2023

Climate 101

This a primer that contextualises the latest research on climate change, with the goal of providing essential knowledge to support discussion and meaningful action.

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The Climate is Changing

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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.

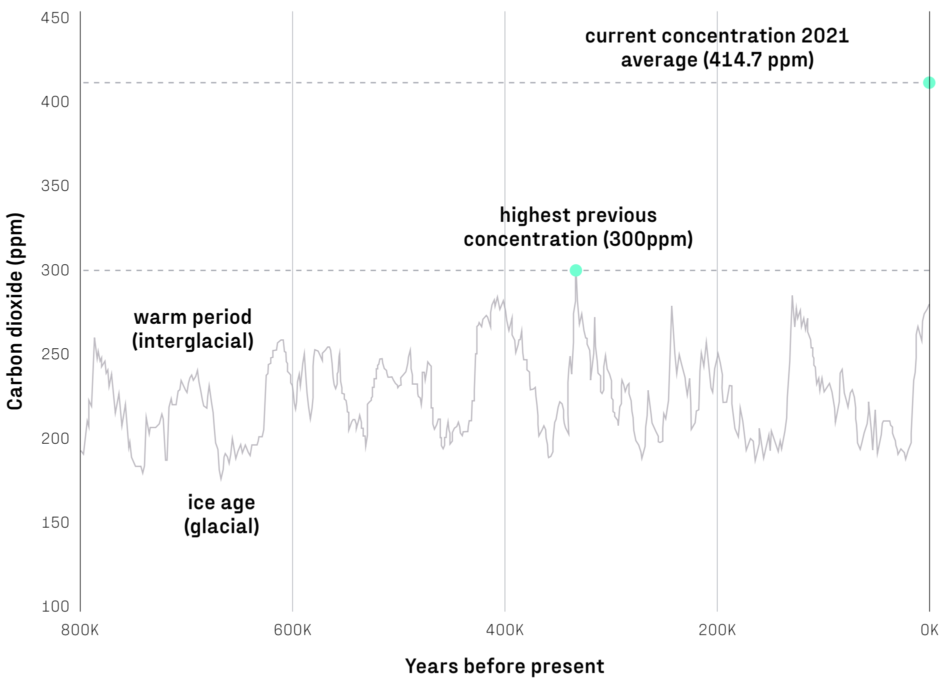
Global surface temperature was 1.09°C higher in the past decade than 1850–1900.

Climate change is already affecting every inhabited region across the globe.

Source: IPCC, 2021, The Physical Science Basis

IPCC, 2021: 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., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Carbon dioxide over 800,000 years



In 2019, atmospheric CO_2 concentrations were higher than at any time in at least 2 million years

Source: IPCC, 2021, The Physical Science Basis

415 ppm average for 2021

Source: Climate.gov

Over the past 800,000 years, atmospheric CO_2 concentration typically ranged between ~170 ppm - 300ppm. But in just the last century, we have increased atmospheric CO_2 from <300 to 415 ppm.

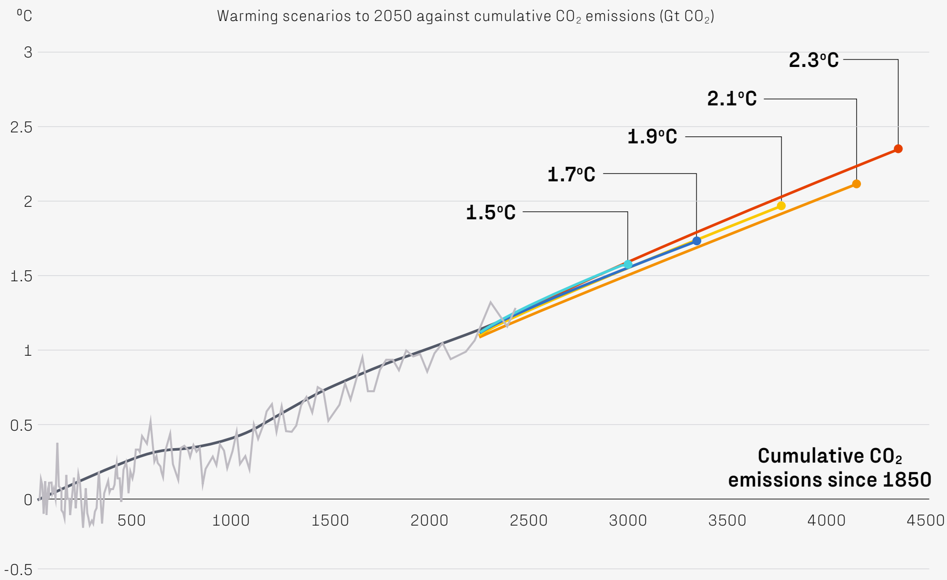
Source: Climate.gov

Graph sourced and adapted from NOAA Climate.gov based on data from Lüthi, et al., 2008, via NOAA NCEI Paleoclimatology Program.

