The
Food and Land Use
Coalition

Why Nature? Why Now?

How nature is key to achieving a 1.5°C world

October 2021

Contents

1. Climate change: greenhouse gas emissions, sources and sinks

Human activity has increased the release of greenhouse gases (GHGs) into the atmosphere

GHGs are the gaseous constituents that trap heat in the atmosphere. They are released through natural processes (e.g. decomposition of biomass) and as a result of human activity (e.g. the burning of fossil fuels). Some gases are naturally occurring (e.g. carbon dioxide) while others are human-made (e.g. the halocarbons). **Carbon dioxide (CO_2) is the largest single contributor to climate change.** The United Nations Framework Convention on Climate Change covers the below GHGs:

Carbon dioxide

CO_2

CO_2 is naturally occurring but is also a by-product of burning fossil fuels, of burning biomass, of land-use changes and of industrial processes.

Methane

CH_4

CH_4 is the major component of natural gas and it is associated with all hydrocarbon fuels. Significant emissions also occur as a result of animal husbandry, waste management and agriculture.

Nitrous oxide

N_2O

The main anthropogenic source of N_2O is agriculture, in addition to sewage treatment, fossil fuel combustion, and chemical industrial processes. N_2O is also produced naturally, e.g. through microbial action in wet tropical forests.

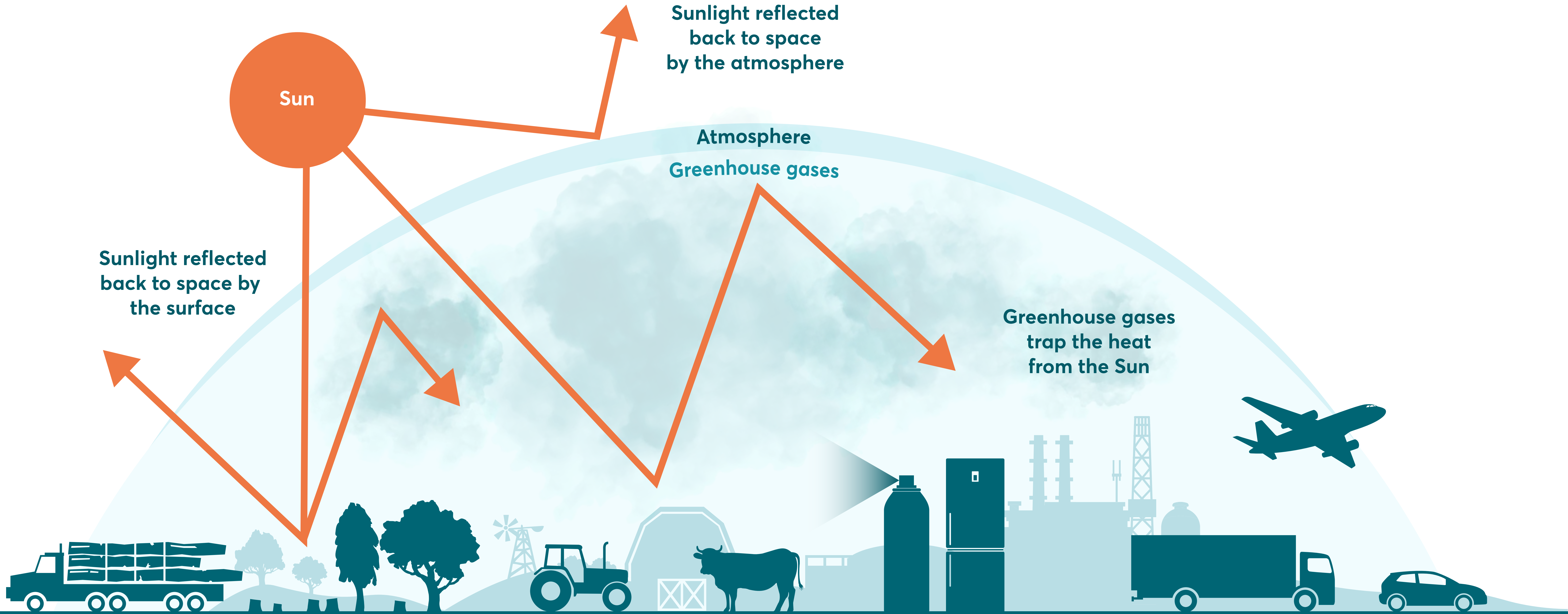
Fluorinated gases

F-gases

F-gases include **sulphur hexafluoride** (man-made chemical primarily used in electrical transmission and distribution systems, and in electronics), **hydrofluorocarbons and perfluorocarbons** (alternatives to ozone depleting substances, these by-products of industrial processes are powerful GHGs).

[1] Forster, P. et al. 2021: The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., et al. (eds.)]. Cambridge University Press. https://www.ipcc.ch/assessment-report/ar6/.

Increasing concentrations of GHGs in the atmosphere have caused a warming of the Earth's mean surface temperature. This is referred to as the greenhouse effect



Human activities release greenhouse gases

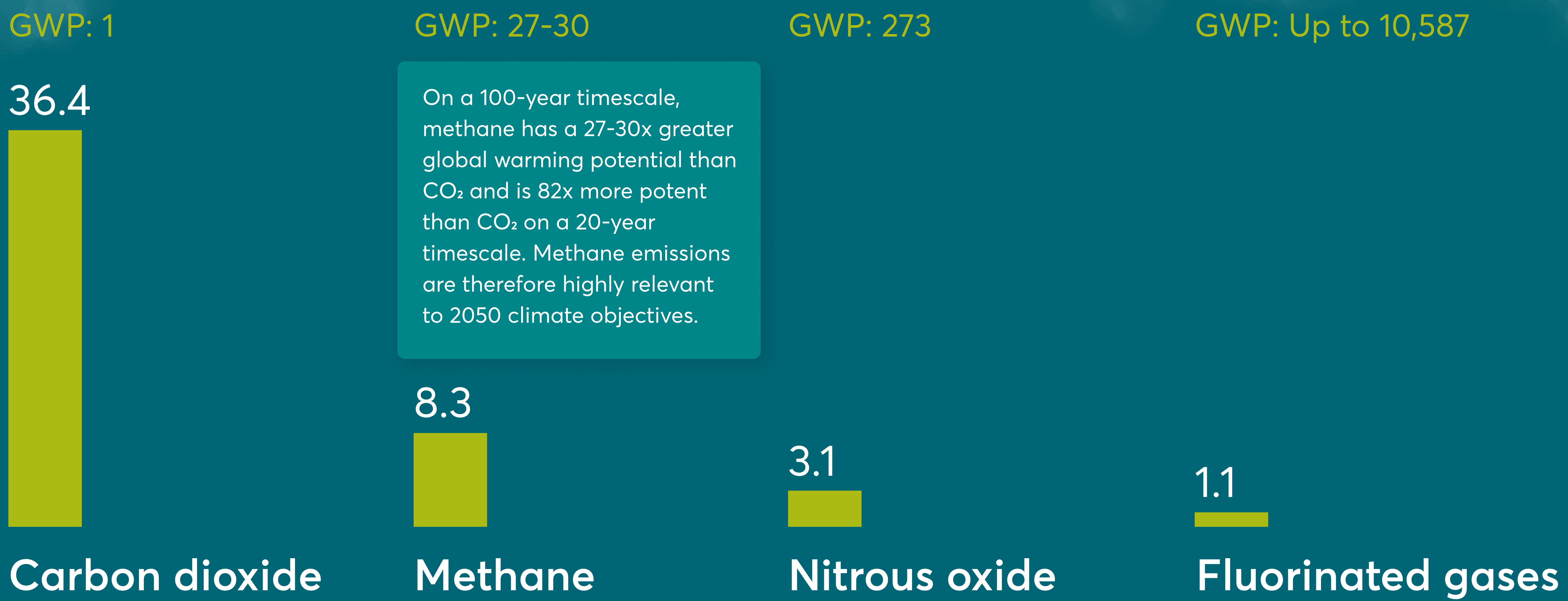
Carbon dioxide
Oil
Coal
Deforestation

Methane
Cattle
Fertilizer

CFCs and Haloalkane
Refrigerators
Aerosols

Nitrous oxide
Gasoline
Agriculture

Net anthropogenic GHG emissions in 2018 ($GtCO_2e$)[2] and their Global Warming Potential (GWP) on a hundred-year time horizon[1]



On a 100-year timescale, methane has a 27-30x greater global warming potential than CO_2 and is 82x more potent than CO_2 on a 20-year timescale. Methane emissions are therefore highly relevant to 2050 climate objectives.

The GWP allows comparisons of the global warming impacts of different gases over specific timeframes. CO_2 is the reference gas and so the GWP is 1.

[1] Forster, P. et al. 2021: The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., et al. (eds.)]. Cambridge University Press. https://www.ipcc.ch/assessment-report/ar6/.

[2] Climate Watch, 2021: Historical Greenhouse Gas (GHG) Emissions. World Resources Institute https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990

The three main systems capable of storing carbon and nitrogen, known as “stocks” or “pools”, include the land ecosystems, the ocean and the Earth’s crust.

The carbon and nitrogen not stored in these pools reside in the atmosphere as a component of greenhouse gases.

Land ecosystems (such as forests and peatlands): Plants absorb carbon through photosynthesis. The carbon they capture is stored in vegetation or integrated into soils when plants die. The breakdown of plant material and soil by microorganisms leads to emissions.[1,2]

The Earth’s deep mantle sequesters carbon through sedimentation and other geological formations, on geological timescales (many millennia).[3] Carbon is released into the atmosphere through the extraction and combustion of fossil fuels.[1]

Atmospheric CO_2 dissolves into the **ocean**, and phytoplankton also sequester carbon by photosynthesis, while deep cold waters absorb carbon.[1]

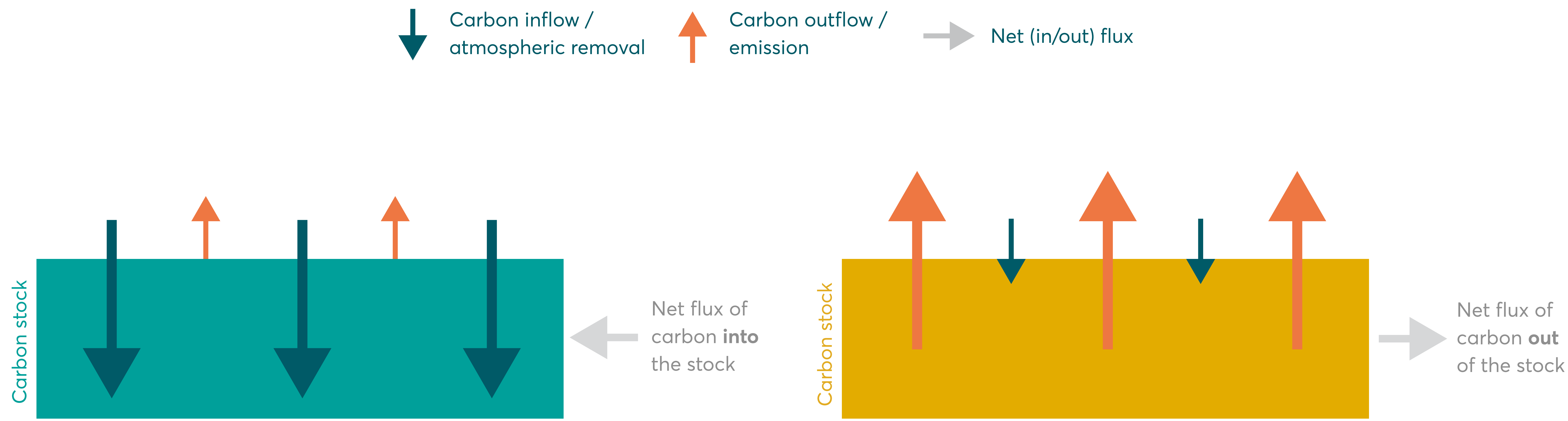
What is released or cannot be stored by other carbon stocks accumulates into the **atmosphere**.[1]

[1] Quéré, L. et al. 2021: Briefing 7 – The carbon cycle: Better understanding carbon-climate feedbacks and reducing future risks. The Royal Society. https://royalsociety.org/-/media/policy/projects/climate-change-science-solutions/climate-science-solutions-carbon-cycle.pdf.

[2] Gorte, R. W. 2009: Carbon Sequestration in Forests. Congressional Research Service. https://fas.org/sgp/crs/misc/RL31432.pdf.

[3] Regier, M.E. et al. 2020: The lithospheric-to-lower-mantle carbon cycle recorded in superdeep diamonds. Nature 585, 234–238 https://doi.org/10.1038/s41586-020-2676-z.

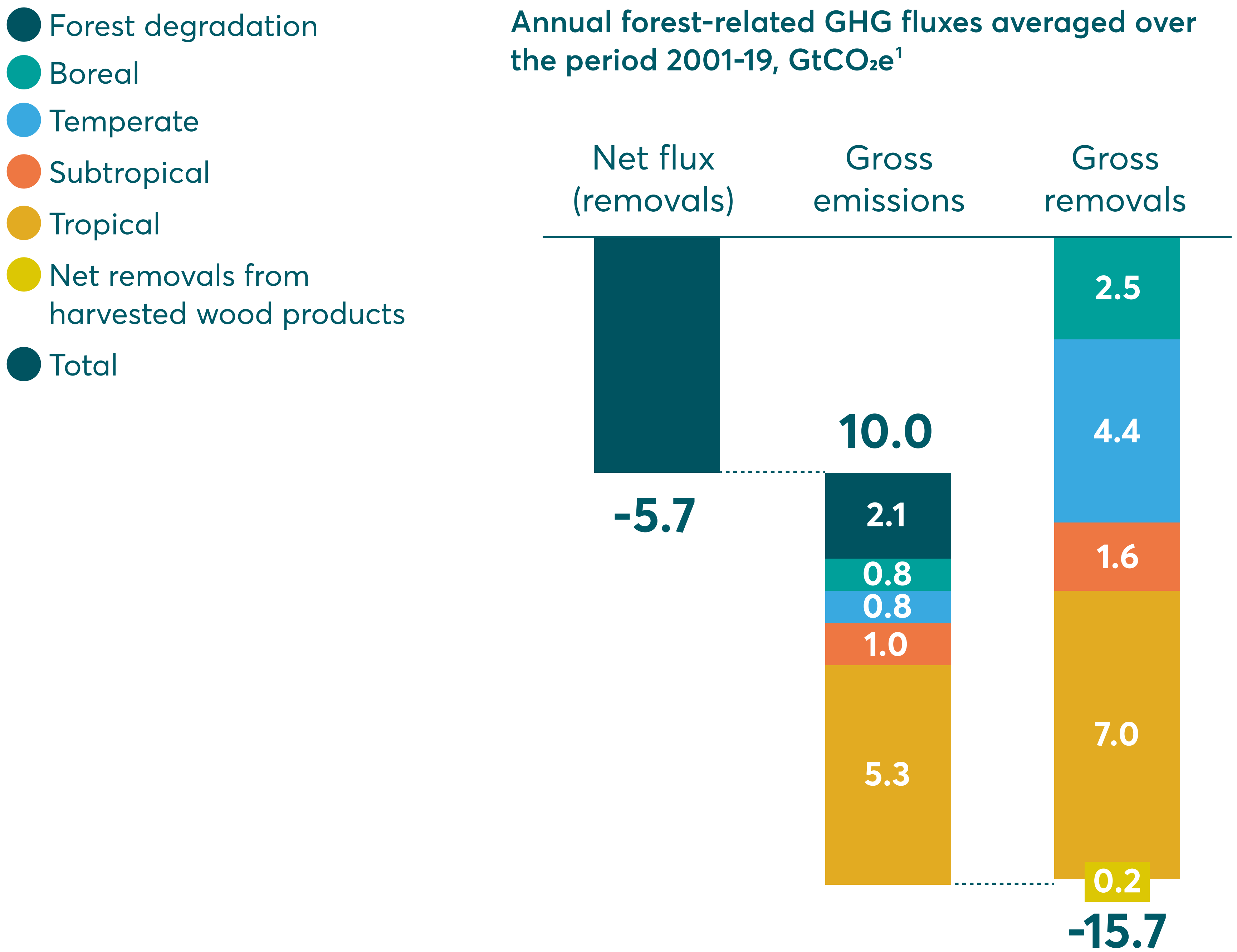
Whether a stock is considered a "sink" or a "source" of greenhouse gases depends on the net flux of 1) emissions out of the stock and into the atmosphere and 2) removals from the atmosphere and into the stock



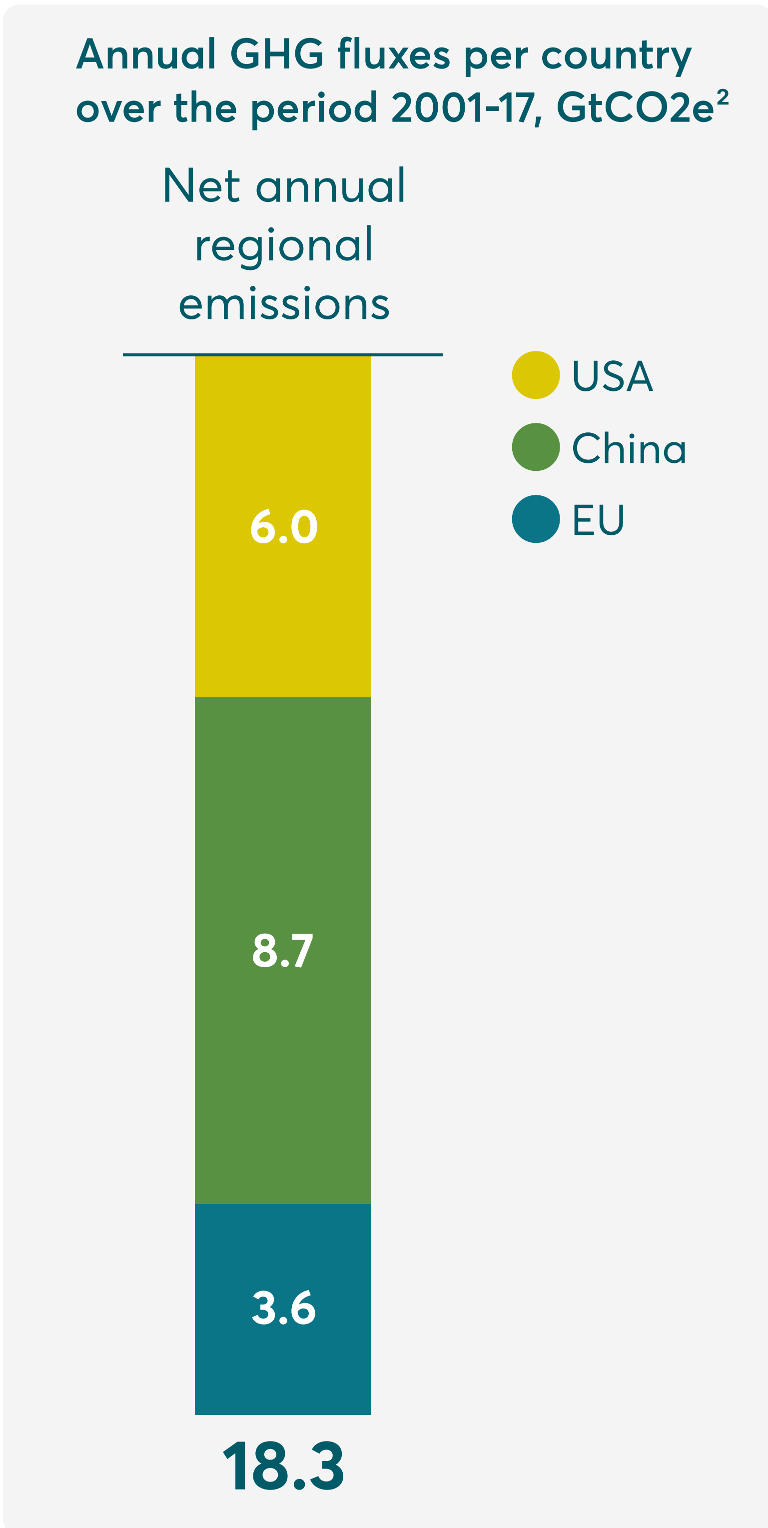
Carbon sinks are the carbon pools capable of sequestering more carbon than they emit. They include the ocean and the land biosphere.

