



II. Climate Change (CC)

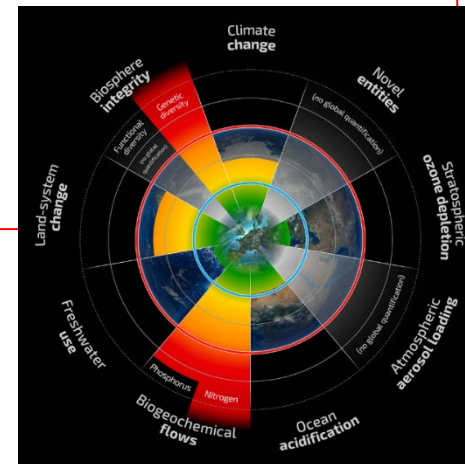
Earth System process	Control variable	Threshold avoided or influenced by slow variable	Planetary Boundary (zone of uncertainty)	State of knowledge*
Climate change	Atmospheric CO ₂ concentration, ppm; Energy imbalance at Earth's surface, W m ⁻²	Loss of polar ice sheets. Regional climate disruptions. Loss of glacial freshwater supplies. Weakening of carbon sinks.	Atmospheric CO ₂ concentration: 350 ppm (350–550 ppm) Energy imbalance: +1 W m ⁻² (+1.0–+1.5 W m ⁻²)	1. Ample scientific evidence. 2. Multiple sub-system thresholds. 3. Debate on position of boundary.

Boundary: Atmospheric CO₂ concentration no higher than 350 ppm

Pre-industrial level: 280 ppm

Current level (2020) : 413 ppm

Diagnosis: Boundary exceeded



History of Climate Change Research



Can you guess the year when
the greenhouse effect was DISCOVERED?



CC - history

1824 – Joseph Fourier - greenhouse effect in the atmosphere

1861 – John Tyndall - water vapour
and other gases are GHG



1896 – Svante Arrhenius – hypothesis on enhancement of GH effect due to increase of CO₂ in the atmosphere as a consequence of fossil fuels combustion

- the prognosis on increase of the temperature by several °C when GHG concentration doubles is still valid



CC - history

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1896 – **Svante Arhenius** – hypothesis on enhancement of GH effect due to increase of CO₂ in the atmosphere as a consequence of fossil fuels combustion

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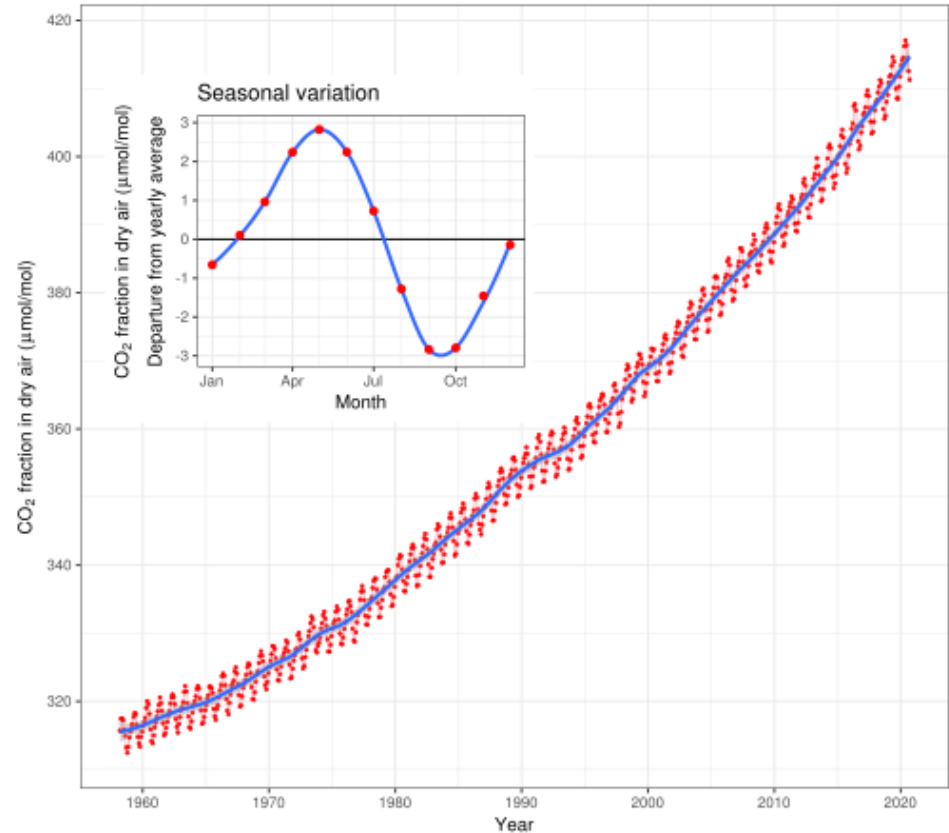
1957 – **oceanographer** Roger Revelle and chemist Hans Suess shown that oceans can not **absorb entire CO₂** produced by people

"Human beings are now carrying out a large scale geophysical experiment.,,"



1950 – Charles David Keeling
continuous measurements
taken at the Mauna Loa
Observatory since 1950
(till now)

Monthly mean CO₂ concentration
Mauna Loa 1958 - 2020



Data : Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (scrippsco2.ucsd.edu/). Accessed: 2020-10-31

CC... and politics



1972 – *UNCHE, Stockholm.*
becomes one of the global priorities

1990 – 1st IPCC report – „temperature increase by **0.3-0.6 °C** is caused also by the human activities“

1992 – *Earth summit* – **UN Framework Convention on CC**

2005 – Kyoto Protocol

2013 - 5th IPCC report „*Scientists are 95% certain that humans are the "dominant cause" of global warming since the 1950s*“

2016, 4.11. – **Paris Treaty** came into force

2022 - 6th IPCC report (synthesis)





Greenhouse Effect and global Climate Change

- Greenhouse effect (GE) – **natural atmospheric effect** essential for life on the Earth
- GE dampens temperature fluctuation between day and night and thus provides favorable conditions for life

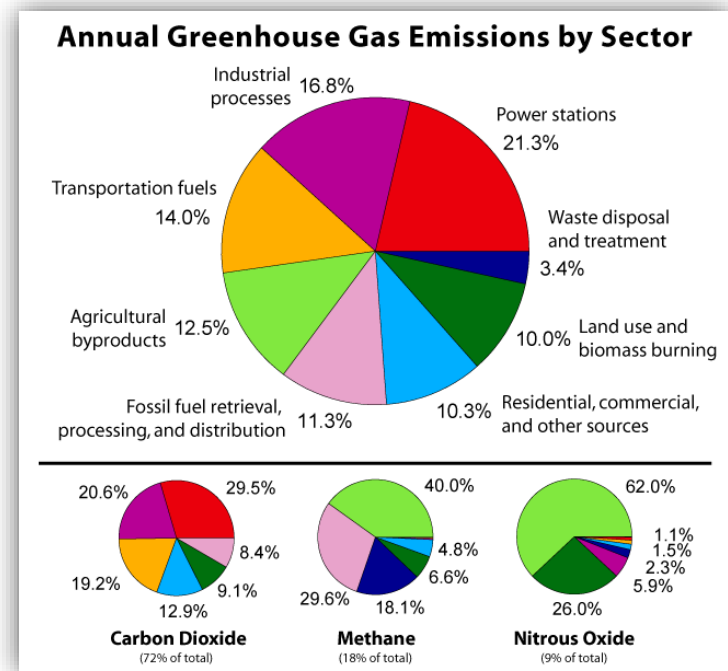


Greenhouse Gasses (GH) in the atmosphere

- the most important GHG is water vapour - $\text{H}_2\text{O}(\text{g})$ that creates some 2/3 of greenhouse effect
- however $\text{H}_2\text{O}(\text{g})$ concentration in the atmosphere is not significantly influenced by human activities
- second most important GHG is CO_2 (~ 20 % GH effect)
- last 13 % of GH effect – mainly gases like CH_4 , N_2O , CFC

	Water	Carbon Dioxide	Methane	Nitrous Oxide
				
Atmospheric Concentration	0.01–4%*	385 ppm	1797 ppb	322 ppb
Rate of Increase	n/a	1.5 ppm/yr	7.0 ppb/yr	0.8 ppb/yr
Atmospheric Lifetime	Very short 1–5 days	Variable 5–200 yr	12 yr	120 yr
Global Warming Potential (GWP)	n/a†	1	21	310

* The amount of water vapor in the air varies according to temperature and density of air (usually ~1–3% of troposphere)
 † Water vapor levels vary strongly according to region, so rates of change and warming potential cannot be assessed

