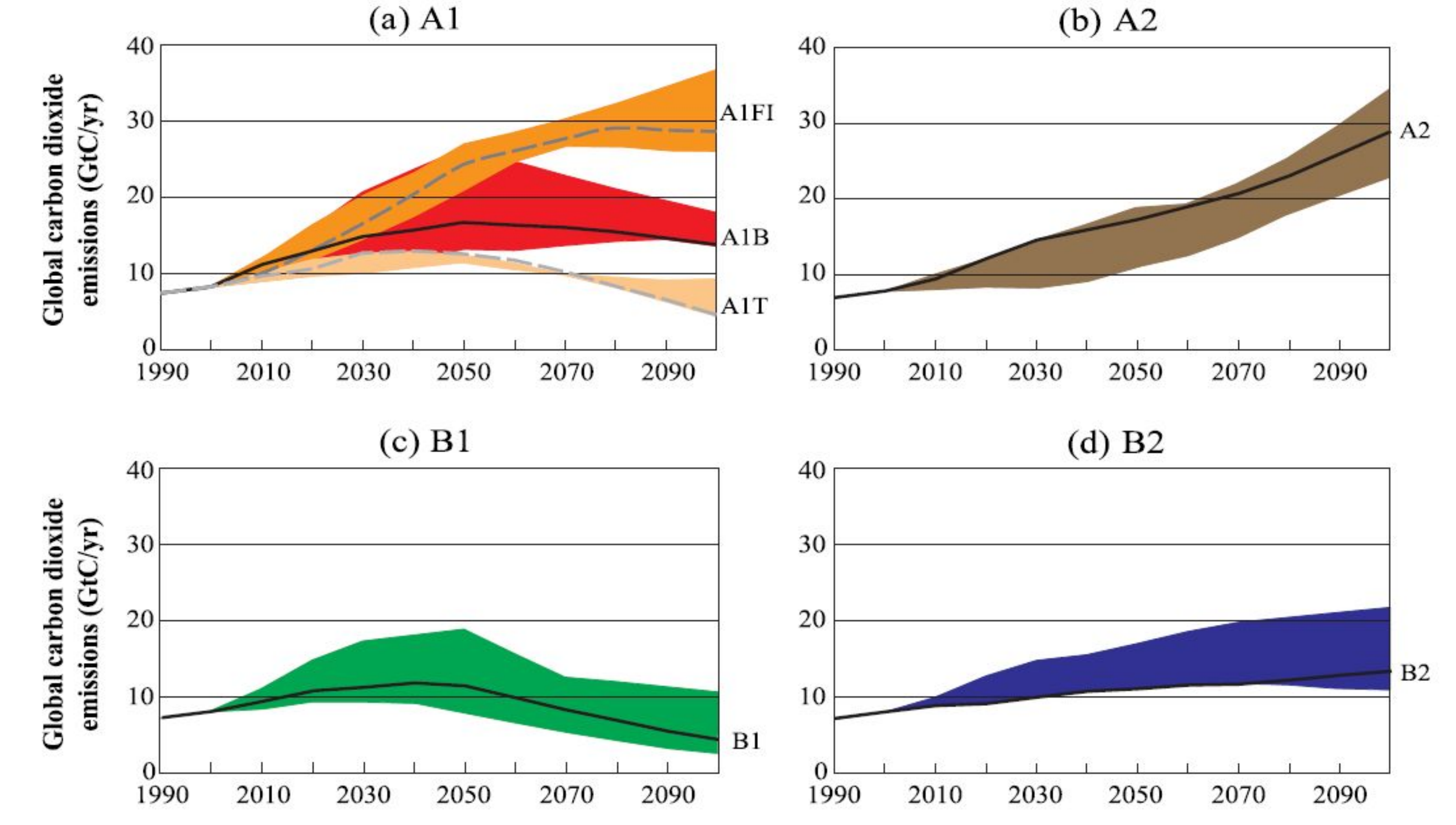
Global CO2 emissions related to energy and industry



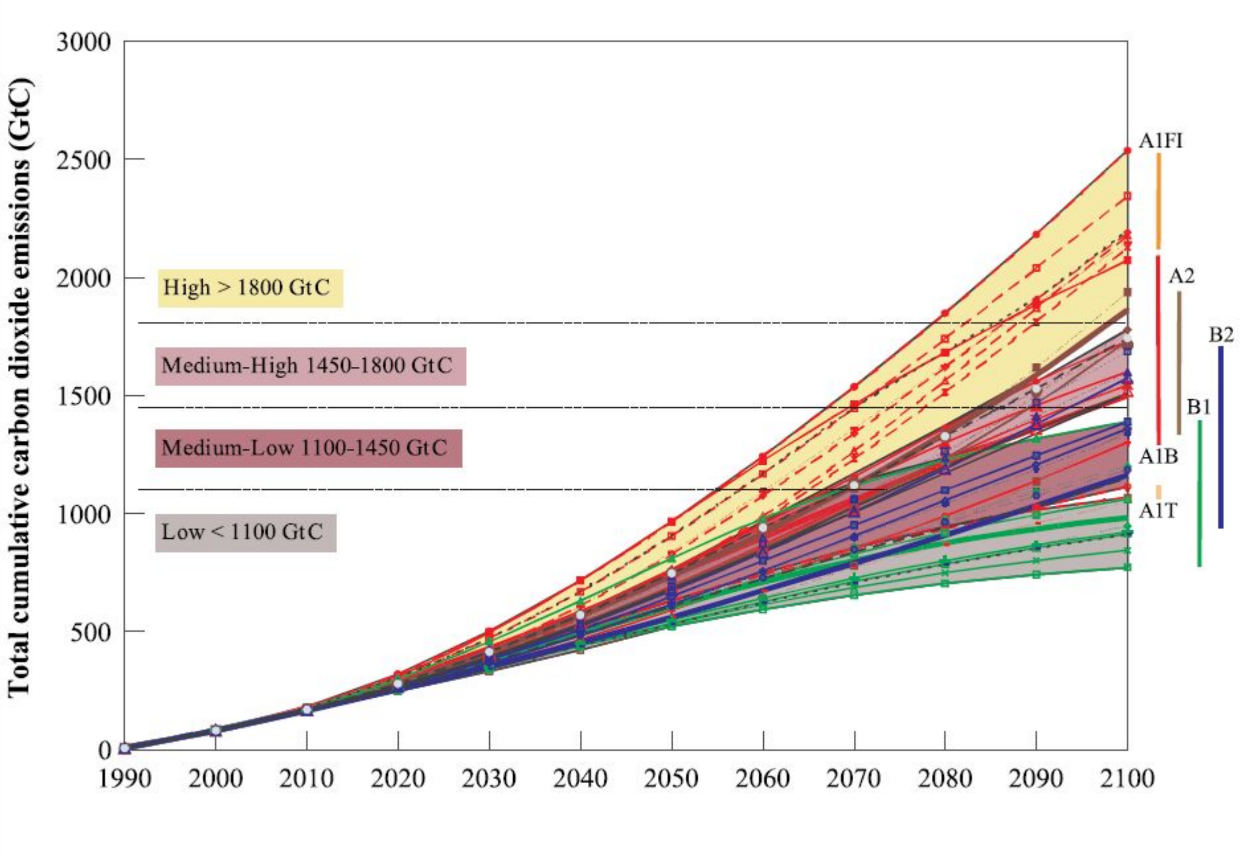
Global CO2 emissions related to land-use changes



Total global annual CO2 emissions from all sources



Total global cumulative CO2 emissions (GtC)



Representative Concentration Pathway (RCP)

