2.6 INTRODUCTION TO CLIMATE CHANGE

Global carbon budget and global greenhouse gas emissions

Important notice
This unit is part of a package of learning materials designed to support understanding of foundational concepts relating to climate-related financial disclosures. These learning materials do not constitute application or regulatory guidance for the preparation of climate-related financial disclosures and are not intended to represent legal or professional advice. We encourage you to seek your own professional advice to find out how the Corporations Act 2001 (Corporations Act) and other relevant laws may apply to you and your circumstances, as it is your responsibility to determine your obligations and comply with them.

Key topics

- Global carbon budget
- Historical greenhouse gas emissions
- Current greenhouse gas emissions

Relevance for climate-related disclosures

The global carbon budget tells us how quickly we need to decarbonise and how likely we are to breach temperature thresholds that will increase physical climate risk. Learning about the global carbon budget helps you to understand a core driver of climate-related transition risk and opportunity, which in turn helps in the identification of climate-related risks and opportunities. Climate-related risks and opportunities are explored further in Modules 3, 4 and 5.

In this unit, you will learn about the global carbon budget and global greenhouse gas emissions that inform global climate-related targets. This in turn informs national targets and business targets and pathways for decarbonisation.

Overview

To keep global warming below a particular level of temperature rise, say 1.5°C, there is a limit to the volume of greenhouse gases we can emit. This is called the global carbon budget. It refers to carbon dioxide (CO_2) emissions while accounting for how much warming is expected from non-CO_2 emissions.

The remaining carbon budget is the remaining volume of CO_2 that can be emitted from a particular date, say 2020. The remaining carbon budget could be lower than estimated.

Global greenhouse gas emissions from human activities have steadily increased since the Industrial Revolution. A small number of developed countries are responsible for a large proportion of historical greenhouse gas emissions.

How quickly the remaining carbon budget is used up depends on the volume of greenhouse gases emitted each year - the global annual level of greenhouse gas emissions. Annual greenhouse gas emissions need to decline in order to remain within the global carbon budget. Currently, these emissions are continuing to increase at a global level, although in some countries, greenhouse gas emissions are declining.

What is the global carbon budget?

Greenhouse gas emissions from human activities (anthropogenic greenhouse gas emissions) have accumulated in the atmosphere and contributed to global warming. While scientists have stated that it is, 'unequivocal that human influence has warmed the atmosphere, ocean and land',[1] the amount of warming cannot be exactly specified due to variable factors in measurement. Therefore, measurements, such as temperature increases, carbon budgets and cumulative greenhouse gas emissions are expressed as a range and a best estimate, or a degree of likelihood. Scientists can measure how much global warming is caused by CO_2 emissions from human activities, expressed as a range and a best estimate.

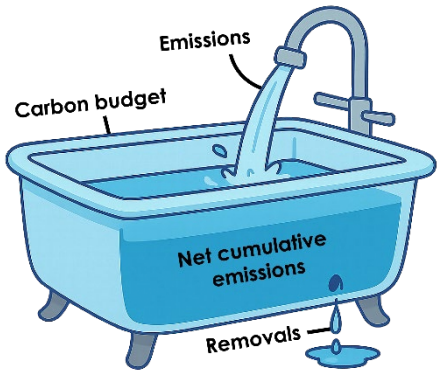
The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) found that 'each 1000 $GtCO_2$ of cumulative CO_2 emissions is assessed to likely cause a 0.27°C to 0.63°C increase in global surface temperature with a best estimate of 0.45°C'.[1]

While greenhouse gases are being released into the atmosphere, some are also being removed through natural and human processes, like reforestation.[2] To account for this, global greenhouse gas emissions to date are expressed as net cumulative emissions.

To keep global warming below dangerous levels, there is a limit to the total amount of net cumulative greenhouse gas emissions that can be put into the atmosphere. This is called the global carbon budget. It refers to CO_2 emissions while accounting for the global warming effect of non-CO_2 emissions.

The total global carbon budget is calculated from 1850[3] and is expressed as: the total cumulative net amount of carbon dioxide (in gigatonnes[4] of carbon dioxide (CO_2) or $GtCO_2$) that can be emitted by human activities while limiting global warming to a given level with a given probability.[5]

It is a bit like filling a bathtub with water from the tap at the same time as draining it out through the plughole. If the bath fills at the same rate that it drains, the level in the bathtub will not change. If more water goes in than goes out, the bathtub will fill up and eventually overflow. The global carbon budget is equivalent to the total amount of water the bathtub can hold without overflowing.



More greenhouse gas emissions are being released into the atmosphere than are being removed. If greenhouse gas emissions going into the atmosphere continue to exceed the greenhouse gas emissions removed from the atmosphere, the global carbon budget will eventually be exceeded.

What is the remaining global carbon budget?

