CFRF CLIMATE FINANCIAL RISK FORUM

CLIMATE FINANCIAL RISK FORUM GUIDE 2022

A Carbon Budget Primer for Financial Institutions

Contents

This paper represents the output of the Transition to Net Zero Working Group (TNZ WG), part of the Climate Financial Risk Forum (CFRF).

Overview and Acknowledgements

Carbon budget is a notion that is at the core of climate change and the effort to mitigate it and manage its consequences.

There is a rich literature on the topic, thanks to the many academics and experts who have worked on it and continue to do so. We have a debt of gratitude to them all.

This paper has drawn on available resources to provide finance practitioners with a base-level understanding of the science behind the carbon budget, as well as its implications for financial institutions.

A number of sources are listed, which I hope practitioners will also seek to consult to further develop their understanding of this critical topic.

In the spirit of the CFRF, this paper has been written by finance practitioners for practitioners, as part of the Transition to Net Zero Working Group, which includes banks, asset managers, asset owners, insurers and service providers to the financial industry.

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1 Introduction and purpose

Carbon budget is a core concept behind most of the strategies and investment decisions that financial practitioners need to make to transition the emission profile of their portfolios.

Carbon Dioxide (CO2) and other greenhouses gases constantly cycle the atmosphere at a nearly balanced rate, i.e. CO2 are released into the atmosphere almost at the same speed as it is absorbed by the land and ocean. Such process is known as the natural carbon cycle. This keeps the earth habitable and is known as the greenhouse effect.

However, human activities, mainly associated with the use of fossil fuels, have created an imbalance by increasing the amount of emissions, causing higher concentrations of CO2 in the atmosphere and thus resulting in an overall warming of temperatures and a number of consequences in our planet’s ecosystem (e.g. sea level rises, ocean acidifications etc.).

Given that imbalance, climate scientists have assessed the amount of further greenhouse gases that are permissible to be released into the atmosphere while limiting the environmental consequences. This amount is defined as remaining “carbon budget”.

This paper is split into two sections:

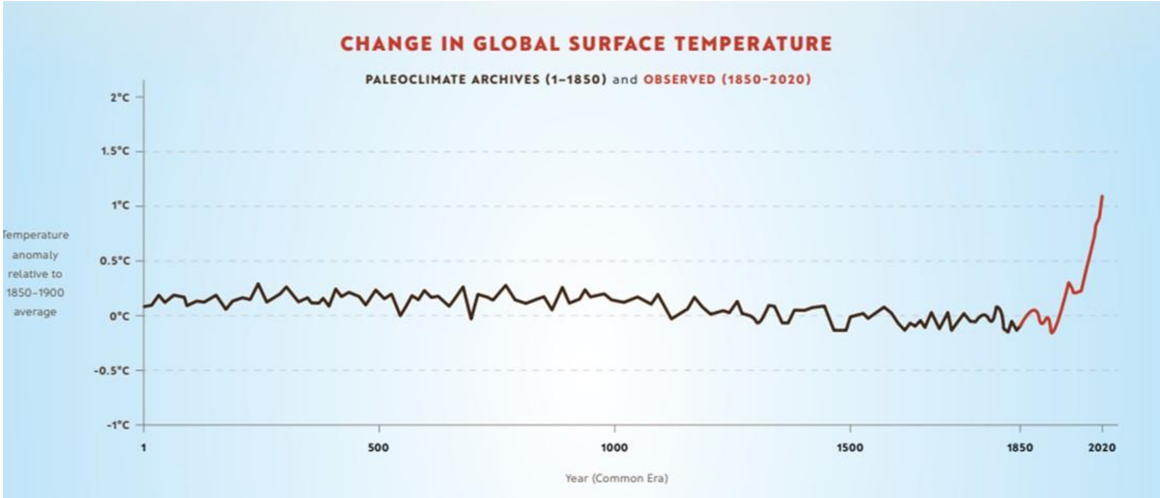
- **The Science of Net Zero** – provides an overview of climate science and global warming and how that relates to carbon cycle and carbon budget.
- **Carbon Budget, from Science to Practices** – explains how the carbon budget, which is global in nature, can be allocated to individual nations or industrial sectors to enable practical actions. Such allocations help design incentive mechanisms to decarbonise the economy and also set benchmarks for financial institutions to effectively measure and manage their own transition plan and climate strategy.

2 The Science of Net Zero

2.1. Climate Science and Global Warming

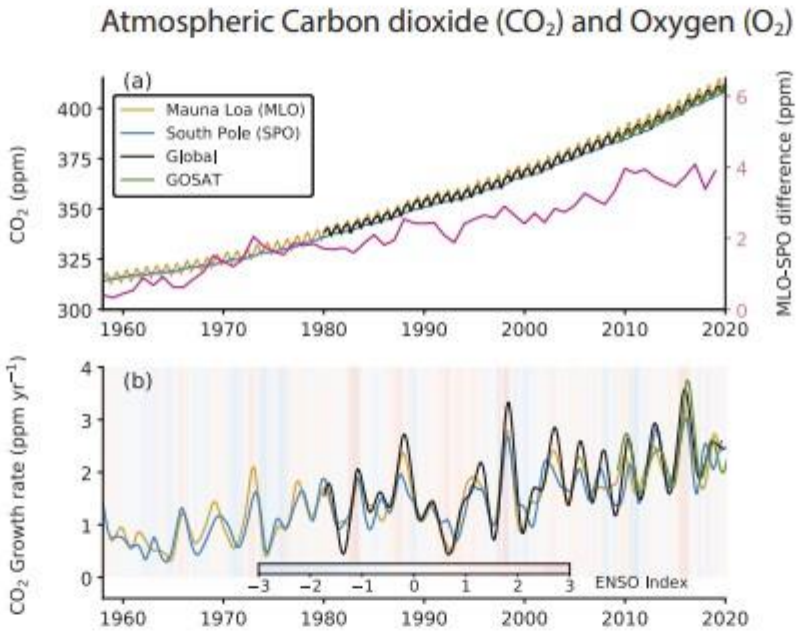
Gases that absorb radiation, trapping heat in the atmosphere, are commonly referred to as Greenhouse Gases (GHG). Carbon dioxide (CO2), methane (CH4), nitrous oxide (NO2), some halogenated species, ozone and water vapor[1] are all considered GHGs. This report will focus on the highest emitted GHG from human activity: CO2.

Average global temperatures have increased by 1.2°C since 1880, with the largest changes happening in recent decades. Land areas have warmed more than the sea surface and the Arctic has warmed the most — by more than 2°C since the 1960s. A popular illustration, first published in 1998[2] and often called the hockey-stick graph, shows how temperatures remained relatively stable for hundreds of years (the shaft of the stick) before rapidly increasing (the blade) over the last 150 years.