Introduction and information regarding RCP

- What is RCP
- RCP calculation

Emission Categories

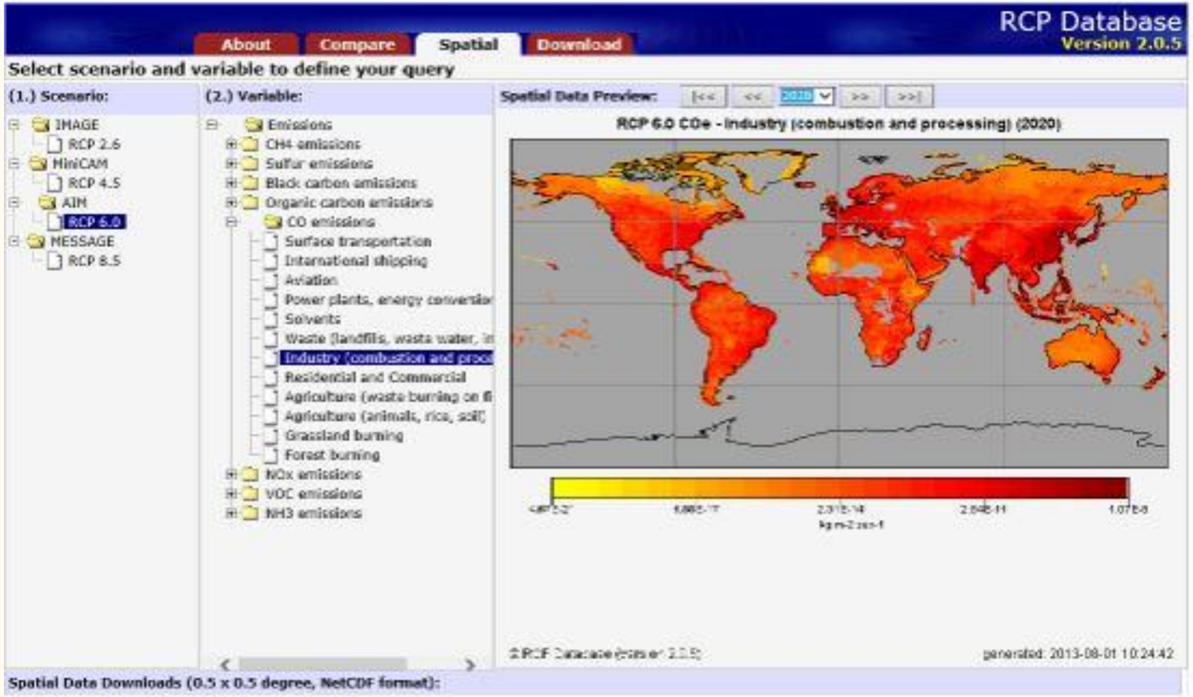


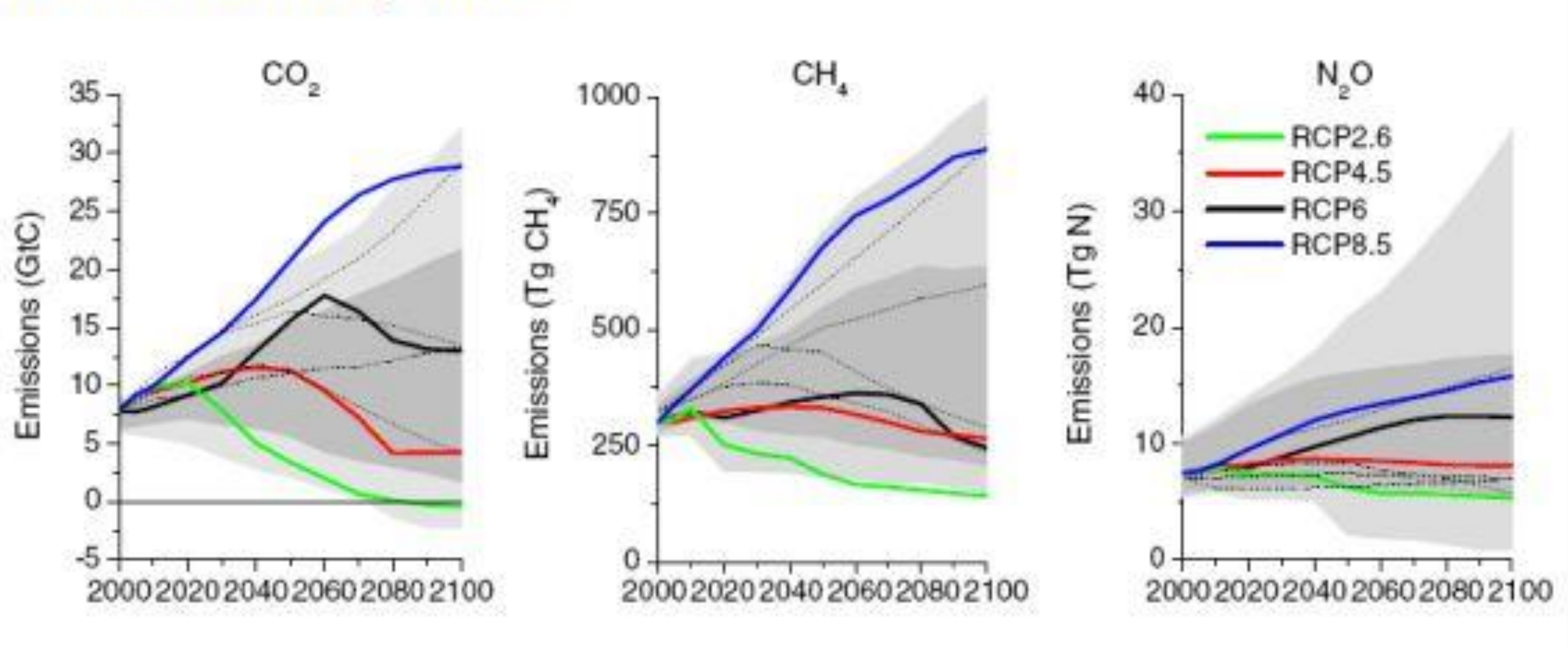
Figure 2: *RCP on-line database showing RPC6 spatial data for industry CO2e emissions for the year 2020. (Click here to see full-sized image in a new window)*

RCPs & Resulations

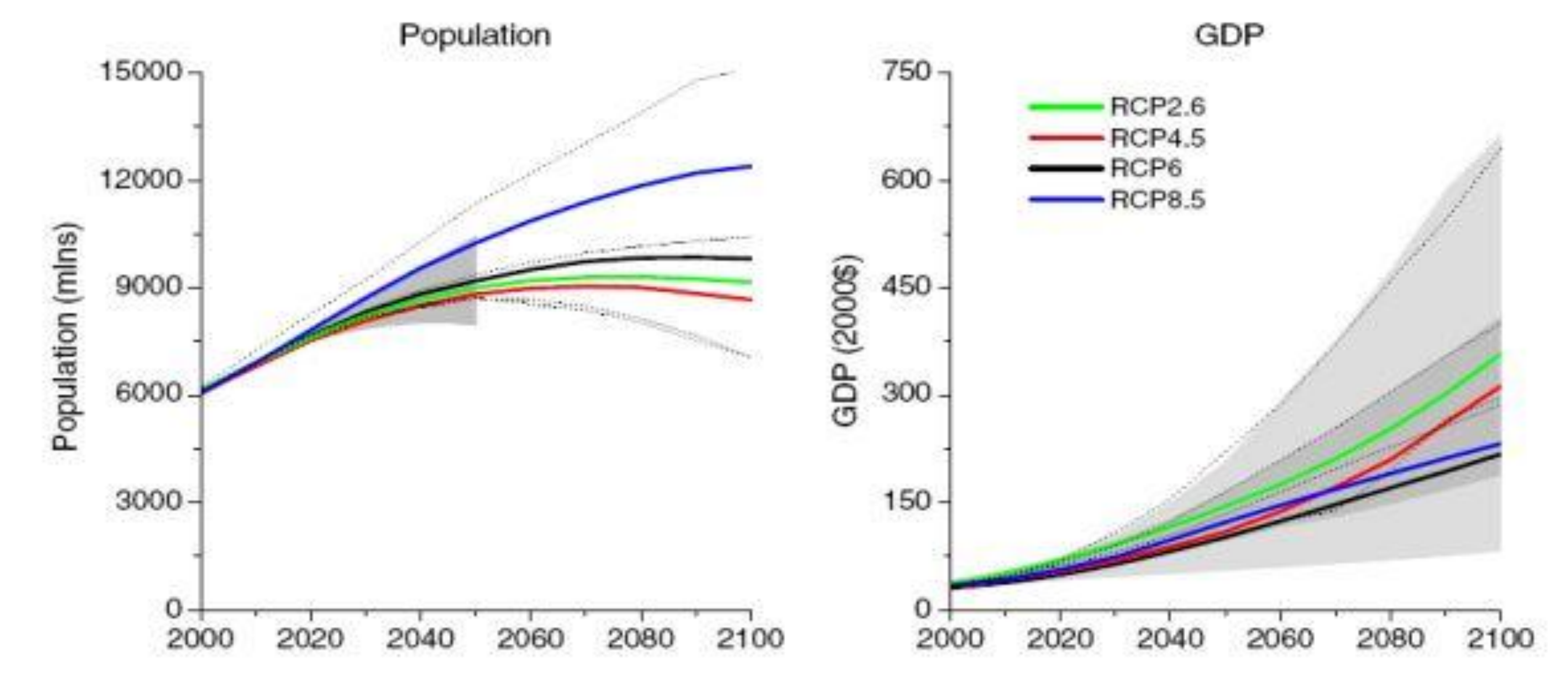
Available information from RCPs and resolution		
	Resolution (sectors)	**Resolution (geographical)**
Emissions of greenhouse gases		
CO_2	Energy/industry, land	Global and for 5 regions
CH_4	12 sectors	0.5°×0.5° grid
N_2O, HFCs, PFCs, CFCs, SF_6	Sum	Global and for 5 regions
Emissions aerosols and chemically active gases		
SO_2, Black Carbon, Organic Carbon, CO, NO_x, VOCs, NH_3	12 sectors	0.5°×0.5° grid
Speciation of VOC emissions		0.5°×0.5° grid
Concentration of greenhouse gases		
(CO_2, CH_4, N_2O, HFCs, PFCs, CFCs, SF_6)		Global
Concentrations of aerosols & chemically active gases		
(O_3, Aerosols, N deposition, S deposition)		0.5°×0.5° grid
Land-use/land-cover data	Cropland, pasture, primary vegetation, secondary vegetation, forests	0.5°×0.5° grid with subgrid fractions, (annual maps and transition matrices including wood harvesting)

Table 3: from van Vuuren et.al. 2011

RCP Emission Trajectories



RCP vs Population & GDP



- Pathways of RCP
- Purpose for RCP model use
- Improvements over SRES

Overview of RCP development process with Products :