There is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause.

Every tonne we emit matters

Global surface temperature increase since 1850-1900 (°C) as as function of cumulative CO_2 emissions (GtCO_2)



Source: IPCC, 2021, The Physical Science Basis

Data retrieved and adapted from: Rogelj, J.; Trewin, B.; Haustein, K.; Canadell, P.; Szopa, S.; Milinski, S.; Marotzke, J.; Zickfeld, K. (2021): Summary for Policymakers of the Working Group I Contribution to the IPCC Sixth Assessment Report - data for Figure SPM.10 (v20210809). NERC EDS Centre for Environmental Data Analysis, 09 August 2021.

SSP1-1.9
Paris Agreement alignment
Global emissions cut to meet net-zero by 2050, with negative net-emissions from 2050 onward. Warming hits 1.5°C but falls back to 1.4°C by 2100.

SPP1-2.6
Sustainable pathway
Global emissions cut to net-zero after 2050, with negative net emission increasing to the end of the century. Temperatures stabilise at 1.8°C warming by 2100.

(Other scenarios)

SSP2-4.5
Middle-of-the-road
Global emissions hover around current levels, start to fall by 2050, but do not reach net-zero by 2100. Warming reaches 2.7°C by 2100.

SSP3-7.0
Regional rivalry
Global emissions steadily rise through the century, doubling by 2050, with warming reaching 3.6°C by 2100.

SSP5-8.5
Fossil fuel rich development
Global emissions double by 2050, and warming reaches 4.4°C by 2100.

Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Observed changes are extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones.

Source: IPCC, 2021, The Physical Science Basis

Certain amounts of warming are locked in even if we hit net-zero by 2050

Global surface temperature will continue to increase until at least midcentury under all emissions scenarios considered.

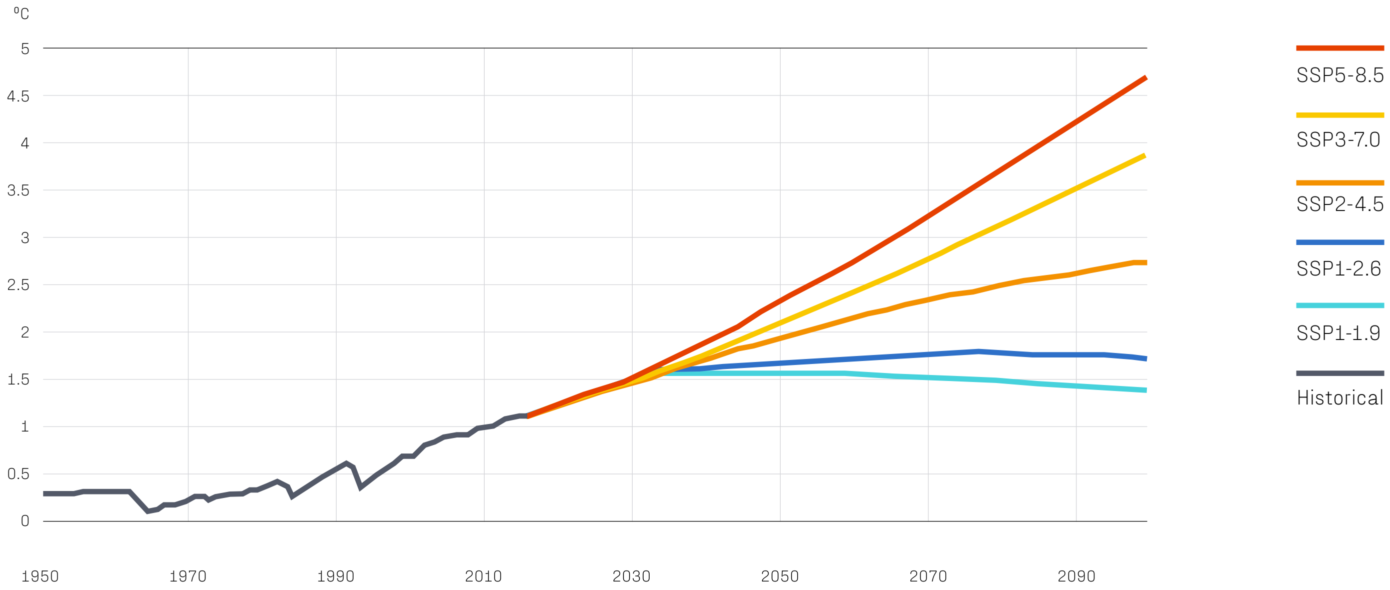
Global warming of 1.5°C and potentially 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades.