With the aid of climate models that account for human, solar, volcanic and internal climate drivers, paleoclimate archives and direct temperature observations since the 1850s, the international scientific community has suggested that it is highly likely that the global surface temperature increase is due to human activity[3]. Since the industrial revolution, human activity has increased the emission of CO_2 and other greenhouse gases (GHGs) by an estimated 50%[4] due to an increased combustion of fossil fuels, deforestation, and land use changes. To understand why climate scientists state that human activities (i.e., anthropogenic emissions) are the main cause of Global Warming, we first need to understand the Greenhouse Effect.

[1] Water vapor is constantly cycling the atmosphere, entering the air by evaporation, then re-condensing into clouds, and returning to Earth by precipitation at a balanced rate. A warmer weather can accelerate the speed of evaporation and increases water vapor in the air that intensifies the greenhouse effect. Additionally, aircraft engines will create a human-made cloud – contrails, that traps water vapor. Although contrails last only a short time, there is evidence that it has greater impact on daily temperature raises than CO2 emissions from aircrafts.
[2] https://agupubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1029/1999GL900070
[3] IPCC (2021), Sixth Assessment Report, Working Group 1: The Physical Science Basis
[4] Causes | Facts – Climate Change: Vital Signs of the Planet (nasa.gov)



Source: IPCC Sixth Assessment Report, Chapter 5: [Global Carbon and Other Biogeochemical Cycles and Feedbacks]

The Greenhouse Effect

The greenhouse effect is a natural phenomenon that arises because the Earth's atmosphere allows radiation in the visible spectrum (shorter wavelengths) to pass through largely unimpeded but absorbs radiation of longer (infrared) wavelengths. The sun emits radiation mostly at short wavelengths, in the visible part of the spectrum. Of the solar energy that reaches the top of the Earth's atmosphere, about a third is reflected back into space. The rest passes largely unimpeded through the atmosphere where it is absorbed by the Earth's surface and reflected back at longer (infrared) wavelengths, given its lower temperature. The GHGs in the atmosphere trap some of this outgoing infrared radiation, acting as a blanket that maintains the planet at a habitable temperature (about 15°C on average). Some concentration of GHGs is therefore critical to the survival of life on Earth. In the absence of GHGs, the Earth's average temperature would drop as low as -18°C, making the planet inhabitable.

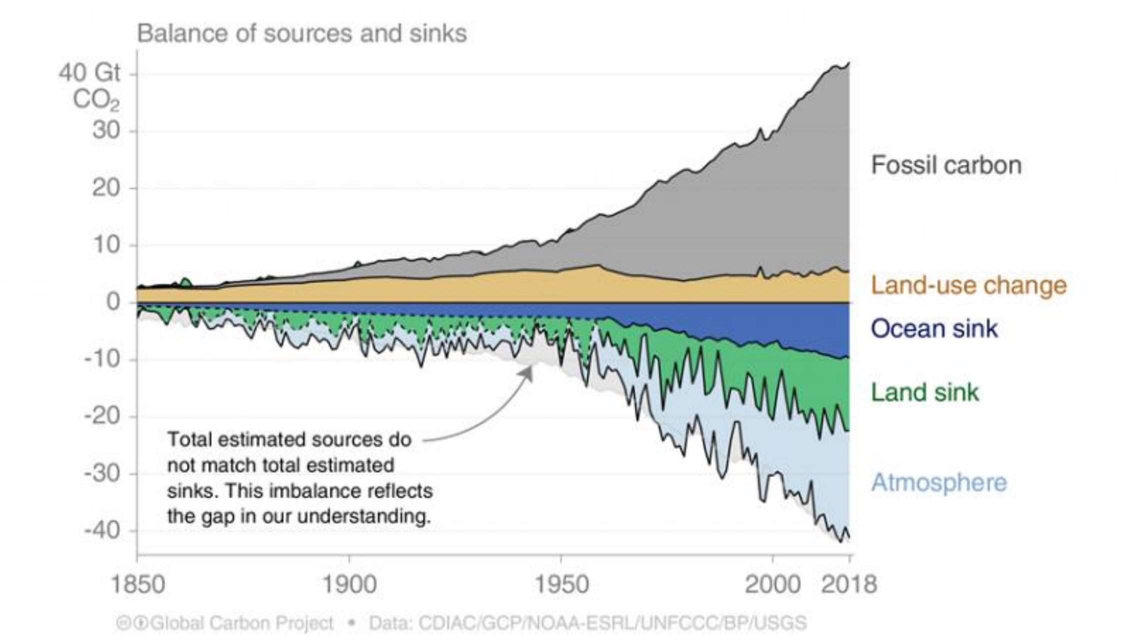
However, the concentration of GHGs has been increasing since industrialization, resulting in more outgoing longwave radiation being trapped in the atmosphere. This Enhanced Greenhouse Effect has pushed the Earth out of its equilibrium, leading to increasing; temperatures.

Human Impacts on Natural Carbon Cycle

The flow of carbon between the atmosphere and the Earth is known as the carbon cycle. Carbon can be stored in the following systems, commonly referred to as "carbon reservoirs":

- The Earth's uppermost surface layer: an inorganic reservoir of carbonate and fossil 'reservoirs' which store all fossil fuels such as coal, oil and natural gas
- Terrestrial ecosystem: living matter such as plants, animals, microorganisms, etc.
- Ocean reservoirs: Carbon dissolved in the ocean, living matter, mostly found near the surface and sedimentary matter
- Atmospheric reservoir: the air above the surface, which has the most rapid effect on Global Warming

The natural carbon cycle is kept in near balance, however since the industrial revolution, human activities (such as the extraction and combustion of fossil fuels, deforestation and land use changes), have cause a net increase in carbon concentrations in the atmosphere, soil, and oceans.



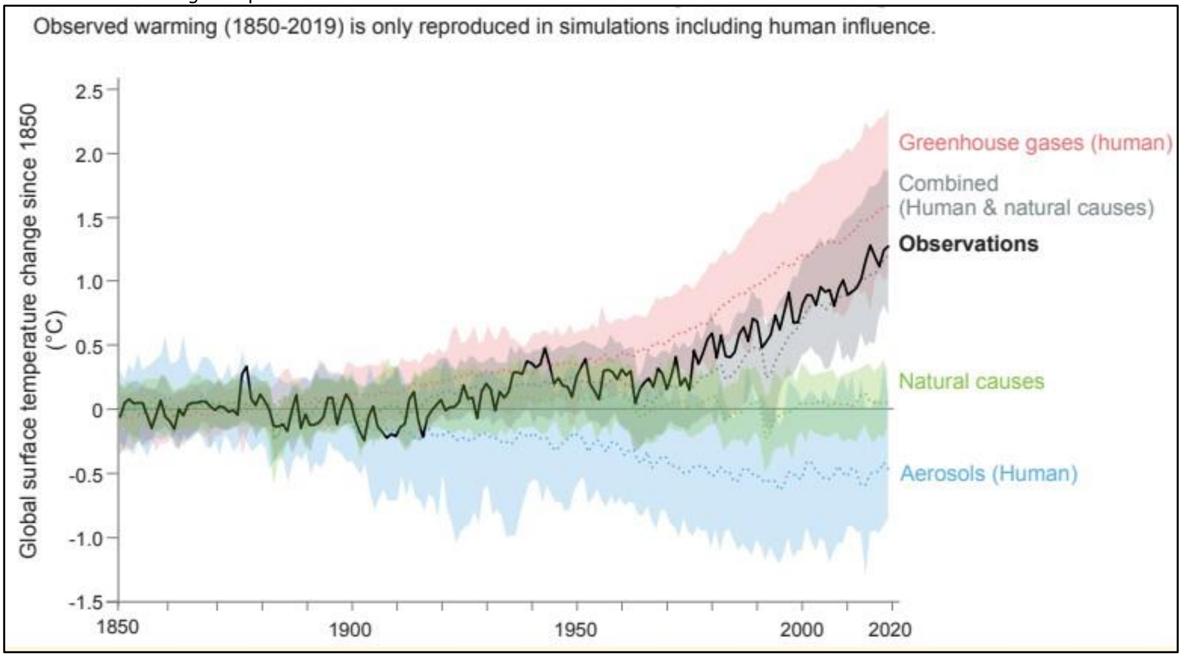
Source: Our World in Data, Atmospheric Concentrations