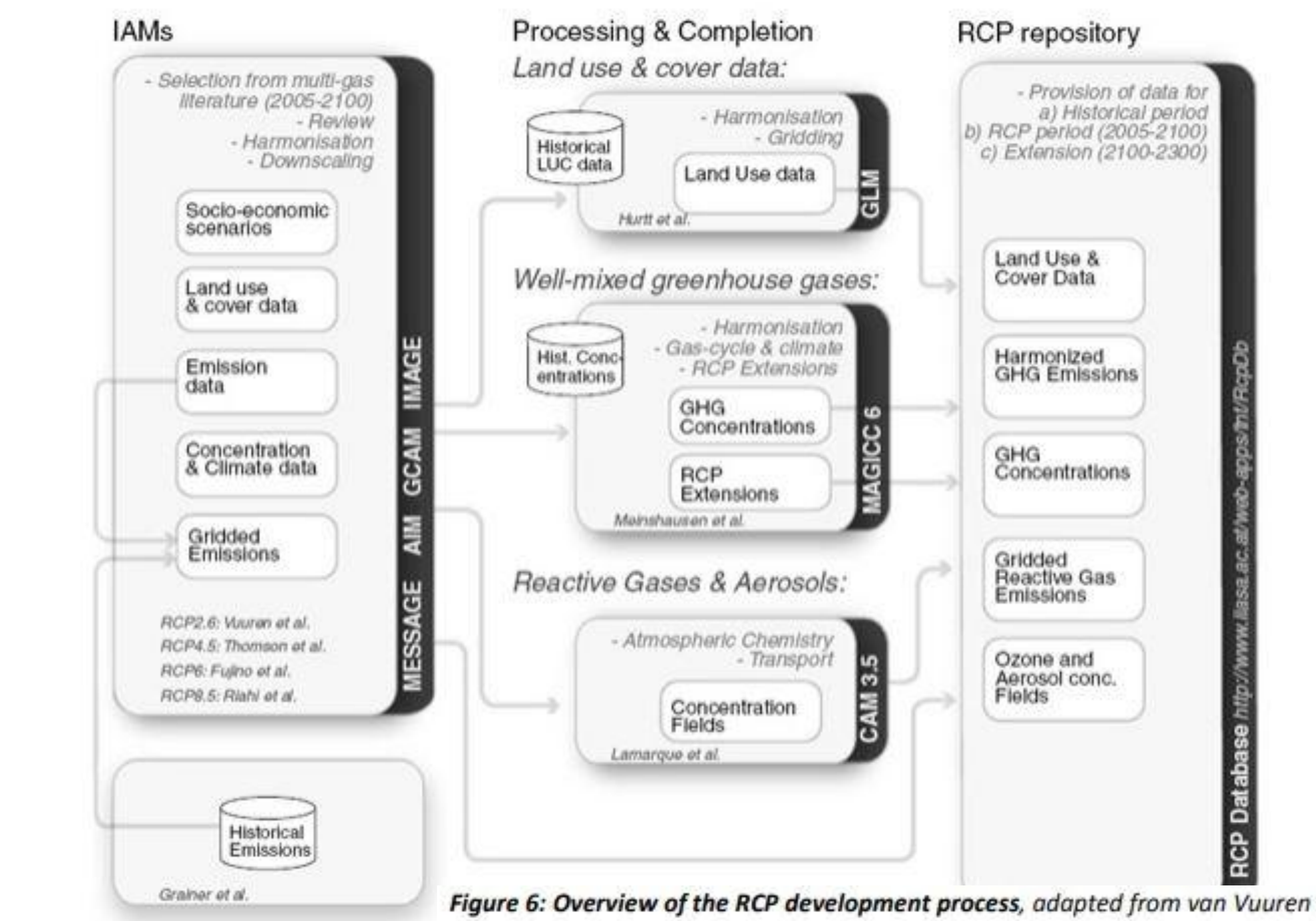


***Figure 6: Overview of the RCP development process**, adapted from van Vuuren et.al. 2011*

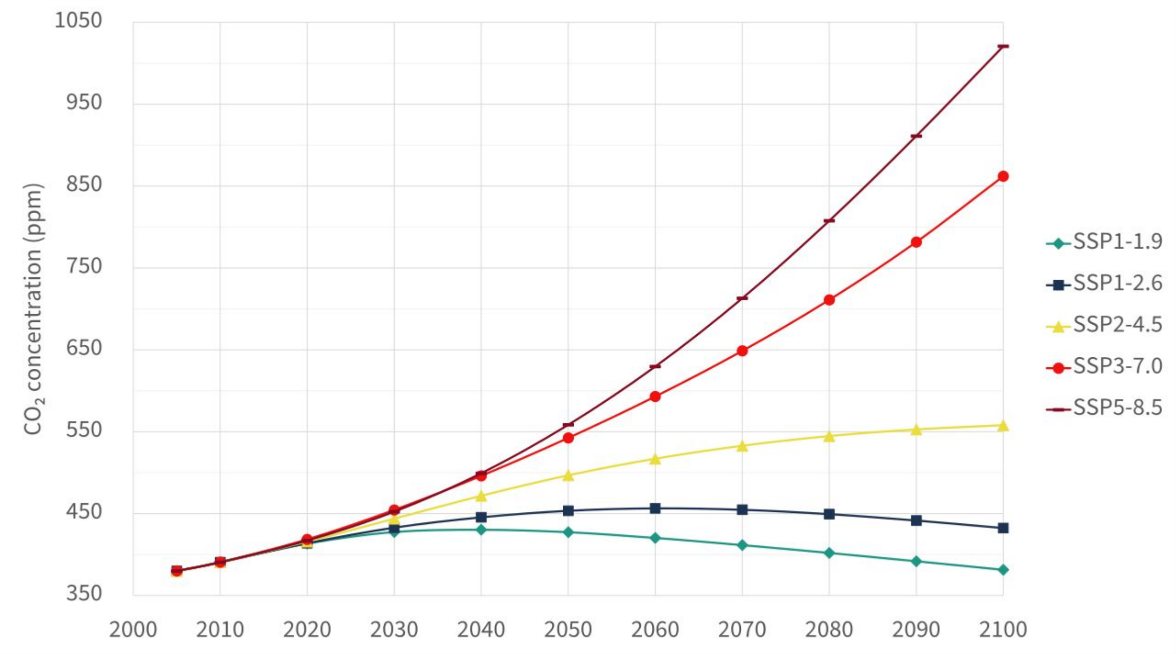
- Four Representative concentration pathways (RCPs)
- RCP-based climate model ensembles and pattern scaling
- New IAM scenarios
- Global narrative storylines
- Integrated scenarios

Shared Socioeconomic Pathways (SSPs)

Introduction

Shared Socioeconomic Pathways are:

- 5 scenarios of socioeconomic global changes in XXI century
- complementary with RCP scenarios
- going to be published in IPCC Sixth Assessment Report on Climate Change in 2021



Methodology

Key scenarios drivers:

- population
- urbanization
- economic growth (GDP per capita)

Also:

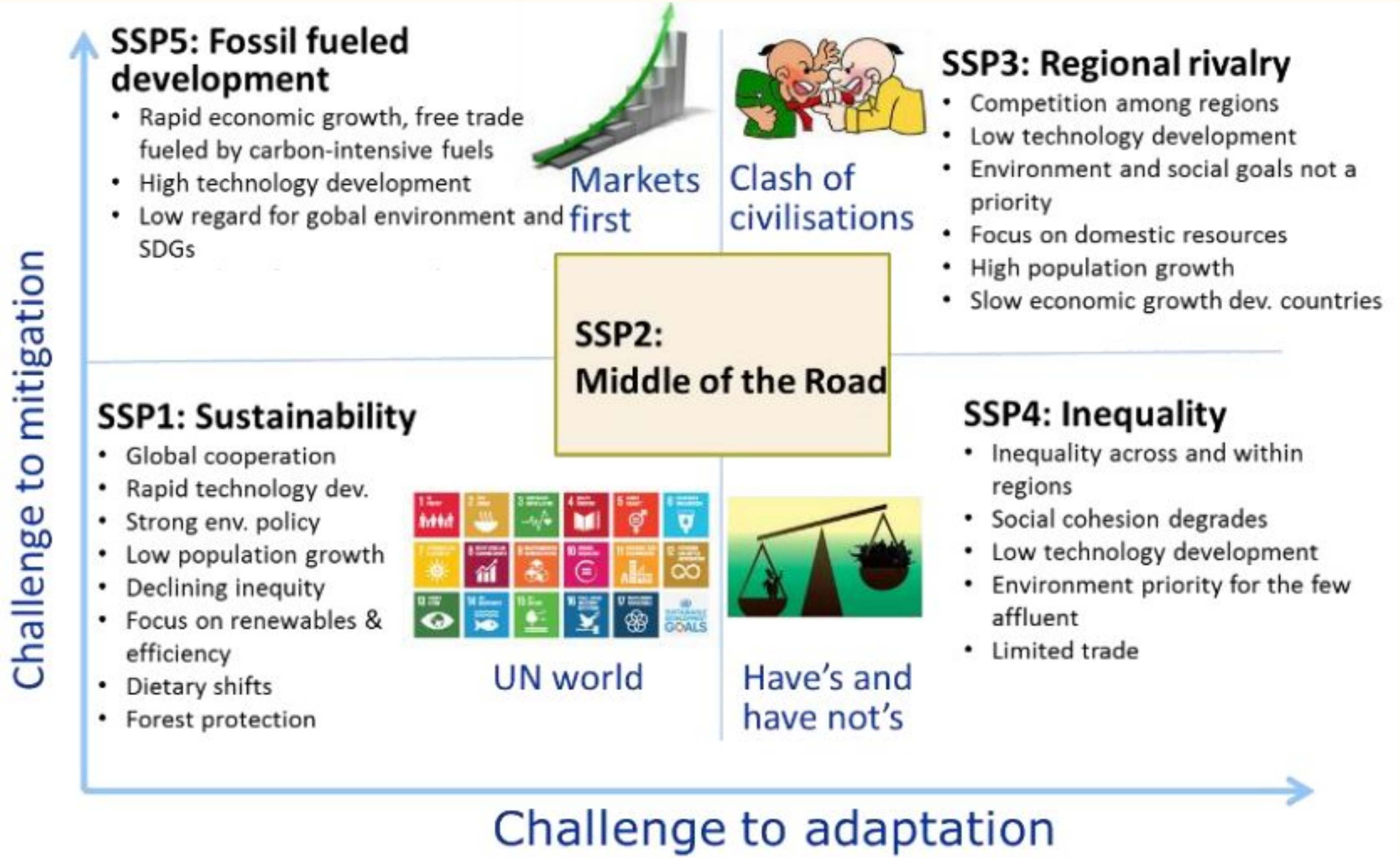
- education
- rate of technological development
- resources availability