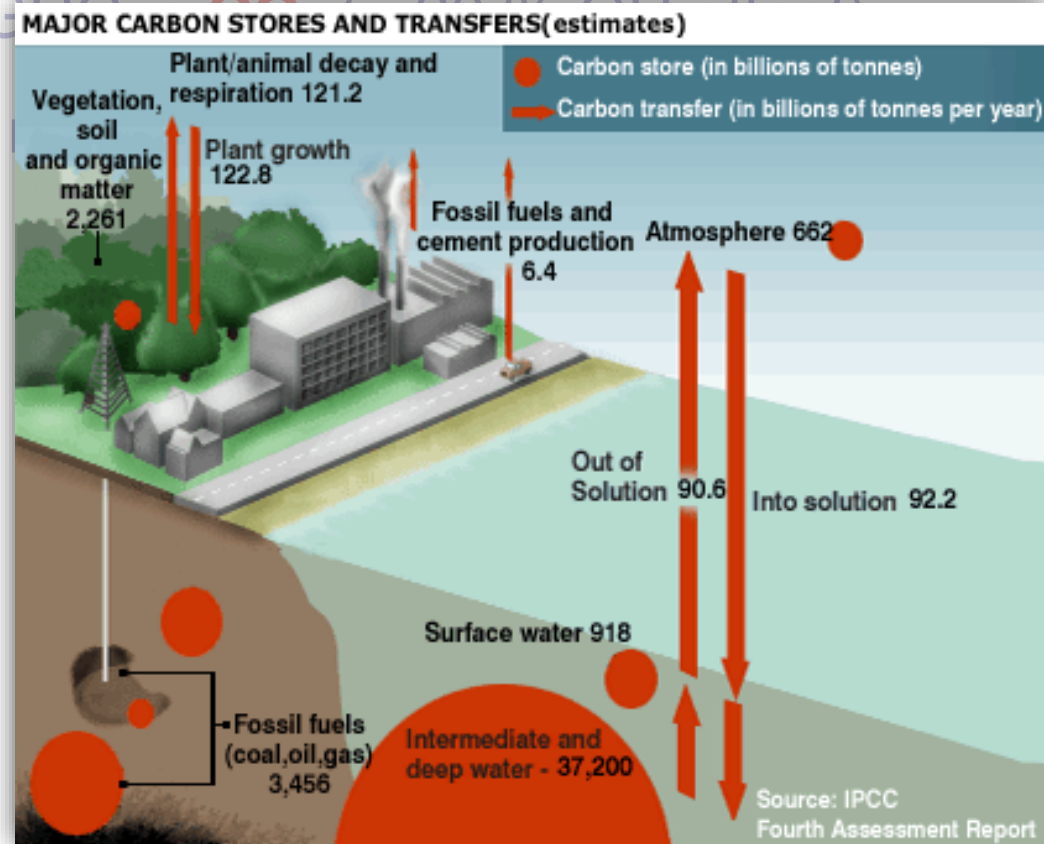


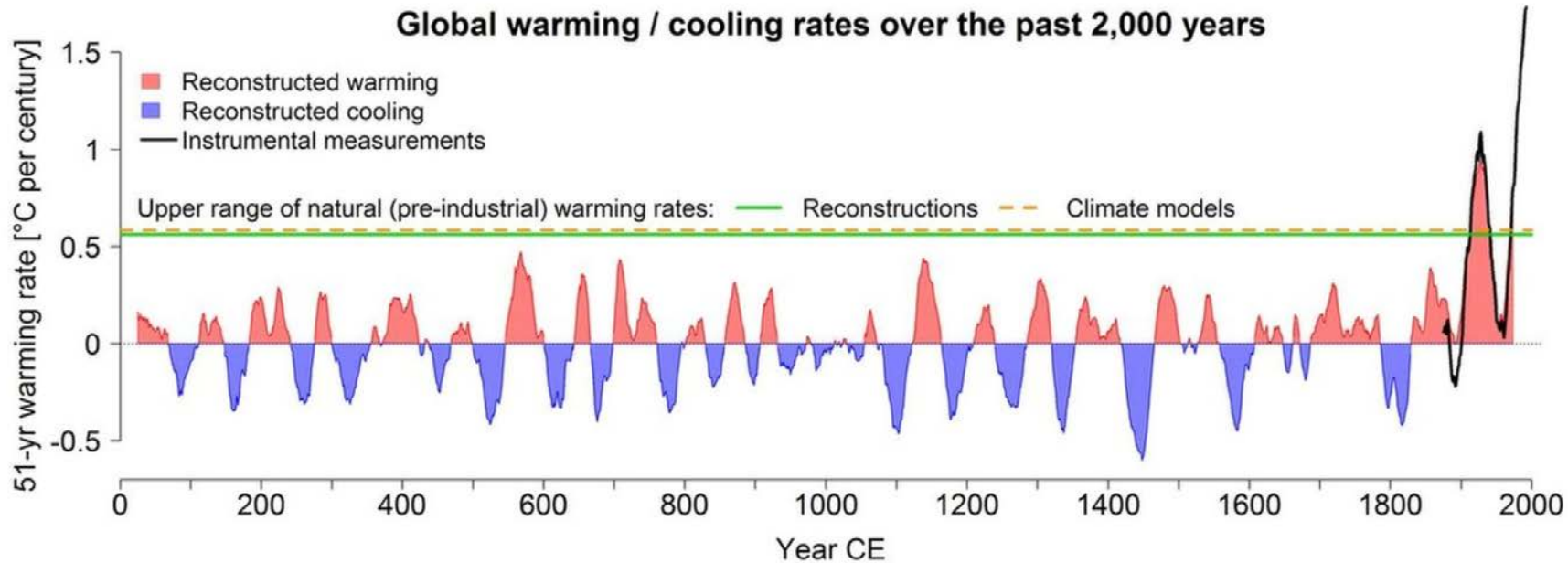
Greenhouse Gasses (GH) in the atmosphere

- the most important GHG is water vapour - $\text{H}_2\text{O}(\text{g})$ that creates some 2/3 of greenhouse effect
- however $\text{H}_2\text{O}(\text{g})$ concentration in the atmosphere is not significantly influenced by human activities
- second most important GHG is CO_2 (23%)
- last 13 % of GH effect –

Problem

- increase of CO_2 level in the atmosphere due to the antropogenic action - disruption of the balance between release and absorption of CO_2 in the carbon geochemical cycle





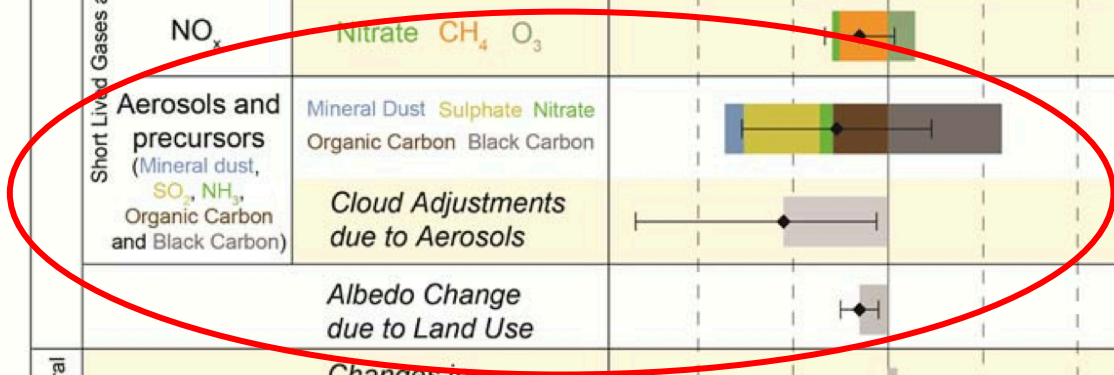
GLACIAL/INTERGLACIAL PERIOD



Radiative Forcing by Emissions and Drivers

Level of Confidence

Emitted Compound		Resulting Atmospheric Drivers	Radiative Forcing by Emissions and Drivers		Level of Confidence
Anthropogenic	Well-Mixed Greenhouse Gases	CO ₂	CO ₂	1.68 [1.33 to 2.03]	VH
		CH ₄	CO ₂ H ₂ O ^{str} O ₃ CH ₄	0.97 [0.74 to 1.20]	H
		Halo-carbons	O ₃ CFCs HCFCs	0.18 [0.01 to 0.35]	H
		N ₂ O	N ₂ O	0.17 [0.13 to 0.21]	VH
	Short Lived Gases and Aerosols	CO	CO ₂ CH ₄ O ₃	0.23 [0.16 to 0.30]	M
		NMVOC	CO ₂ CH ₄ O ₃	0.10 [0.05 to 0.15]	M
		NO _x	Nitrate CH ₄ O ₃	-0.15 [-0.34 to 0.03]	M
	Natural	Aerosols and precursors (Mineral dust, SO ₂ , NH ₃ , Organic Carbon and Black Carbon)	Mineral Dust Sulphate Nitrate Organic Carbon Black Carbon	-0.27 [-0.77 to 0.23]	H
			Cloud Adjustments due to Aerosols	-0.55 [-1.33 to -0.06]	L
			Albedo Change due to Land Use	-0.15 [-0.25 to -0.05]	M
Natural	Changes in Solar Irradiance	0.05 [0.00 to 0.10]	M		
Total Anthropogenic RF relative to 1750			2011	2.29 [1.13 to 3.33]	H
			1980	1.25 [0.64 to 1.86]	H
			1950	0.57 [0.29 to 0.85]	M