Source: IPCC, 2021, The Physical Science Basis

1.9 scenario below is in line with the 1.5°C pathway meeting the goals of the Paris Agreement. This includes negative net emissions from around 2050 onward.

2.6 scenario sees emissions dropping to net-zero after 2050, with negative net emission increasing to the end of the century.

Global surface temperature change relative to 1850–1900 (1950–2100)



Source: IPCC, 2021, The Physical Science Basis

Data retrieved and adapted from: Fyfe, J.; Fox-Kemper, B.; Kopp, R.; Garner, G. (2021): Summary for Policymakers of the Working Group I Contribution to the IPCC Sixth Assessment Report - data for Figure SPM.8 (v20210809). NERC EDS Centre for Environmental Data Analysis, 09 August 2021.

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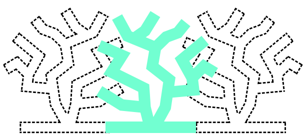
There is a big difference between 1.5 and 2 degrees of warming

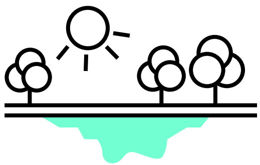
Category	1.5ºC Warming	2ºC Warming	Difference
Extreme Heat Global population exposed to severe heat at least once every 5 years	14%	37%	**2.6x worse**
Sea-Ice Free Arctic Number of ice-free summers	1 / 100 years	1 / 10 years	**10x worse**
Sea Level Rise Amount of sea level rise by 2100	0.4 meters	0.46 meters	**0.06 meters worse**
Ecosystems Amount of Earth's land where ecosystems will shift to a new biome	7%	13%	**1.86x worse**
Permafrost Amount of Arctic permafrost that will thaw	4.8 million km2	6.6 million km2	**38% worse**
Species Loss Vertebrates Vertebrates that lose at least half of their range	4%	8%	**2x worse**
Species Loss Plants Plants that lose at least half of their range	8%	16%	**2x worse**
Species Loss Insects Insects that lose at least half of their range	6%	18%	**3x worse**
Crop Yields Reduction in maize harvest in tropics	3%	7%	**2.3x worse**
Coral Reefs Further decline in coral reefs	70 - 90%	99%	**Up to 29% worse**
Fisheries Decline in marine fisheries	1.5 million tonnes	3 million tonnes	**2x worse**

Source: IPCC, 2018: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 616 pp. Kelly Levin, World Resources Institute, 2018.

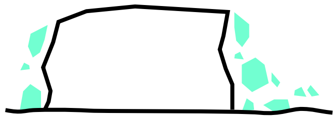
Even under ideal Paris aligned scenarios, the world is going to change a lot. Some **'tipping points'** will be reached that will change major global systems:



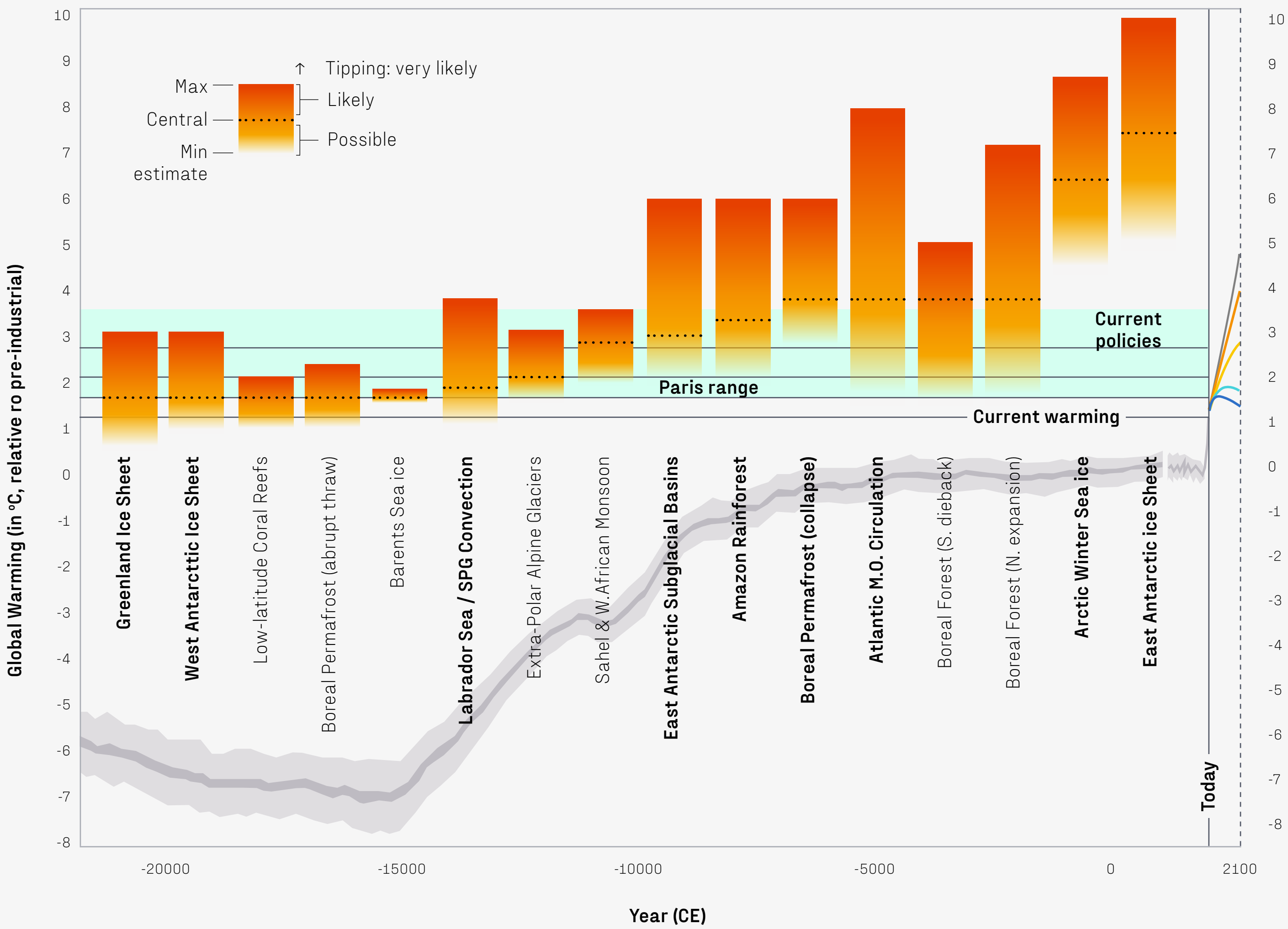
We will lose low-latitude coral reefs and the Barents sea ice



We will see abrupt thawing of Boreal Permafrost



The Labrador Sea / sub-polar gyre is likely to collapse



Source: Armstrong McKay, David I., et al.
"Exceeding 1.5 C global warming could trigger multiple climate tipping points." Science 377.6611 (2022): eabn7950. Science

We need to decarbonise quickly

↑54% Global annual GHG emissions have increased 54% since 1990

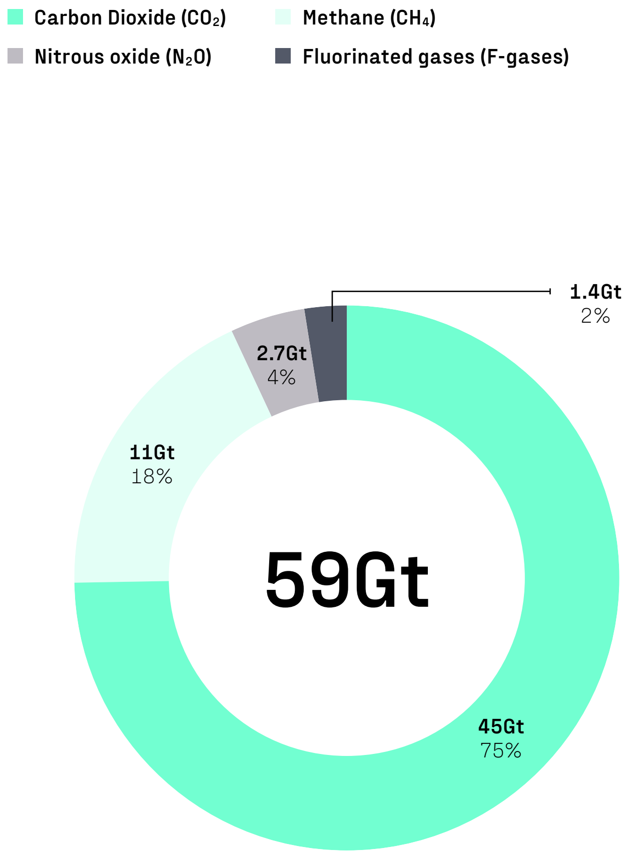
Remaining 'carbon budgets' are limited. The table below shows the Gt CO_2e we have left to emit to keep warming below certain levels.