Models used:

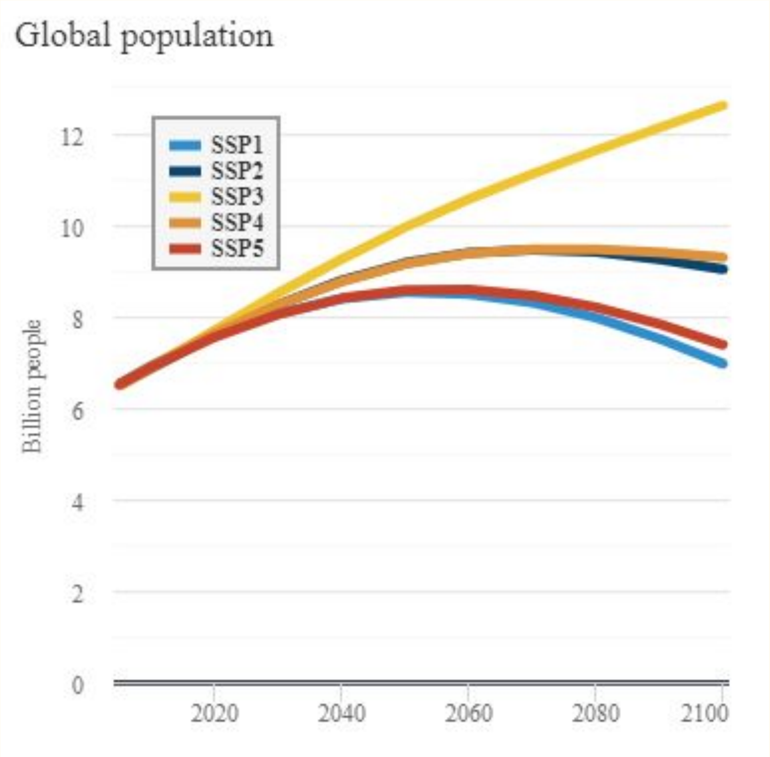
- Multi-model approach - using IAMs (Integrated Assessment Models) and MAGICC-6

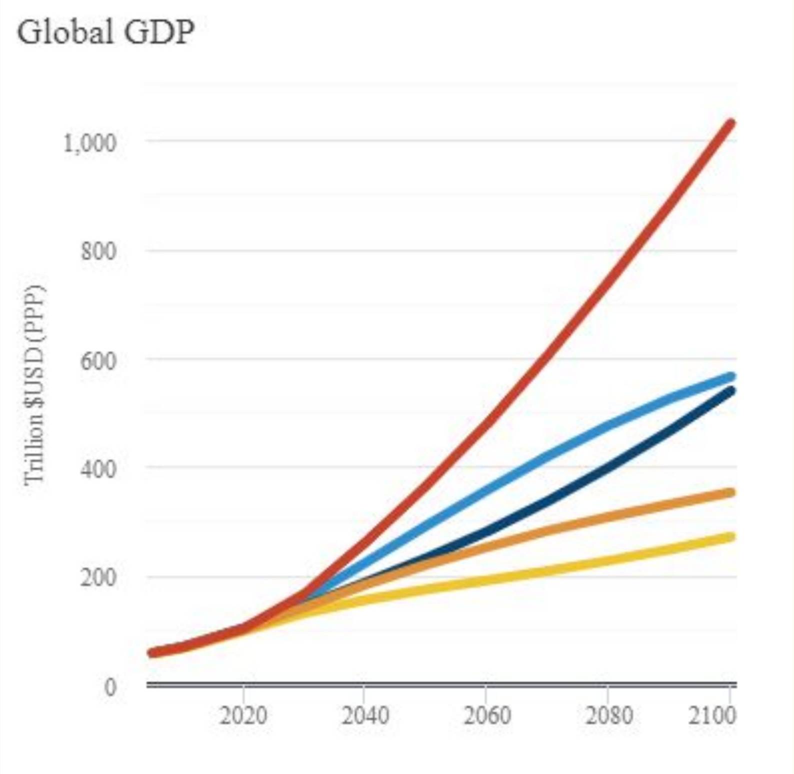
Pathways


★ SSP 5
(Mitigation challenges dominate)
Fossil-fueled development
Taking the Highway
★ SSP 3
(High challenges)
Regional rivalry
A Rocky Road
★ SSP 2
(Intermediate challenges)
Middle of the road
★ SSP 1
(Low challenges)
Sustainability
Taking the Great Road
★ SSP 4
(Adaptation challenges dominate)
Inequality
A Road Divided
Socio-economic challenges for mitigation
Socio-economic challenges for adaptation


SSP5: Fossil fueled development
Rapid economic growth, free trade fueled by carbon-intensive fuels
High technology development
Low regard for gobal environment and SDGs
Markets first
Clash of civilisations
SSP3: Regional rivalry
Competition among regions
Low technology development
Environment and social goals not a priority
Focus on domestic resources
High population growth
Slow economic growth dev. countries
SSP2: Middle of the Road
SSP1: Sustainability
Global cooperation
Rapid technology dev.
Strong env. policy
Low population growth
Declining inequity
Focus on renewables & efficiency
Dietary shifts
Forest protection
UN world
Have's and have not's
SSP4: Inequality
Inequality across and within regions
Social cohesion degrades
Low technology development
Environment priority for the few affluent
Limited trade
Challenge to mitigation
Challenge to adaptation

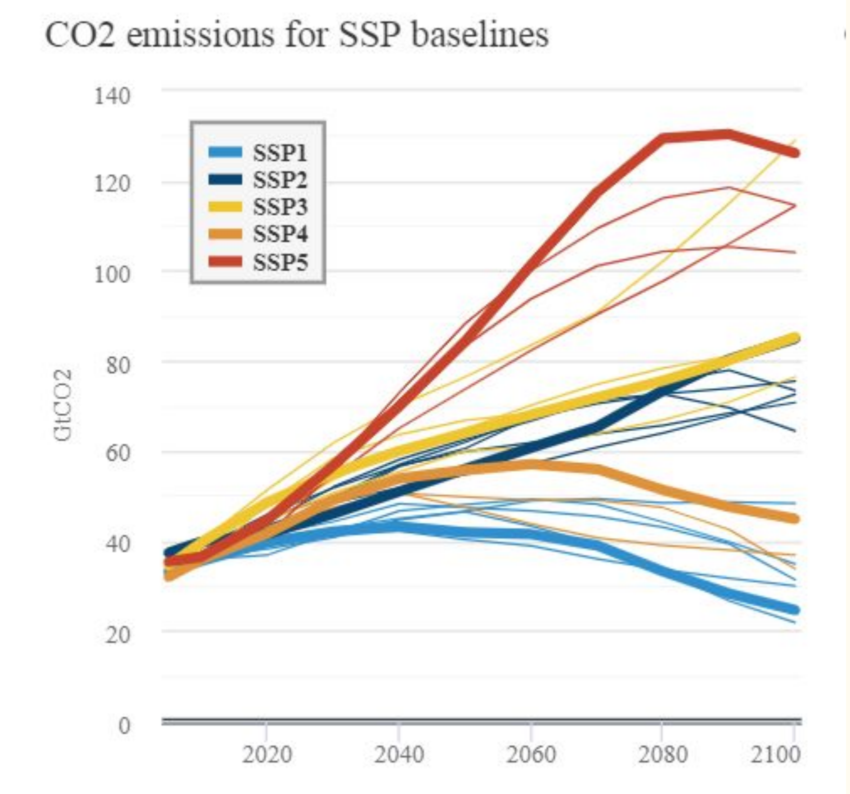
Future scenarios for population and economic growth

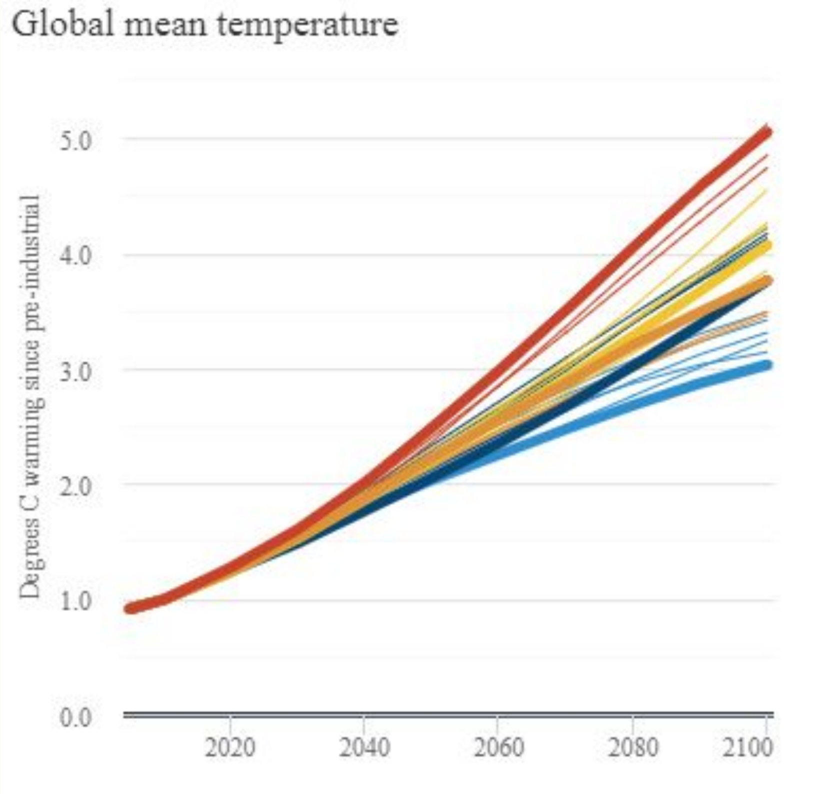




Global population (left) in billions and global gross domestic product (right) in trillion US dollars on a purchasing power parity (PPP) basis. Data from the SSP database; chart by Carbon Brief using Highcharts.