Anthropogenic Emissions and Global Warming

According to World Resources Institute (WRI), 73.2% of the anthropogenic net emissions (2016 as base year) are related to fossil fuel use: Industry (24%), Transportation (16%) and Buildings (17%). 5.8% of the emissions are associated directly with fugitive emissions from Energy sector itself before reaching their end-users, i.e., leaks or irregular emissions during fossil fuel extractions, refining, processing and transportation. Agriculture, forestry and other land use (AFOLU) is another significant net source of GHG emissions, contributing to about 18.4% of anthropogenic emissions.

Prior to the Industrial Revolution, people's influence on the environment has been relatively minor. However, with the introduction of electric power, and the use of oil and gas to meet energy needs, anthropogenic impacts on the environment have accelerated rapidly. Over the past 150 years, human activity has placed increased pressure on the Earth's ecosystems. Of particular concern is the release of GHGs, which are disrupting the Earth's climate.

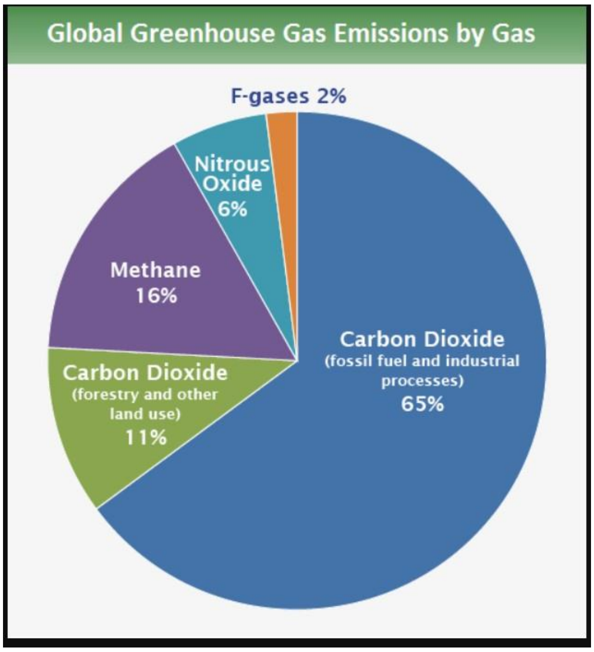
The IPCC's climate models (AR6, WG1) show that the high temperatures observed (black line) are likely only to explained by human activities (grey band); in particular, the increasing concentrations of GHGs. The graph also clearly shows that natural processes by themselves (green band), such as the El Niño or emissions from large volcanoes, have not caused the increase in temperatures. Although the overall warming effect of GHGs (red band) is partially offset by human induced aerosols (blue band), the influence of combined natural and anthropogenic factors indicates that the overall increase in temperatures can be attributed largely, if not completely, to human activities.



Source: IPCC Sixth Assessment Report, Chapter 3: Human Influence on the Climate System

Global Warming Potential [5]

Anthropogenic emissions cover various sources of carbon. Typically, GHGs are referred to as the basket of Kyoto gases (CO_2, CH_4, N_2O as well as F-gases).



Source: IPCC AR5 (2014) based on global emissions from 2010.

Different GHGs have different effects on Global Warming. Two main ways in which these gases differ from each other are their ability to absorb energy (their "radiative efficiency"), and how long they persist in the atmosphere (also known as their "lifetime").

To understand the differing effects of the various GHGs on global temperatures, the Global Warming Potential (GWP) was developed. This is a measure of how much energy the emissions of 1 tonne of a GHG will absorb over a given period of time, relative to the emissions of 1 tonne of carbon dioxide (CO_2), i.e. CO_2 is given a GWP value of 1. The larger the GWP, the more a given GHG warms the Earth compared to CO_2 over that time period.

[5] epa.gov/ghgemissions/understanding-global-warming-potentials

The GWPs currently used are those calculated over 20-years or 100-year time horizons. Some argue that 20-year GWP is preferred, since it matches the 2050 net zero target (discusses later in this section), while the scientific community usually refers to 100-year GWP values.

	Lifetime	20 years GWP	100 years GWP
Carbon dioxide (CO_2)	150-300	1	1
Methane (CH_4)	12	84	28
Nitrous oxide (N_2O)	121	265	264

Take methane (CH_4) as an example, which is estimated to have a GWP of about 28 over 100 years. CH_4 emitted today stays in the atmosphere for about a decade on average, which is a much shorter time period than for CO_2. However, CH_4 also absorbs much more energy than CO_2, meaning it traps more outgoing infrared radiation in the atmosphere of the Earth. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. GWP is useful when calculating the CO_2-equivalent emissions for various GHGs. For example, the CO_2 equivalent of 100 kg of CH_4 is 2.8 tonnes (= 100/1000 * 28).

Because GHGs can stay in the atmosphere for hundreds or even thousands of years, recent emissions – and the resulting temperature increase from these emissions – are effectively permanent, except in the case of a large net removal of CO_2 ("carbon sinks") from the atmosphere over a sustained period. Moreover, it takes time for the climate system to respond to an increase in greenhouse gas concentrations, so even if we were to abruptly stop all emissions today, the climate would continue to warm until it reaches a new stable equilibrium. Some degree of continuing climate change is therefore already "locked in".

2.2. Balancing the carbon cycle and conserving the carbon budget

The Earth's rising temperatures can only be halted by eliminating anthropogenic GHG emissions. As some degree of continued warming is unavoidable, a target for 2050 of 1.5°C warming above the pre-industrial global average temperature has been set to limit the future consequences climate change.