-1 0 1 2 3

Radiative Forcing relative to 1750 (W m⁻²)

CC indicators

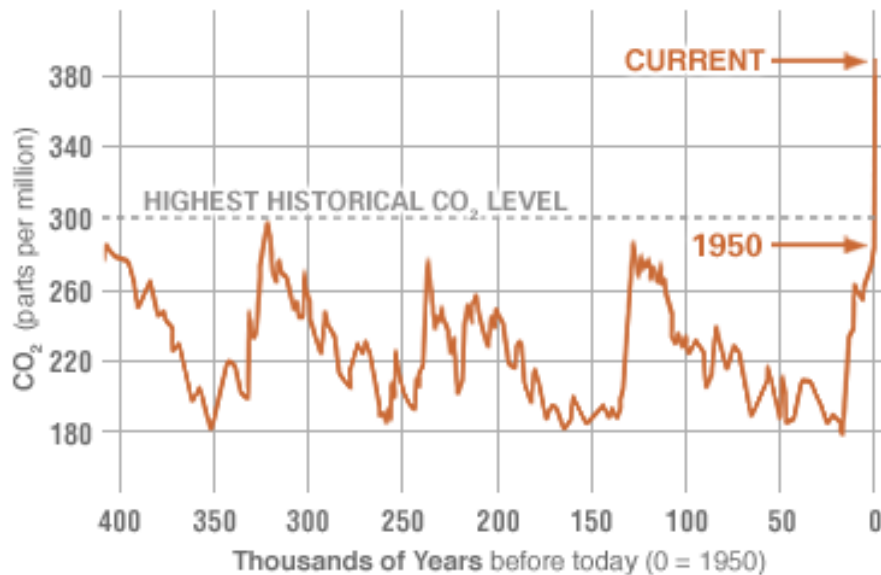
Increase of CO₂ level

- CO₂ level increased more than >25 % since 1950
- level of other greenhouse gases increases as well
- main source of this increase is fossil fuels combustion

PROXY (INDIRECT) MEASUREMENTS

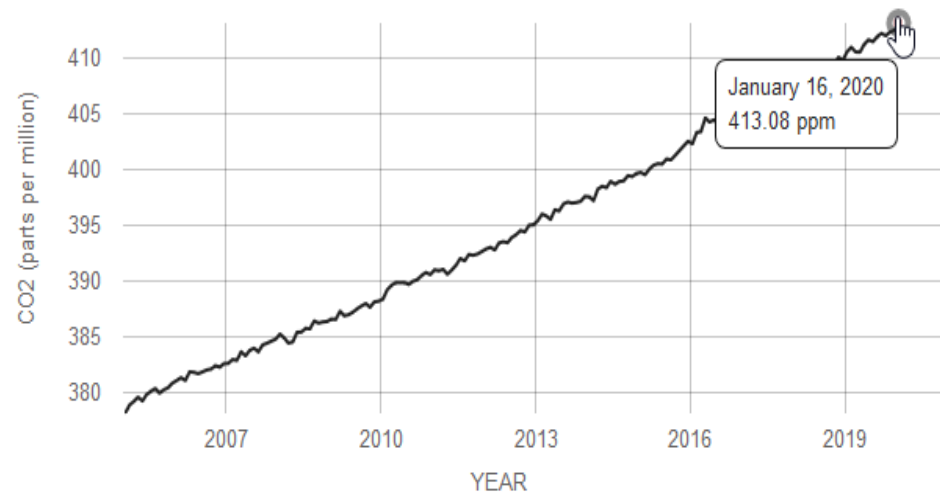
Data source: Reconstruction from ice cores.

Credit: [NOAA](#)

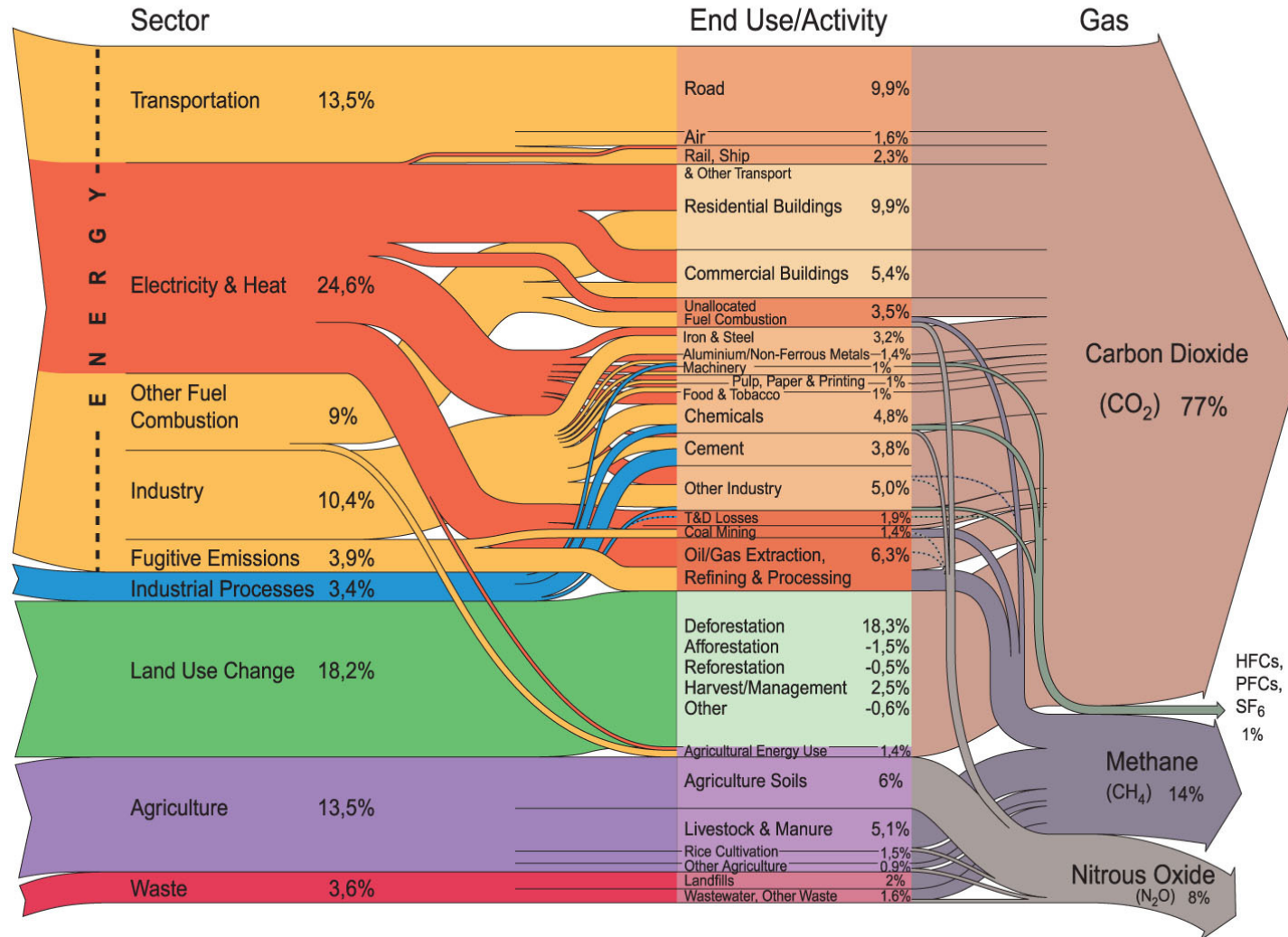


DIRECT MEASUREMENTS: 2005-PRESENT

Data source: Monthly measurements (average seasonal cycle removed). Credit: [NOAA](#)



World Greenhouse gas emissions by sector



All data is for 2000. All calculations are based on CO₂ equivalents, using 100-year global warming potentials from the IPCC (1996), based on a total global estimate of 41 755 MtCO₂ equivalent. Land use change includes both emissions and absorptions. Dotted lines represent flows of less than 0.1% percent of total GHG emissions.