Carbon sources are those systems that emit more CO_2 than they sequester over a period of time.

For example, forests are the largest terrestrial sink - globally, their net removal of carbon is equivalent to 5.7 billion metric tonnes of carbon dioxide ($GtCO_2$) a year. This represents 45% of carbon dioxide sequestration from the land sink.



Illustrative comparator



[1] Harris, N. L. et al. 2021: Global maps of twenty-first century forest carbon fluxes. Nat. Clim. Chang. https://doi.org/10.1038/s41558-020-00976-6.

[2] Climate Watch, 2021: Historical Greenhouse Gas (GHG) Emissions. World Resources Institute https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990.

But disturbances of land, ocean and geological stocks can result in net emissions of GHGs into the atmosphere, reducing the size of the global sinks

The California wildfires in 2020 released more than 91 million metric tonnes of carbon dioxide into the atmosphere, 25% more than California's annual emissions from fossil fuels.[1] A large portion of these emissions will be recovered over coming centuries by vegetation regrowth; however, the increasing frequency of fire disturbance raises the possibility of long-term losses of forest carbon stocks to the atmosphere.

Forests, such as the Amazon or Russia's boreal forests, are exposed to tipping points and Earth system feedback loops[2] which could see them turn into net sources of carbon.[3,4] The more the climate warms, the more likely these accelerating feedbacks and tipping points become.[5]

The increasing frequency of regional disturbances such as fire can diminish regional sinks or trigger those sinks to become sources of GHGs. The more widespread these regional changes, the greater influence on the global GHG sinks.

[1] Global Fire Emissions Database, 2020: https://globalfiredata.org/pages/2020/09/22/amazon-fire-activity-in-2020-surpasses-2019/.

[2] Tipping points and carbon-climate feedback loops are explained later in this work.

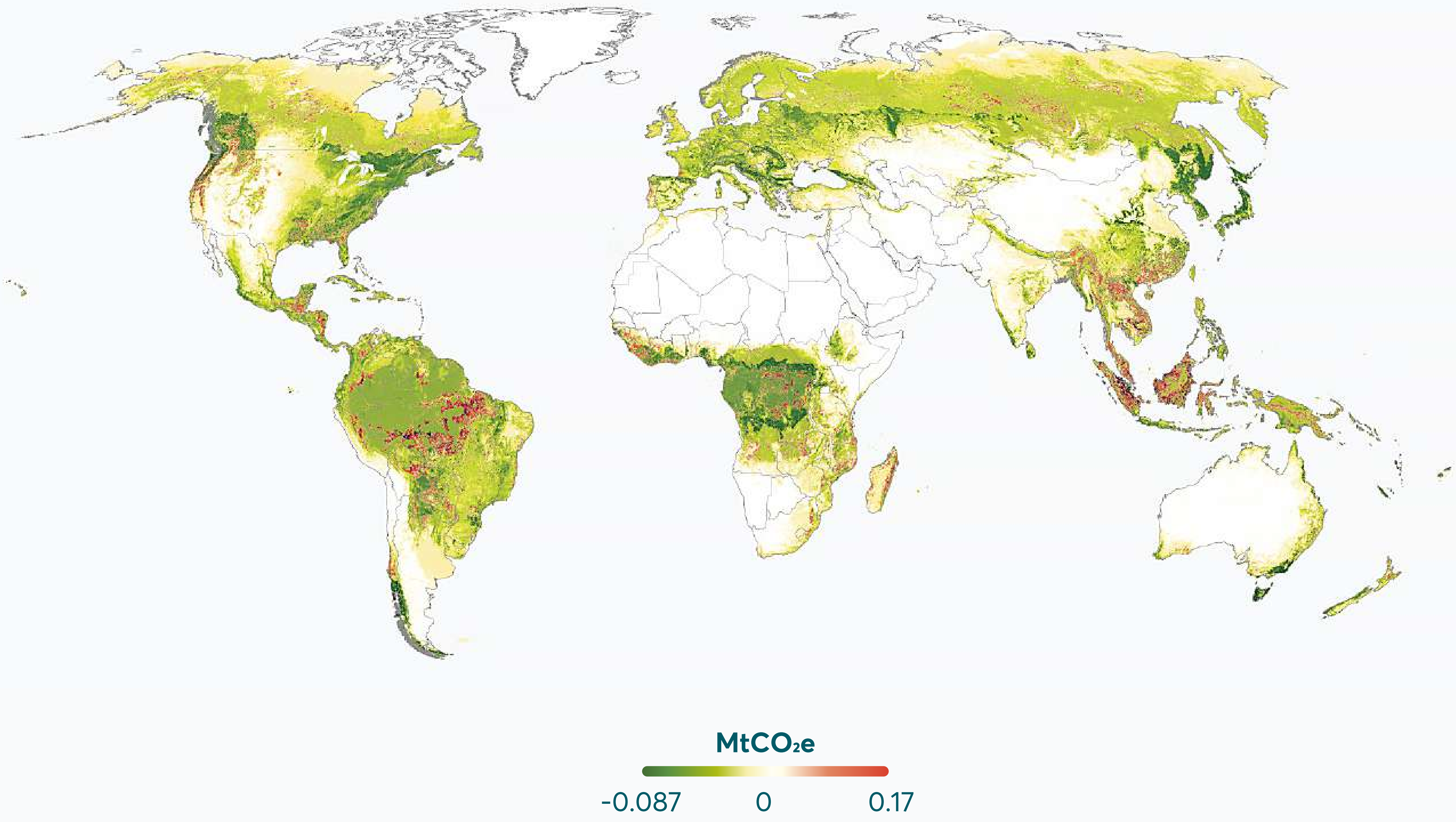
[3] Gatti, L. V. et al. 2021: Amazonia as a carbon source linked to deforestation and climate change. Nature vol. 595, 388-393. https://doi.org/10.1038/s41586-021-03629-6.

[4] Schaphoff, S. et al. 2016: Tamm Review: Observed and projected climate change impacts on Russia's forests and its carbon balance. Forest Ecology and Management. https://doi.org/10.1016/j.foreco.2015.11.043.

[5] Lenton et al. 2019: Climate tipping points — too risky to bet against. Nature. https://www.nature.com/articles/d41586-019-03595-0.

This is already happening in forest areas across the tropical belt…

This map shows the net carbon sinks **(green)** and sources **(red)** from forests across the period 2001-19 ($MtCO_2e$). The largest sinks are found in tropical forests. The largest sources are found in disturbed tropical forests.



Net annual fluxes in forest-related greenhouse gases[1]

[1] Harris, N. et al. 2021: Forests that regrow naturally may store more carbon. The Nature Conservancy https://www.nature.org/en-us/what-we-do/our-insights/perspectives/climate-potential-natural-regrowth-forests/.

2. Stock-take: the flow of greenhouse gas emissions into and out of the atmosphere today

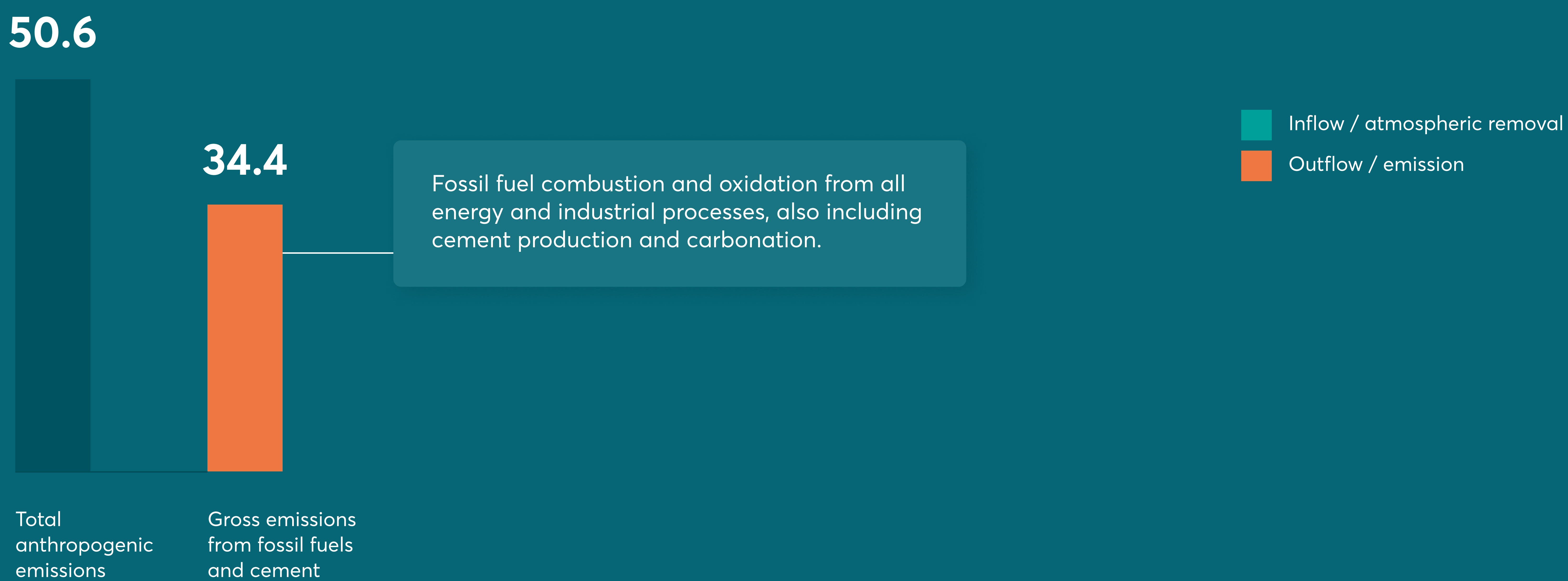
In the case of CO_2, human activity resulted in an average of 50.6 billion tonnes of gross anthropogenic CO_2 emissions a year over the period 2010 to 2019

Average annual carbon dioxide fluxes 2010-19 ($GtCO_2$)[1]

[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

Which includes 34.4 billion tonnes of CO_2 emissions from fossil fuels and cement

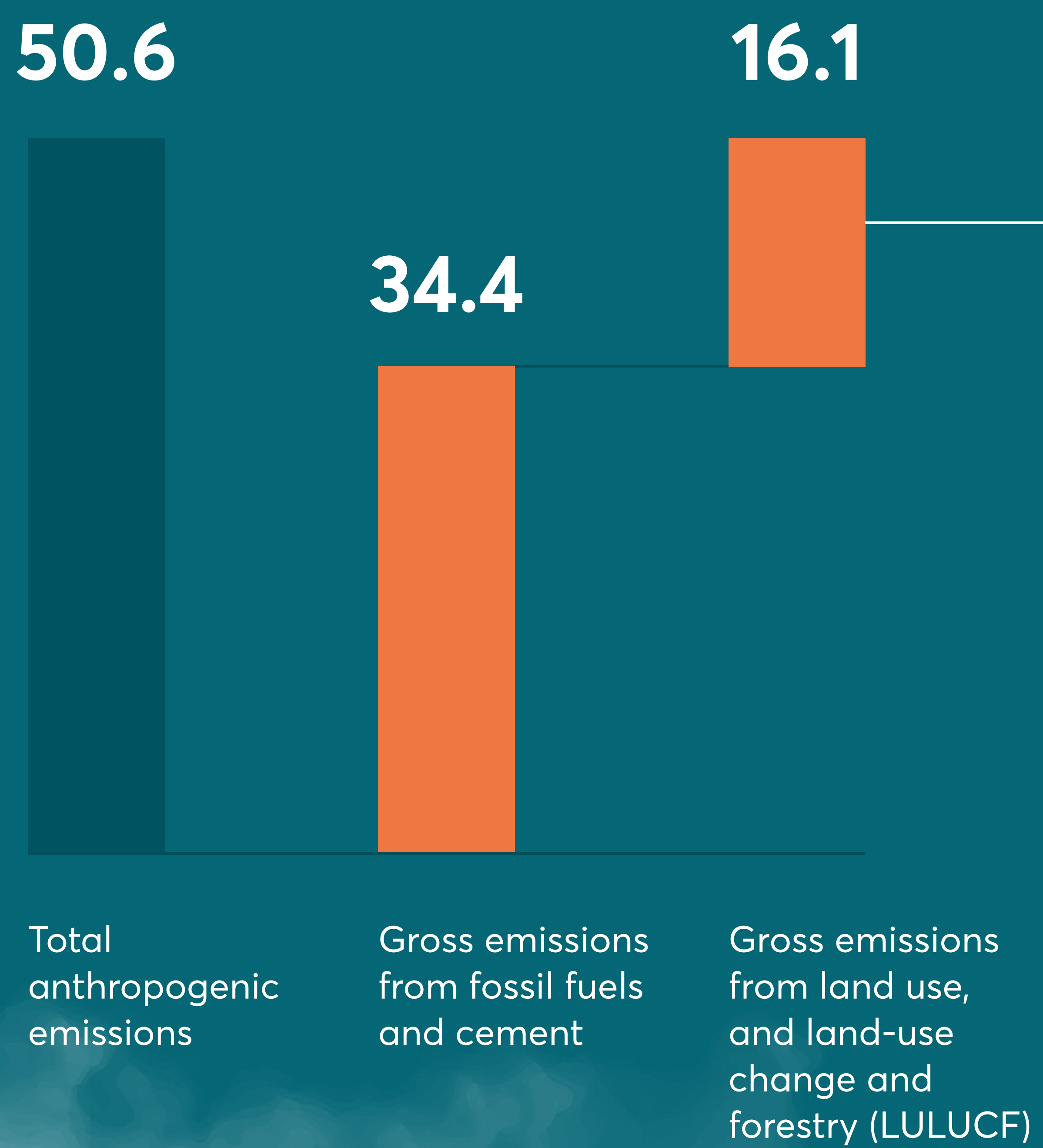
Average annual carbon dioxide fluxes 2010-19 ($GtCO_2$)[1]



[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

And 16.1 billion tonnes of CO_2 emissions from human activities on land, including those leading to land-use change and forestry (often referred to as Land Use and Land Use Change and Forestry or LULUCF emissions).

Average annual carbon dioxide fluxes 2010-19 ($GtCO_2$)[1]



Gross carbon emissions from land use, land use change and forestry (LULUCF): the emissions resulting from human activities on land, including those leading to land-use change. This include the CO_2 emissions from deforestation, logging and forest degradation (including harvest activity).

Note: *From an accounting perspective, this doesn't include emissions from wildfires as these are not accounted for as "anthropogenic" activities. Yet, an increasing share of wildfires is induced as a result of climate change linked to human activity (e.g. forest edge disturbance raises the susceptibility of forests to wildfire).*[2]

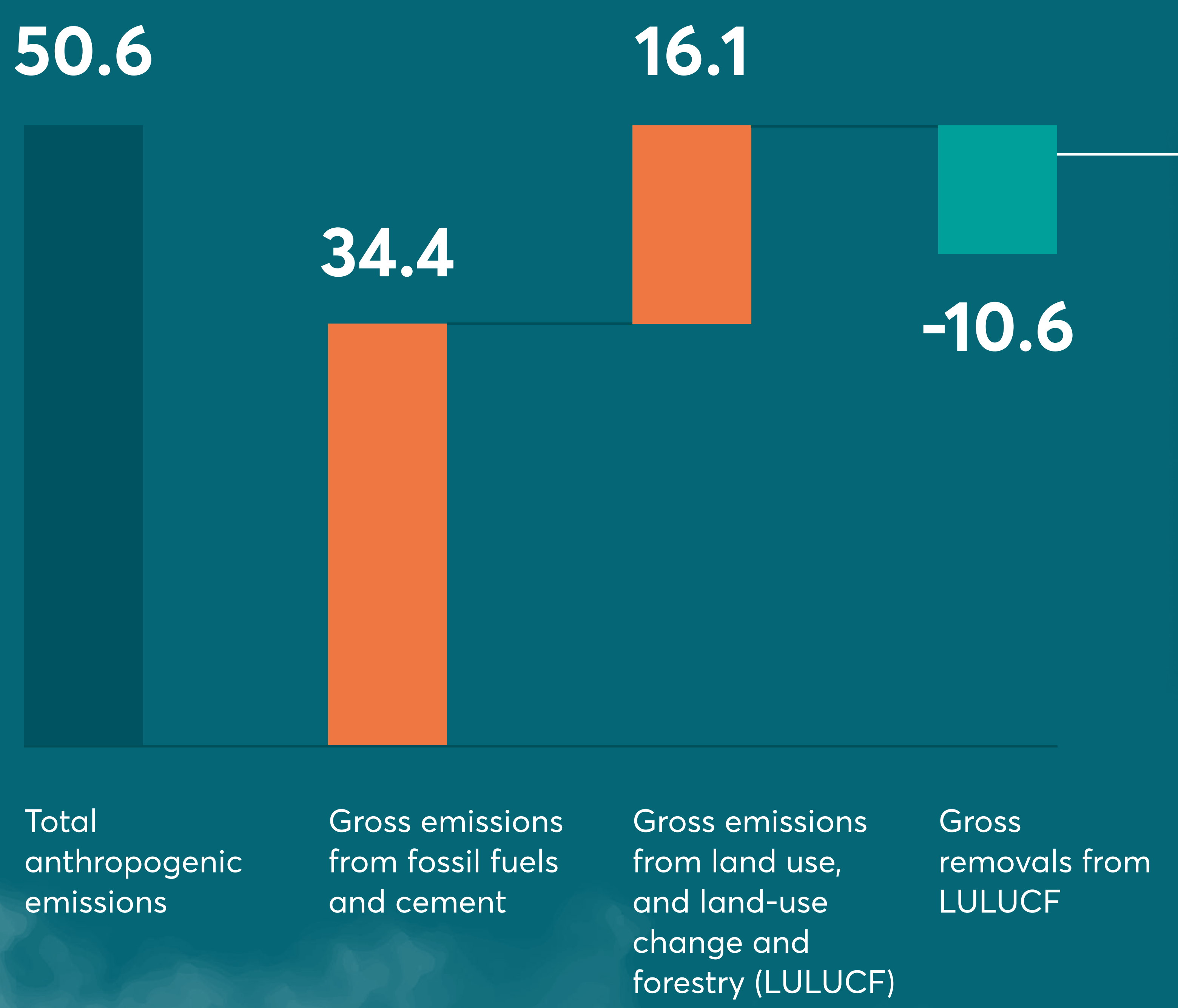
Due to rounding, gross emissions add up to 50.5 $GtCO_2$, not 50.6 $GtCO_2$.

[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

[2] Silva Junior et al. 2021: Amazonian forest degradation must be incorporated into the COP26 agenda. Nature Geoscience. https://www.nature.com/articles/s41561-021-00823-z.

Human activities on land can also result in atmospheric removals, for example through reforestation, afforestation or switching to regenerative agricultural practices. Over the same period, these human activities resulted in the removal of 10.6 billion tonnes of CO_2 each year (on average).