- At the current pace, we have less than 10 years of emissions left to have a 50% chance of limiting warming to 1.5°C
- For a 50% chance at 2°C, current emissions levels afford a budget closer to 2050

Source: IPCC, 2022, Mitigation

IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA.

59 Gt CO_2e were emitted in 2019



Source: IPCC, 2022, Mitigation

Estimates of historical carbon dioxide (CO_2) emissions and remaining carbon budgets

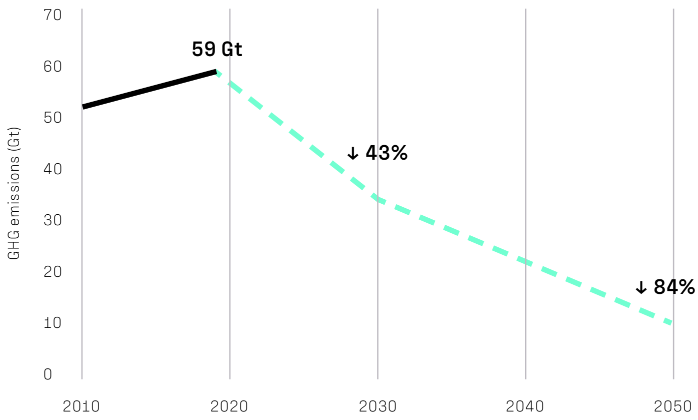
Global warming relative to 1850-1900 until temperature limit (°C)	Additional global warming from 2010-2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) Likelihood of limiting global warming to temperature limit		
		33%	50%	67%
1.5 °C	0.43 °C	900	500	400
1.7 °C	0.63 °C	1450	850	700
2.0 °C	0.93 °C	2300	1350	1150

Source: IPCC, 2021, The Physical Science Basis

Pathways to decarbonise

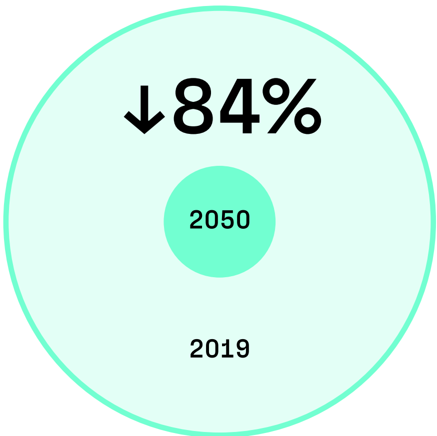
Warming limit	Year of Net-Zero CO_2 emissions	% chance
1.5ºC	Early 2050s	50%
2ºC	Early 2070s	67%
Net negative CO_2 emissions continue after the point of net-zero		

Limit warming to 1.5ºC



To limit warming to 1.5ºC, **global greenhouse gas emissions must peak before 2025** at the latest and be reduced by 43% by 2030 compared to 2019 levels; this includes cutting CO_2 emissions by half and methane by about a third.

Net GHG emissions must be cut by...



Net GHG emissions must be cut by 84% (73-98% range) by 2050 to limit warming to 1.5ºC.