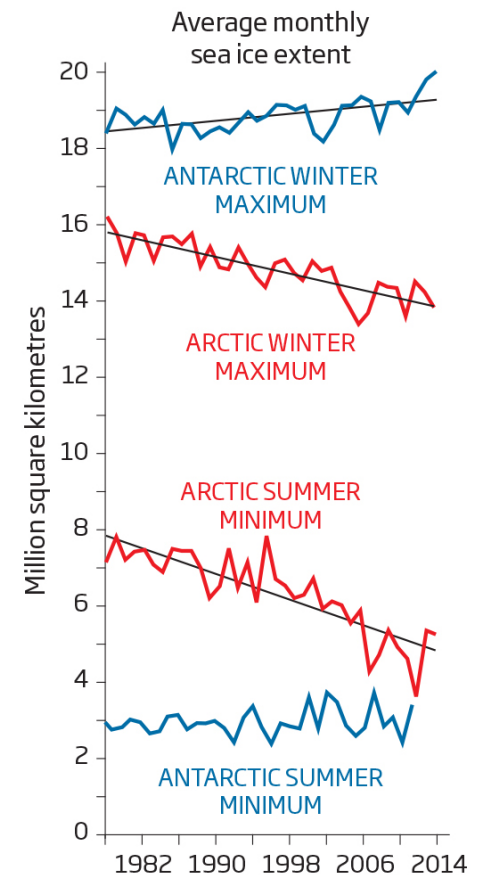
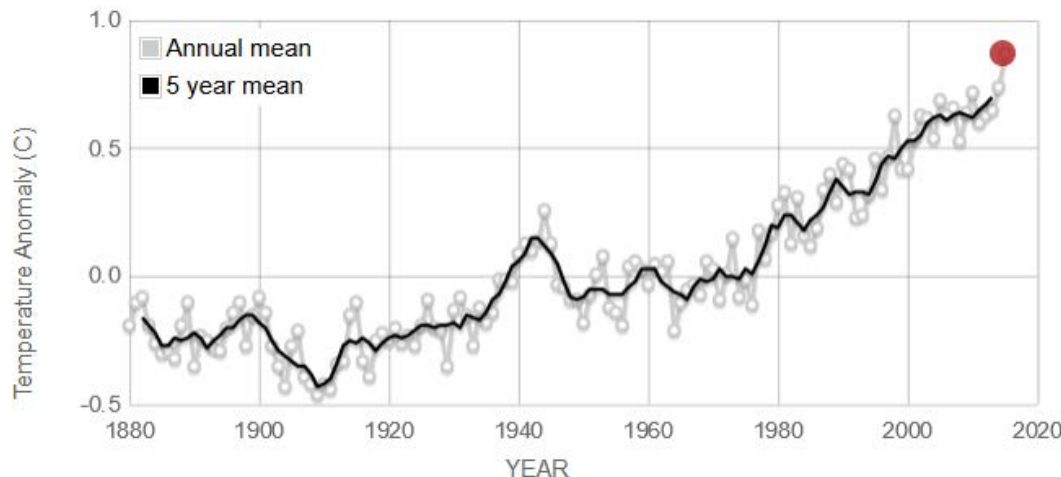
Source: World Resources Institute, Climate Analysis Indicator Tool (CAIT), Navigating the Numbers: Greenhouse Gas Data and International Climate Policy, December 2005; Intergovernmental Panel on Climate Change, 1996 (data for 2000).

Other indicators (variables) of CC

- changes in temperature
- changes in ice cover in Arctic ocean
- changes in ice cover in North and South pole
- sea level rise

GLOBAL LAND-OCEAN TEMPERATURE INDEX

Data source: NASA's Goddard Institute for Space Studies (GISS).
Credit: NASA/GISS



Less ice in the Arctic ocean

- new naval routes from Europe to Asia

iDNES.cz / Zprávy Pondělí 29. září 2014. Michal | Přihlásit

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Domácí | **Zahraníční** | Černá kronika | Očíma čtenářů | Počasí | MF DNES | Komerční články

Ledy tají, lodě testují severní cestu z Asie do Evropy

10. září 2009 10:05 f t + o

Projekt s nákladem euroasijský kontinent přes Severní ledový oceán se zdá být dobrý nápad. Ušetříte peníze i dny cesty, které by spolkla cesta přes Suezský průplav. Nyní se o to pokouší první západní rejdářství. Proč až nyní, když jsou výhody tak zřejmé? Ona totiž nechtěla příliš spolupracovat.



Dvě nákladní lodě hamburského rejdářství v Barentsově moři. | foto: Beluga Shipping

Cestu uvolnilo až globální oteplování, kvůli němuž již severní vody nezůstávají v jedné neproniknutelné kůře ledu, ale roztávají a rozpadají se tak, že jimi propluje nejen ledoborec, ale i nákladní loď. Alespoň v určitém období roku a na většině cesty.



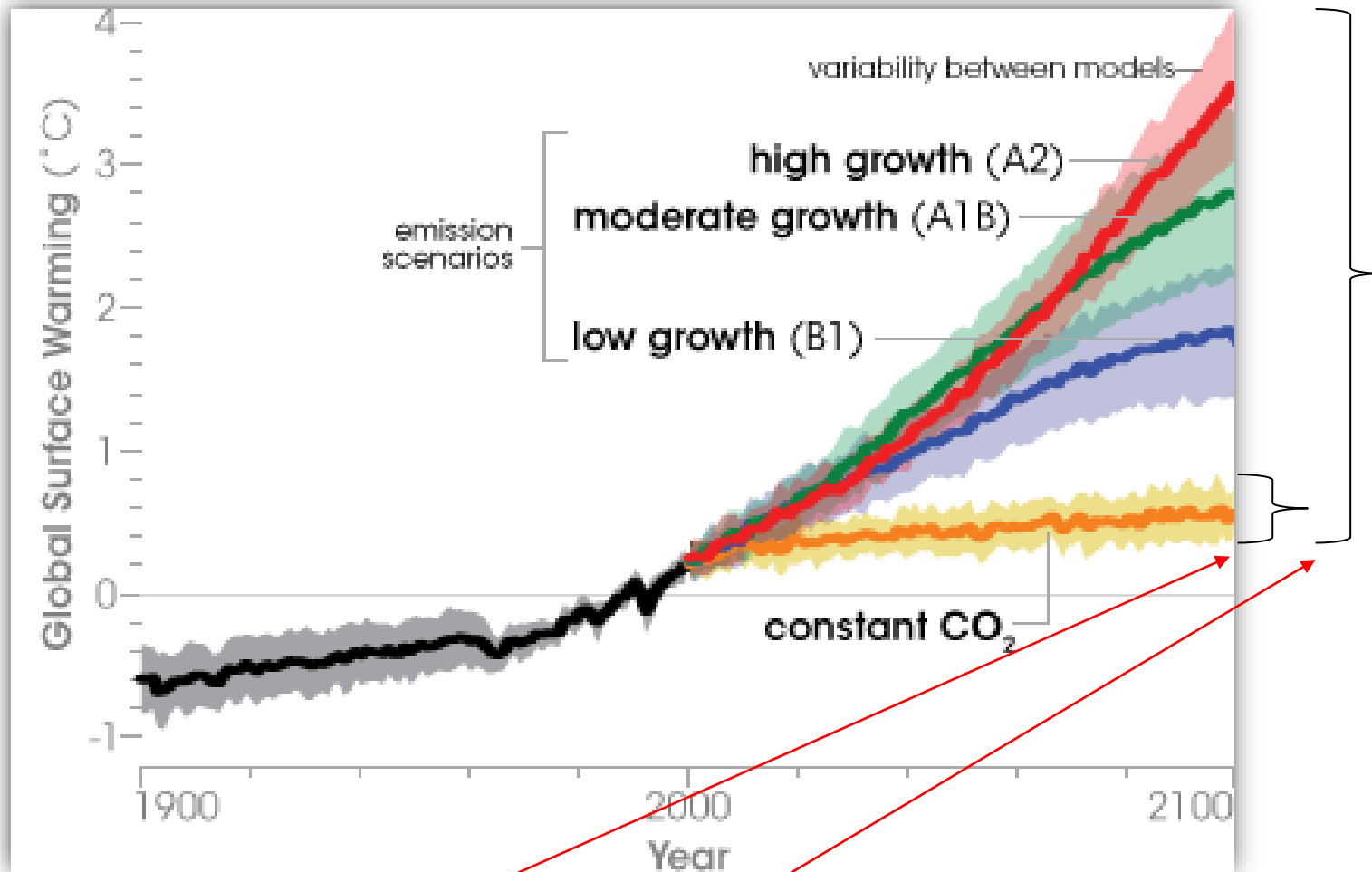
Glacier calving in Arctic ocean



Glacier Watching Day 17

"CHASING ICE" captures largest glacier calving ever filmed - OFFICIAL VIDEO

Temperature rise scenarios to 2100



- scientific vs. political uncertainty

CC consequences

Consequences of CC

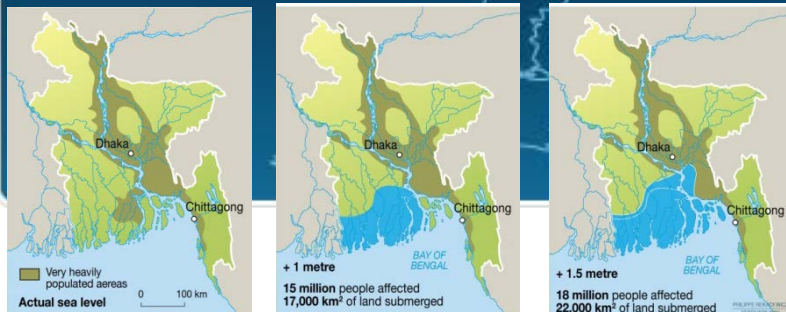
- regionally specific
- e.g. increasing vs. decreasing yields in some regions