The remaining carbon budget is measured from a specific point in time, accounting for cumulative CO_2 emissions to that date, and extending to when global greenhouse gas emissions reach net zero (that is, when emissions of CO_2 to the atmosphere from human activities are balanced by emissions removals from human activities over a specified period).[6] In simple terms, it is an estimate of the volume of CO_2 we can put into the atmosphere to keep total global warming below dangerous levels.

Using the bathtub analogy, our net cumulative emissions to date are equivalent to the water already in the bathtub. The remaining carbon budget is how much more water we can add before the tub overflows.

The IPCC estimates the remaining carbon budget from 2020 in AR6.[7] Module 2, Unit 7 covers the remaining carbon budget in more detail.

The remaining carbon budget could be lower than we think

There are uncertainties in the estimation of carbon budgets, such as:

- the amount of historical warming
- the amount of warming that is a result of greenhouse gas emissions8
- the impacts from feedback loops in Earth systems due to global warming, such as carbon release from future permafrost thawing.

Due to these uncertainties, remaining carbon budgets could be significantly lower than the IPCC estimations.

What are historical greenhouse gas emissions?

Before the Industrial Revolution, atmospheric greenhouse gas levels were relatively stable for thousands of years. Greenhouse gas emissions were mostly from natural sources including respiration of plants and animals, decomposition of vegetation and other organic materials, and volcanic eruptions.

From the Industrial Revolution onwards, greenhouse gas emissions from human activities increased, particularly emissions from burning fossil fuels like coal, and deforestation (land-use change). These greenhouse gas emissions accelerated rapidly in the second half of the 20th century.

While climate change is a global issue, a small number of developed countries that industrialised early are responsible for a large proportion of historical greenhouse gas emissions. Figure 1 below shows the current share of total global cumulative fossil CO_2 (fossil CO_2 is carbon dioxide emissions from fossil fuels and industry)[9] emissions from the pre-industrial era to 2024 for some of the largest emitters.

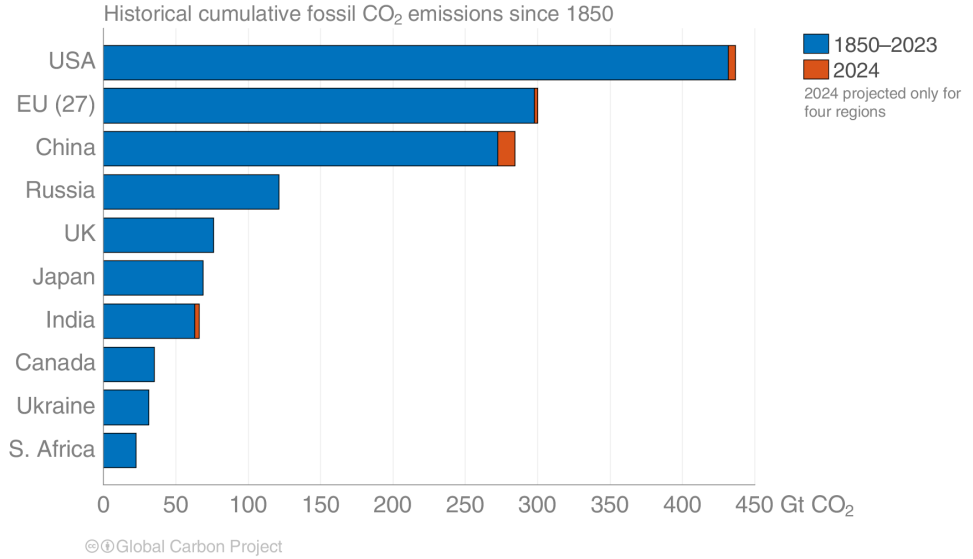


Figure 1: Historical cumulative fossil CO_2 emissions since 1850[10]

Some of the countries that were historically responsible for a high proportion of greenhouse gas emissions are now being overtaken by emerging economies with large populations.

What are current greenhouse gas emissions?

As of 2025, scientific data shows that rather than declining, global greenhouse gas emissions are continuing to rise at the global level, although they are declining in some countries. In 2023, global greenhouse gas emissions increased by 1.3% compared to 2022, reaching a total of 57.1 gigatonnes of carbon dioxide equivalent ($GtCO_2$-e)[11]. The average rate of growth from 2010-2019 was 0.8% per year. Figure 2 illustrates the continued growth in global emissions.