Average annual carbon dioxide fluxes 2010-19 ($GtCO_2$)[1]

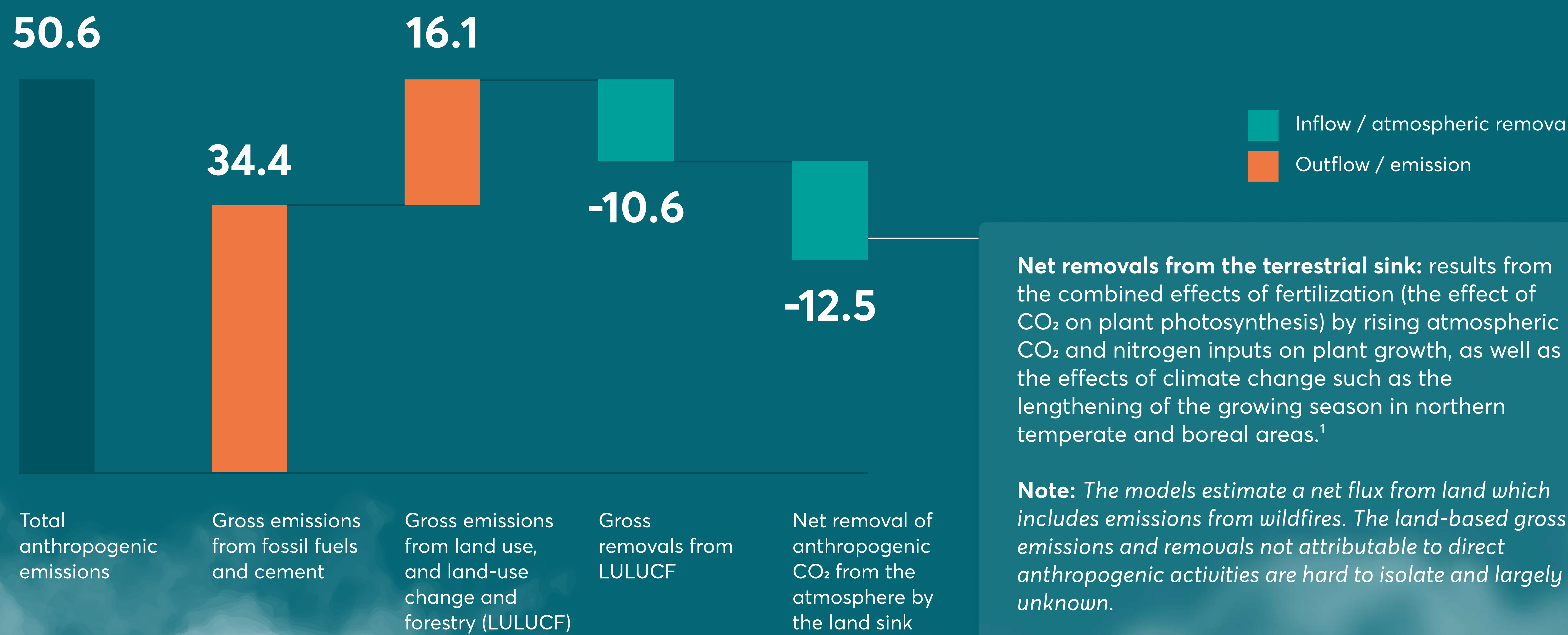


Gross removals from land use, land-use change and forestry: the removals resulting from human activities on land. This includes the CO_2 sequestration from e.g., reforestation and afforestation, shifting towards more regenerative cultivation techniques, and regrowth of forests following wood harvest or abandonment of agriculture.[1]

[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

A further 12.5 billion tonnes of CO_2 were removed by the natural terrestrial sink (i.e. through natural processes not related to human activity)

Average annual carbon dioxide fluxes 2010-19 ($GtCO_2$)[1]



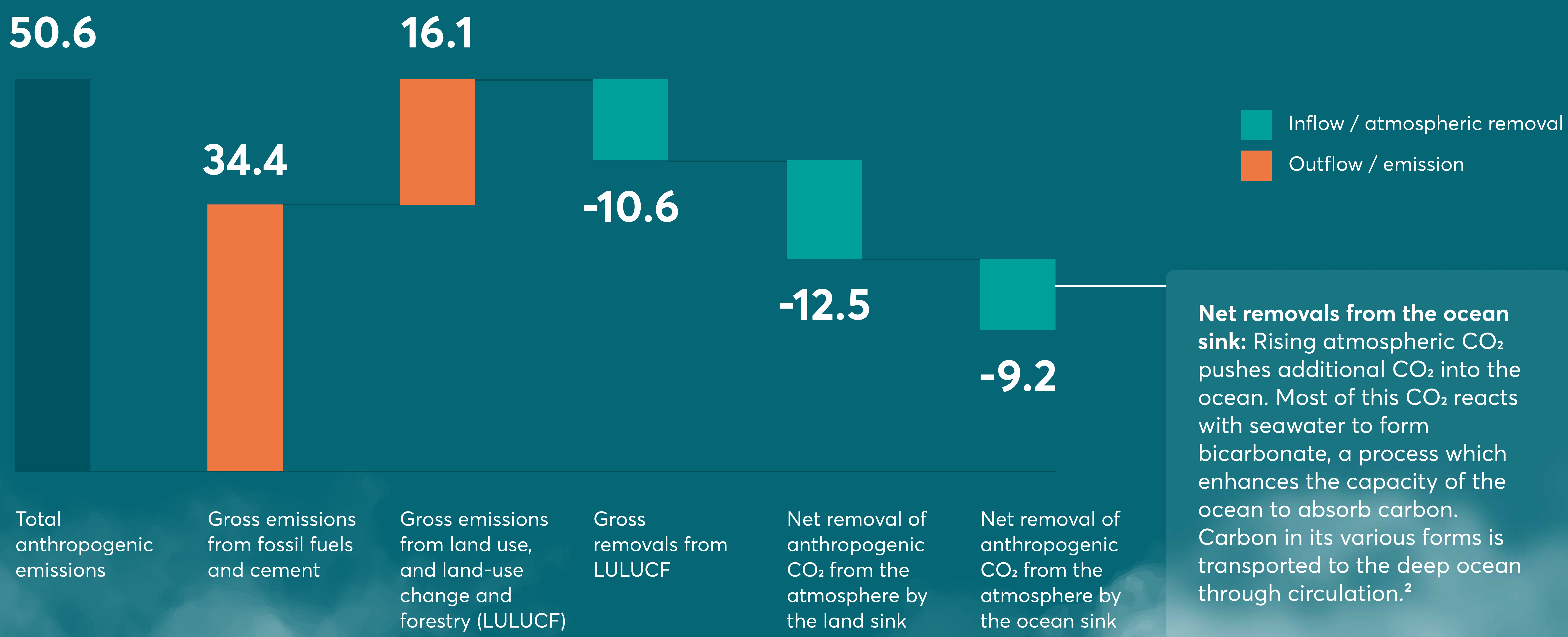
Net removals from the terrestrial sink: results from the combined effects of fertilization (the effect of CO_2 on plant photosynthesis) by rising atmospheric CO_2 and nitrogen inputs on plant growth, as well as the effects of climate change such as the lengthening of the growing season in northern temperate and boreal areas.[1]

Note: *The models estimate a net flux from land which includes emissions from wildfires. The land-based gross emissions and removals not attributable to direct anthropogenic activities are hard to isolate and largely unknown.*

[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

And 9.2 billion tonnes of CO_2 were removed by the natural ocean sink

Average annual carbon dioxide fluxes 2010-19 ($GtCO_2$)[1]



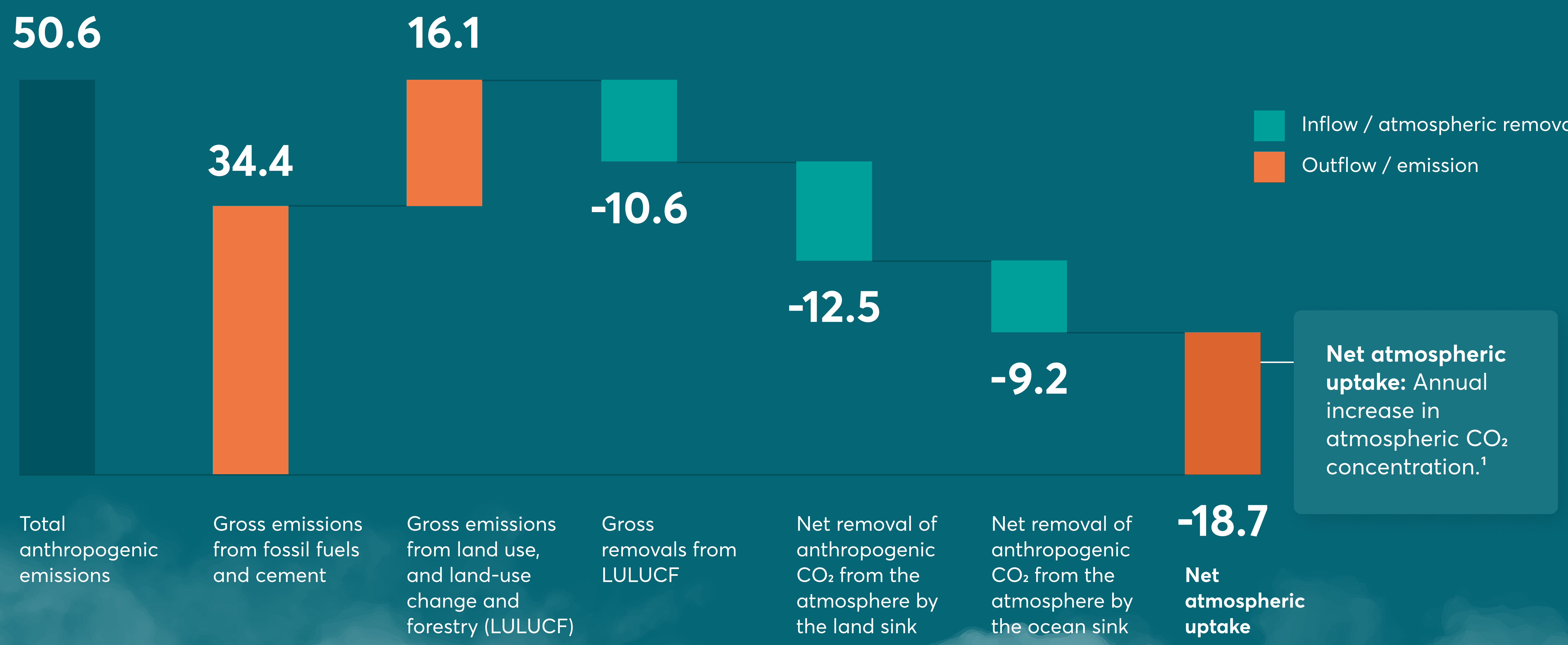
Net removals from the ocean sink: Rising atmospheric CO_2 pushes additional CO_2 into the ocean. Most of this CO_2 reacts with seawater to form bicarbonate, a process which enhances the capacity of the ocean to absorb carbon. Carbon in its various forms is transported to the deep ocean through circulation.[2]

[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

[2] Quéré, L. et al. 2021: Briefing 7 – The carbon cycle: Better understanding carbon-climate feedbacks and reducing future risks. The Royal Society. https://royalsociety.org/-/media/policy/projects/climate-change-science-solutions/climate-science-solutions-carbon-cycle.pdf.

18.7 billion tonnes of CO_2 remained in the atmosphere

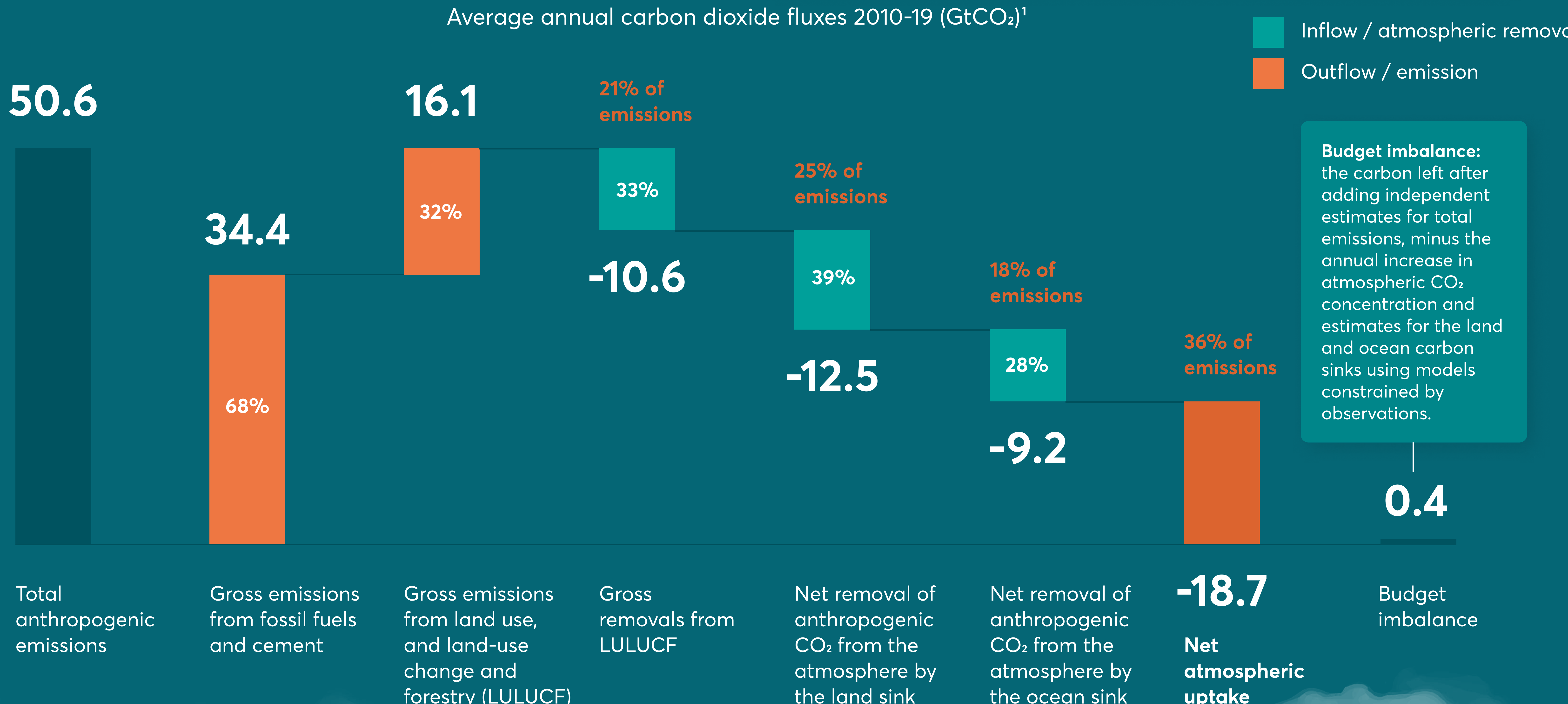
Average annual carbon dioxide fluxes 2010-19 ($GtCO_2$)[1]



[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

In summary, we are emitting more CO_2 than can be removed by Earth's systems…

LULUCF fluxes are the result of human intervention and are sometimes referred to as "managed", as opposed to "unmanaged" fluxes (e.g. net removals from the land / ocean sinks) which occur as the result of purely natural processes. However, this distinction is becoming increasingly irrelevant as the frontier between managed and unmanaged is blurry; a growing evidence base suggests that anthropogenic activities impact both "managed" and "unmanaged" land. This distinction originated from the need to find a proxy for (non-)anthropogenic emissions in countries' GHG accounting, but the exclusion of unmanaged lands in national GHG inventories may lead to a scientifically incomplete understanding of the carbon cycle and an underemphasis of the role of land systems in climate mitigation.[2]



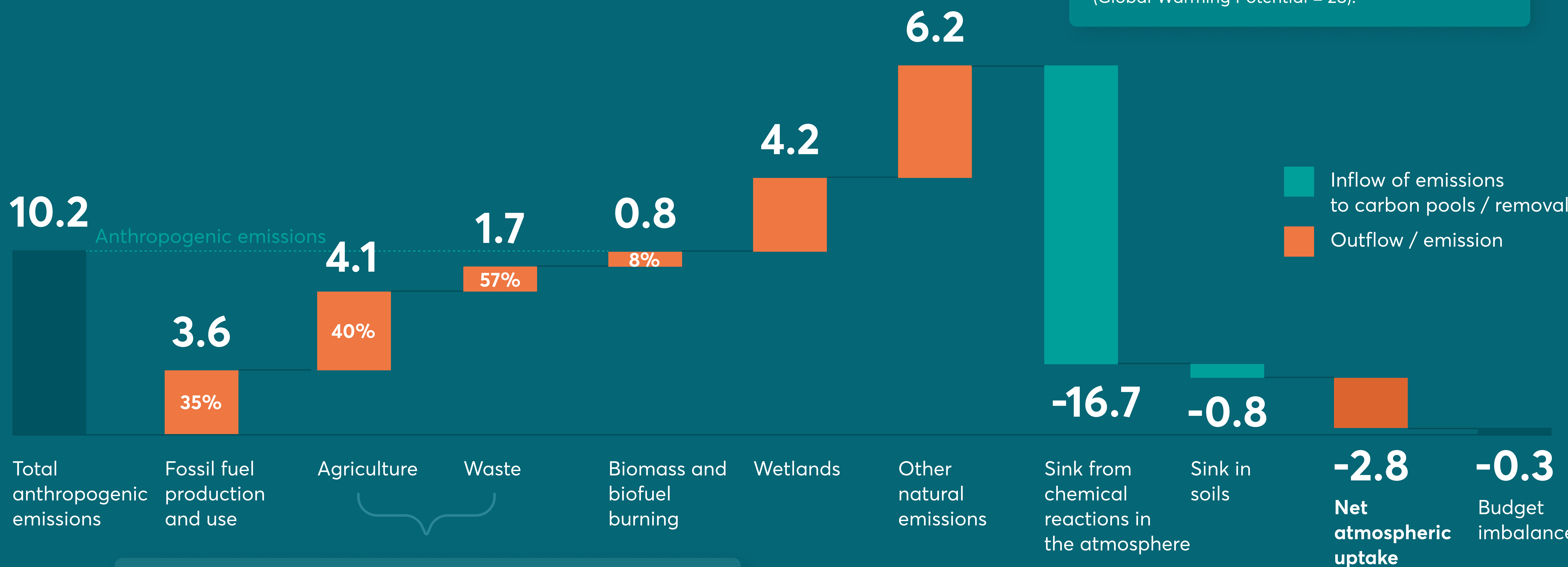
[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

[2] Ogle, S. M. et al. 2018: Delineating managed land for reporting national greenhouse gas emissions and removals to the United Nations framework convention on climate change. Carbon Balance Manage. https://doi.org/10.1186/s13021-018-0095-3.

And the story is similar for other greenhouse gases such as methane…

Average annual methane fluxes 2008-17 ($GtCO_2e$*)[1]

* 1 tonne of methane released in the atmosphere is equivalent to releasing 28 tonnes of carbon dioxide (Global Warming Potential = 28).[2]



The "Agriculture and Waste" estimate provided by the GCP (5.8 $GtCO_2e$[1]) is disaggregated into "Agriculture" and "Waste" by apportionment based on Climate Watch data (71% and 29% respectively).[3]

[1] Saunois, M. et al. 2020: The Global Methane Budget 2000–2017, Earth Syst. Sci. Data, 12, 1561–1623, https://doi.org/10.5194/essd-12-1561-2020.
[2] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC. https://www.ipcc.ch/report/ar5/syr/.
[3] Climate Watch, 2021: Historical Greenhouse Gas (GHG) Emissions. World Resources Institute https://www.climatewatchdata.org/ghg-emissions?end_year=2018&start_year=1990.

… and nitrous oxide

* 1 tonne of nitrous oxide released in the atmosphere is equivalent to releasing 265 tonnes of carbon dioxide (Global Warming Potential = 265).[2]

Average annual nitrous oxide fluxes 2007-16 ($GtCO_2e$*)[1]

[1] Tian, H. et al. 2020: A comprehensive quantification of global nitrous oxide sources and sinks, Global Carbon Project, Nature, 586. https://doi.org/10.1038/s41586-020-2780-0.