Likely Scenarios if Climate Change Continues

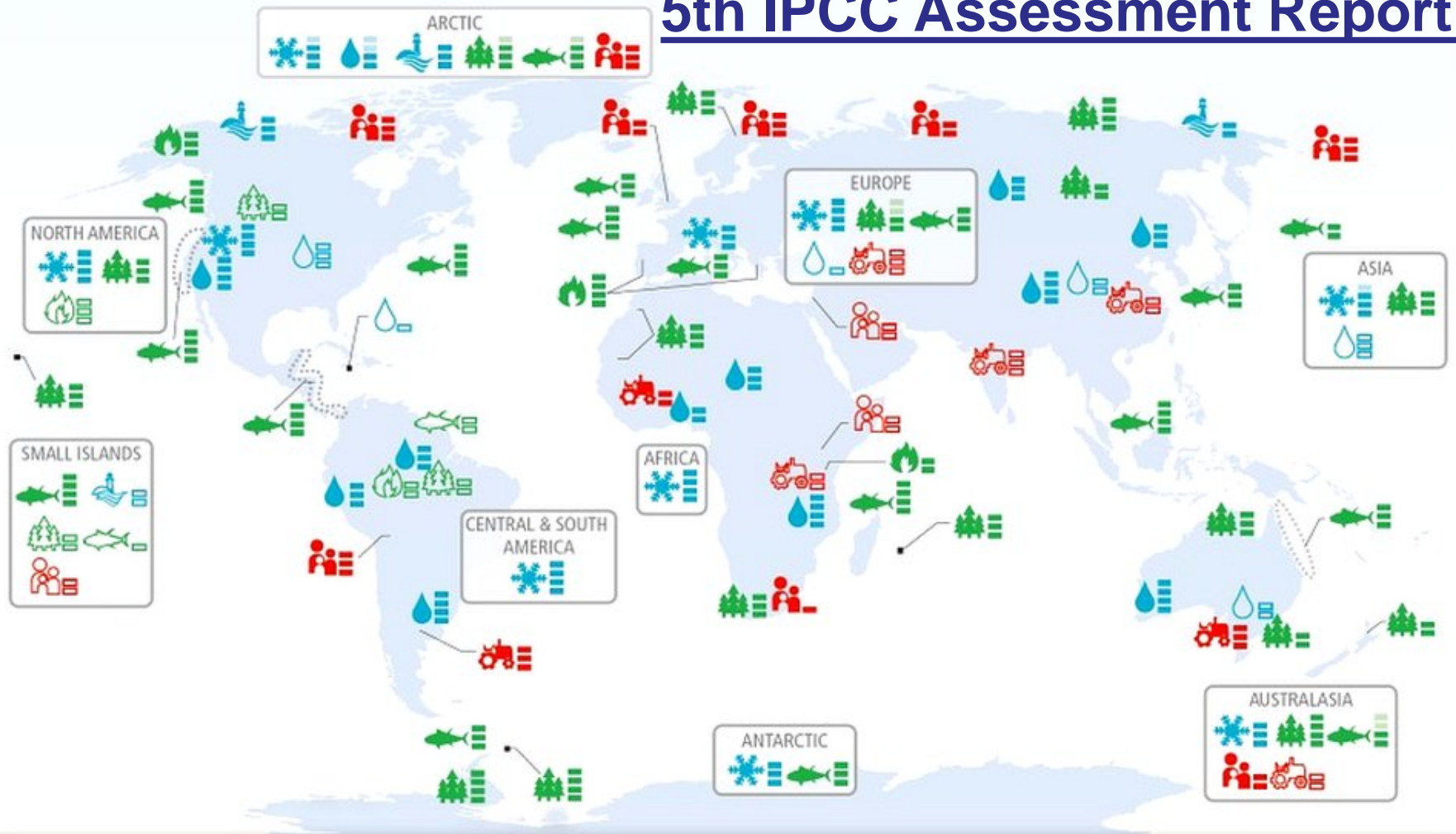
▼ SELECT CLIMATE IMPACTS



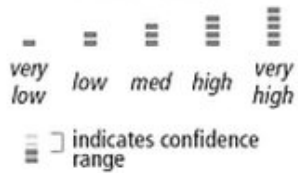
WHAT YOU CAN DO TO HELP ►



5th IPCC Assessment Report



Confidence in attribution to climate change

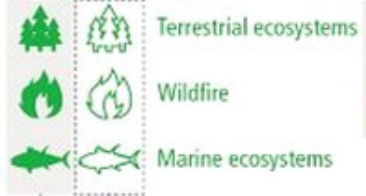


Observed impacts attributed to climate change for

Physical systems



Biological systems



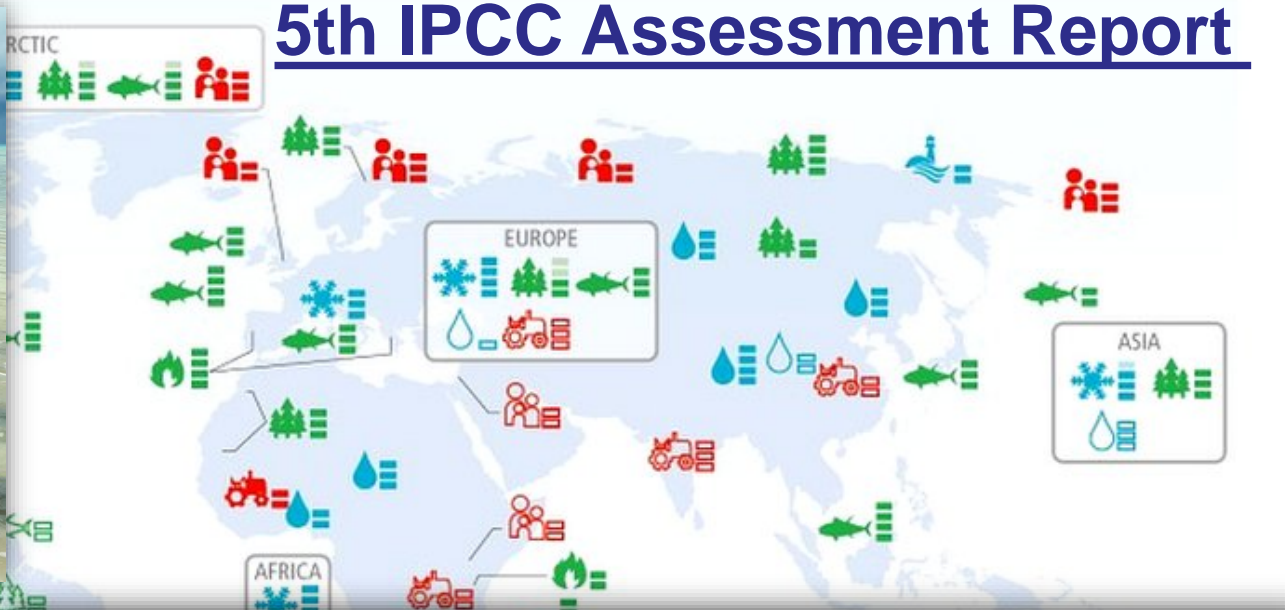
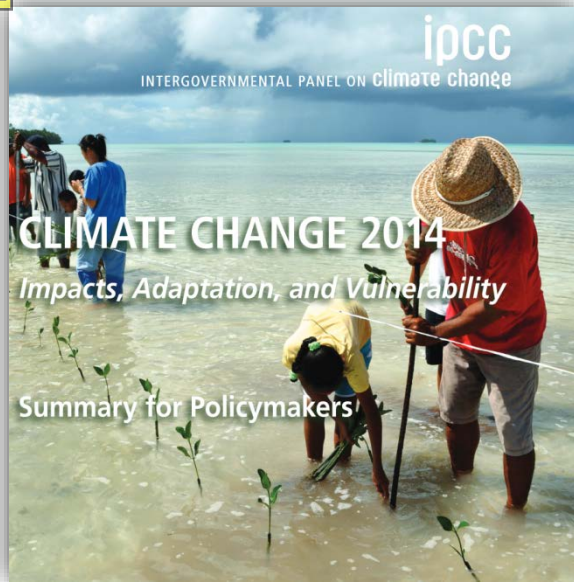
Human and managed systems



▭ Regional-scale impacts

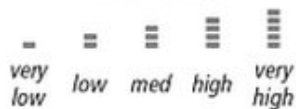
Outlined symbols = Minor contribution of climate change
 Filled symbols = Major contribution of climate change