Carbon budgets are a simplified way to measure the additional emissions that can enter the atmosphere, if global warming is to be limited to levels such as 1.5°C under a given certainty. They are calculated based on the expected temperature increase as a result of a certain amount of CO_2 emissions. For example, in 2018, the IPCC AR6 report estimated that the remaining budget for a 66% chance of limiting warming to 1.5°C was about 420 $GtCO_2$.

Earth System Feedbacks

Since the carbon budget is based on relationship between global warming and anthropogenic emissions, apart from direct impacts captured by the current climate models, there are uncertain feedback effects that can cause the remaining carbon budget to deplete faster than estimated. Some of these Amplifying Climate Feedbacks ("tipping points") are:

- Thawing of permafrost: Permafrost is estimated to contain 5,500 Bn tonnes of CO_2, which is twice as much as CO_2 as is currently present in the atmosphere. For every 1°C of temperature increase by 2100, the thawing of permafrost is estimated to release an additional 3 to 41 Bn tonnes of carbon into the atmosphere.
- Shifts in forest ecosystems: Forests store carbon and are therefore considered to be a carbon sink. Deforestation reduces the amount of carbon that can be absorbed from the atmosphere. Furthermore, the burning of trees and plant matter releases the carbon that has previously been stored in them, further increasing CO_2 concentrations in the atmosphere.

- Clouds: Clouds act as an additional "blanket" in the atmosphere, which can trap some of the outgoing infrared radiation. Overall, clouds are expected to amplify human-induced Global Warming.

Model Used and Methodological Choices

Most carbon budget calculations assume an almost linear relationship between peak global mean temperature and cumulative emissions of carbon. While some climate models use only CO_2 concentrations in the atmosphere as an input, others are able to take into account past and future emissions and consider the dynamics of carbon cycle. However, this can cause large differences in the resulting carbon budget.

Another source of model uncertainties comes from the estimated temperature increases. A commonly used approach is to calculate the air temperature slightly above the surface of the Earth, i.e. the surface air temperature (SAT). However, the SAT has been found to overestimate the temperature increase by close to 0.1°C, while a blend of SAT over land with sea surface temperature (SST) over oceans, which measures the water temperature at the ocean's surface rather than the air temperature, is considered to track temperature changes more accurately. To put this into context, per IPCC AR6, using a blend of SAT and SST temperatures would increase the remaining carbon budget for limiting Global Warming to 1.5°C from 420 $GtCO_2$ to 570 $GtCO_2$ under the 66% probability pathway.

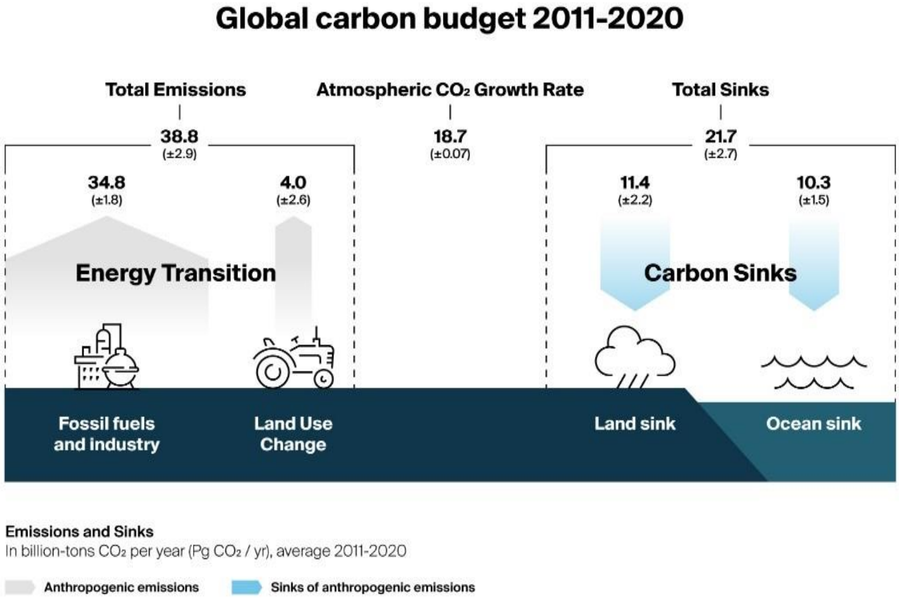
Finally, carbon budgets can be based only on temperature increases expected from CO_2 emissions, or, alternatively, can take into account temperature changes caused by other GHGs and aerosols as well. Carbon budgets that only consider CO_2-induced warming tend to overestimate the remaining carbon budget. However, it should be noted that the temperature change resulting from future emissions of methane, nitrous oxide, aerosols and other GHGs remain largely unknown. The AR6 report states that these uncertainties could influence the remaining carbon budget by −400 to +200 GtCO2.

Path to Net Zero

Despite these uncertainties, scientific consensus acknowledges that there is a limited volume of the remaining carbon budget left, emphasizing the need for net zero CO_2 emissions targets.

The below graphic shows the average anthropogenic emissions and sinks between 2011 to 2020, which results in a net contribution of nearly 19 $GtCO_2$ per annum. When taking into account the current average growth rate of atmospheric CO_2 emissions, the carbon budget of 420 $GtCO_2$ estimated by AR6 would be depleted in about 20 years[6].

[6] The latest UNEP GAP report states that the remaining carbon budget for 1.5°C will be exhausted around the end of this decade, unless significant emission reductions are rapidly achieved.



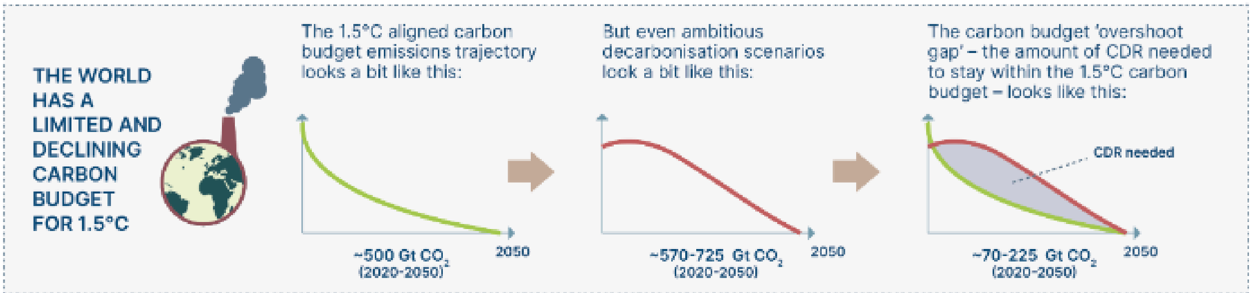
Source: NOAA-ESRL; Friedlingstein et al 2021; Canadell et al 2021 (IPCC AR6 WG1 Chapter 5); Global Carbon Project 2021

Hence, the most critical policy implication of the carbon budget is the necessity to drastically reduce CO_2 emissions and to transition to a net zero economy by 2050.