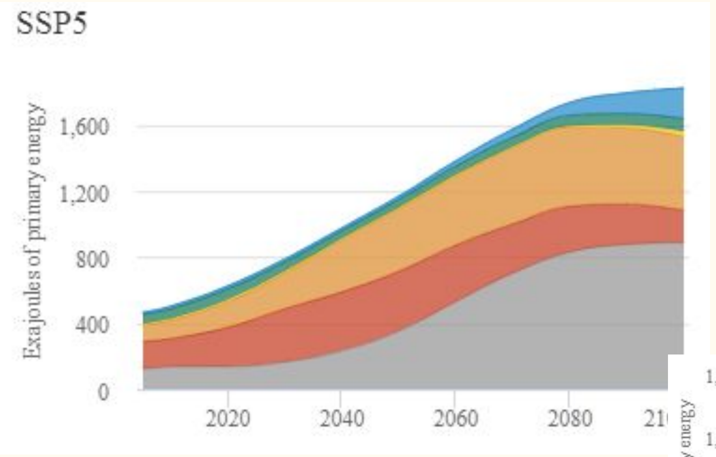
Baseline CO2 emissions and warming

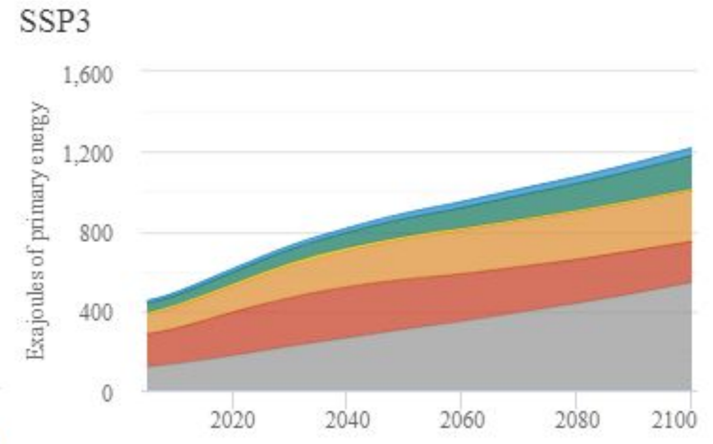


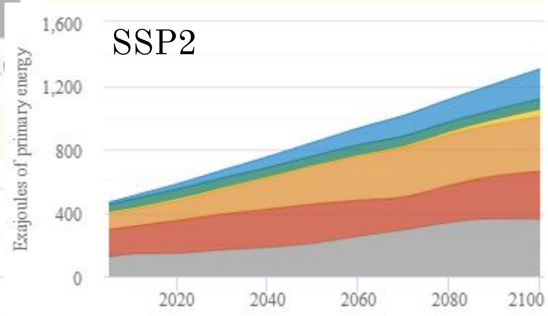


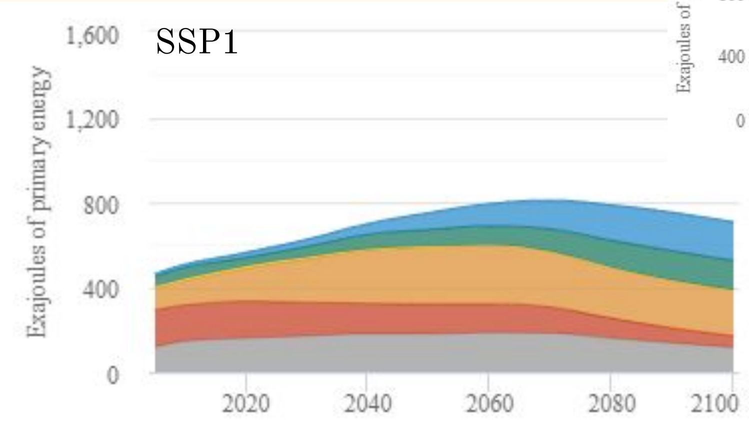
CO_2 emissions (left) in gigatonnes ($GtCO_2$) and global mean surface temperature change relative to pre-industrial levels (right) in degrees C across all models and SSPs for baseline no-climate-policy scenarios. The "marker" model for each SSP is shown by a thicker line, while all other model runs for that SSP have thin lines. Data from the SSP database; chart by Carbon Brief using Highcharts.