5th IPCC Assessment Report



Europe	
Snow & Ice, Rivers & Lakes, Floods & Drought	<ul style="list-style-type: none"> Retreat of Alpine, Scandinavian, and Icelandic glaciers (<i>high confidence</i>, major contribution from climate change) Increase in rock slope failures in western Alps (<i>medium confidence</i>, major contribution from climate change) Changed occurrence of extreme river discharges and floods (<i>very low confidence</i>, minor contribution from climate change) <p>[18.3, 23.2-3, Tables 18-5 and 18-6; WGI AR5 4.3]</p>
Terrestrial Ecosystems	<ul style="list-style-type: none"> Earlier greening, leaf emergence, and fruiting in temperate and boreal trees (<i>high confidence</i>, major contribution from climate change) Increased colonization of alien plant species in Europe, beyond a baseline of some invasion (<i>medium confidence</i>, major contribution from climate change) Earlier arrival of migratory birds in Europe since 1970 (<i>medium confidence</i>, major contribution from climate change) Upward shift in tree-line in Europe, beyond changes due to land use (<i>low confidence</i>, major contribution from climate change) Increasing burnt forest areas during recent decades in Portugal and Greece, beyond some increase due to land use (<i>high confidence</i>, major contribution from climate change) <p>[4.3, 18.3, Tables 18-7 and 23-6]</p>
Coastal Erosion & Marine Ecosystems	<ul style="list-style-type: none"> Northward distributional shifts of zooplankton, fishes, seabirds, and benthic invertebrates in northeast Atlantic (<i>high confidence</i>, major contribution from climate change) Northward and depth shift in distribution of many fish species across European seas (<i>medium confidence</i>, major contribution from climate change) Plankton phenology changes in northeast Atlantic (<i>medium confidence</i>, major contribution from climate change) Spread of warm water species into the Mediterranean, beyond changes due to invasive species and human impacts (<i>medium confidence</i>, major contribution from climate change) <p>[6.3, 23.6, 30.5, Tables 6-2 and 18-8, Boxes 6-1 and CC-MB]</p>
Food Production & Livelihoods	<ul style="list-style-type: none"> Shift from cold-related mortality to heat-related mortality in England and Wales, beyond changes due to exposure and health care (<i>low confidence</i>, major contribution from climate change) Impacts on livelihoods of Sámi people in northern Europe, beyond effects of economic and sociopolitical changes (<i>medium confidence</i>, major contribution from climate change) Stagnation of wheat yields in some countries in recent decades, despite improved technology (<i>medium confidence</i>, minor contribution from climate change) Positive yield impacts for some crops mainly in northern Europe, beyond increase due to improved technology (<i>medium confidence</i>, minor contribution from climate change) Spread of bluetongue virus in sheep and of ticks across parts of Europe (<i>medium confidence</i>, minor contribution from climate change) <p>[18.4, 23.4-5, Table 18-9, Figure 7-2]</p>

Confidence in attribution to climate change



▬ indicates confidence range

Physical systems



Coastal erosion and/or sea level effects

Marine ecosystems

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

Main consequences of CC - summary

Present trends caused by CC.

Very likely >90 %, Likely >60 %

Phenomena	Likelihood that trend occurred in late 20th century
Cold days, cold nights and frost less frequent over land areas	Very likely
More frequent hot days and nights	Very likely
Heat waves more frequent over most land areas	Likely
Increased incidence of extreme high sea level *	Likely
Global area affected by drought has increased (since 1970s)	Likely in some regions
Increase in intense tropical cyclone activity in North Atlantic (since 1970)	Likely in some regions

* Excluding tsunamis, which are not due to climate change.

Future trends caused by CC.

Virtually certain >99 %, Very likely >90 %, Likely >60 % .

Phenomena	Likelihood of trend
Contraction of snow cover areas, increased thaw in permafrost regions, decrease in sea ice extent	Virtually certain
Increased frequency of hot extremes, heat waves and heavy precipitation	Very likely to occur
Increase in tropical cyclone intensity	Likely to occur
Precipitation increases in high latitudes	Very likely to occur
Precipitation decreases in subtropical land regions	Very likely to occur
Decreased water resources in many semi-arid areas, including western U.S. and Mediterranean basin	High confidence

- Scientific language is very brief and talking in the words of probability

CC - controversy



The video player shows two men in a split-screen format. On the left, a man with glasses and a dark suit (Peter Robinson) is speaking. On the right, a man with light hair and a dark t-shirt (Bjorn Lomborg) is speaking. The background of the left side shows a living room with a bookshelf and a red chair. The background of the right side shows a room with a staircase and several potted plants.

UNCOMMON KNOWLEDGE WITH PETER ROBINSON

HOOVER INSTITUTION

Keeping Your Cool on the Climate Debate with Bjorn Lomborg

54 588 zhladnutí • 10. 3. 2021

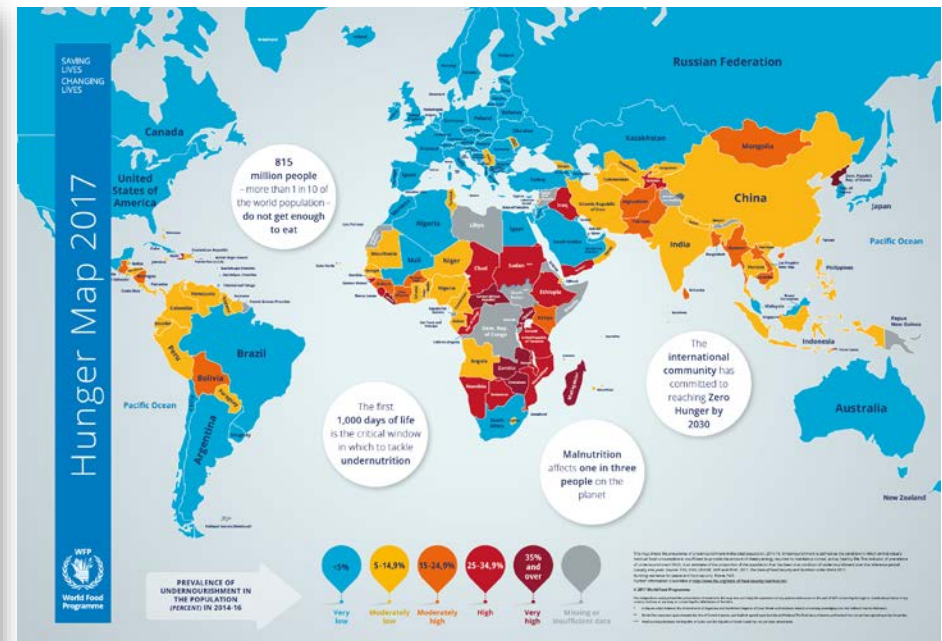
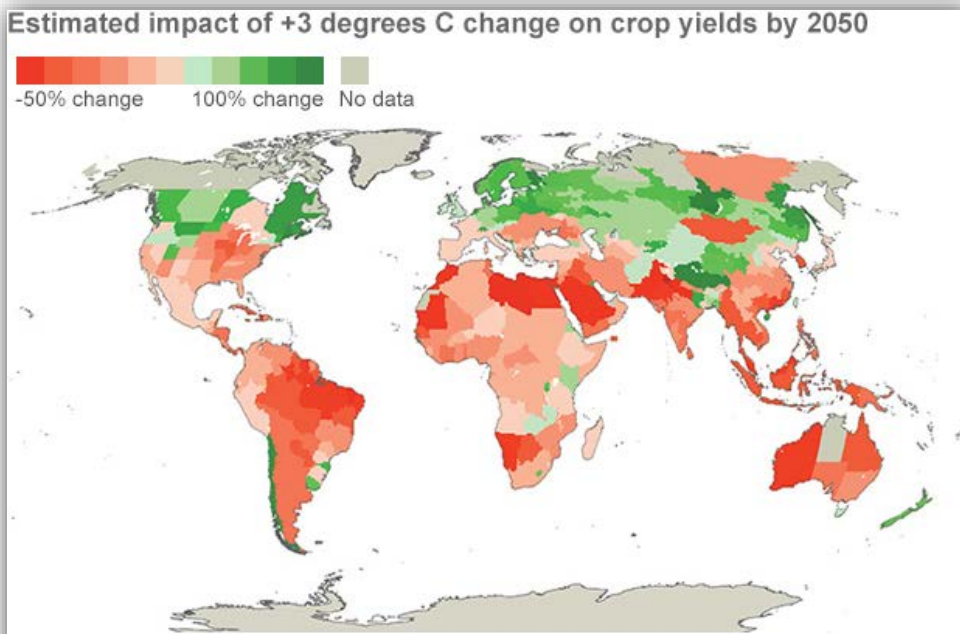
1,1 TIS. 68 ZDIELANIE ULOŽIŤ ...

<https://www.youtube.com/watch?v=0Te5aI2APrQ>

Moral dimension of CC

„...more heat will damage crop growth in many warmer climates, but it means better agricultural production in cold countries. And, CO₂ is a fertiliser — commercial greenhouses pump in extra CO₂ to grow bigger tomatoes. So overall, we can expect agriculture to gain from global warming in the short and medium term...“ B. Lomborg

– yes, increasing yields, but mainly in countries with the actual overproduction, while the agrarian countries in developing world (with significant hunger) will experience even drop in the production



Climate change: The great civilisation destroyer?