The Energy Transitions Commission (ETC)[7] estimates that US$4trillion of gross capital investment per year is required to stay on average to stay on a 1.5°C pathway and achieve net zero by 2050 – this is a broken down into investment in six sectors: power, fuel supply and hydrogen, industry, buildings, transport and removals.

Box 1: Recognising the need for technology-based carbon removals

Apart from natural-based sinks (e.g. forests, savannas, grasslands and peatlands), Carbon Removal Technology, although nascent and not at-scale, is one of the most commonly referred levers to achieve net zero emissions and therefore the temperature target of 1.5°C. Depending on the curve when the emission peaks, almost all decarbonisation pathways rely on Carbon Dioxide Removals (CDR) to offset the "overshoot gap" in carbon budget to some extent, as shown below.



Source: Energy Transitions Commissions (2022), "Mind the Gap: How Carbon Dioxide Removals Must Complement Deep Decarbonisation to Keep 1.50C Alive"

CDR involves removing carbon emissions from the atmosphere and storing them for a period that is sufficiently long to neutralize their impact on climate. Below are two carbon removal technologies and their estimated cost in [US$/tonne CO_2] as indicated by BCG (2022)[8]:

1. Bioenergy with Carbon Capture and Storage (BECCS): Involves capturing CO_2

[7] Forthcoming Energy Transitions Commission (ETC) analysis (2022/23), Financing the Transition
[8] BCG (2022), Let Science be the Guide for Net-Zero Targets, https://www.bcg.com/publications/2022/let-science-guide-net-zero-targets

from a biogenic source (e.g. oak and pine tree forests) and storing it permanently. Costs are estimated in the range US$20-288/tonne CO2[9]

2. Direct Air Capture with Carbon Capture and Storage (DACCS): Involves capturing CO_2 directly from the atmosphere. There are currently 18 direct air capture plants operating in the world capturing 0.01MtCO_2/year, but only two of them stores the captured CO_2[10]. Capturing CO_2 from the atmosphere is currently more energy intensive and expensive than capturing from a point source as CO_2 is more dilute than point source emissions. Current costs range from US$100-300/tonne CO_2[11].

[9] Global CCS Institute, https://www.globalccsinstitute.com/wp-content/uploads/2019/03/BECCS-Perspective_FINAL_18-March.pdf
[10] IEA (2022), https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage
[11] IPCC AR6 TS-96 https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_TechnicalSummary.pdf

3 Carbon Budget – from science to practice

The carbon budget is determined at a global level, given the nature of the underlying physical processes.

In order to lead to practical actions, it first needs to be allocated down between various parties. This allocation is typically done either to individual nations (e.g. to support national pledges under the Paris Agreement) or to individual sectors (e.g. to provide reference pathways for the decarbonisation of each sector as part of the whole economy).

Such allocations in turn support policy makers in designing incentives to decarbonise the economy, which typically take the form of financial or regulatory incentives.

For financial institutions, those allocations and incentives provide a canvass to concretely incorporate the carbon budget into their climate strategy.

3.1. Carbon budget allocation

3.1.1 Understanding countries' NDCs and how they are calibrated to net-zero

The overall goal of the Paris Agreement is to "[hold] the increase in the global average temperature to well below 2°C above pre-industrial levels and [pursue] efforts to limit the temperature increase to 1.5°C above pre-industrial levels". As part of these efforts, parties to the Agreement are required to submit new or updated nationally determined contributions (NDCs) every five years, which set out countries proposed actions across their economies to reduce their emissions in line with Paris. By January 2022, 156 countries had submitted new or updated NDCs.

While the Agreement itself does not reference carbon budgets, we can think of the Paris Agreement global temperature rise goals in terms of the remaining permissible carbon budget associated with that outcome. Introducing carbon budgets in this way provides a useful means of assessing the adequacy of commitments made to date and the further action required to meet its goals. Many studies have been carried out in this space to assess the ambition level of the proposed NDCs with respect to their environmental effectiveness[12].

The voluntary nature of the Paris Agreement is reflected not only in the language ('contributions' rather than 'commitments') but also in the lack of criteria to assess the adequacy of NDCs or their enforcement. Instead, the Agreement refers to broad principles i.e. "This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."

Nonetheless, many researchers have been focusing on such an assessment.

In 2021, the IEA published a report, which showed that if all national net zero commitments are met in full and on time (including updated NDC commitments made at COP26), they would be enough to hold the rise in global temperatures to 1.8°C by the end of the century. This was the first time that governments have announced targets of sufficient ambition to hold global warming to below 2°C, however it remains insufficient to fulfil the aspiration of limiting warming to 1.5°C. The report also states that pledges made need to be turned into clear and credible policy actions and strategies. As at 23 September 2022, 166 nations (up from 152 at COP26) have submitted NDCs, representing 91% of GHG emissions. The IEA and its partners will continue to publish the results of their tracking work every year drawing on their Global Roadmap to Net Zero by 2050.

Assessing the "fairness" of the allocation of the carbon budget at country level is not straightforward. An extensive literature has discussed the various constraints in such

[12] Rogelj, J., Fricko, O., Meinshausen, M. et al. Understanding the origin of Paris Agreement emission uncertainties. Nat Commun 8, 15748 (2017). https://doi.org/10.1038/ncomms15748

allocation to make sure those countries that are most responsible for past emissions should not prolong their benefits and those that are under-developed will not be of deprived their basic needs[13]. Some research has categorised global carbon budget distribution based on three equity principles - “responsibility”, “capability”, “equity”[14], and more recent work has focused on numerous approaches to apply each of these principles[15].

Despite some challenges in assessing its adequacy, NDCs provide profound value in sending clear signal to the economy that incentives will be put in place to achieve those “contributions”. This in turn help inform financial institutions’ engagement with companies operating in those market. It as well help inform their advocacy for policies or initiatives to achieve the NDCs and to better align with global carbon budget.

3.1.2 Using sectoral pathways to allocate the carbon budget to different sectors of the economy

While national carbon budgets, as stated in countries’ NDCs, provide a useful framework for a corporate or financial institution operating in a given jurisdiction, they are not sufficient to provide a cross-border or cross-sector view of the carbon budget relevant to their business.

Per the UNEP Emissions Gap report[16], there are 95 current NDCs now cover all sectors, from parties representing 55% of global GHG emissions (for comparison, there are 166 countries submitted NDCs as of Sept 2022, representing 91% of global GHG emission in total). Additionally, when we look at the countries with long-term or net zero targets (88 in total), nearly one third (31 NDCs) do not specify sectoral coverage. This means that NDCs cannot be relied on alone to provide a comprehensive view of decarbonisation requirements across all sectors and all regions.

It is important to understand the sources of emissions (i.e., which economic activity or sectors are producing the most emissions) and, in doing so, determine which economic agents are responsible for reducing them.

It is also imperative to have an appreciation of how the emissions within a given sector should be reduced over time for the world to remain within its carbon budget, and the associated policy and technology constraints to achieving this. This information is key for economic agents operating in different jurisdictions to understand what the Paris Agreement means for them, and to think about how to take action to remain consistent with their global carbon budget.