[2] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC. https://www.ipcc.ch/report/ar5/syr/.

Emissions from human activities on land, including those leading to land-use change and forestry (LULUCF emissions) are often cited as accounting for 10-15% of global CO_2 emissions (~38.5 $GtCO_2$).[1]

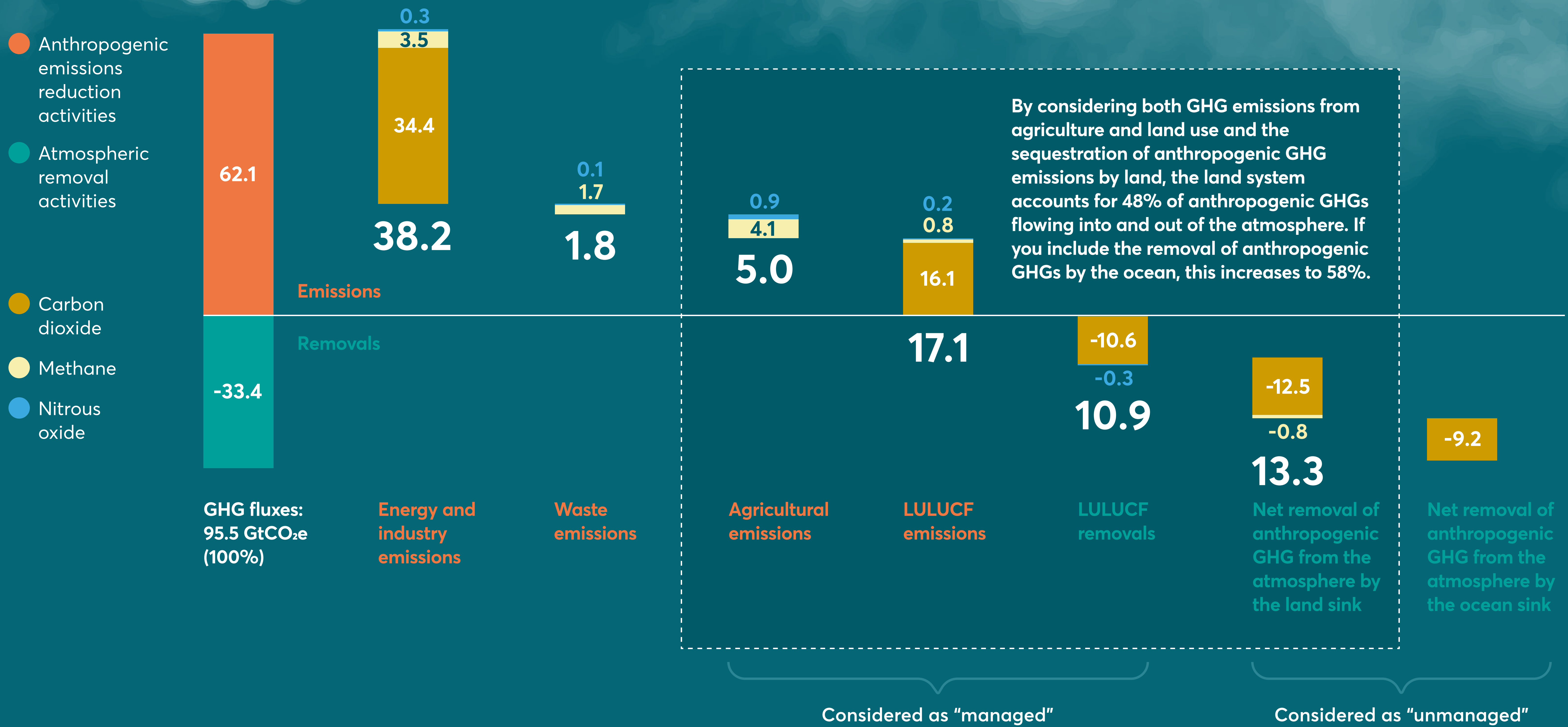
But by focusing on net CO_2 fluxes, this approach underplays the significance of the land sector in climate mitigation.[2]

Considering non-CO_2 gases and looking at the gross fluxes instead of net emissions, the contribution of the land system to climate change is startling, representing 48% of all anthropogenic GHGs flowing in and out of the atmosphere.

[1] IPCC, 2019: Mitigation pathways compatible with 1.5°C in the context of sustainable development. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. https://www.ipcc.ch/sr15/chapter/chapter-2/.

[2] Wolosin, M. & Harris, N. 2018: Tropical forests and climate change: the latest science. World Resources Institute. https://www.wri.org/research/ending-tropical-deforestation-tropical-forests-and-climate-change-latest-science.

Annual emissions and removals for carbon[1] (average 2010-19), methane[2] (av. 2008-17) and nitrous oxide[3] (2007-16), $GtCO_2e$



[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

[2] Saunois, M. et al. 2020: The Global Methane Budget 2000–2017, Earth Syst. Sci. Data, 12, 1561–1623, https://doi.org/10.5194/essd-12-1561-2020.

[3] Tian, H. et al. 2020: A comprehensive quantification of global nitrous oxide sources and sinks, Global Carbon Project, Nature, 586, 248-256, https://doi.org/10.1038/s41586-020-2780-0.

3. Rising risk of catastrophic impacts: temperature thresholds, carbon budgets, and tipping points

We have already reached 1.09˚C of warming compared to pre-industrial times (circa 1850) as a result of increasing greenhouse gas emissions into the atmosphere[1]

[1] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte, et al. Cambridge University Press.

Sixth Assessment Report

"It is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred."

"The scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years."

"The last decade was more likely than not warmer than any multi-centennial period after the Last Interglacial, roughly 125,000 years ago."

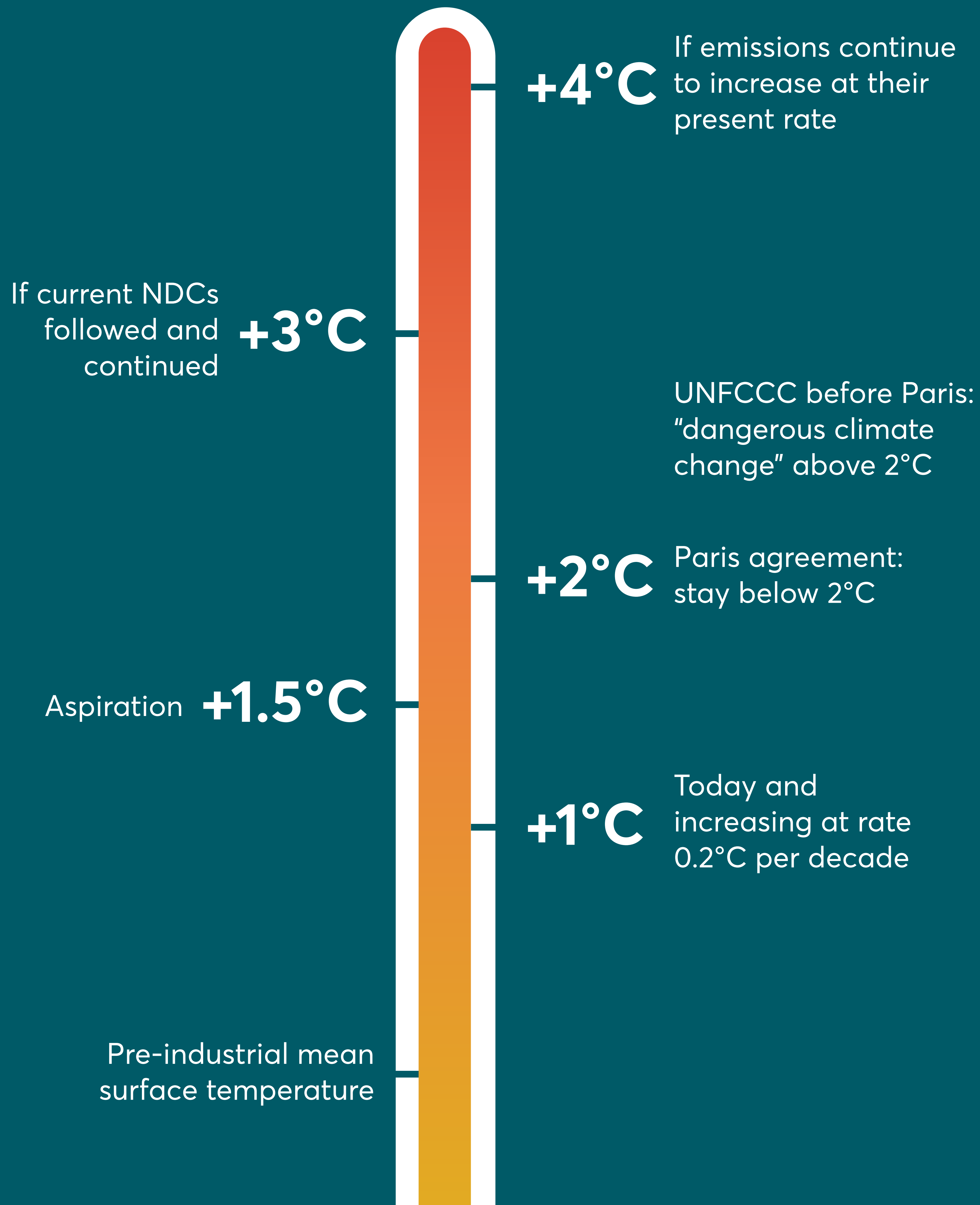
Scientists have established 1.5˚C as the safer upper limit for warming (compared to pre-industrial times) to avoid the catastrophic impacts of climate change

Climate change will significantly impact our society's production systems, vital economic and social infrastructures, government facilities, threatening our jobs and livelihoods.[1]

The frequency of disasters, the survival of plants and animals, the spread of diseases, the stability of our global climate system and – ultimately – the possibility for humanity to survive on this planet hinge on these few degrees.[2]

[1] Rogelj, J. et al. 2018: Chapter 2 — Global Warming of 1.5°C. https://www.ipcc.ch/sr15/chapter/chapter-2/.

[2] McSweeney, R. 2018: The Impacts of climate change at 1.5C, 2C and beyond. The Carbon Brief. https://interactive.carbonbrief.org/impacts-climate-change-one-point-five-degrees-two-degrees/.



	1.5°C	2°C	>3°C
Extreme heat Increase in global marine heatwave days per year	x16	x23	x41
Thawing Probability of ice-free Arctic summer at least once before hitting temperature limit	10%	80%	100%
Droughts Average drought length (month)	2	4	10
Ecosystems Proportion of species losing >50% of their climatic range (inc. vertebrates, plants and mammals)	4%	11%	51%
Economy Global impact on GDP of energy demand for heating and cooling	-0.05%	-0.19%	-0.9%
Livelihoods Global reduction in maize yields in tropics[2]	-3%	-7%	-2.3x

The Paris Agreement signatories committed to keep global warming well below 2˚C above pre-industrial levels and pursue efforts to limit it to 1.5˚C. Even with 1.5˚C of warming the world will face severe climate impacts, but these get significantly worse with 2˚C.[1]

[1] Rogelj, J. et al. 2018: Chapter 2 — Global Warming of 1.5°C. https://www.ipcc.ch/sr15/chapter/chapter-2/.

[2] WRI, 2018: Half a Degree and a World Apart: The Difference in Climate Impacts Between 1.5˚C and 2˚C of Warming. https://www.wri.org/insights/half-degree-and-world-apart-difference-climate-impacts-between-15c-and-2c-warming.

Based on this safer upper limited, scientists have defined a "remaining carbon budget"

The budget is the maximum net difference between CO_2 emissions and removals that can be emitted before reaching 1.5°C of warming.

Remaining "budget" of carbon dioxide (CO_2) emissions during this century[1]

500 $GtCO_2$

For a 50% chance of limiting global warming to 1.5°C

400 $GtCO_2$

For a 67% chance…

In other words, the maximum amount of cumulative net global anthropogenic CO_2 emissions that would result in limiting global warming to 1.5°C, taking into account the effect of other anthropogenic climate forcers (such as other GHG like methane and nitrous oxide), should not exceed 400 $GtCO_2$ from now on for a 67% chance of actually managing to limit global temperatures to 1.5°C.[1]

Given an average, over the past decade, of 40 $GtCO_2$ net annual anthropogenic emissions, we need to reach net zero CO_2 emissions in 10 years.

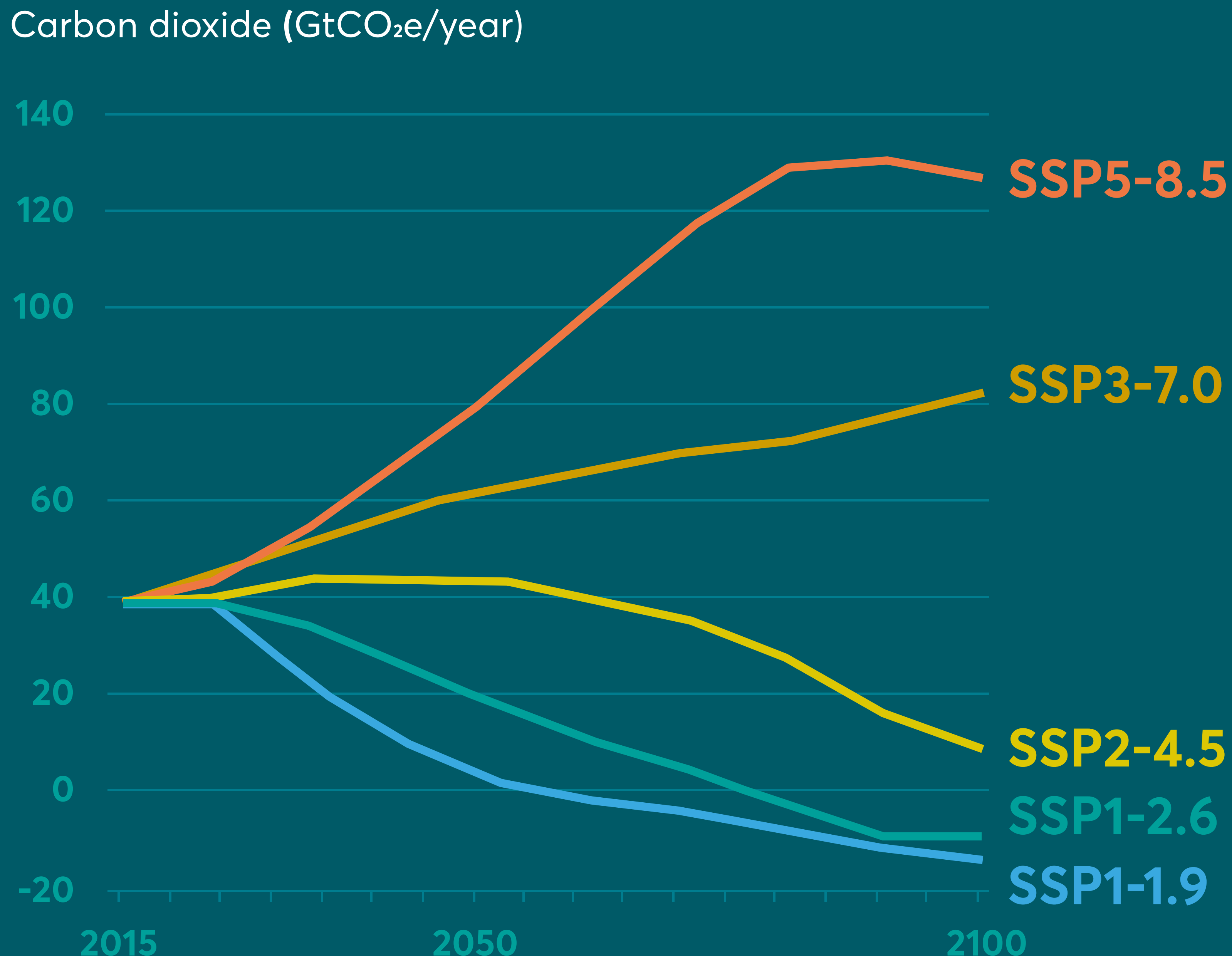
[1] Canadell et al. 2021: Chapter 5: Global Carbon and other Biogeochemical Cycles and Feedbacks. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the IPCC. Masson-Delmotte, et al. Cambridge University Press. https://www.ipcc.ch/assessment-report/ar6/.

[2] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

[3] Cain et al. 2019: Improved calculation of warming-equivalent emissions for short-lived climate pollutants. Climate and Atmospheric Science. https://doi.org/10.1038/s41612-019-0086-4.

Best estimates suggest that we will reach 1.5˚C by 2040, even under the most ambitious scenarios

Future annual emissions of CO_2 based on five illustrative scenarios that cover the range of possible future development of human drivers of climate change



Estimated warming impact in the near-, mid- and long-term for each of the five illustrative scenarios

	Near term, 2021-2040		Mid-term, 2041-2060		Long term, 2081-2100	
Scenario	Best estimate (˚C)	Very *likely* range (˚C)	Best estimate (˚C)	Very *likely* range (˚C)	Best estimate (˚C)	Very *likely* range (˚C)
SSP1-1.9	1.5	1.2 to 1.7	1.6	1.2 to 2.0	1.4	1.0 to 1.8
SSP1-2.6	1.5	1.2 to 1.8	1.7	1.3 to 2.2	1.8	1.3 to 2.4
SSP2-4.5	1.5	1.2 to 1.8	2.0	1.6 to 2.5	2.7	2.1 to 3.5
SSP3-7.0	1.5	1.2 to 1.8	2.1	1.7 to 2.6	3.6	2.8 to 4.6
SSP5-8.5	1.6	1.3 to 1.9	2.4	1.9 to 3.0	4.4	3.3 to 5.7

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.

SSP1-1.9 and SSP1-2.6 are scenarios with 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.

IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte, et al. Cambridge University Press.

But there is uncertainty associated with the remaining budget due to the existence of "tipping points" where the land and ocean processes that capture GHGs could begin to weaken[1,2,3]

Scientists are increasingly concerned about the existence of tipping points (defined as "critical thresholds beyond which a system reorganizes, often abruptly and/or irreversibly"[3]) linked to a number of "Earth system feedbacks".

For example, increased GHG concentration in the atmosphere leads to warming, which in turn results in reduced rates of carbon sequestration by the land and ocean sink (for example, either by causing wildfires or by reducing the rate of photosynthesis in plants) which further accelerates the change in atmospheric GHG concentration and climate.[1,2,3]

Latest research suggests that rising temperatures could lead to a near halving of the land sink strength due to reduced photosynthesis by as early as 2040.

While the latest carbon budget – as set out in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change - takes into account a number of these Earth system feedbacks such as permafrost thawing, there is a high degree of uncertainty, meaning the remaining carbon budget could be overestimated.[4,5,6] Recent research suggests that the budget for remaining below 1.5˚C has a 17% chance of already being negative (i.e. we have already surpassed it).[7]

To reduce the risk of triggering these ecological and climate tipping points, we must reduce emissions as rapidly as possible and protect and enhance the remaining natural carbon sinks.[3]

[1] Lowe, J. A. & Bernie, D. 2018: The impact of Earth system feedbacks on carbon budgets and climate response. Philos. Trans. R. Soc. https://dx.doi.org/10.1098%2Frsta.2017.0263.

[2] Quéré, L. et al. 2021: Briefing 7 – The carbon cycle: Better understanding carbon-climate feedbacks and reducing future risks. The Royal Society. https://royalsociety.org/-/media/policy/projects/climate-change-science-solutions/climate-science-solutions-carbon-cycle.pdf.

[3] IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Masson-Delmotte, et al. Cambridge University Press.

[4] Lenton et al. 2019: Climate tipping points — too risky to bet against. Nature. https://www.nature.com/articles/d41586-019-03595-0.

[5] Ripple et al. 2021: World Scientists' Warning of a Climate Emergency 2021. BioScience. https://doi.org/10.1093/biosci/biab079.