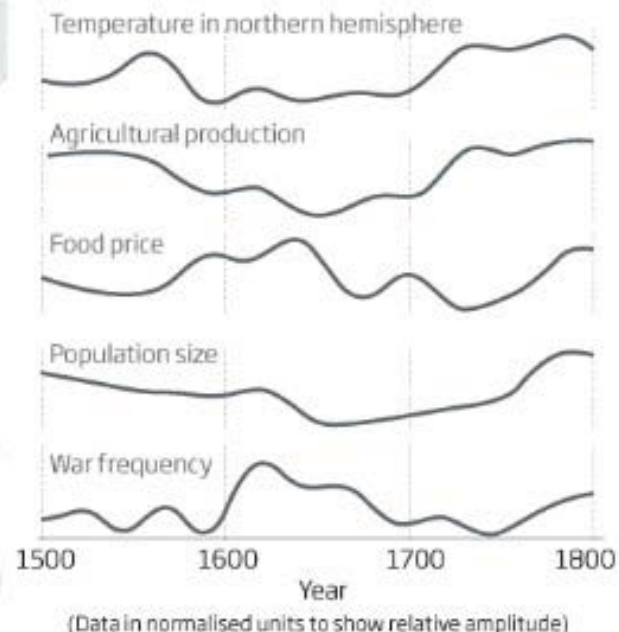
War and unrest, and the collapse of many mighty empires, often followed changes in local climates. Is this more than a coincidence?



More than coincidence?

©NewScientist

The decline and fall of many civilisations coincided with periods of climate change, and there are also correlations between climate change, population size and the frequency of wars, as data from Europe shows (right)



Solutions of CC?



The Nobel Peace Prize 2007

Intergovernmental Panel on Climate Change , Al Gore

Share this:      67 

The Nobel Peace Prize 2007

IPCC

INTERGOVERNMENTAL
PANEL ON
CLIMATE CHANGE



WMO



UNEP

Intergovernmental
Panel on Climate
Change (IPCC)

Prize share: 1/2



Photo: Ken Opprann

Albert Arnold (Al)
Gore Jr.

Prize share: 1/2

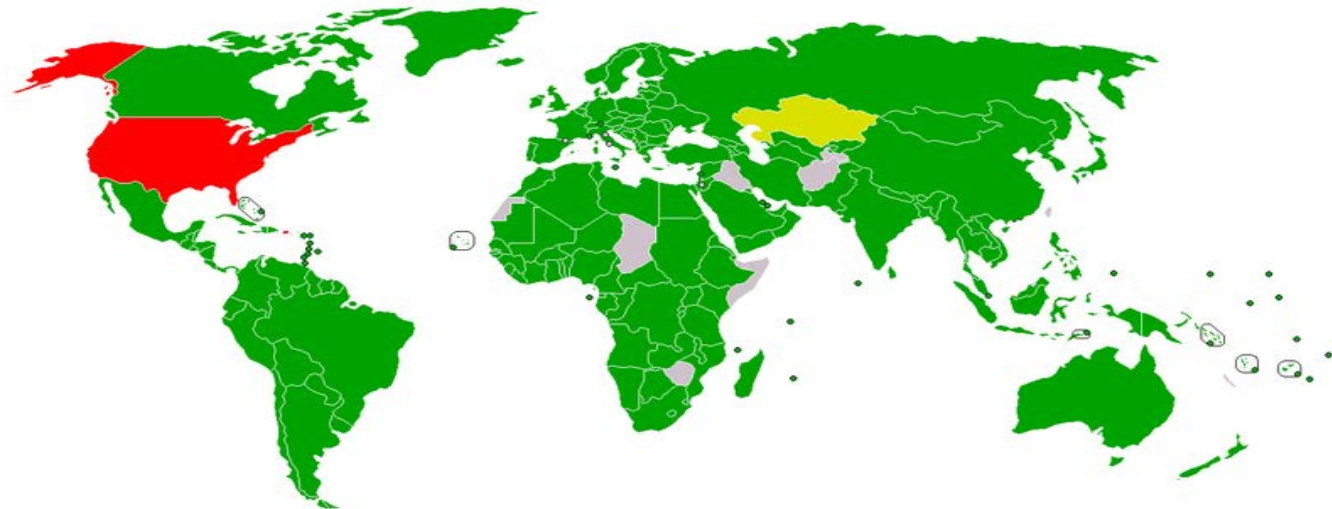
The Nobel Peace Prize 2007 was awarded jointly to Intergovernmental Panel on Climate Change (IPCC) and Albert Arnold (Al) Gore Jr. *"for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change"*

Politics on CC

- main aim – decrease the GHG emissions, mainly CO₂
- 1992: UN Framework Convention on Climate Change
- 1997: Kyoto protocol (in force from 2005)
- industrial countries should decrease their GHG emissions until the year 2012 for 4.2 % compared to the year 1990
- different threshold for different countries (e.g. EU 8%)
- however, industrial countries (Annex I countries with Kyoto targets) contributed „only“ with 24 % of global CO₂ emission (2010)

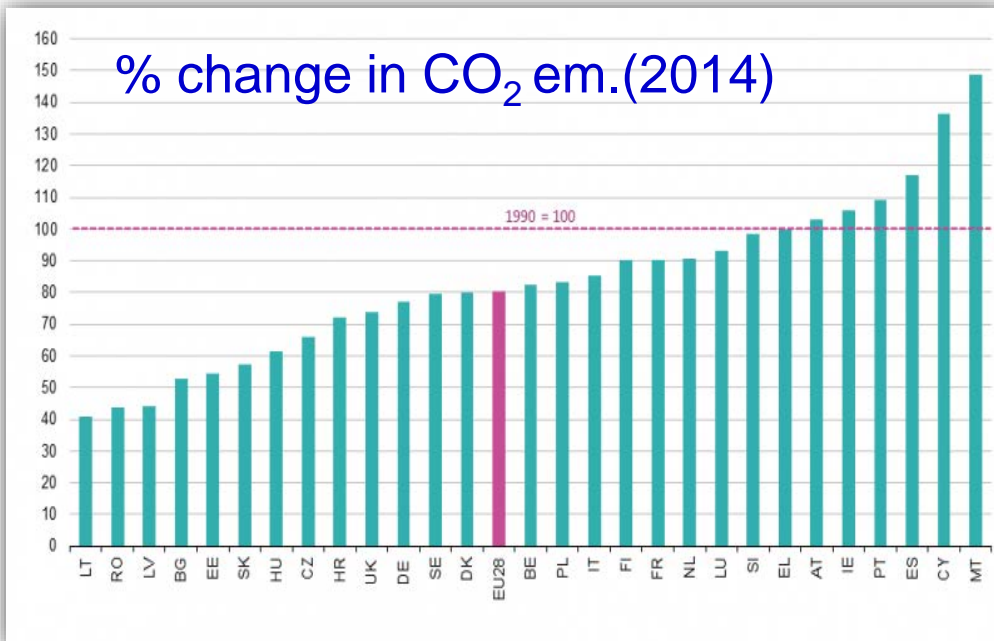
Participation in the Kyoto Protocol

- Signed and ratified
- Signed, ratification pending
- Signed, ratification declined
- [citation needed]
- Non-signatory



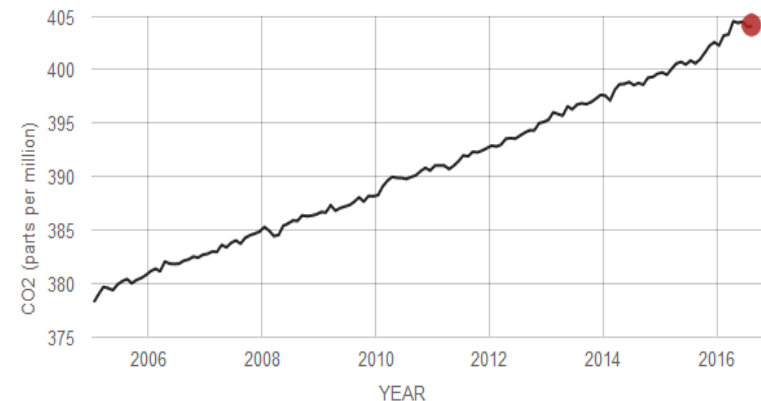
Kyoto protocol – result (2012)

- industrial countries (Annex I countries with Kyoto targets) **reduced their emissions for 24.2 % !** (much more than promised target 5.2 %)
- however, emission in other countries have risen so fast, that global CO₂ emissions increased by 32 % from 1990 to 2010 ☹
- extension of the Kyoto Protocol until 2020
- certain countries (the EU and a few other countries) have committed themselves to further reducing CO₂ emissions.
- EU e.g. by 20-30% compared to 1990
- Average – 18% - generally achieved



DIRECT MEASUREMENTS: 2005-PRESENT

Data source: Monthly measurements (average seasonal cycle removed). Credit: [NOAA](#)



Paris treaty (2015)

- continuation of the prolonged Kyoto protocol (2020)
- aim: Limit the temperature rise not more than 2 °C compared to pre-industrial era
- **came into force April 4th 2016**



How to decrease CO₂ emissions?