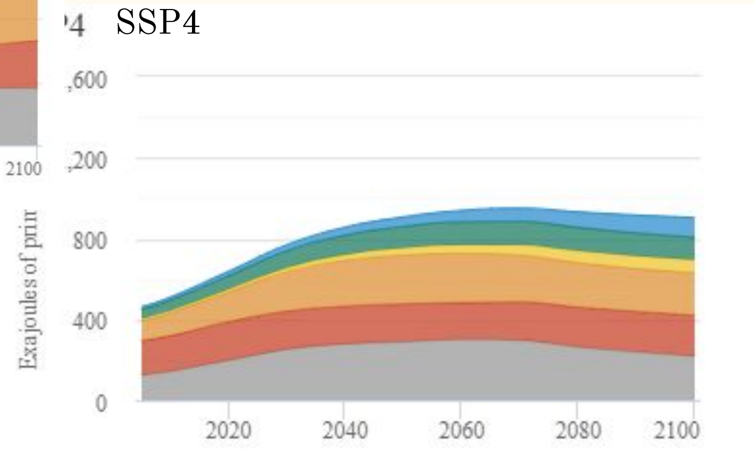
Global energy use changes









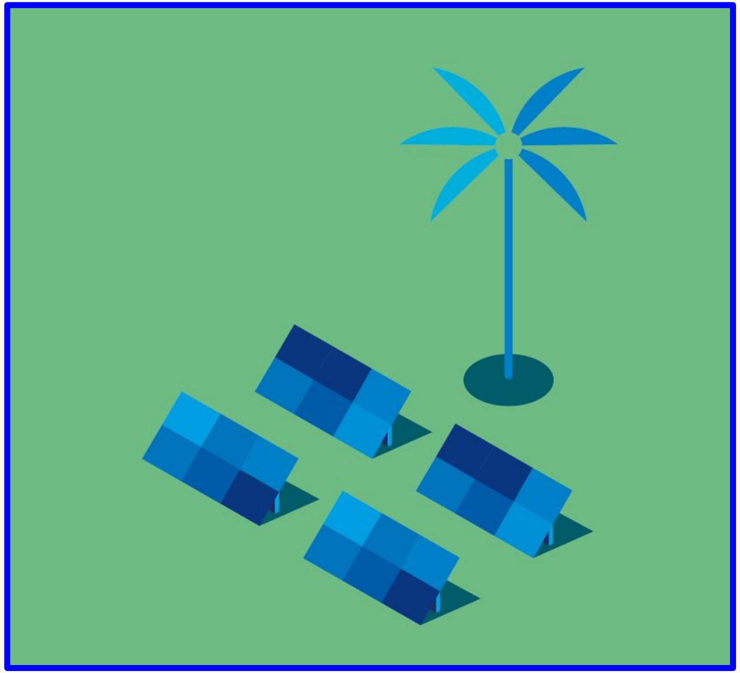


Emissions Gap Report 2019

United Nations, 2019

Emission Gap

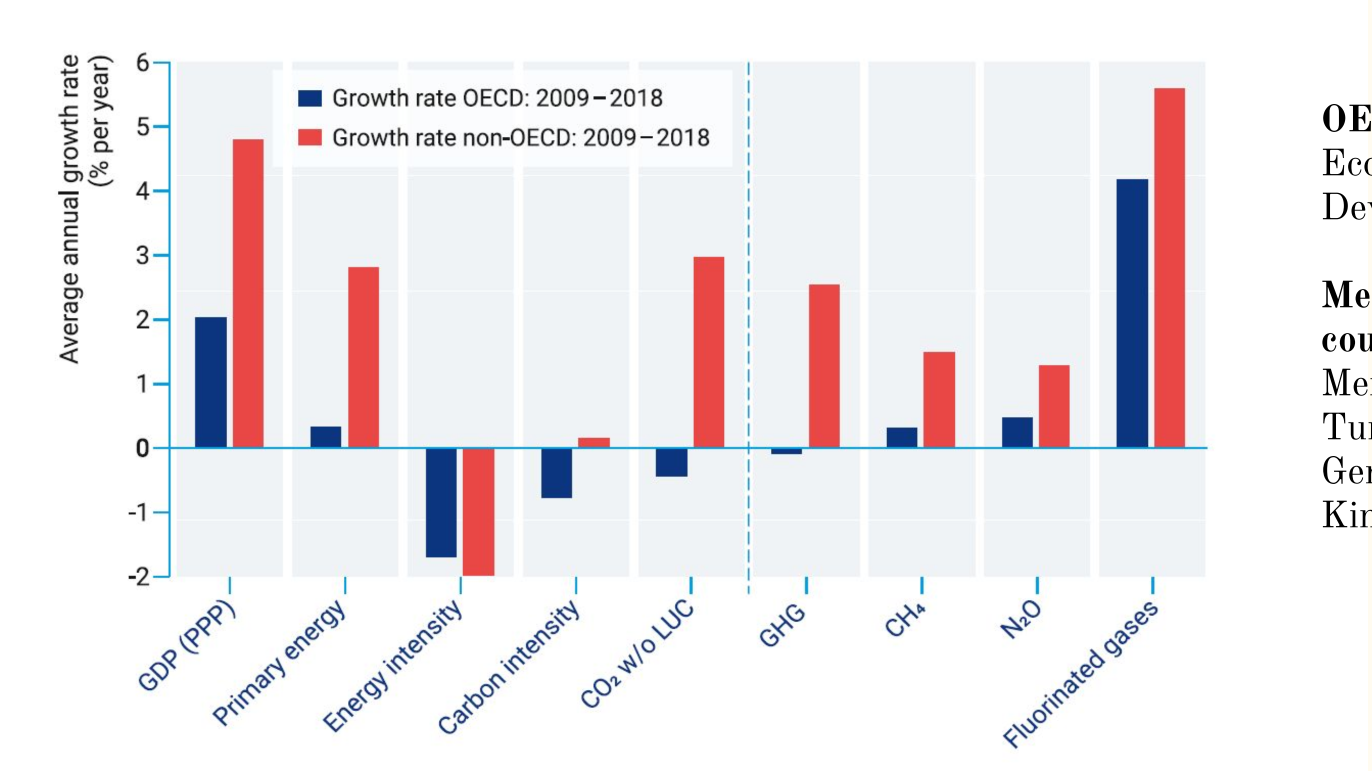
Emissions gap: The difference between the greenhouse gas emission levels consistent with a specific probability of limiting the **mean** global temperature rise to below **2°C or 1.5°C** in **2100** above pre-industrial levels and the GHG emission levels consistent with the global effect of the NDCs, assuming full implementation from 2020.



Summary of the report

Countries collectively **failed** to stop the growth in global GHG emissions, meaning that **deeper and faster cuts are now required.** However, a number of encouraging developments have taken place and the political focus on the climate crisis is growing in several countries, with voters and protestors, particularly youth, making it clear that it is their **number one issue**. In addition, the technologies for rapid and cost-effective emission reductions have improved significantly.

Average annual growth rates of key drivers of global CO2 emissions



OECD: Organisation for Economic Co-operation and Development

Member of OECD 37 countries, such as: Canada, Mexico, Poland, Spain, Turkey, United States, Germany, and United Kingdom.

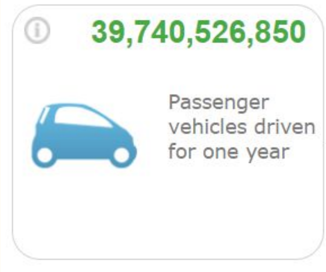
GHG emissions continue to rise, despite scientific warnings and political commitments.

Facts and figures

- GHG emissions have risen at a rate of **1.5% per year in the last decade**, stabilizing only briefly between 2014 and 2016. Total GHG emissions, including from land-use change, reached a record high of **<u>55.3 GtCO2e</u>** in 2018.
- Fossil CO2 emissions from energy use and industry, which dominate total GHG emissions, **grew 2.0% in 2018, reaching a record 37.5 GtCO2 per year.**
- By **2030**, emissions would need to be **25% and 55% lower than in 2018** to put the world on the least-cost pathway to limiting global warming to below 2°C and 1.5°C respectively.

How much is 55.3 GtCO2e?

GHG emissions from:

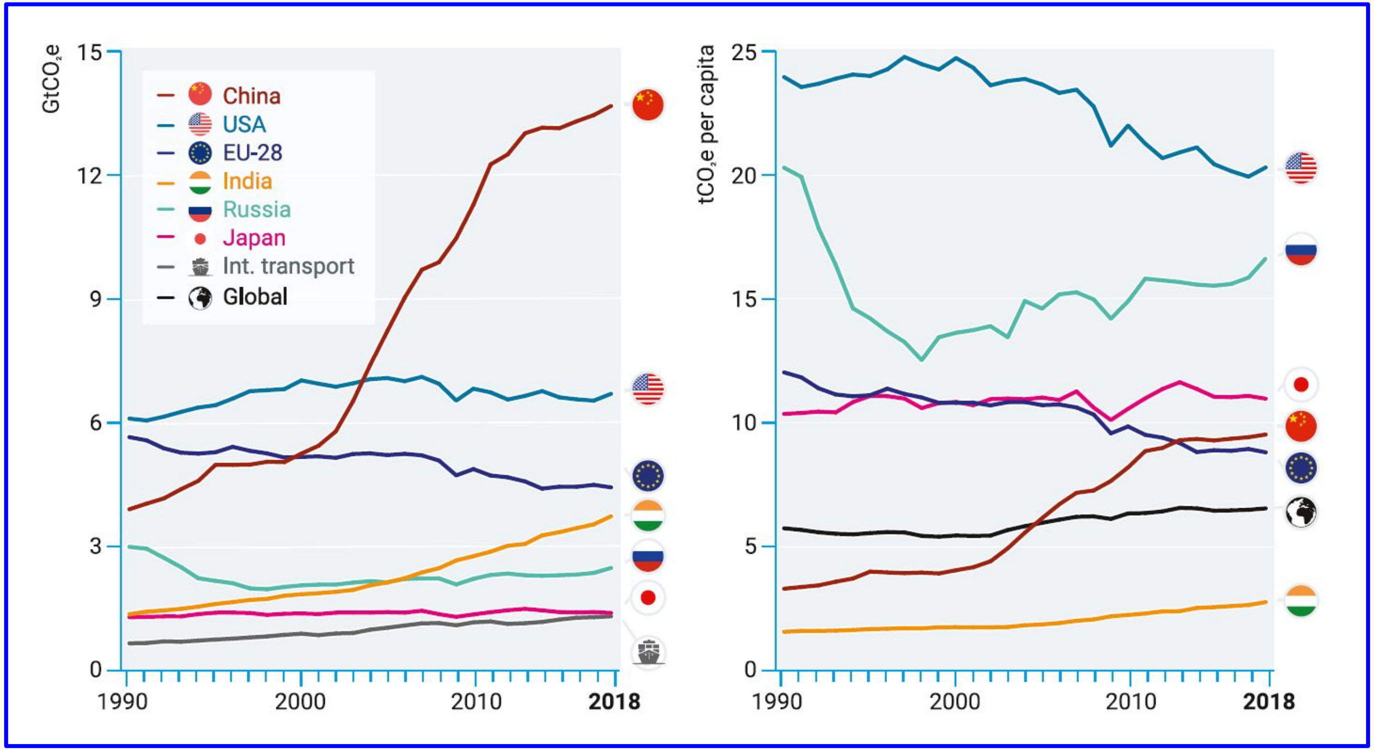


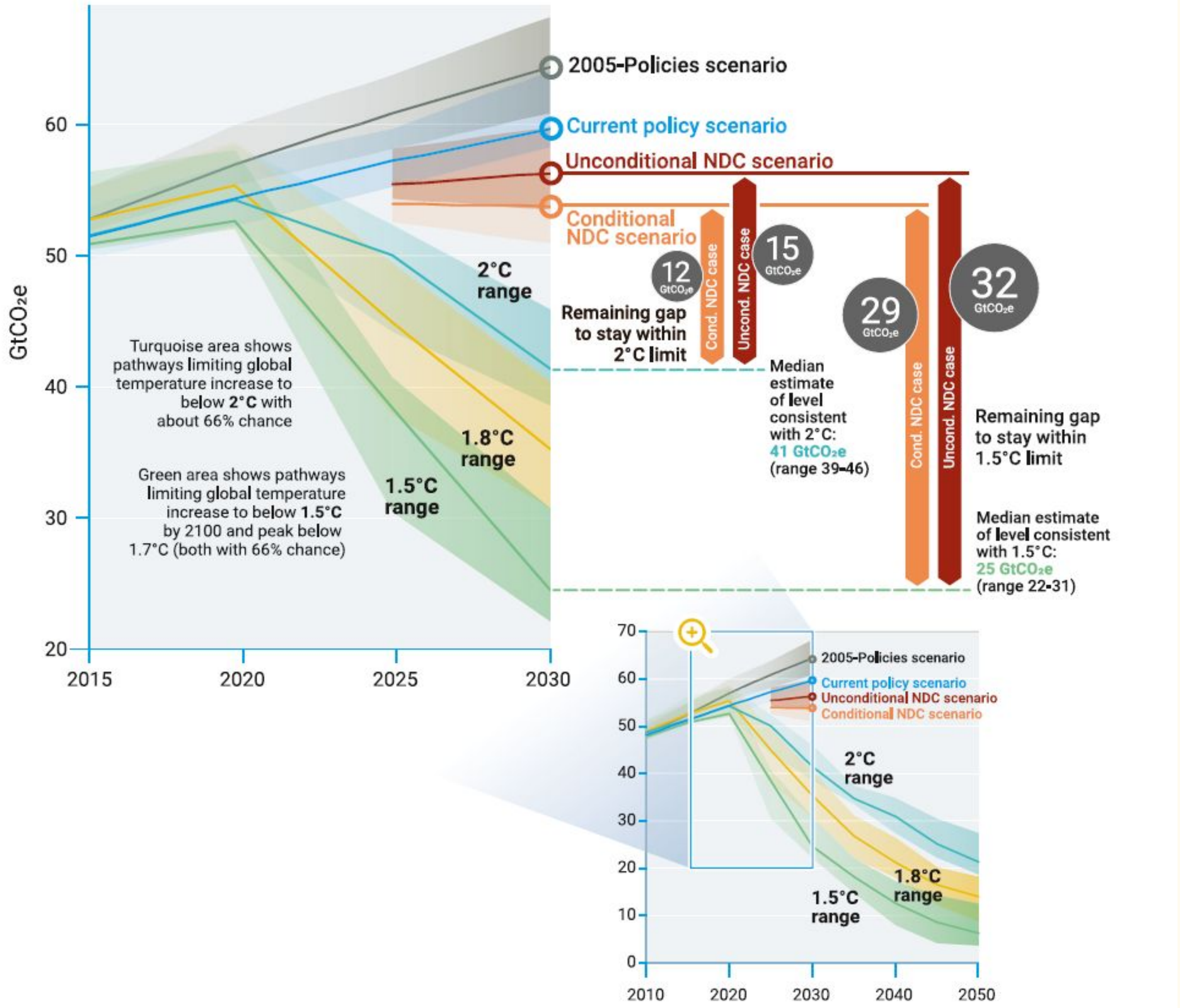
CO2 emissions from:

GHG emissions avoided by:

Source: EPA

Top greenhouse gas emitters



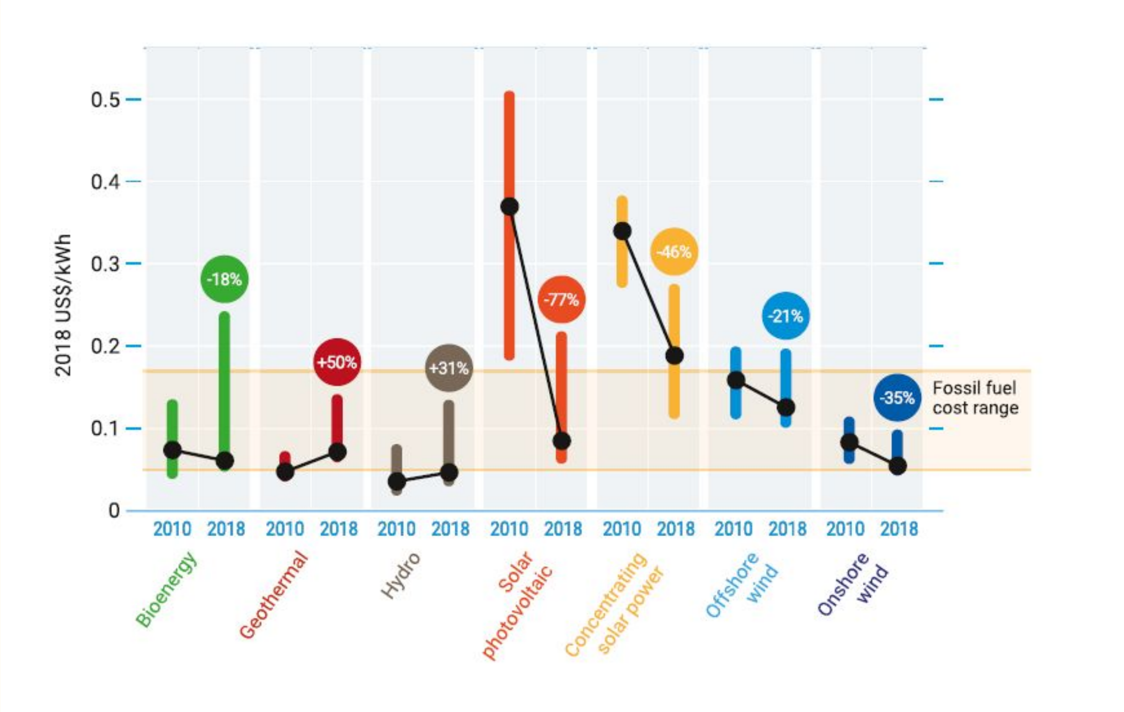


Global GHG emissions under different scenarios and the emissions gap by 2030

Current opportunities with ambitious climate actions and targets - European Union

- ➔ Adjust the framework and policies to enable **100% carbon-free electricity** supply by between 2040 and 2050.
- ➔ Step up efforts to **phase out coal-fired plants.**
- ➔ Define a strategy for **zero-emission industrial processes.**
- ➔ **Ban** the sale of **internal combustion** engine cars and buses and/or set targets to move towards 100% of new car and bus sales being zero-carbon vehicles in the coming decades.
- ➔ Shift towards **increased use of public transport** in line with the most ambitious Member States.

Changes in global levelized cost of energy for key renewable energy technologies, 2010-2018



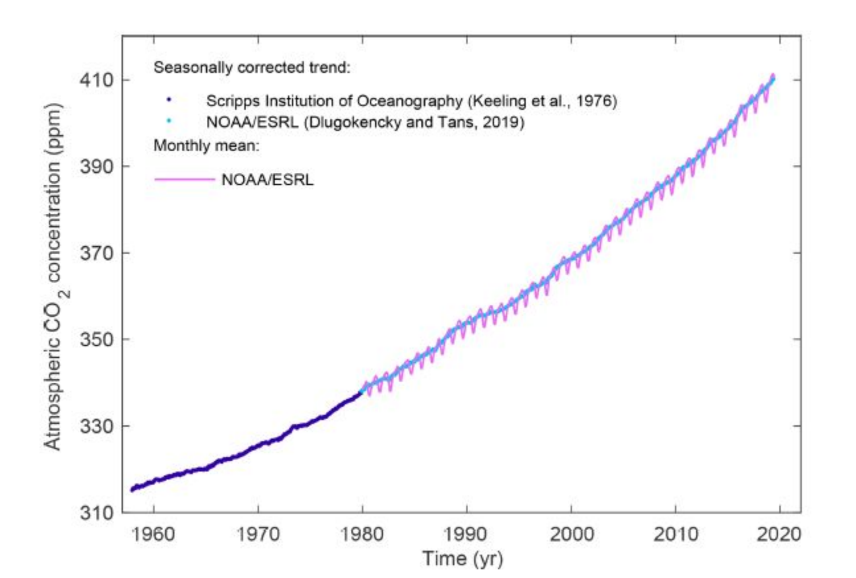
Global Carbon Budget 2019

Friedlingstein et al, 2019
Copernicus Publications

Introduction

The atmospheric CO_2 increase above pre-industrial levels was, initially, primarily caused by the release of carbon to the atmosphere from deforestation and other land use change activities.

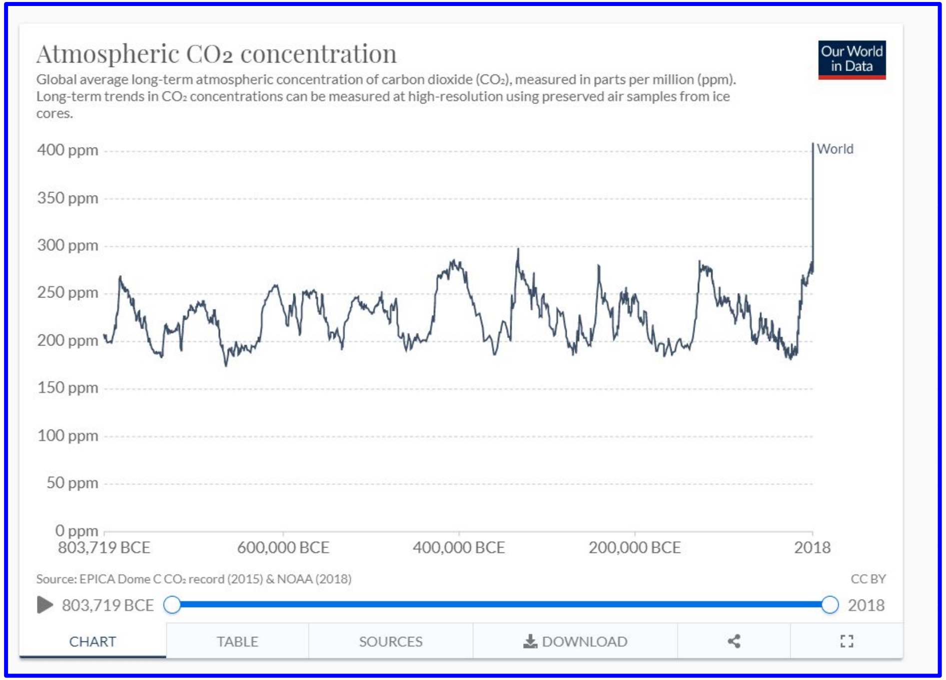
While emissions from **fossil fuels** started before the Industrial Era, they only became the dominant source of anthropogenic emissions to the atmosphere from around **1950** and their relative share has continued to increase until present.



Surface average atmospheric CO2 concentration (ppm)

Importance

Accurate assessment of anthropogenic carbon dioxide (CO2) emissions and their redistribution among the atmosphere, ocean, and terrestrial biosphere – the "global carbon budget" – is important to better understand the global carbon cycle, support the development of climate policies, and project future climate change.