[6] Duffy, K. A. et al. 2021: How close are we to the temperature tipping point of the terrestrial biosphere? Science Advances 7. https://doi.org/10.1126/sciadv.aay1052.

[7] Matthews et al. 2021: An integrated approach to quantifying uncertainties in the remaining carbon budget. Communications Earth and Environment. https://doi.org/10.1038/s43247-020-00064-9.

Example of an Earth system feedback: permafrost thawing[1]

Thawing releases CO_2 and CH_4 into the atmosphere, which increases warming and causes further thawing of the permafrost.

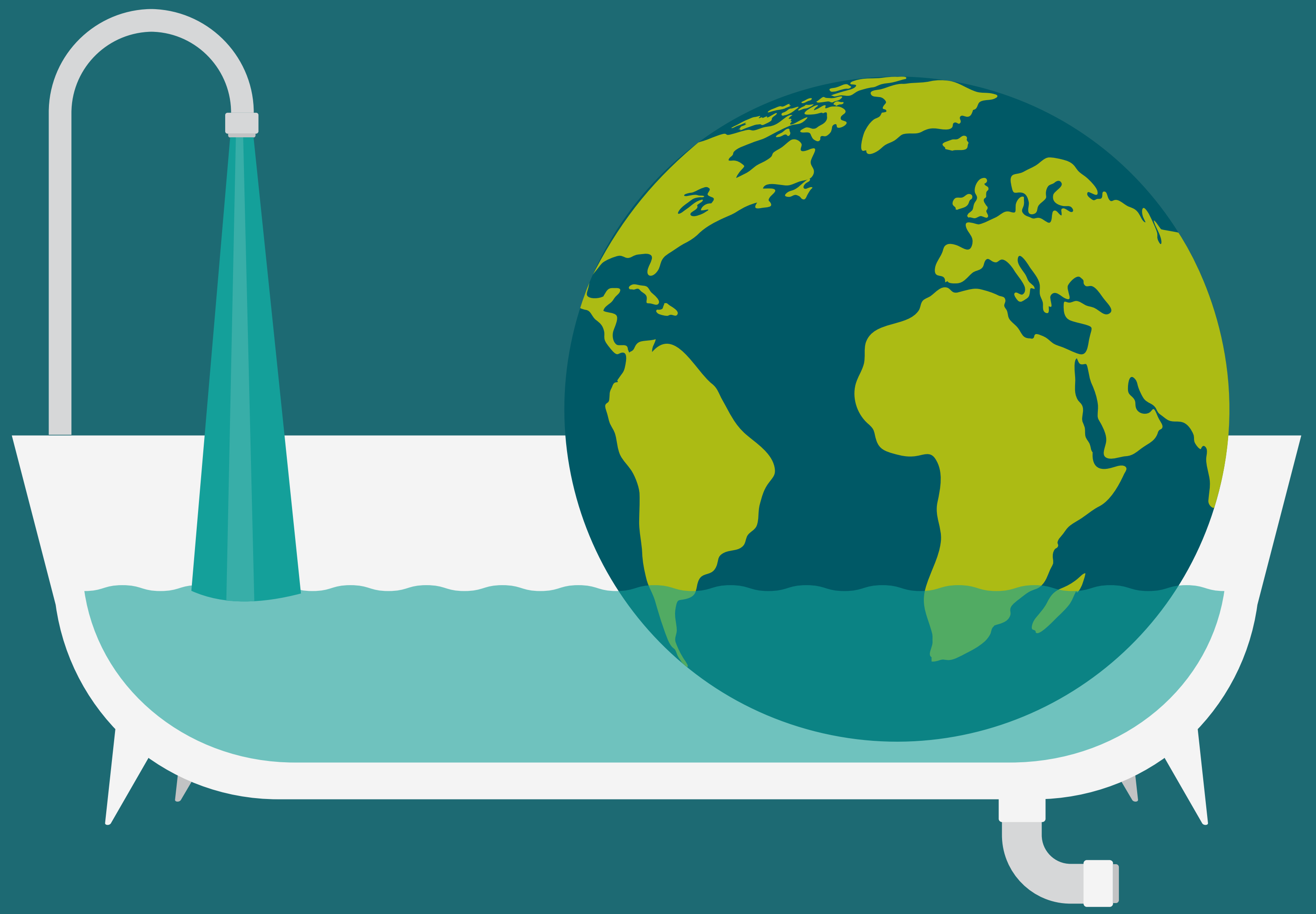
[1] Quéré, L. et al. 2021: Briefing 7 – The carbon cycle: Better understanding carbon-climate feedbacks and reducing future risks. The Royal Society. https://royalsociety.org/-/media/policy/projects/climate-change-science-solutions/climate-science-solutions-carbon-cycle.pdf.

This is complicated stuff… To help you find your "Eureka" moment, let's simplify it with the analogy of the bath tub…

Focus on these pages is on carbon dioxide.

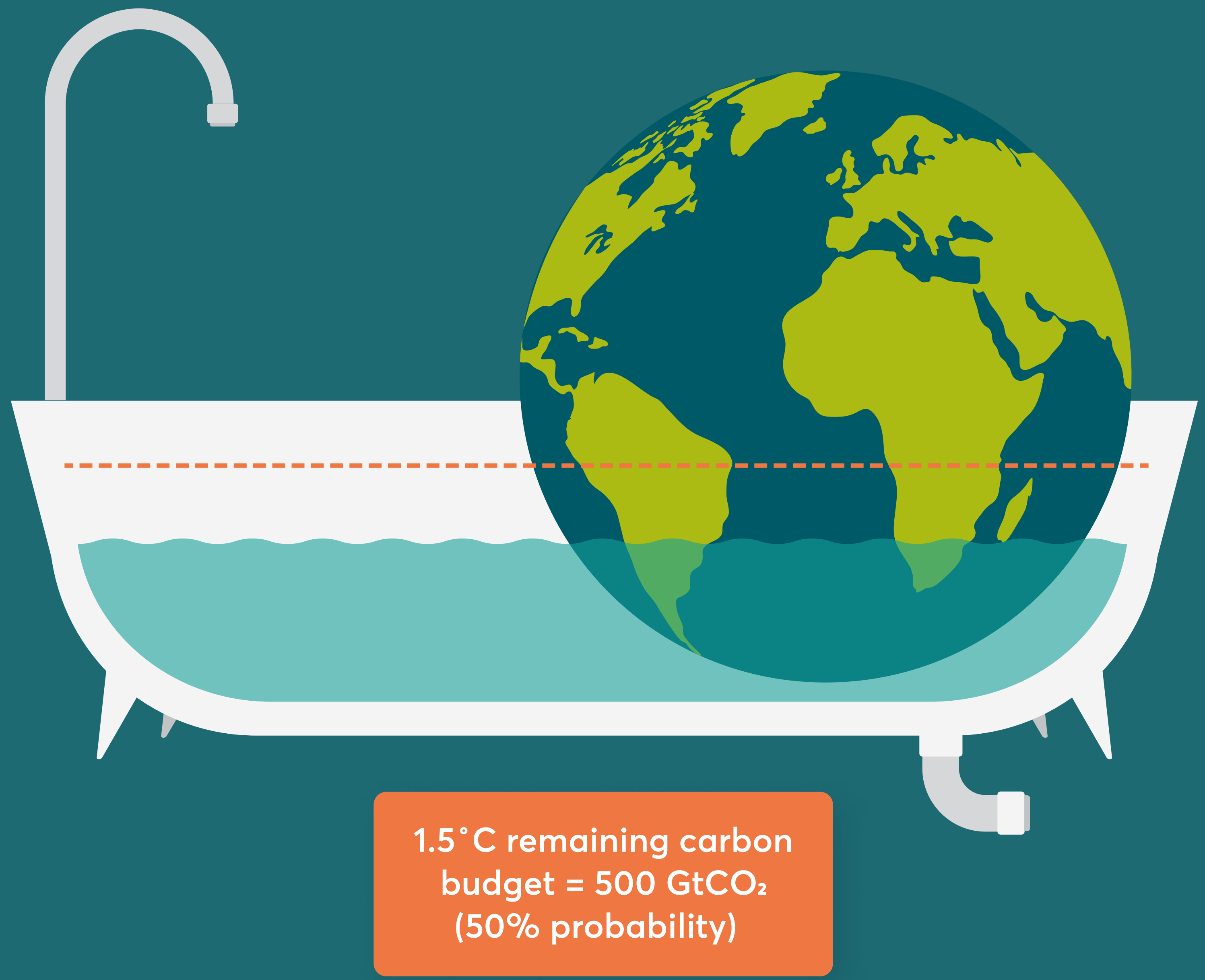
The water level represents the stock/ pool of carbon dioxide and other greenhouse gases in the atmosphere

The inflow of water represents flows of emissions into the atmosphere, e.g. from burning fossil fuels. The more water flowing in, the more the tub fills



The water draining out represents the sequestration or removal of emissions out of the atmosphere and into the sinks such as forests and the ocean.

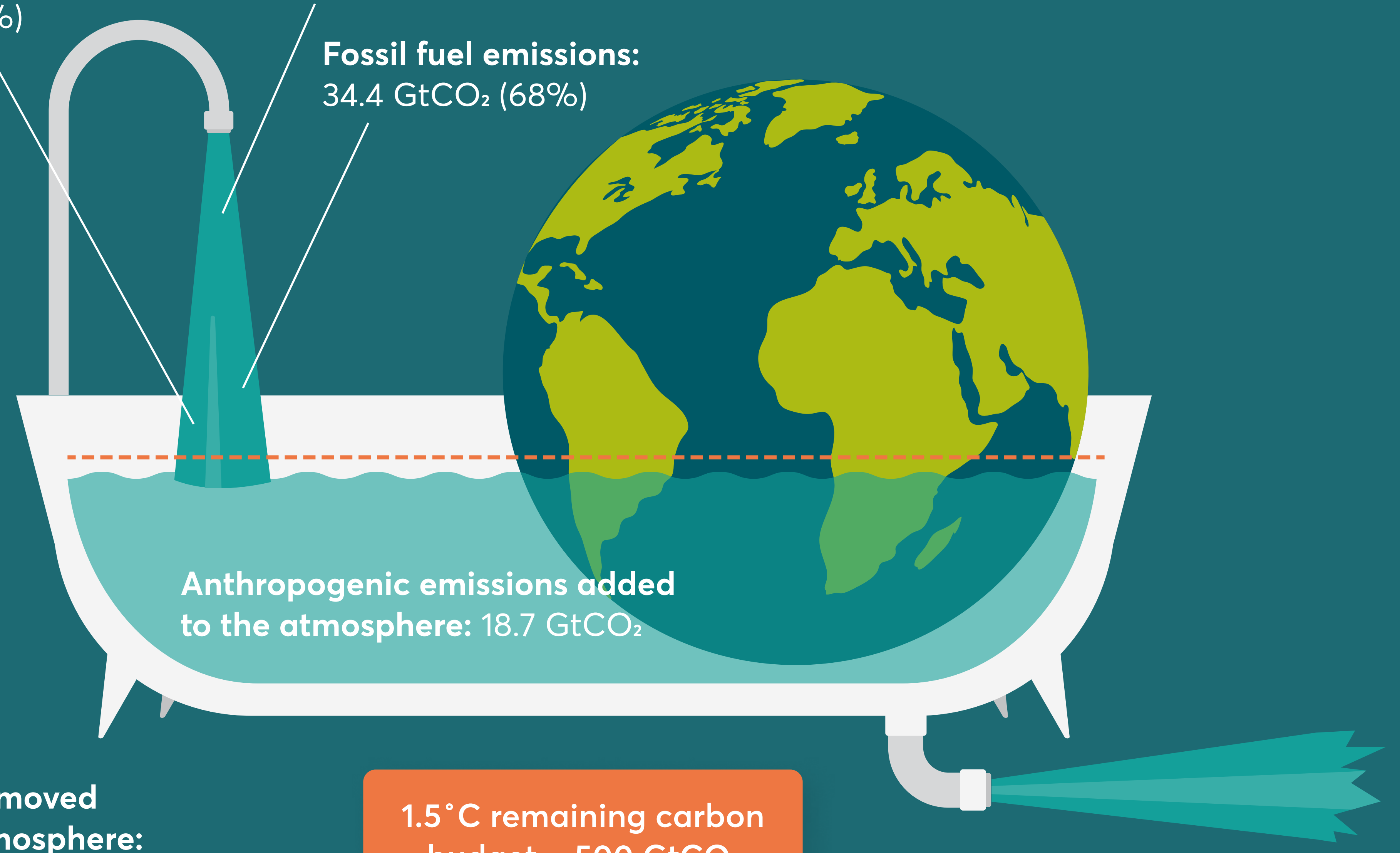
The remaining carbon budget is the limit before the bathtub overflows



The bathtub is dangerously close to overflowing

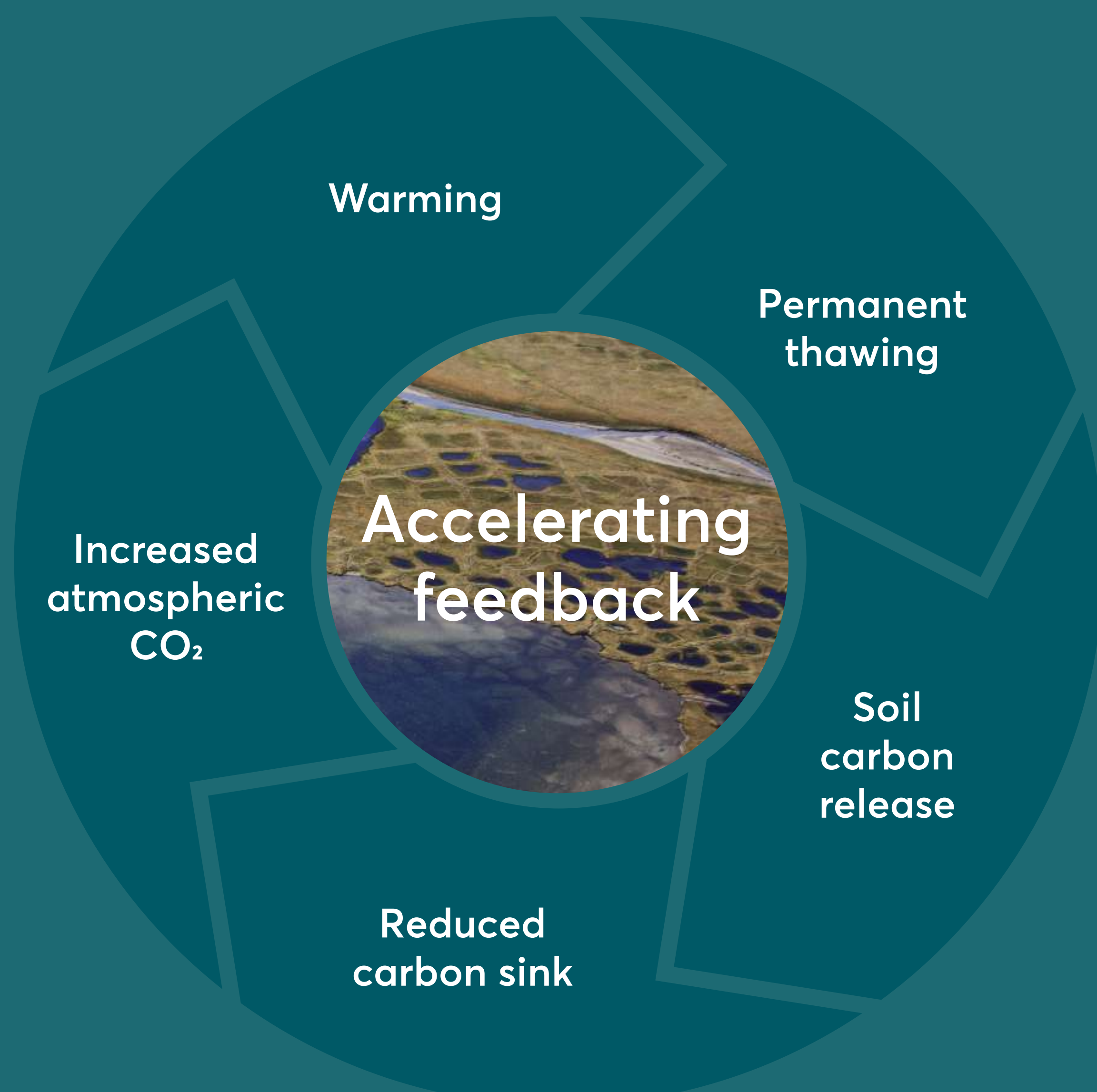
Annual CO_2 fluxes ($GtCO_2$) in 2010-19[1]

Figures are average emissions / removals for the period 2010-19, from the Global Carbon Project (2020)[1].



[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

And ecological tipping points could accelerate it even further



So, what do we do?

4. Two levers for action on climate: reduce emissions, protect and enhance the sinks

Lever 1

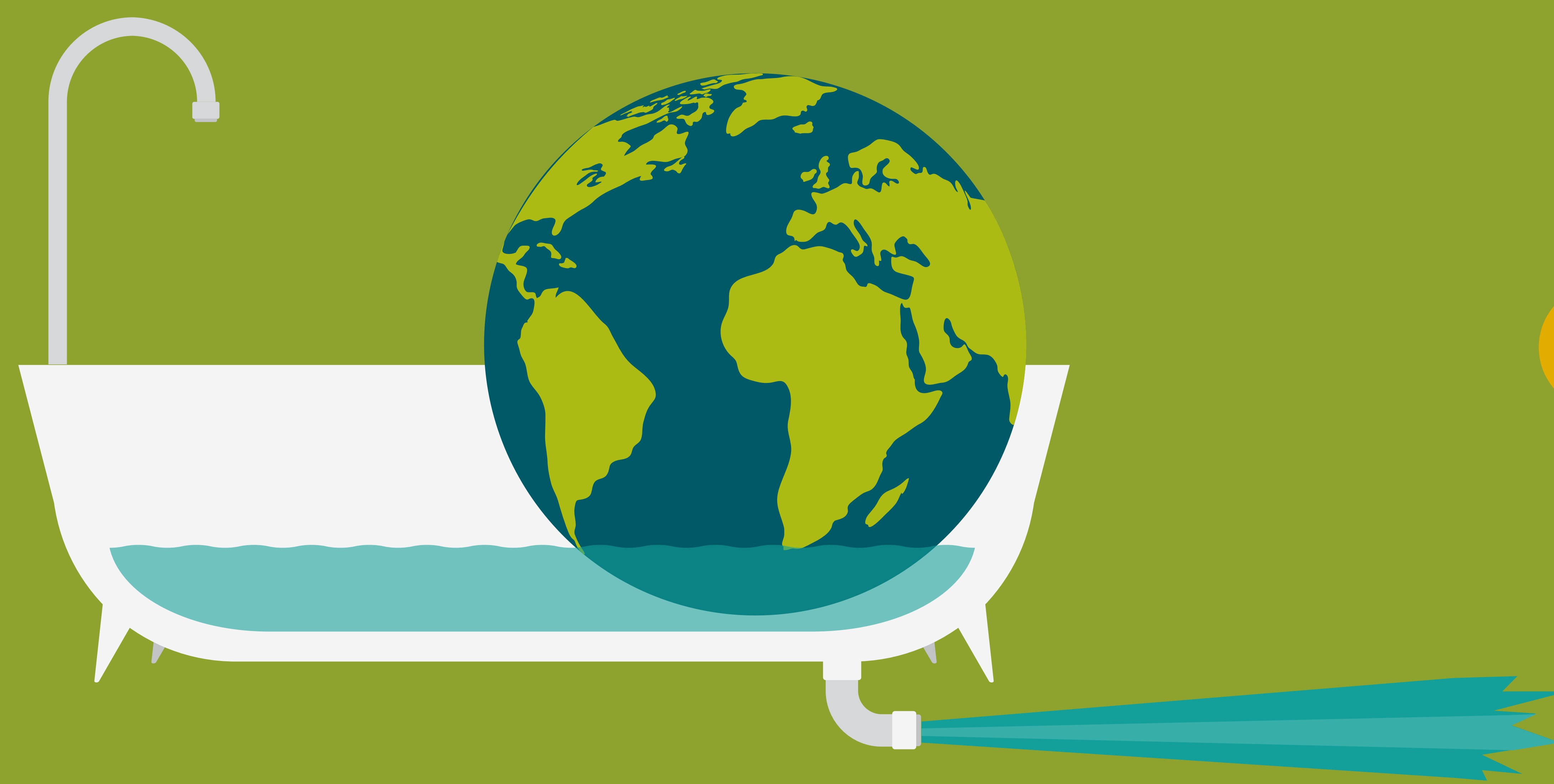
Stop the flow:

GHG emission reductions

Lever 2

Pull the plug:

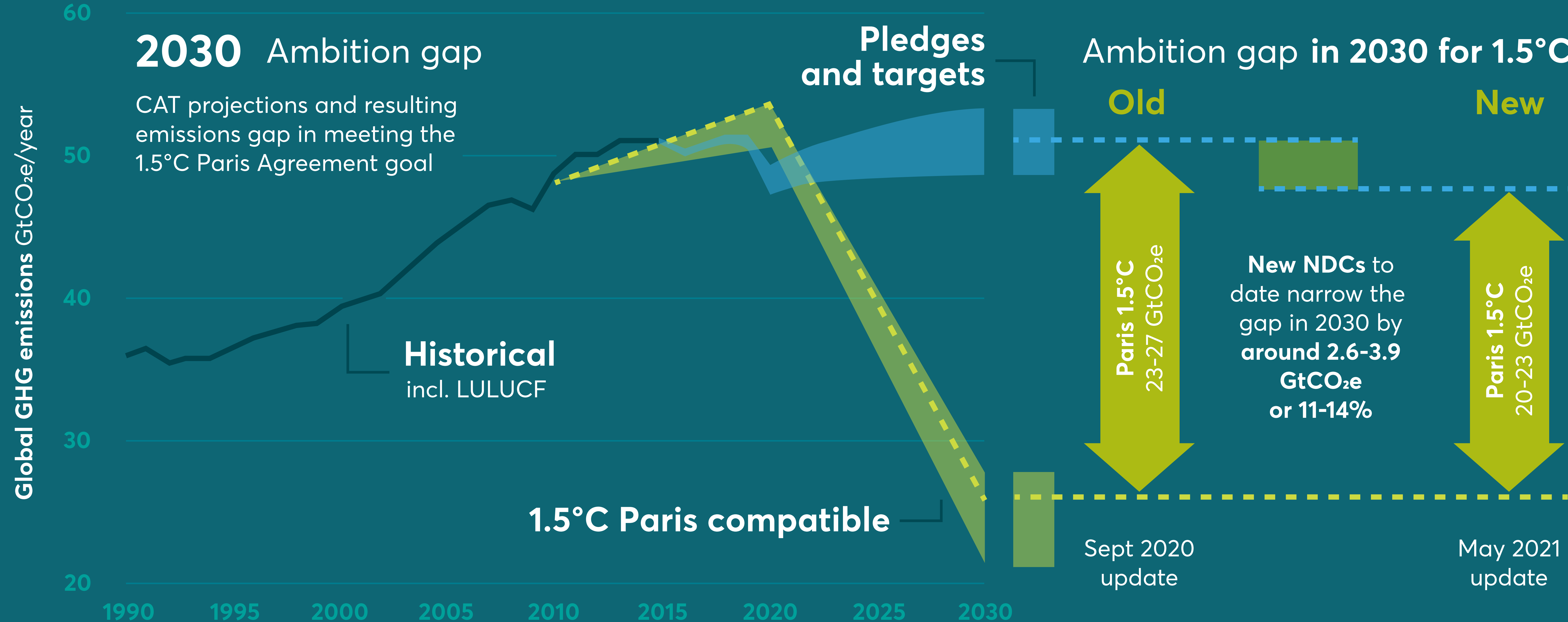
GHG removals (i.e. protect and enhance the capacity of sinks)



We need to do both, at the same time!

Focusing only on reducing emissions overshadows the significant role that protecting and enhancing natural sinks can play in climate change mitigation.

A bottom-up assessment of the Nationally Determined Commitments provided by countries as of May 2021 shows that a substantial ambition gap remains based on the levels of net emissions expected in 2030.



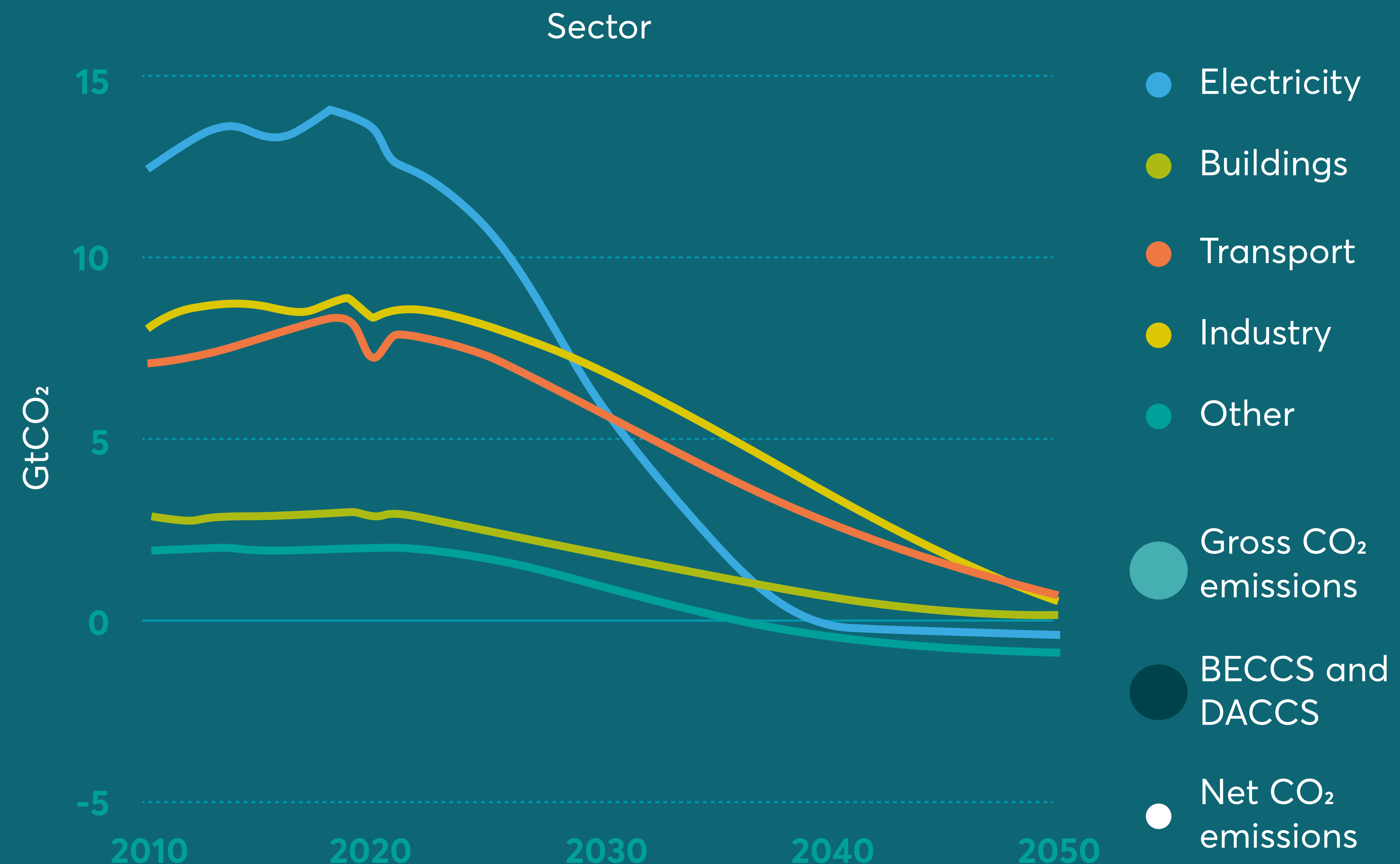
[1] Adapted from: Climate Action Tracker, 2021: CAT Emissions Gap. https://climateactiontracker.org/global/cat-emissions-gaps/.

We therefore need to significantly raise ambition and speed on reducing emissions (lever 1) in both the energy sector… (1 of 2)

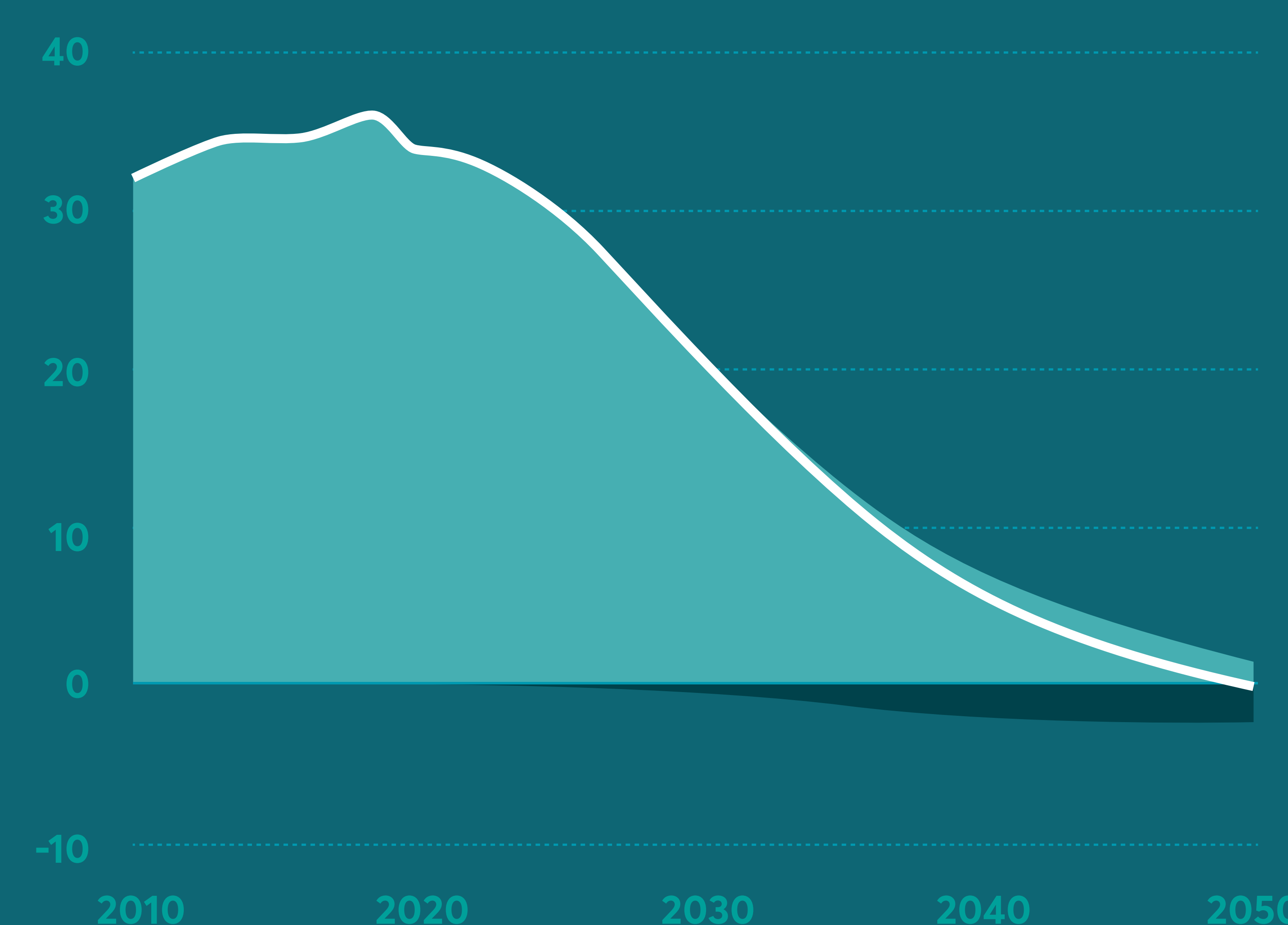
Achieving net zero emissions by 2050 (and thus keeping within 1.5˚C) requires all governments and companies to raise their ambitions.

In the energy sector, reaching net zero emissions by 2050 will require a global, system-wide transformation that is unparalleled both in its speed and scope.

Pathways to net zero emissions by 2050 ($GtCO_2e/yr$)[1]



Gross and net CO_2 emissions



[1] International Energy Agency, 2021: Net Zero by 2050: A Roadmap for the Global Energy Sector https://www.iea.org/reports/net-zero-by-2050.

We therefore need to significantly raise ambition and speed on reducing emissions (lever 1) in both the energy sector… (2 of 2)

Systems wide transformation includes:

By 2025:

- No new sales of fossil fuel boilers
- No new unabated coal plants, coal mines (or extensions) or oil and gas fields approved for development

By 2030:

- Universal energy access
- All new buildings zero-carbon ready
- 60% of global car sales are electric
- Phase-out of unabated coal in advanced economies

2035:

- 50% of heavy truck sales are electric
- No new internal combustion engine car sales
- Overall net zero emissions electricity in advanced economies

2040:

- 50% existing buildings retrofitted to zero-carbon-ready levels
- 50% fuels in aviation are low emission
- Net zero emissions electricity globally

2045:

- 50% of heating demand met by heat pumps

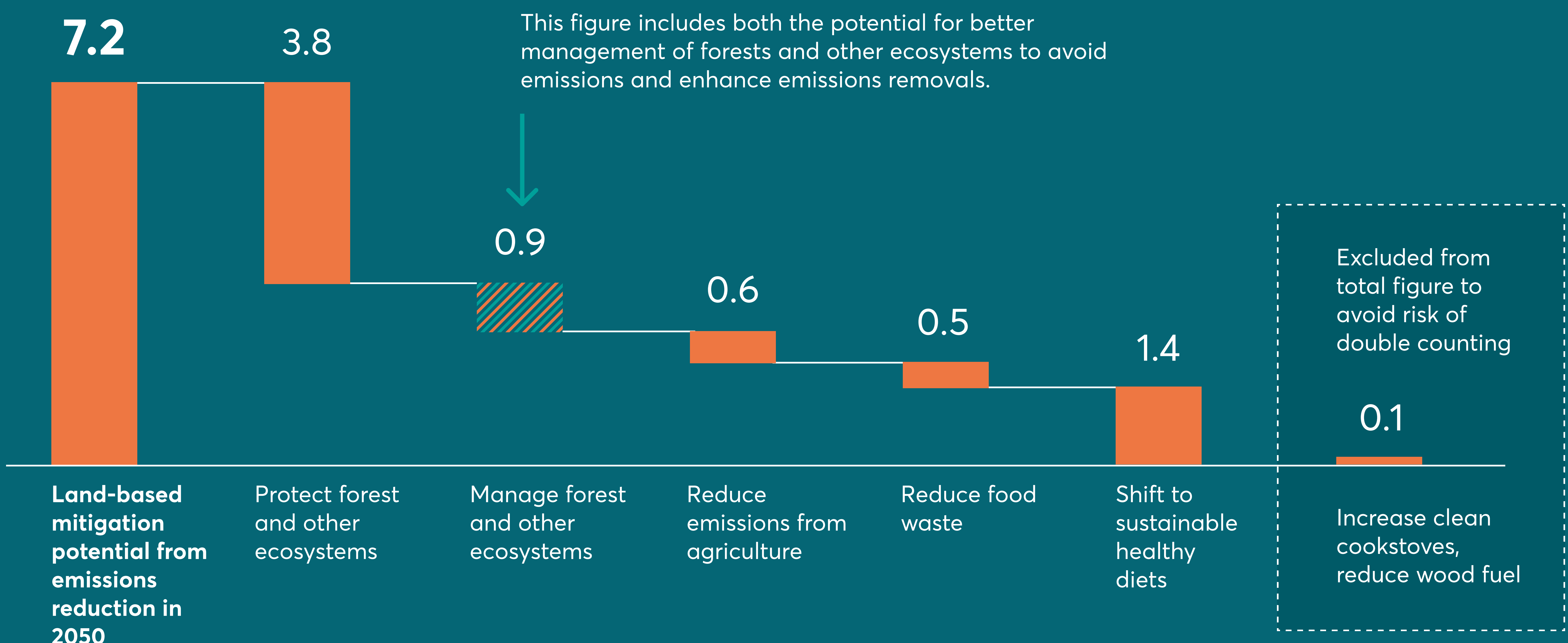
2050:

- More than 85% of buildings zero-carbon ready
- Almost 70% of electricity generation globally from solar PV and wind

… and the land sector

Emissions reduction potential in the Agriculture, Forestry and Other Land Use sector can reach 7 $GtCO_2e$ per annum to meet the 1.5°C warming target by 2050.[1]

Average annual feasible and cost-effective (< $100/$tCO_2e$) emissions reduction potential in the AFOLU sector, per reduction strategy between 2020 and 2050 ($GtCO_2e$/yr)

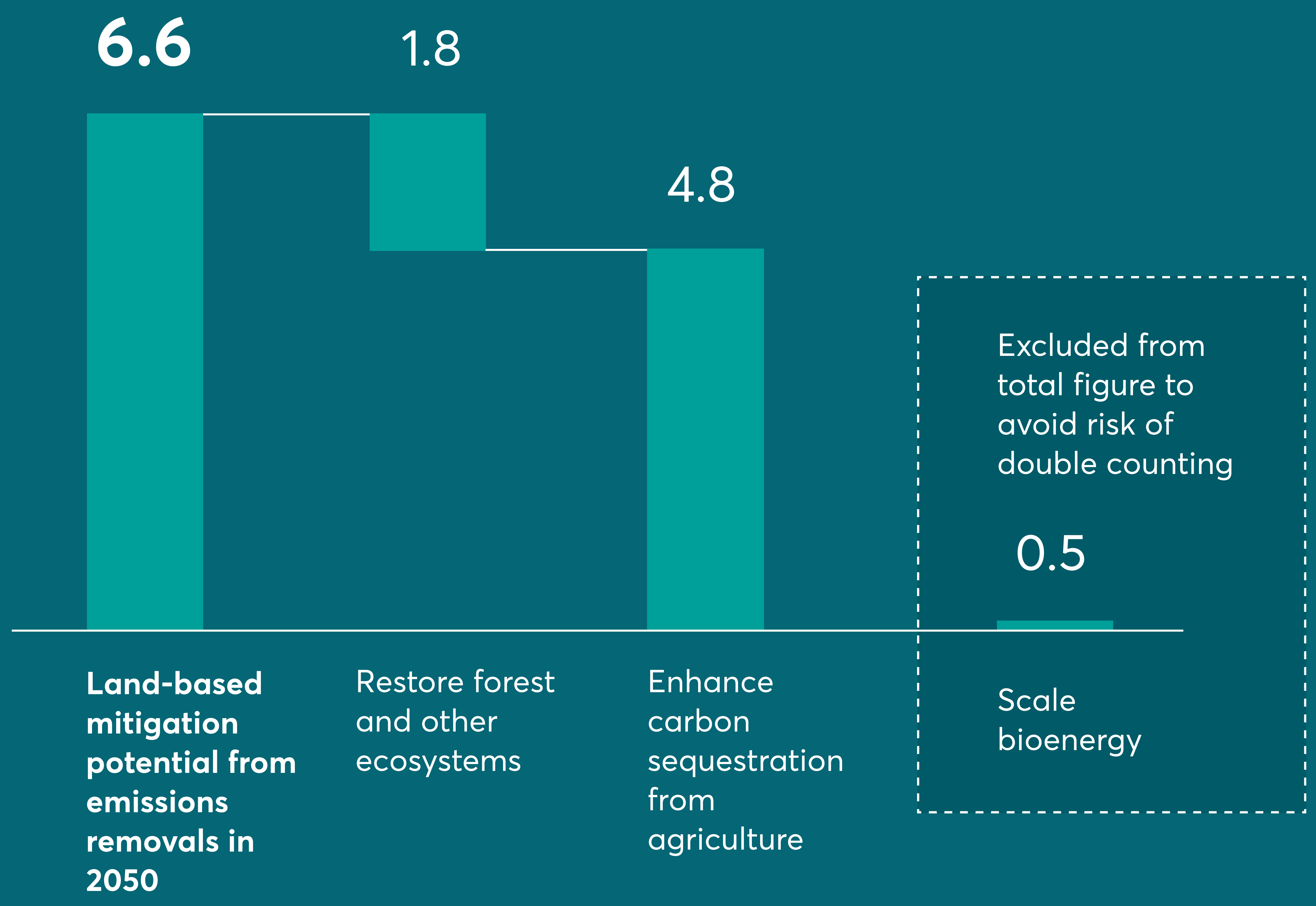


[1] Roe, S. et al. 2021: Land-based measures to mitigate climate change: potential and feasibility by country. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15873