Projected usage decline in 2050

Coal	↓95%
Oil	↓60%
Gas	↓45%

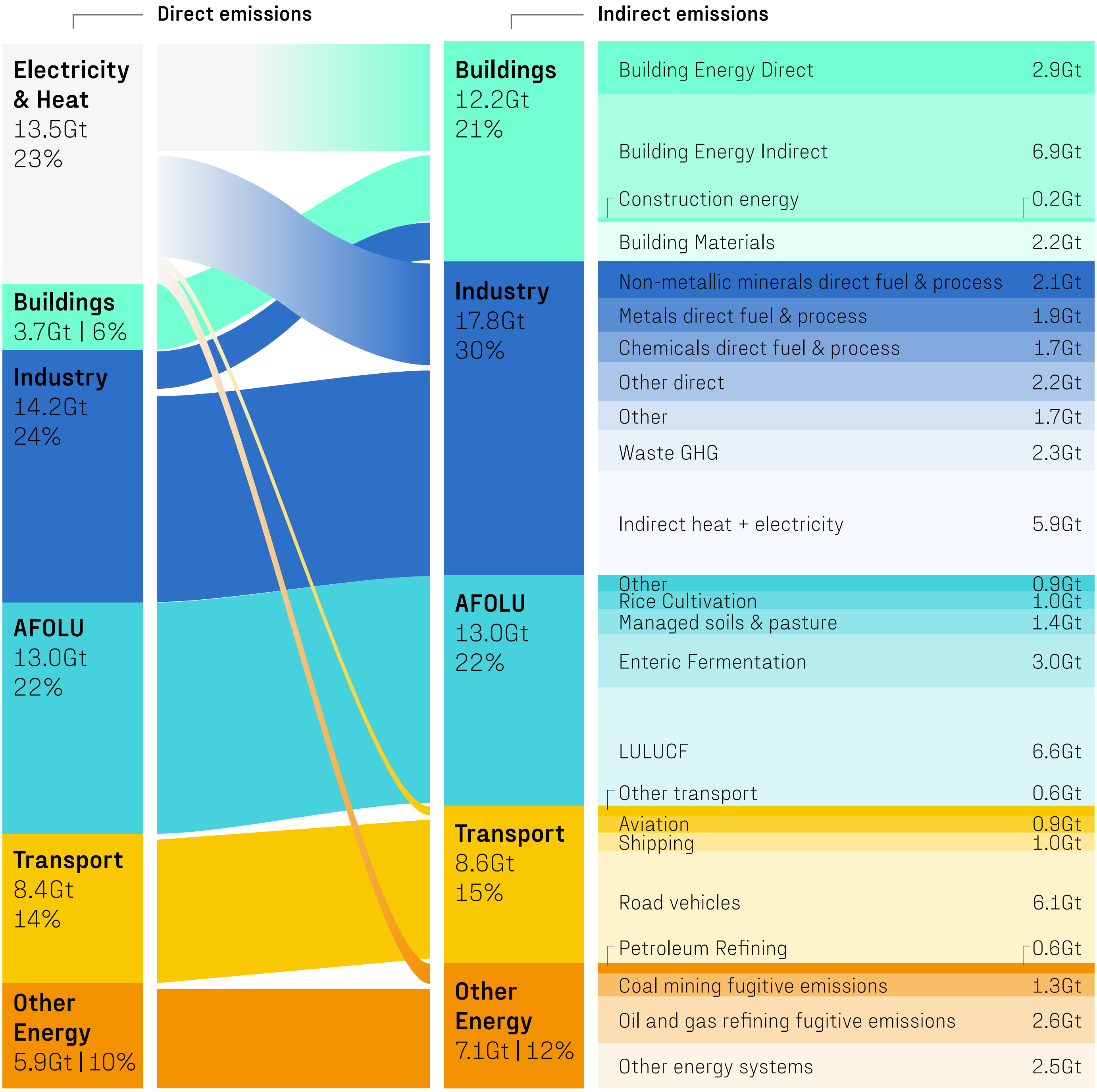
In modelled pathways that limit warming to 1.5°C (>50%) with no or limited overshoot, the global use of coal, oil and gas in 2050 is projected to decline with median values of about 95%, 60% and 45% compared to 2019.

Source: IPCC, 2022, Mitigation

What are major sources of emissions?

The vast majority of emissions growth, and practically all growth in CO_2 emissions, is attributed to the combustion of fossil fuels.

The graph below shows emissions, direct and indirect, by sector and subsector:

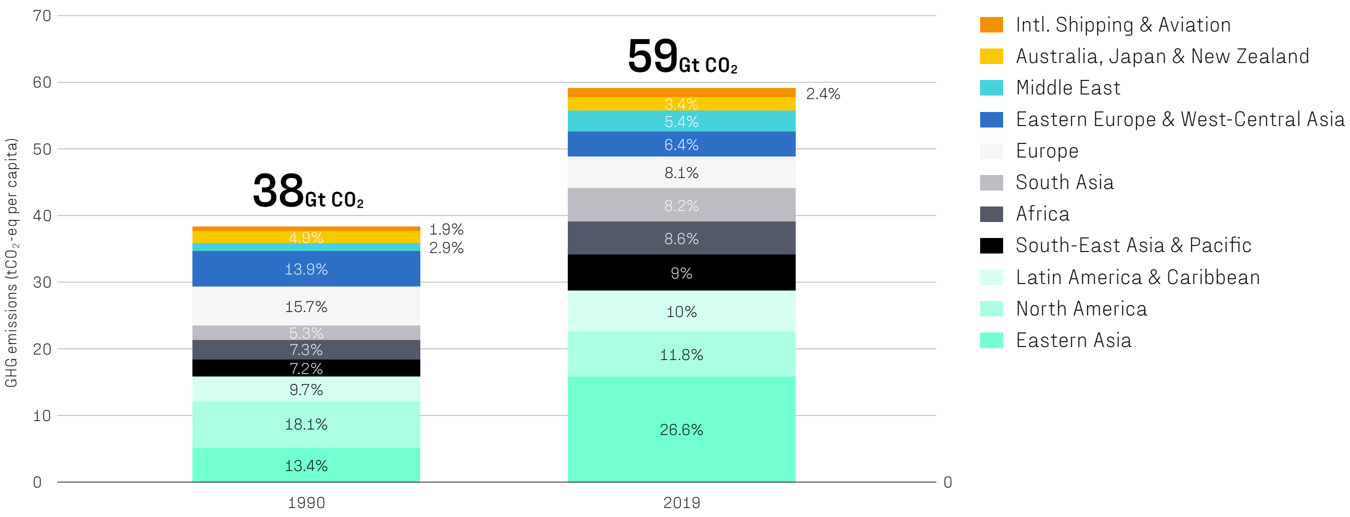


Source: IPCC, 2022, Mitigation

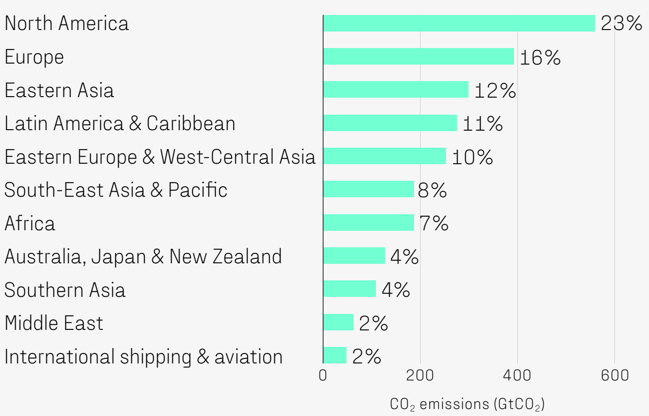
Who is emitting?

Eastern Asia is now the largest annual emitter of GHGs, but North America has historically emitted the most and continues to do so at the highest rate per capita.

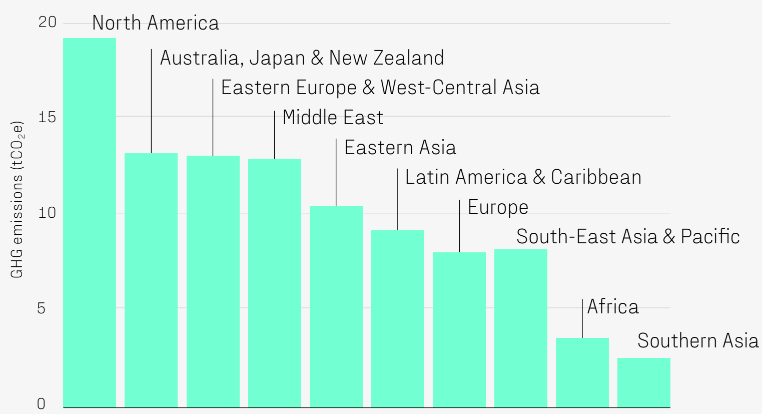
Global Net Anthropogenic CO_2 Emissions Per Region (1990-2019)



Historical cumulative CO_2 emissions ($GtCO_2$)



Net anthropogenic GHG emissions per capita



Source: IPCC, 2022, Mitigation

Data retrieved and adapted from: Lamb, W. F.; Niklas Döbbling; Michael Grubb; Arunima Malik; Jan Minx; Shonali Pachauri (2022): Data for Figure SPM.2 - Summary for Policymakers of the Working Group III Contribution to the IPCC Sixth Assessment Report. MetadataWorks, 04 April 2022.

How much will the transition to net-zero cost?

While there are a range of estimates of the cost of the net-zero transition, the common conclusion is that current spending is insufficient.

2021 climate finance was $850–$940 billion

Source: CPI

IPCC finds that mitigation finance needs to increase between 3 to 6 times current levels depending on region and sector. This is in line with Climate Policy Initiative (CPI) estimates as well.