Source: Our World in Data

Method

The global carbon budget presented refers to the **mean, variations, and trends** in the perturbation of CO_2 in the environment, referenced to the beginning of the Industrial Era (defined here as 1750).

Variables

- CO_2 emissions from human activities
- the growth rate of atmospheric CO_2 concentration,
- resulting changes in the storage of carbon in the land and ocean reservoirs

Budget imbalance components

E_{FF} fossil fuel combustion and oxidation from all energy and industrial processes and cement production.

E_{LUC} the emissions resulting from deliberate human activities on land, including those leading to land use change.

G_{ATM} the growth rate of atmospheric CO2 concentration.

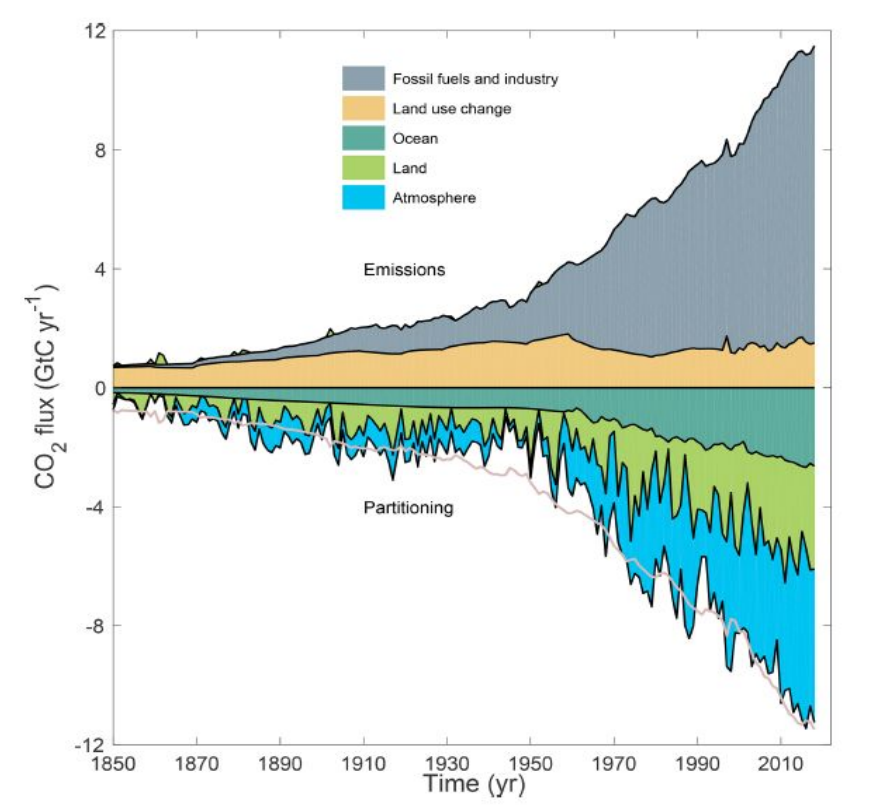
S_{OCEAN} the uptake of CO2 in the ocean.

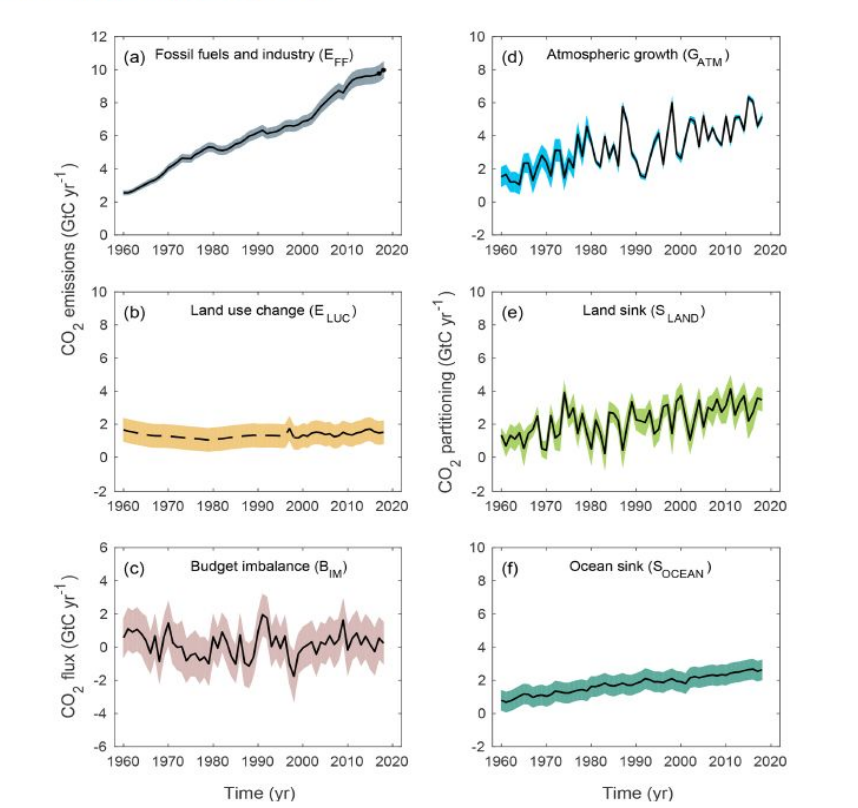
S_{LAND} the uptake of CO2 in the land.

B_{IM} **budget imbalance** which is a measure of the mismatch between the estimated emissions and the estimated changes in the atmosphere, land, and ocean, with the full global carbon budget as follows:

$$E_{FF} + E_{LUC} = G_{ATM} + S_{OCEAN} + S_{LAND} + B_{IM}$$

Components of the global carbon budget





Cumulative CO2 in gigatonnes of carbon (GtC)

Units of GtC	1750–2018	1850–2014	1959–2018	1850–2018	1850–2019[a]
Emissions					
Fossil CO_2 emissions (E_{FF})	440 ± 20	400 ± 20	365 ± 20	440 ± 20	450 ± 20
Land use change CO_2 emissions (E_{LUC})	235 ± 75[b]	195 ± 60[c]	80 ± 40[d]	205 ± 60[c]	205 ± 60
Total emissions	675 ± 80	600 ± 65	445 ± 30	645 ± 65	655 ± 65
Partitioning					
Growth rate in atmospheric CO_2 concentration (G_{ATM})	275 ± 5	235 ± 5	200 ± 5	255 ± 5	260 ± 5
Ocean sink (S_{OCEAN})[e]	170 ± 20	150 ± 20	105 ± 20	160 ± 20	160 ± 20
Terrestrial sink (S_{LAND})	220 ± 50	185 ± 40	130 ± 25	195 ± 40	200 ± 40
Budget imbalance					
$B_{IM} = E_{FF} + E_{LUC} - (G_{ATM} + S_{OCEAN} + S_{LAND})$	10	30	10	30	30

Conclusions of the Carbon Budget

Over the last decade we have seen **<u>unprecedented changes</u>** in the human and biophysical environments (e.g. changes in the growth of fossil fuel emissions, Earth's temperatures, and strength of the carbon sinks), which call for frequent assessments of the state of the planet, a better quantification of the causes of changes in the contemporary global carbon cycle, and an improved capacity to anticipate its evolution in the future.

Comparison

Comparison

	SRES	RCPs	SSPs
Year of release	Released in 2000, used in **Third** and **Fourth** IPCC report.	Released in 2014, used in **Fifth** IPCC report.	Published in 2017, but about to be used in **Sixth** IPCC report.
General definition	Future **storylines** based on possible socio-economic change in the future.	Greenhouse gas **concentration** trajectories.	Scenarios of projected socioeconomic global changes up to 2100.
Number of scenario groups	Four families of storylines (A1, A2, B1, B2)	Originally four pathways (RCP2.6, RCP4.5, RCP6, and RCP8.5)	Five scenarios (SSP1, SSP2, SSP3, SSP4, SSP5)
Probability of scenarios	No scenario stated to be more possible than the other.	RCP7 is a baseline outcome.	SSP2 is the reference scenario (Current Trends Continue Scenario).
Consideration of climate policies	Policies not taken into consideration; unrealistic predictions of fossil fuel use.	GHG mitigation policies	Different climate policies considered in the scenarios.

Criticism

- ➔ Using MER (market exchange rates) instead of international dollar which accounts for purchasing power.

- ➔ Exaggerated resource availability

> "Climate projections are based on emission scenarios. The emission scenarios used by the IPCC and by mainstream climate scientists are largely derived from the predicted demand for fossil fuels, and in our view take insufficient consideration of the constrained emissions that are likely due to the depletion of these fuels."
>
> ~Wang et al, 2016

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Similarities

SSP1	SRES B1
- Fast technological development - Low population growth - Shifting to a more sustainable path and inclusive development	- Rapid economic growth - Population rising to 9 million and then declining - More integrated and ecologically friendly world

SSP5	SRES A1F1
- Exploitation of abundant fossil fuel resources - Rapid technological progress and development of human capital - Rapid growth of the global economy - Global population peaks and declines in the 21st century	- Fossil intensive - Rapid economic growth - Extensive social and cultural interactions worldwide - A global population that reaches 9 billion in 2050 and then gradually declines

The IPPC reports (along with reports such as Emissions Gap Report and Global Carbon Budget) are the most state-of-art assessments available of greenhouse gas emissions.

How the governments, organisations and policymakers will use the information provided by this powerful tool, may decide on the future state of our world.

Summary and discussion

References:

https://archive.ipcc.ch/ipccreports/sres/emission/index.php?idp=0

https://skepticalscience.com/rcp.phph

https://www.unenvironment.org/resources/emissions-gap-report-2019

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