…and simultaneously pull much harder on our second lever to protect and enhance GHG sinks

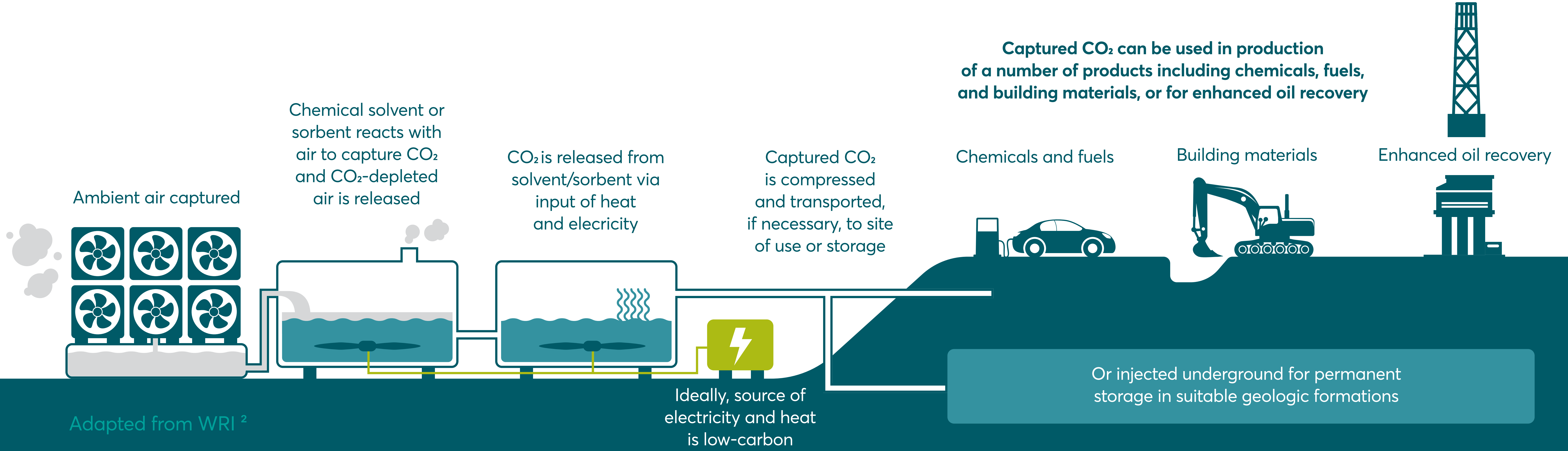
For example, the Agriculture, Forestry and Other Land Use sector could cost-effectively contribute about 7 GtCO$_2$e per annum in additional carbon removals to meet the 1.5°C warming target by 2050. This is in addition to the existing 13.3 GtCO$_2$e of net removal of greenhouse gases from the land sink.[1]

Average annual feasible and cost-effective (< $100/tCO$_2$e) potential to increase carbon removals in the AFOLU sector, per removal strategy between 2020 and 2050 (GtCO$_2$e/yr)



[1] Roe, S. et al. 2021: Land-based measures to mitigate climate change: potential and feasibility by country. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15873

We can also enhance sinks through engineered "negative emission technologies"



Adapted from WRI [2]

GHGs can be removed from the atmosphere with biological or engineered chemical processes and stored for long periods of time in the ground, ocean or built environment.[1]

These human engineered negative emissions technologies will undoubtedly complement nature-based removals but their costs are much higher, their potential for mitigation is highly uncertain, they lack co-benefits associated with wider SDGs and they have the potential to drive further inequality and wealth concentration.

[1] Royal Society, 2018: Greenhouse Gas Removal. https://royalsociety.org/topics-policy/projects/greenhouse-gas-removal/.

[2] Mulligan, J. 2020: Carbonshot: federal policy options for carbon removal in the United States. World Resources Institute. https://www.wri.org/research/carbonshot-federal-policy-options-carbon-removal-united-states.

Single actions (such as protecting standing forests) can pull on both levers at the same time

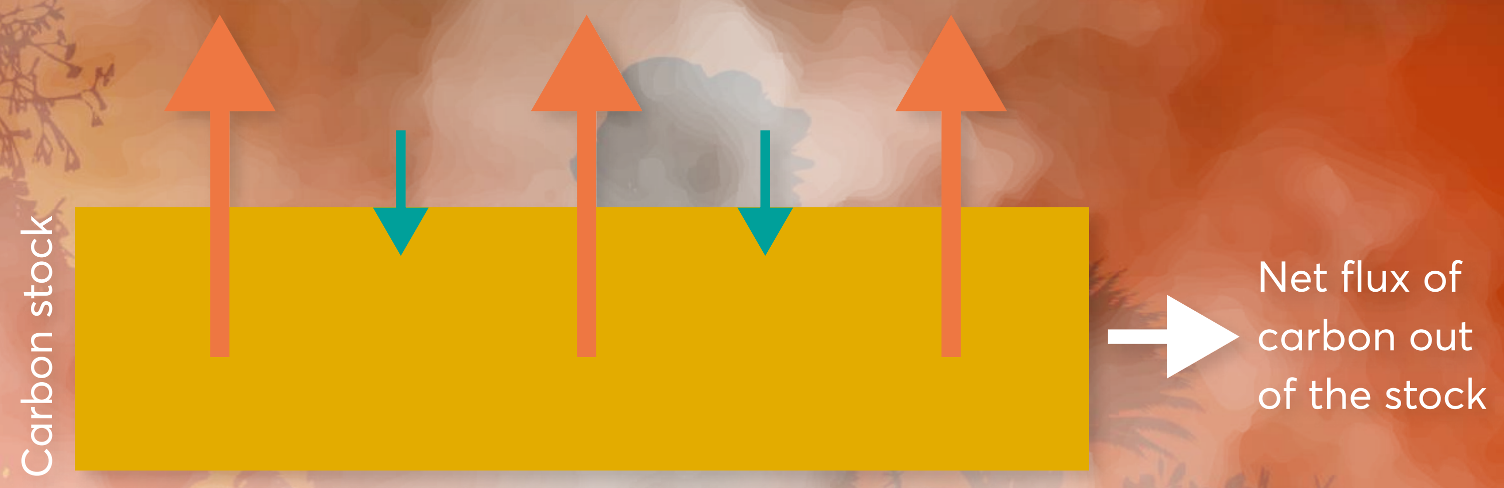
For example: protect tropical forests and improve their management

Gross carbon inflow / removal

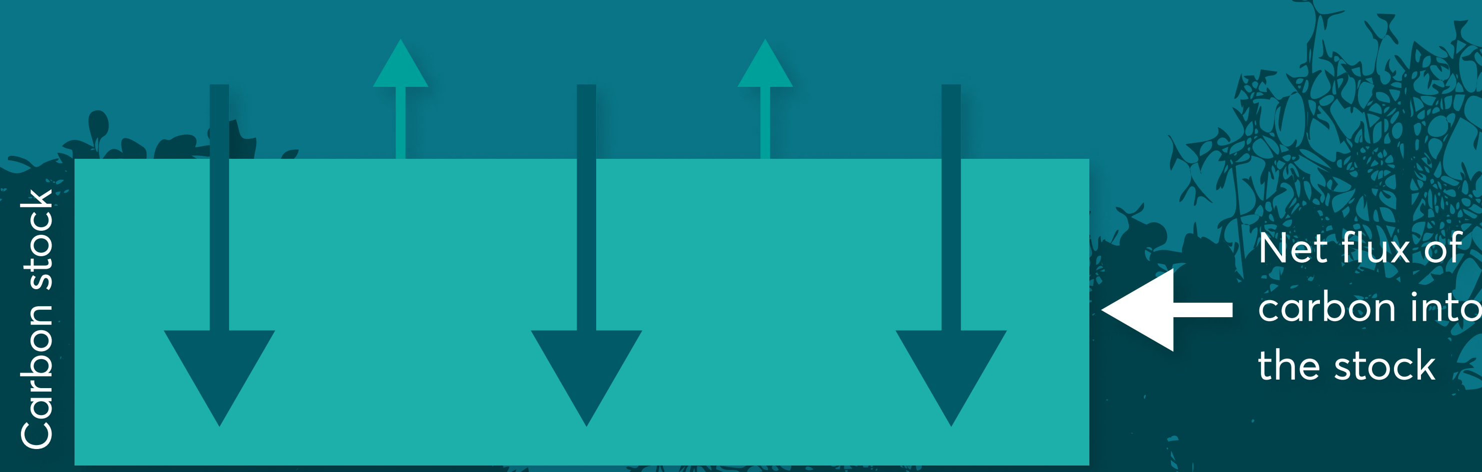
Gross carbon outflow / emission

Net flux

Prevents the forest carbon sink from becoming a source of emissions through combustion of biomass.



Maintains the capacity of the protected forest to sequester carbon dioxide both today and in the future.



It is also important to note that plantations are much poorer at storing carbon than natural forests, which develop with little or no disturbance from humans. Hence the importance of protecting existing, natural forests.[1]

[1] Lewis et al. 2019: Restoring natural forests is the best way to remove atmospheric carbon. Nature. https://www.nature.com/articles/d41586-019-01026-8.

If nothing is done to protect existing natural carbon sinks, gigantic quantities of carbon could be released in the atmosphere and make it virtually impossible to maintain temperatures below 1.5°C warming

In fact, **at least 260 billion tonnes of irrecoverable carbon (GtCO$_2$)** are stored in ecosystems highly impacted by human activities around the world, particularly in peatlands, mangroves, old-growth forests and marshes.[1]

Irrecoverable carbon means that, if released, it would not be possible to recapture that carbon on a timeframe relevant to meeting the target of zero net emissions by 2050 and maintaining temperatures below 1.5°C.

This carbon is **highly vulnerable to release into the atmosphere as a result of human management/ use of land.**

[1] Goldstein et al. 2020: Protecting irrecoverable carbon in Earth's ecosystems. Nature Climate Change https://doi.org/10.1038/s41558-020-0738-8.

5. Natural climate solutions: climate mitigation, co-benefits and cost-effectiveness

Natural climate solutions (NCS) are the activities that reduce land and marine emissions and protect and enhance land and marine removals

NCS are defined as: conservation, restoration, and/or improved land and ocean management actions to increase carbon storage and/or avoid greenhouse gas emissions across global marine ecosystems, forests, wetlands, grasslands, and agricultural lands.[1]

Categories of natural climate solutions[2,3]

Emissions removal · Emissions reduction

Demand side	Supply side: Land and ocean use	Supply side: Carbon dioxide removal	Supply side: Agriculture
Reduce food waste	Reduce deforestation	Afforestation / reforestation	Enteric fermentation
Shift to healthier diets	Reduce mangrove conversion (and other blue carbon ecosystems*)	Restore mangrove (and other blue carbon ecosystems*)	Manure management
Increase cleaner cookstoves	Reduce peatland degradation	Restore peatland	Nutrient management
	Improve forest management	Soil carbon sequestration in grazing lands	Rice cultivation
	Grassland fire management	Soil carbon sequestration in croplands	Agroforestry
		Biochar application	Biochar from crop residues
		Bioenergy with carbon capture and storage	Soil organic carbon in croplands
		Ocean fertilization and alkalinity	Soil organic carbon in grasslands

* Blue carbon ecosystems are defined as the vegetated coastal and marine ecosystems that sequester and store carbon (e.g. mangroves, salt marshes, and seagrass beds)[3]

[1] This definition was adapted from Griscom et al. (2017) to include ocean-based solutions: Griscom, B. W. et al. 2017: Natural climate solutions. PNAS. https://doi.org/10.1073/pnas.1710465114.

[2] Hoegh-Guldberg. O., et al. 2019: The Ocean as a Solution to Climate Change: Five Opportunities for Action. World Resources Institute. https://www.oceanpanel.org/climate.

[3] Roe, S. et al. 2021: Land-based measures to mitigate climate change: potential and feasibility by country. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15873

While the ocean sink has a major regulating role in the climate system, we must be careful about relying on the ocean to remove CO_2 from the atmosphere since this increases its acidity with negative impacts on marine ecosystems

Rising atmospheric CO_2 pushes additional CO_2 into the ocean. Most of this CO_2 reacts with carbonate ions in seawater to form bicarbonate, a process which enhances the capacity of the ocean to absorb carbon. Carbon in its various forms is transported to the deep ocean through circulation.[4]

The ocean is a major regulating force in the Earth's climate system, capturing slightly less than 1/5 of anthropogenic CO_2 emissions per year.[1,2]

But greater concentrations of CO_2 also contribute to a rise in ocean acidification which results in negative implications for marine ecosystems,[5] and the effect of ecosystem changes on the CO_2 absorbed by the ocean is unknown.[6]

If the risk of acidification was mitigated, significant opportunities could be developed to enhance ocean-based removals, through:

- **blue carbon projects:** actions to enhance the capacity of vegetated coastal and marine ecosystems that sequester and store carbon (e.g. mangroves, salt marshes, and seagrass beds).[3]
- **ocean fertilization:** applying nutrients to the ocean to increase photosynthesis and sequester carbon.[4]
- **ocean alkalinity:** increasing ocean concentration of ions like calcium to increase uptake of CO_2 into the ocean, and reverse acidification caused by enhanced CO_2 uptake.[4]

While blue carbon projects could reach a strong mitigation potential in 2050 (0.5-1.4 $GtCO_2e$ per year)[3], ocean fertilization and alkalinity have highly uncertain feasibility and environmental impacts at this stage.[4]

[1] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

[2] IUCN, 2009: The ocean and climate change: coastal and marine nature-based solutions to support mitigation and adaptation activities. https://www.iucn.org/sites/dev/files/import/downloads/oceans_and_cc_brochure_final_1011.pdf.

[3] Hoegh-Guldberg. O., et al. 2019: The Ocean as a Solution to Climate Change: Five Opportunities for Action. World Resources Institute. https://www.oceanpanel.org/climate.

[4] Royal Society, 2018: Greenhouse Gas Removal. https://royalsociety.org/topics-policy/projects/greenhouse-gas-removal/.

[5] Brown, M. S. et al. 2019: Enhanced oceanic CO2 uptake along the rapidly changing West Antarctic Peninsula. Nat. Clim. Chang. https://doi.org/10.1038/s41558-019-0552-3.

[6] Quéré, L. et al. 2021: Briefing 7 – The carbon cycle: Better understanding carbon-climate feedbacks and reducing future risks. The Royal Society. https://royalsociety.org/-/media/policy/projects/climate-change-science-solutions/climate-science-solutions-carbon-cycle.pdf.

As such, we focus here on land-based or "terrestrial" NCS which can also deliver critical outcomes relating to climate adaptation and resilience, biodiversity and sustainable development

CO_2 sequestration through photosynthesis is the most cost-efficient and oldest carbon removal technology on Earth.[1,2]

Forests play an essential role in regulating climate and water cycles, protecting against flood, drought and erosion, and maintaining soil and water health.[2]

Mangrove forests provide more than $80 billion per year in avoided losses from coastal flooding and directly protect 18 million people in coastal areas. They also contribute $40–50 billion annually through fisheries, forestry and recreation benefits.[3]

	Co-benefits[4]						
Terrestrial NCS strategies	Biodiversity	Water	Soil	Air quality	Resilience & Adaptation	Food security	Livelihoods
Reducing emissions from deforestation	✓	✓	✓	✓	✓	✓	✓
Agriculture		✓	✓	✓	✓	✓	✓
Shift to healthier diets	✓	✓	✓	✓	✓	✓	
Reduce food waste	✓	✓	✓	✓	✓	✓	✓
Restoring carbon-rich ecosystems (including afforestation and reforestation)	✓	✓	✓	✓	✓	✓	✓
Improve forest management and agroforestry	✓	✓		✓	✓		✓
Enhancing soil carbon sequestration	✓	✓	✓	✓	✓	✓	✓
Bioenergy Carbon Capture and Storage (BECCS)							✓

[1] Griscom, B. W. et al. 2017: Natural climate solutions. PNAS. https://doi.org/10.1073/pnas.1710465114.

[2] Roe, S. et al. 2019: Contribution of the land sector to a 1.5 °C world. Nature Climate Change 9. https://doi.org/10.1038/s41558-019-0591-9.

[3] Konar, M and Ding, H, 2020. A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs. https://oceanpanel.org/sites/default/files/2020-07/Ocean%20Panel_Economic%20Analysis_FINAL.pdf.

[4] Dinerstein, E. et al. 2019: A Global Deal For Nature: Guiding principles, milestones, and targets. Sci. Adv 5. https://www.advances.sciencemag.org/content/5/4/eaaw2869.full.