Sectoral pathways have been developed to describe plausible, coherent and internally consistent decarbonisation pathways across different sectors of the economy that dictate the pace of emission reductions needed towards a given climate goal. Box 2 provides further insights on these.

Box 2: Understanding sectoral pathways

Sectoral pathways provide the link between the science of the remaining carbon budget and the changes within a specific sector that will drive the transition to the required emissions level within a given timeframe. Emissions reduction pathways need to be sector-specific because some sectors are more exposed to risks associated with the transition to net zero than others. Specifically, some sectors such as cement, steel, aviation and chemicals industries are considered hard-to-abate sectors given the current lack of scalable technological solutions to enable substantial emissions reductions. These industries may therefore be subject to greater costs associated with the transition, for example through higher taxes on their emissions or through greater capex needed to develop the technology required

13 H¨ohne et al., 2014, Keith Williges et al. 2022

14 Clarke et al., 2014 - *Responsibility*: Use of historical emission to derive future reduction goals. *Capability*: Disregarding causal and moral responsibility, approaches relating mitigation goals to capability (or capacity) to pay for – or most efficiently to contribute to – emission reduction or approaches aiming at securing people’s capability of leading a sufficiently good (decent) life. *Equality*: Allocation based on equal emissions per person, applying current and/or future population projections.

15 One example is the COP27 Net Zero Atlas report from FTSE Russell & Beyond Ratings Research, which describes a statistical approach to allocate the carbon budget at the national level based on these principles and assesses the adequacy of the NDCs and current policies. https://content.ftserussell.com/sites/default/files/the_cop27_net_zero_atlas_2.pdf

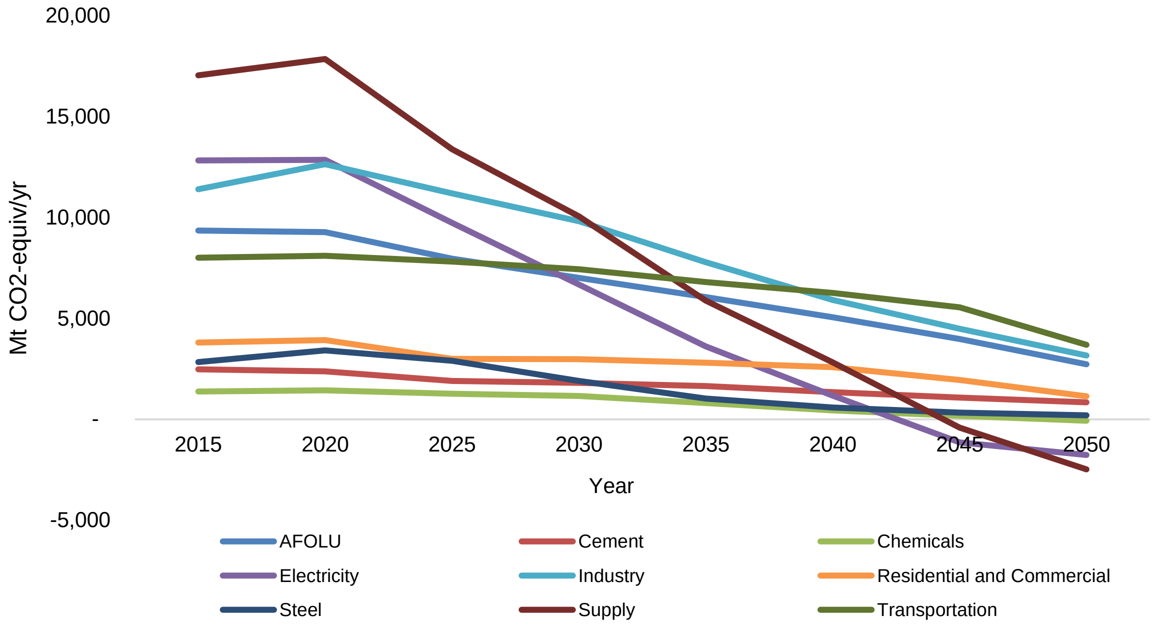
16 https://www.unep.org/resources/emissions-gap-report-2022

to transition.

It is important to remember that a given set of sectoral pathways presents only one possible trajectory to achieve a given temperature outcome. It is possible to conceive other possible trajectories to achieve net zero. The choice depends heavily on the emergence of new technologies, shifts in trends of consumption and social behaviors and the effectiveness of global cooperation in reducing emissions at earlier stages of each pathway.

Several institutions publish sectoral pathways. These include the International Energy Agency (IEA), University of Technology Sydney (UTS), and Network of Central Banks and Supervisors for Greening the Financial System (NGFS)[17]. Conceptually, sectoral pathways aim to allocate the carbon budget in a 'fair' way to different sectors in the economy, noting the respective transformations each sector is required to take to remain consistent with different global warming outcomes. In practice, this involves using so-called Integrated Assessment models (IAMs). These solve a least-cost optimization algorithm, considering the constraints from technological, policy and economic developments, to keep within total carbon budgets. For example, the IEA uses its Global Energy and Climate Model (GECM)[18] model to generate sectoral pathways within its Net Zero Emission by 2050 scenario (NZE). The NGFS scenarios are created using three well established IAMs (GCAM, REMIND-MAgPIE and MESSAGEix-GLOBIOM)[19]. The below provides an illustration of sectoral pathways from the NGFS family.

Figure 1: Sectoral pathways produced by the NGFS under a Net Zero 2050 global warming scenario



Source: © NGFS Scenario Explorer.

Notes: Representative global sectoral pathways from the GCAM 5.3+NGFS model under the Net Zero 2050 scenario, expressed in Mt CO2-equiv/yr. Pathways contain total Kyoto GHG emissions, including CO2, CH4, N20 and F-gases and use 100-year GWPs from AR4 for aggregation of different gases.

Sectoral pathways have so far focused primarily on energy and energy-intensive sectors. For example, the IEA's NZE 2050 scenario takes the current situation in the energy sector as a starting point (e.g. existing capacity stock, operating cost and conversion efficiencies to renewables), and considers the technical and economic characteristics of new technologies that could be added to the energy system in the future. The model driving the sector pathway then determines the least-cost technology mix by solving an optimization algorithm to meet the energy demand from four end-use sectors, i.e. agriculture, buildings, industry and

[17] https://www.ngfs.net/en
[18] https://iea.blob.core.windows.net/assets/3a51c827-2b4a-4251-87da-7f28d9c9549b/GlobalEnergyandClimateModel2022Documentation.pdf
[19] technical_documentation-_ngfs_scenarios_phase_3.pdf

transport.

3.2. Incentives to remain within the carbon budget

3.2.1 The merits of a broader use of carbon pricing

Over the past decade, policymakers around the globe have been considering putting a price on carbon to incentivize the path to net zero. Many economists consider carbon pricing or similar as the most economic efficient instrument through which to accelerate emission reductions.