Source: IPCC, 2022, Mitigation, CPI

Higher estimate of climate finance needed per year is $9.4 trillion between now and 2050

Source: SWISS RE

$9.4 trillion

Climate finance needed per year between now and 2050

Total cost of the transition ranges from $125 trillion to $275 trillion

All estimates assume large increases in new spending and redistribution of investment from fossil fuels to low-emission assets

Source: GFANZ, McKinsey

UNEP sees the need for up to an additional $500 billion per year in adaptation funding to 2050

Source: UNEP

Inaction will cost more than immediate action

The cost of developing fossil fuels to meet future demands will cost more than shifting to a low-carbon system

Incorporating falling cost of renewable energy, a 2022 study from Oxford University found “that compared to continuing with a fossil fuel-based system, a rapid green energy transition is likely to result in trillions of net savings. Hence, even without accounting for climate damages or climate policy co-benefits, transitioning to a net-zero energy system by 2050 is likely to be economically beneficial”. In particular, the authors calculate expected net present savings from a fast transition of $5 trillion (5% discount rate) to $12 trillion (1.4% discount rate).

Source: Way et al., 2022

Empirically grounded technology forecasts and the energy transition.” Joule 6.9 (2022): 2057-2082. Joule

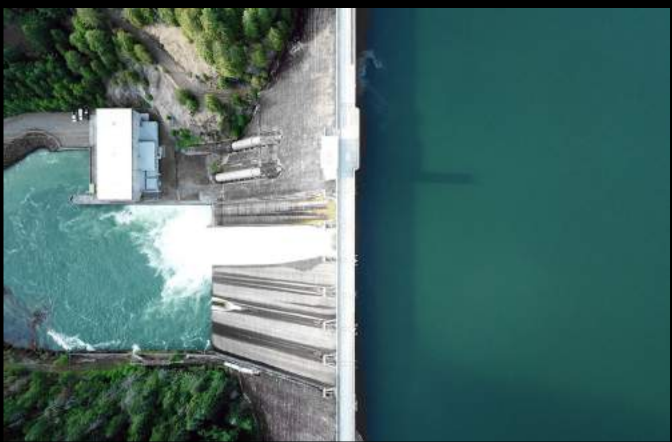
What are the key solutions to get to net-zero?

Getting to net-zero will require an all hands on deck approach to action. Every part of the economy needs to transition to low-carbon systems by adopting new solutions and improving existing infrastructure. The following is a high-level overview of major levers in core economic sectors that can drive the shift to climate neutrality.

Buildings

- Efficient building envelopes — windows, insulation, seals
- Electric and efficient building energy systems — heating, ventilation, and air conditioning (HVAC), temperature controls
- Low-carbon construction materials — wood, low-carbon cement, low-carbon steel
- Low-carbon construction methods — modular construction, novel machinery, logistics and supply chain, deconstruction and recycling
- Renewables and storage integration — rooftop solar, energy storage, flexibility measures, direct use geothermal
- High performance new building design
- Efficient appliances and lighting
- Digital optimization
- Incorporate nature based solutions and urban greening

Energy



- Renewable energy — wind, solar, geothermal, hydropower, and biomass
- Hydrogen production, transmission, storage, and end-use
- Nuclear power
- Grid modernization and optimization
- Carbon capture, and storage (CCS) and carbon capture and usage (CCU)
- Bioenergy carbon capture and storage (BECCS)
- Reduce methane emissions from oil, gas, and coal (CH_4)

Industry

- Energy efficiency and industrial electrification
- Circular economy, material efficiency, and waste management
- Low-carbon fuels, feedstocks, and energy sources
- Carbon capture, utilisation, and storage (CCUS)
- Low-carbon cement, steel, chemicals, and mining
- Reduce non-CO_2 GHGs such as methane (CH_4), nitrous oxides (N_2O), and hydrofluorocarbons (HFCs)
- Industrial water supply, use, and wastewater treatment

Transport

- Modal shift to public transit, bikes, e-bikes and non-motorized transport
- Battery electric vehicles (BEVs) and charging infrastructure
- Hydrogen fuel cell electric vehicles (FCEVs) and hydrogen internal combustion engines
- Route optimization and logistics
- Fuel efficiency and alternative fuels
- Limit Urban Sprawl

Agriculture Forestry & Other Land Use (AFOLU)

- Carbon sequestration in agriculture
- Reduce methane (CH_4) and nitrous oxides (N_2O) from agriculture
- Reduce land use change and improve land management
- Ecosystem restoration, afforestation, and reforestation
- Reduce food loss and food waste
- Dietary shift

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For more information
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