They are also highly cost-effective forms of mitigation, especially when it comes to removing carbon, with the potential to sequester 1.2 $GtCO_2$ for under $30 per tCO_2[1]

NCS removals

Method	Annual cost and mitigation potential[1]
Afforestation, Reforestation and Forest management	• 1.2 $GtCO_2$ < $30 /$tCO_2$ per annum[2] • 0.4 $GtCO_2$ < $3 /$tCO_2$ p.a.[2] • In 2100: $15-30 /$tCO_2$[3]
Wetland, peatland and coastal habitat restoration	• 0.4-18 tCO_2 per ha p.a. (wetland restoration) • $10-100 per tCO_2 (peatland restoration)[4]
Soil carbon sequestration	• 1.1-11.4 $GtCO_2$ p.a. • Range from a saving of $12 per tCO_2 to a cost of $3
Biochar	• 2.1-4.8 tCO_2 per tonne of biochar • $18-166 per tCO_2[5]
Bioenergy with carbon capture and storage	• Approx. 10 $GtCO_2$ p.a. • $140-$270 per tCO_2
Ocean fertilization	• Max. 3.7 $GtCO_2$ p.a.[6] • ~$10 per tCO_2
Building with biomass	• 0.5-1 $GtCO_2$ p.a.[7] • Costs negligible

Despite this, estimates suggest that just 3% of public climate funding is currently allocated to NCS, while between $4 - 6 trillion of subsidies each year damage nature.[11,12]

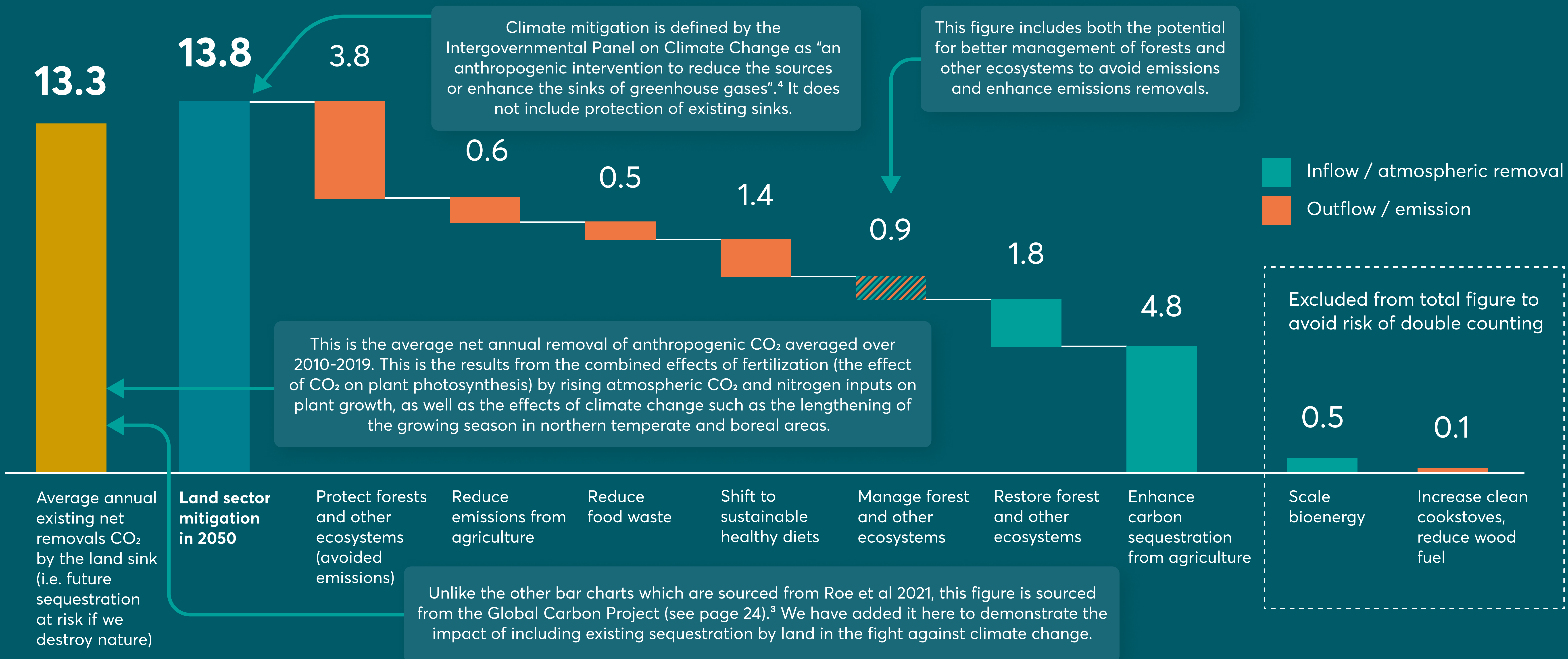
Human engineered removals and geoengineering

Method	Annual cost and mitigation potential[1]
Enhanced terrestrial weathering	• 0.5-4.0 $GtCO_2$ p.a. by 2100[3] • $52-480 per tCO_2[8]
Mineral carbonation	• Uncertain • $50-300 /$tCO_2$ (ex situ), $17 /$tCO_2$ (in situ)
Ocean alkalinity	• As much as 3,500 $GtCO_2$ by 2100[9] • $72-159 per tCO_2
Direct air capture and carbon storage	• Estimated storage capacity of the order of 900 $GtCO_2$[10] • $200-600 per tCO_2
Low-carbon concrete	• Uncertain • $50-300 per tCO_2

[1] Royal Society, 2018: Greenhouse Gas Removal. https://royalsociety.org/topics-policy/projects/greenhouse-gas-removal/.
[2] Griscom, B. W. et al. 2017: Natural climate solutions. PNAS. https://doi.org/10.1073/pnas.1710465114.
[3] Smith, P. et al. 2015: Biophysical and economic limits to negative CO2 emissions. Nature Climate Change. 6. http://dx.doi.org/10.1038/nclimate2870.
[4] Worrall F et al. 2009: Can carbon offsetting pay for upland ecological restoration? Science of The Total Environment. http://dx.doi.org/10.1016/j.scitotenv.2009.09.022.
[5] Woolf D. et al. 2010: Sustainable biochar to mitigate global climate change. Nature Communications. http://dx.doi.org/10.1038/ncomms1053.
[6] Zahariev K. et al. 2008: Preindustrial, historical, and fertilization simulations using a global ocean carbon model with new parameterizations of iron limitation, calcification, and N2 fixation. Progress in Oceanography. http://dx.doi.org/10.1016/j.pocean.2008.01.007.
[7] McLaren D. 2012: A comparative global assessment of potential negative emissions technologies. Process Safety and Environmental Protection. http://dx.doi.org/10.1016/j.psep.2012.10.005.
[8] Renforth P. 2012: The potential of enhanced weathering in the UK. International Journal of Greenhouse Gas Control. http://dx.doi.org/10.1016/j.ijggc.2012.06.011.
[9] González MF, Ilyina T. 2016: Impacts of artificial ocean alkalinization on the carbon cycle and climate in Earth system simulations. Geophysical Research Letters. http://dx.doi.org/10.1002/2016GL068576.
[10] Holloway S. 2008: Sequestration - the underground storage of carbon dioxide. In Climate Change and Energy Pathways for the Mediterranean. https://doi.org/10.1007/978-1-4020-5774-8_4.
[11] Climate Policy Initiative, 2018: Global Climate Finance: an updated view 2018. https://climatepolicyinitiative.org/wp-content/uploads/2018/11/Global-Climate-Finance-An-Updated-View-2018.pdf.
[12] Dasgupta, P, 2021. The Economics of Biodiversity. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/962785/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf

Terrestrial NCS is often cited as 30% of the cost effective and feasible mitigation needed for 1.5°C.[1] But this just considers the potential for reducing emissions from human activity on land (e.g. deforestation) and the potential for enhanced removals on land through human intervention. It does not consider the actions that humankind can take to protect and maintain the existing natural carbon sink e.g. protecting intact tropical forest on land that is not considered as "managed" by humans. As such, the role of the land system in the fight against climate change is far greater than 30%.

The average annual cost-effective (< $100/t$CO_2$e) and feasible terrestrial mitigation needed between 2020 and 2050 to deliver on the 1.5°C target (GtCO2e/yr)[2], in addition to the existing 13.3 GtCO_2e of net removals from the land sink which needs to be protected[3]



[1] Roe, S. et al. 2019: Contribution of the land sector to a 1.5 °C world. Nature Climate Change 9. https://doi.org/10.1038/s41558-019-0591-9.
[2] Roe, S. et al. 2021: Land-based measures to mitigate climate change: potential and feasibility by country. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15873
[3] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.
[4] IPCC. https://www.ipcc.ch/sr15/chapter/glossary/

The largest share of terrestrial mitigation comes from protecting, restoring and managing forests and other ecosystems[1,2]

Deforestation impacts climate change through both **foregone carbon sequestration** *(decreased sink capacity)* and, when trees are burned or left to decompose, the **release of the carbon stored** over the tree's lifetime *(carbon emissions)*.

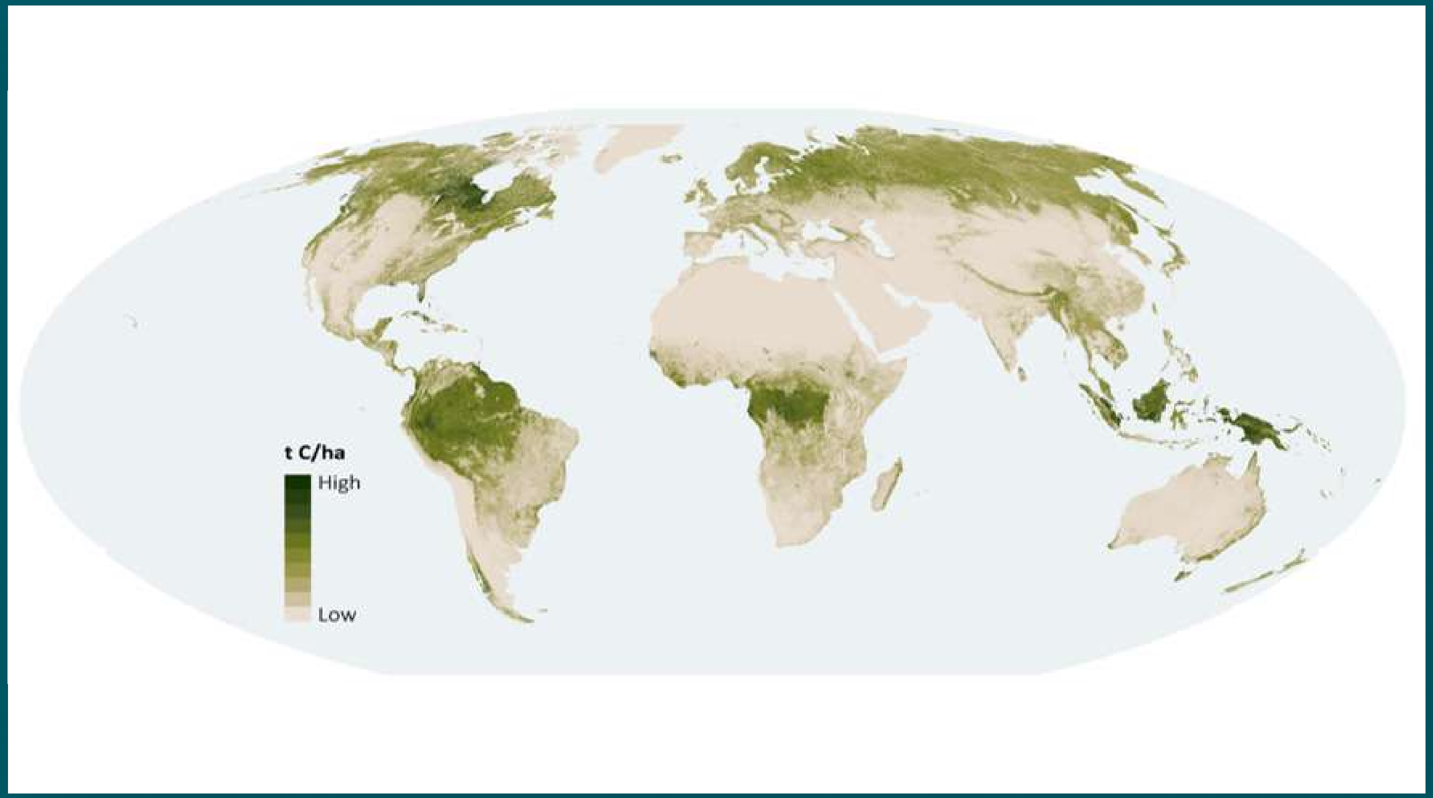
Human activities have led to the loss of around

40%

of the world's forests.[3]

[1] Roe, S. et al. 2021: Land-based measures to mitigate climate change: potential and feasibility by country. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15873
[2] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020
[3] Forests Practice. World Wide Fund for Nature https://wwf.panda.org/discover/our_focus/forests_practice/

Tropical forests and peatlands are high priority for protection and restoration as they are critical carbon sinks



The tropical belt is a high priority region in terms of carbon storage…

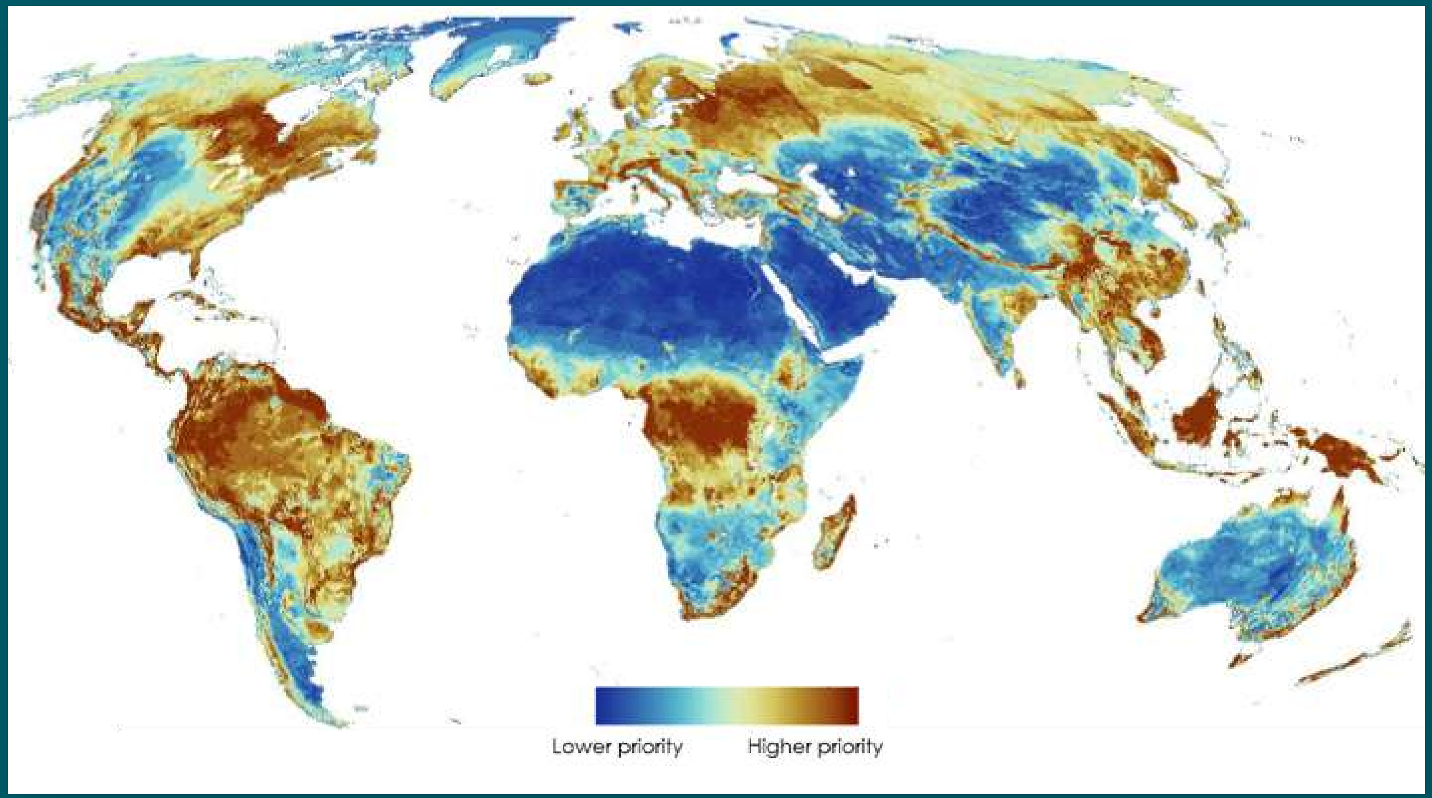
By combining data on global biomass carbon and distributions of soil carbon stocks vulnerable to land-use change, Nature Map produced an integrated map of carbon stocks (biomass and soils) that are vulnerable to human impact.[1]

The tropical belt is a region with high carbon stocks that are particularly vulnerable to human impact.

… as well as biodiversity and clean water supply

The Nature Map developed an integrated global map of biodiversity, carbon storage, and clean water supply to support countries to integrate nature and climate in decision making.

The tropical belt should be prioritised for urgent protection and restoration measures but there are clearly other important non-tropical areas as well.



[1] Jung, M. et al. 2021: Areas of global importance for conserving terrestrial biodiversity, carbon and water. Nature Ecology & Evolution. https://doi.org/10.1038/s41559-021-01528-7.

6. Summary of key takeaways

1 RECAP ON THE NUMBERS

Emissions from human activities on land, including those leading to land-use change and forestry (LULUCF emissions) are often cited as accounting for 10-15% of global CO_2 emissions (~38.5 $GtCO_2$)[1].

But by considering CO_2 and non-CO_2 emissions from agriculture and land use, as well as the sequestration of anthropogenic GHG emissions by land, the land system accounts for 48% of anthropogenic GHGs flowing into and out of the atmosphere (46 $GtCO_2e$).

Similarly, it is often cited that a third of climate **mitigation** can cost-effectively and feasibly be delivered by terrestrial Natural Climate Solutions. This is equivalent to 14 $GtCO_2e$ per annum, at less than $100/$tCO_2e$.[2]

However, this just considers the potential for reducing emissions from human activity on land (e.g. deforestation) and the potential for enhanced removals on land through human intervention. It does not consider the actions that humankind can take to protect and maintain the existing natural sink e.g. protecting intact tropical forest on land that is not considered as "managed" by humans. As such, the role of the land system in the fight against climate change is far greater than 30%.

2 RECAP ON THE LEVERS FOR MITIGATION

Scientists have defined 1.5°C as the safer upper limit of warming. Best estimates suggest that we will reach 1.5°C by 2040, even under the most ambitious scenarios.[4]

We therefore need to **urgently and simultaneously pull on two levers** to address climate change:

1. reduce global greenhouse gases emissions (from both land and energy systems) and
2. increase the capture and storage of greenhouse gases.

[1] IPCC, 2019: Mitigation pathways compatible with 1.5°C in the context of sustainable development. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. https://www.ipcc.ch/sr15/chapter/chapter-2/.

[2] Roe, S. et al. 2021: Land-based measures to mitigate climate change: potential and feasibility by country. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15873.

[3] Friedlingstein, P. et al. 2020: Global Carbon Budget 2020. Earth Syst. Sci. Data. https://doi.org/10.5194/essd-12-3269-2020.

[4] Rogelj, J. et al. 2018: Chapter 2 — Global Warming of 1.5°C. https://www.ipcc.ch/sr15/chapter/chapter-2/.

3 THE WONDERS OF NATURAL CLIMATE SOLUTIONS

Natural Climate Solutions (NCS) can feasibly and cost-effectively activate both these "levers" through 1) avoiding emissions associated with activities such as deforestation and 2) maintaining and enhancing the capacity of nature to remove GHGs from the atmosphere.

The largest NCS mitigation potential is attributed to the protection, restoration and management of forests and other ecosystems.

Despite their central role in the fight against climate change, estimates suggest that just 3% of public climate funding is currently allocated to NCS, while between $4-6 trillion of subsidies each year damage nature.[5,6]

If nothing is done to protect existing natural carbon sinks, irreversible ecological tipping points could cause gigantic quantities of carbon to be released in the atmosphere and make virtually impossible to maintain temperatures below 1.5°C warming.[7]

There really is **no path to net zero without nature**.

4 IT'S NOT JUST ABOUT CLIMATE MITIGATION!

We are already feeling the impact of climate change and a 1.5°C world will entail further damage to human life, wellbeing and livelihoods and to ecosystems and biodiversity.[8]

Natural Climate Solutions are often seen as **win-win investments as they also deliver critical outcomes or "co-benefits"** relating to climate adaptation and resilience, biodiversity and sustainable development.

[5] Climate Policy Initiative, 2018: Global Climate Finance: an updated view 2018. https://climatepolicyinitiative.org/wp-content/uploads/2018/11/Global-Climate-Finance-An-Updated-View-2018.pdf.
[6] Dasgupta, P, 2021. The Economics of Biodiversity. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/962785/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf.
[7] Goldstein et al. 2020: Protecting irrecoverable carbon in Earth's ecosystems. Nature Climate Change https://doi.org/10.1038/s41558-020-0738-8.
[8] Rogelj, J. et al. 2018: Chapter 2 — Global Warming of 1.5°C. https://www.ipcc.ch/sr15/chapter/chapter-2/.

5 AN URGENT CALL TO ACTION

We call for urgent investment into Natural Climate Solutions at scale!

Please see FOLU's flagship report "Growing Better: Ten Critical Transitions to Transform Food and Land Use" and, more specifically, Critical Transition 3 on Protecting and Restoring Nature

Authors: Victor Lanel and Scarlett Benson

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Why Nature? Why Now?

How nature is key to achieving a 1.5˚C world