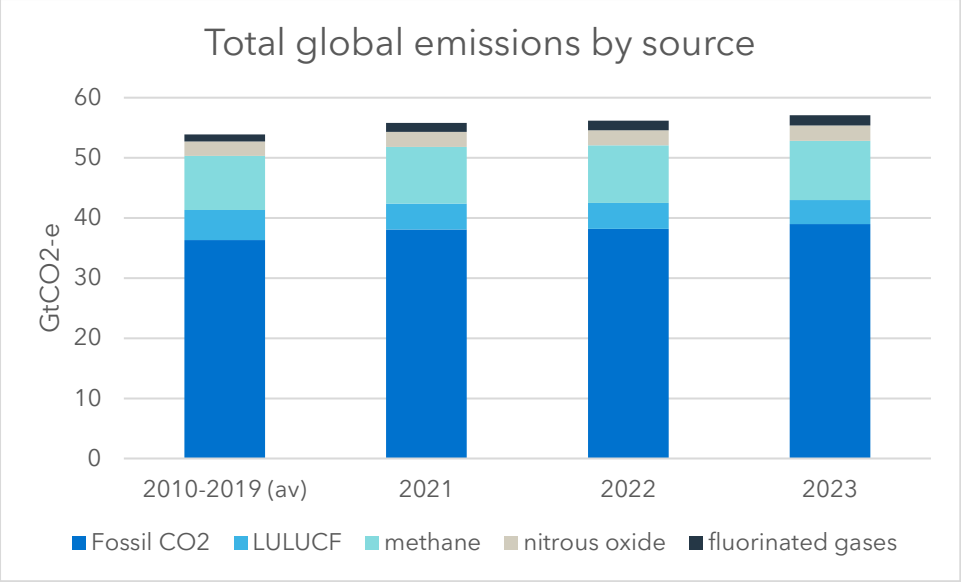


Figure 2: Global greenhouse gas emissions by source[12]

Note: LULUCF = land use, land-use change and forestry - this refers to greenhouse gas emissions and removals from managed lands, for example from deforestation and reforestation.[13]

Annual global emissions

The annual rate of global emissions determines how quickly the remaining carbon budget will be used up. To return to the bathtub analogy – it is equivalent to how much water is added to the bathtub each year. To ensure the remaining global carbon budget is not depleted before reaching net zero emissions on a global basis, greenhouse gas emissions need to significantly reduce.

The remaining carbon budget and the annual emissions rate together tell us the volume and rate at which global emissions should reduce to avoid dangerous warming. This informs global climate targets and decarbonisation pathways (that is, pathways of action to reduce or eliminate greenhouse gas emissions from human activities).

Key takeaways

- The total global carbon budget estimates the total quantity of carbon dioxide that can be emitted from human activities to limit temperature increases to a given level with a given probability.
- The remaining global carbon budget tells us how much more we can emit from a given date.
- The annual level of global greenhouse gas emissions determines how quickly the remaining global carbon budget will be used up. This level needs to rapidly reduce to avoid dangerous temperature increases.
- Net zero CO2 emissions is when CO2 emissions to Earth's atmosphere from human activities are balanced by CO2 removals from Earth's atmosphere from human activities over a specified period.
- Decarbonisation is the process of reducing or eliminating greenhouse gas emissions from human activities.

Sources and explanatory notes

[1] Intergovernmental Panel on Climate Change (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* (PDF 3,623 KB) p4

[2] Intergovernmental Panel on Climate Change *Special Report: Global Warming of 1.5 °C, Glossary*

[3] The total carbon budget is calculated from the beginning of the pre-industrial period. While this is often defined as 1750, for practical reasons most carbon budget calculations start from 1850 as limited data is available before this time

[4] 1 Gigatonne = 1 billion tonnes

[5] Intergovernmental Panel on Climate Change (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* (PDF 3,623 KB), p28-29

[6] Intergovernmental Panel on Climate Change *Special Report: Global Warming of 1.5 °C, Glossary*

[7] Intergovernmental Panel on Climate Change (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* (PDF 3,623 KB), p28-29

[8] Referred to as the transient climate response to cumulative CO_2 emissions

[9] United Nations Environment Programme (2024) *Emissions Gap Report 2024: No more hot air … please! With a massive gap between rhetoric and reality, countries draft new climate commitments*, Nairobi.

[10] Global Carbon Project (2024) *Figures from the Global Carbon Budget 2024*, *slide 28.* Used with permission of the Global Carbon Project under the Creative Commons Attribution 4.0 International license

[11] Greenhouse gas emissions are often reported in carbon dioxide equivalent units (CO_2 equivalent, CO_2-e) – this reflects the Global Warming Potential of each greenhouse gas expressed in terms of the global warming potential of one unit of carbon dioxide (see Module 2, Unit 2 for more information on Global Warming Potential)

[12] United Nations Environment Programme (2024) *Emissions Gap Report 2024: No more hot air … please! With a massive gap between rhetoric and reality, countries draft new climate commitments*, table 2.1, Nairobi

[13] Intergovernmental Panel on Climate Change *Special Report: Global Warming of 1.5 °C, Glossary*