There are two ways carbon prices can be enforced. One method of implementing carbon prices is to impose a charge on the emission of GHGs equivalent to the corresponding potential cost caused through future climate change, forcing emitters to take on, or internalise, the cost of pollution. This is called the Social Cost of Carbon (SCC).

Another mechanism for introducing a carbon price would be on desired outcomes. Here carbon prices can be calibrated to achieve a certain emissions target by a specific date, such as net zero by 2050. This is commonly referred to as a 'target-consistent' approach. Under both approaches, a financial incentive is created for an emitter (such as a factory) to reduce its emissions.

Either method of carbon pricing can be applied using one of the two following instruments; a carbon (GHG emissions) tax or a cap-and-trade programme:

- With a **carbon tax**, the government sets the tax rate for each tonne of greenhouse gas emitted and specifies the sources of emissions subject to the tax.
- A **cap-and-trade**, or **emissions trading system** is a quota-based system. The government sets a cap, or limit, on the maximum level of emissions for a given time period and distributes permits or allowances for each unit of greenhouse gas among firms that produce emissions. Some firms find it easier or cheaper to reduce emissions than others and can thus sell allowance to firms for whom the cost for reducing emissions is much higher. Therefore, emissions trading takes place between high-cost and low-cost emitters. As the cap declines over time, the cap-and-trade system has the capacity in principle to phase out emitters based on relative costs.

Apart from economic efficiencies, advocates for carbon price policies also focused on the fact that it officially defines sources of emissions and attributes them to a limited number of emitters. For example, the emissions due to combustion of fossil fuels can be regulated based on the carbon content of each fuel as it enters the jurisdiction's economy rather than at the point of combustion. That reduces the number of entities covered by the tax or cap-and-trade drastically.

A key factor determining the application of a carbon tax versus a cap-and-trade scheme is the desired outcome. Do policymakers want to target a specific emissions price? Or do they want to target total emissions levels? If policymakers prefer more certainty on the future emissions price, then carbon tax may be the relevant policy instrument. Whereas if policymakers prefer certainty on future *emission levels*, cap-and-trade may be more relevant.

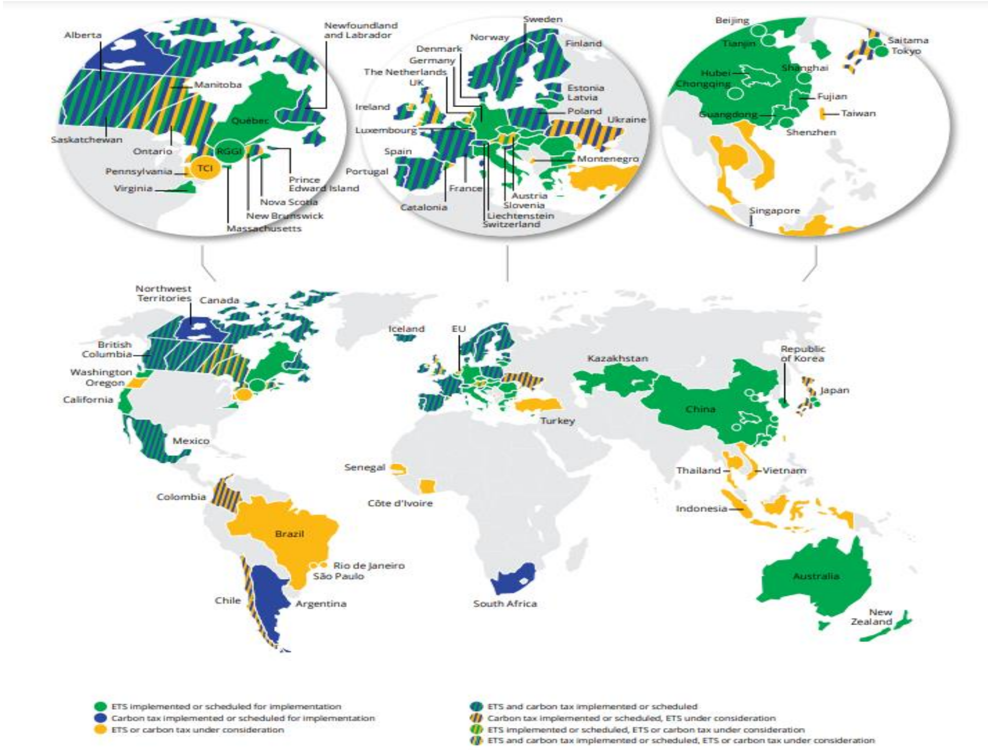
The World Bank has been monitoring which countries apply carbon pricing and the methodologies used, as reported on its carbon pricing dashboard[20]. In the latest report on carbon pricing[21], there are 68 carbon pricing initiatives operating with three more scheduled for implementation – including 34 cap-and-trade programmes and 37 carbon taxes – covering approximately 23% of total global GHG emissions. Figure 2 shows an extract.

It is interesting to note that most jurisdictions have both carbon tax and cap-and-trade, but these often cover different emission sources. Despite this, there are still close to 80% of global GHG emissions not covered by regulated carbon pricing today, representing a significant gap

[20] World Bank Carbon Pricing Dashboard
[21] World Bank State and Trends of Carbon Pricing, April 2022

in the extent to which companies are required to be 'responsible' for their cost of polluting. Such gaps in global coverage of emissions schemes have made it harder to realize the outcomes consistent with the Paris agreement at an institutional level.

Figure 2 – Map of carbon pricing initiatives implemented, scheduled for implementation and under consideration (Cap-and-trade and carbon tax)



Box 3: Understanding the Border Carbon Adjustments (BCA)

BCA is viewed as a key carbon budget design feature to limit freeriding in the path to establish a global common carbon price. Without coordinated global action, a carbon tax imposed in a subset of countries ("Climate Club") may lead to a loss of competitiveness their economies. It could also drive a relocation of carbon intensive activities to countries with less stringent emission policies, rendering the policy instrument largely ineffectual in terms of reducing global carbon emission (McKibbin et al, 2018). To restore pre-tax levels of competitiveness and reduce the risks of carbon leakage, the Climate Club may introduce BCA, in the form of an import tax on goods and services from countries with less-stringent emissions standards. The European Union's Carbon Border Adjustment Mechanism (CBAM) is an example of this type of policy (European Commission, 2022)

Cap-and-trade can be a powerful policy tool to control emission levels over time. However, its effectiveness is only improved by increasing the share of total GHG emissions covered by the cap-and-trade programs. Coverage can also be enhanced by encouraging interoperability between programs. At present, the cap-and-trade systems are very fragmented and vary a lot in terms of ambition levels. If systems with significantly different allowance limits and emission reduction plans link, the risk of goals dilution rises. However, fragmentation raises the risk of carbon leakage, i.e. the shifting of high-emissions production activities outside of a cap-and-trade to areas with a lower carbon price or less-stringent emissions regulations.