- decrease the fossil fuels consumption
 - increase efficiency of the industr. production
 - end the non-effective industr. production
 - save the energy and material
- economic tools to decrease CO₂ - International Emission Trading (IET)
- bio-fuels? Probably not...
- **Geo-engineering?**



Atmos. Chem. Phys. Discuss., 7, 11191–11205, 2007
www.atmos-chem-phys-discuss.net/7/11191/2007/
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N₂O release from agro-biofuel production negates global warming reduction by replacing fossil fuels

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Received: 28 June 2007 – Accepted: 19 July 2007 – Published: 1 August 2007

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Geo-engineering – types and opportunities

Transforming Earth

It is now possible to identify the methods and locations where planetary geoengineering will have to take place

T PLANT TREES
 Plant forests and regularly harvest them. Trees are a carbon sink as long as they are growing, and not allowed to rot.
 Location: unused farmland

BE BECCS (Bioenergy with carbon capture and storage)
 Suck out atmospheric CO2 by growing biofuel crops like sugar cane, burn them for energy, capture the resulting CO2, and bury it.
 Location: the tropics, where growth is fastest

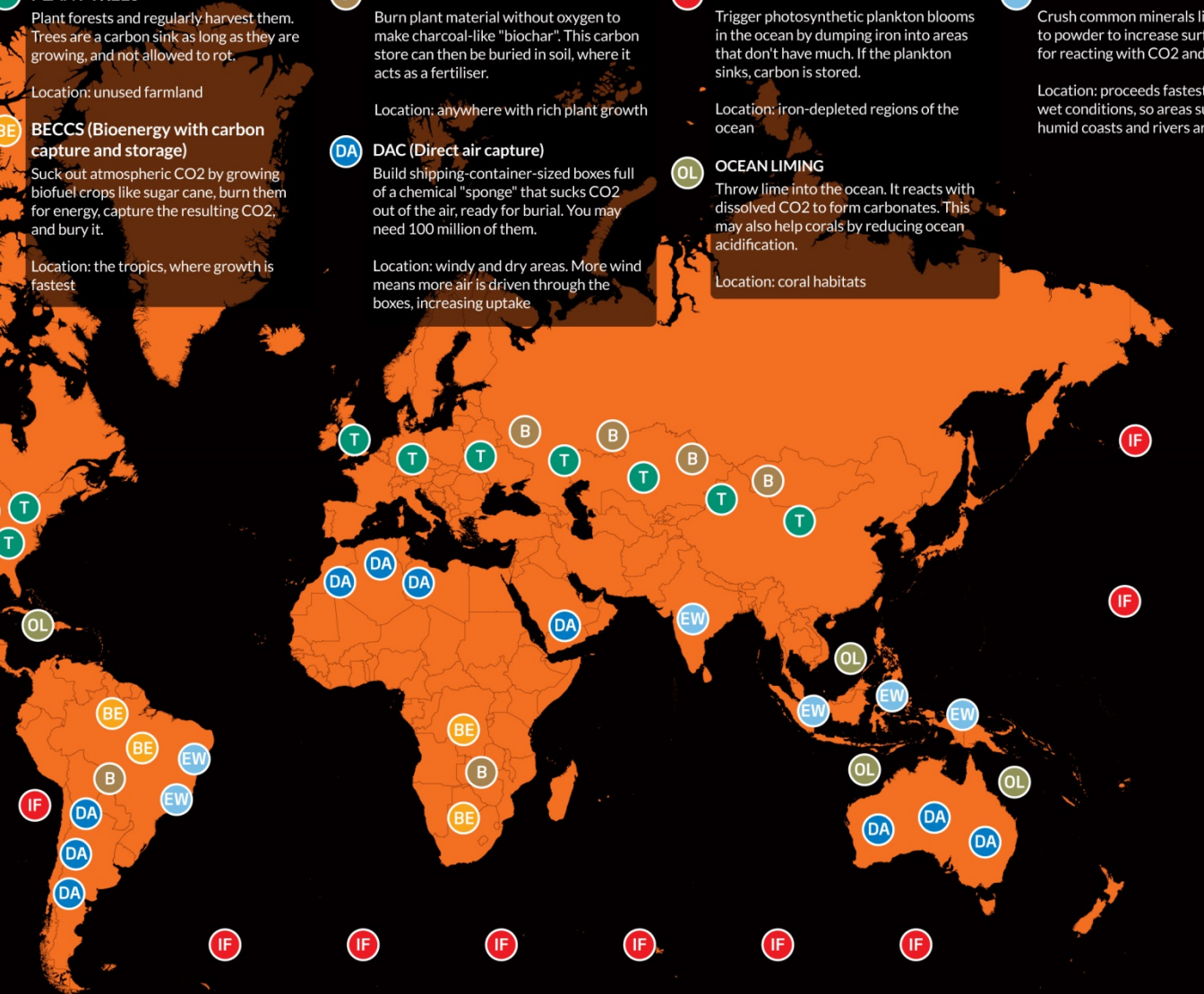
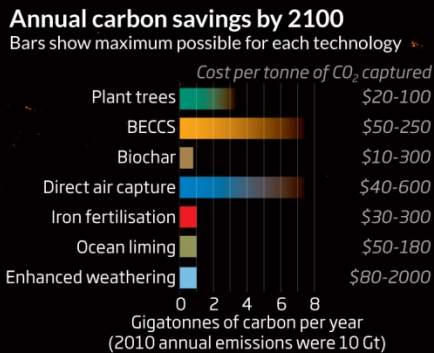
B BIOCHAR
 Burn plant material without oxygen to make charcoal-like "biochar". This carbon store can then be buried in soil, where it acts as a fertiliser.
 Location: anywhere with rich plant growth

DA DAC (Direct air capture)
 Build shipping-container-sized boxes full of a chemical "sponge" that sucks CO2 out of the air, ready for burial. You may need 100 million of them.
 Location: windy and dry areas. More wind means more air is driven through the boxes, increasing uptake

IF IRON FERTILISATION
 Trigger photosynthetic plankton blooms in the ocean by dumping iron into areas that don't have much. If the plankton sinks, carbon is stored.
 Location: iron-depleted regions of the ocean

OL OCEAN LIMING
 Throw lime into the ocean. It reacts with dissolved CO2 to form carbonates. This may also help corals by reducing ocean acidification.
 Location: coral habitats

EW ENHANCED WEATHERING
 Crush common minerals like olivine to powder to increase surface area for reacting with CO2 and water.
 Location: proceeds fastest in warm, wet conditions, so areas such as humid coasts and rivers are best



Transform Earth

It is now possible to use various methods and technologies to capture and store carbon from the atmosphere. These methods have to take into account the need to protect biodiversity.

T PLANT TREES

Plant forests and regularly harvest them. Trees are a carbon sink as long as they are growing, and not allowed to rot.

Location: unused farmland

B BIOCHAR

Burn plant material without oxygen to make charcoal-like "biochar". This carbon store can then be buried in soil, where it acts as a fertiliser.

Location: anywhere with rich plant growth

IF IRON FERTILISATION

Trigger photosynthetic plankton blooms in the ocean by dumping iron into areas that don't have much. If the plankton sinks, carbon is stored.

Location: iron-depleted regions of the ocean

EW ENHANCED WEATHERING

Crush common minerals like olivine to powder to increase surface area for reacting with CO2 and water.

Location: proceeds fastest in warm, wet conditions, so areas such as humid coasts and rivers are best

DA DAC (Direct air capture)

Build shipping-container-sized boxes full of a chemical "sponge" that sucks CO2 out of the air, ready for burial. You may need 100 million of them.

Location: windy and dry areas. More wind means more air is driven through the boxes, increasing uptake

OL OCEAN LIMING

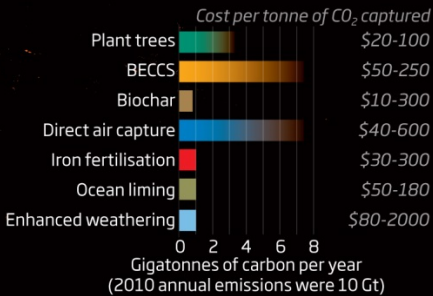
Throw lime into the ocean. It reacts with dissolved CO2 to form carbonates. This may also help corals by reducing ocean acidification.

Location: coral habitats

According to the Convention on Biological Diversity (CBD), all the geo-engineering applications are banned

Annual carbon savings by 2100

Bars show maximum possible for each technology



Gigatonnes of carbon per year
(2010 annual emissions were 10 Gt)

Greta and Fridays for Future