Price levels also need to increase substantially to capture true cost of emissions, from the current global average of <\$5/tCO_2 to an estimated \$50–150/tCO_2 average by 2030. Conservative estimates suggest a need to scale cap-and-trade systems from ~\$170 bn today to $1tn+ in absolute size before 2030 to achieve the 1.5°C ambition[22].

Additionally, putting a price on carbon is also a first move to recognizing the finite nature of fossil fuels and the cost of natural capital. Oil in particular has many uses in the economy beyond energy production and carbon pricing can be used to recognize that burning oil for energy accelerates depletion of a resource that may have greater utility elsewhere. Carbon pricing can also allow more fully for the social costs to cover damages caused by using those resources on the surrounding ecosystems, i.e. clean water, clean air, biodiversity etc.

Whatever gets measured gets done. The more we have a common global currency to measure carbon (or even natural capital), the clearer financing incentives for companies to invest in transitions.

3.2.2 Other Incentive-based policies to reduce GHG emissions

Apart from carbon prices, there are other policy tools that also serve to incentivizing the path to net-zero, such as regulations and subsidies.

Since a fully decarbonised electricity sector is the essential foundation of a net zero energy system, many policies has been focusing on driving transitions in this sector to renewable energies. Figure 3 below[23] provides a summary of six most common models for government policy to drive decarbonisation in this sector, combining them into the categories of emissions pricing, intensity standards, and subsidising zero-carbon generation.

Figure 3: Description of policy options (Energy Policy Institute at the University of Chicago)[24]

Policy	Description	Example
Carbon pricing		
Carbon tax	Imposes a constant $/tonne tax on all GHG emissions	British Columbia carbon tax
Cap-and-trade	Imposes a cap on total GHG emissions, and firms trade compliance permits	EU ETS, Western Climate Initiative, RGGI
Intensity standards		
Emissions intensity standard	Imposes a constraint on the overall emissions intensity in GHG tonnes per MWh	Elements of the 2015 Clean Power Plan
Clean energy standard (CES)	Imposes a minimum share of MWh generated that must come from "clean" sources	U.S. state-level renewable portfolio standards
Subsidizing clean energy		
Zero-emissions energy subsidies	Provides a $/MWh production subsidy to "clean" generation	U.S. wind production tax credit
Zero-emissions capital subsidies	Provides a $/MW capital subsidy to new investments in "clean" energy	U.S. wind and solar investment tax credits

Intensity standards focus on the average level of emissions per unit of power generation, rather than the absolute level of emissions. The two primary approaches under intensity standards are Emission Intensity Standard (EIS) and Clean Energy Standard (CES). The two mainly differ in the way "clean" is measured. EIS does not specify what is "clean" energy, hence it will benefit any power sources with lower-than-average carbon intensities, including

[22] https://www.gfma.org/wp-content/uploads/2021/10/unlocking-the-potential-of-carbon-markets-to-achieve-global-net-zero-full-report-consolidated-vfinal1.pdf
[23] https://epic.uchicago.edu/wp-content/uploads/2022/07/BFI_WP_2022-96.pdf
[24] Note that different researchers may categorise these tools differently

those controversial sources of zero emissions, such as nuclear power. On the other side, CES does not differentiate between “dirty” sources (e.g., between coal-fired and gas-fired generators) and benefits only sources deemed “clean” under law.

Similar to CES, subsidising zero-carbon generation recognizes benefits for clean power generation but imposes no direct penalties on other sources. Such subsidies are often implemented in two forms of tax credit: production tax credit – subsidising corporate tax credits based on production of electricity from a specific technology, e.g., wind; and investment tax credit – subsidising corporate tax credits during the process of creating the capacity for power generation, e.g., often see for solar power.

Although the market mechanism to implement these three policy types are different, all these policies serve the similar role of giving signals to utilities and investors and boosting market confidence.

Apart from clean energy generation, there are other areas in need of policy support for planning and signposting, such are CCUS (e.g., tax credit, tradable certificates and provisions), network infrastructure (including smart transmission and distribution grids), Electric Vehicles (e.g., purchase subsidies, tailpipe CO2 standards, accessibility of EV charging infrastructure etc.); and building retrofitting (e.g. energy codes)[25].

It is important for the financial industry to work with policymakers to identify and articulate incentives and promote a public-private partnership that would enable to scale investment in such areas.

3.3. Application of the Carbon Budget for Financial Institutions

The carbon budget represents a constraint under which the real economy needs to operate.

The real world impact of Financial Institutions (FIs) tends to be mostly indirect and relates to the emissions of the entities or individuals they provide financing to (via investments, loans and underwriting etc.). These “financed emissions” are indeed much larger than the emissions relating to FIs’ direct operations.

At an individual level, the financed emissions of a given FI would typically span across geographies and across sectors, each of which can be allocated a share of the carbon budget going forward.

The allocation of the carbon budget to countries and industries provides a frame of reference for FIs to understand how their financing activity needs to evolve over time. It can inform the setting of emission targets and of credible transition plans.

And the carbon budget provides as a canvas for FIs to think about how climate change may unfold and impact their own financial position, using scenario analysis.

3.3.1 Target setting and credible transition planning

Sectoral pathways can be used to assist companies and financial institutions in setting decarbonisation targets, feeding into net-zero transition planning and disclosures.

Institutions can assess a set of sectoral decarbonisation pathways that align with a desired carbon budget or temperature outcome, and in doing so determine their decarbonisation requirements, based on the sector and geographical location of their operations and (for financial institutions) the size of their financial exposures.

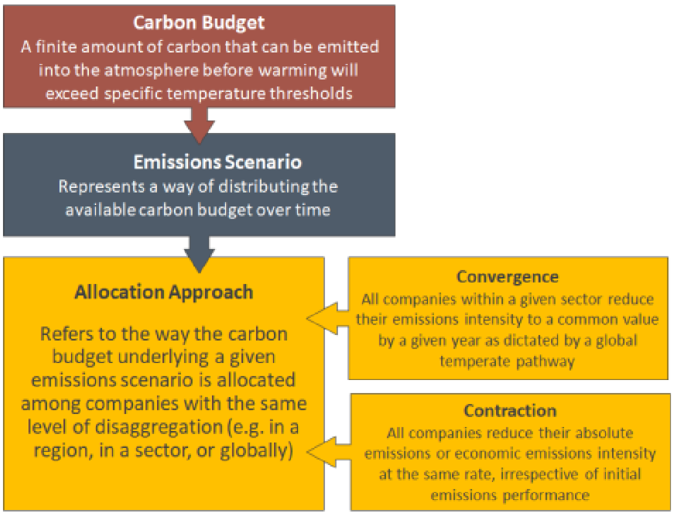
One initiative providing guidance on setting decarbonisation targets is the Science-based

[25] Refer to CFRF Mobilising Investment into Climate Solutions Report – Annex 1 ‘CCUS’, Annex 2 ‘EV infrastructure’ and Annex 3 ‘Retrofitting CRE’ (2022) for further insights on this technology

Targets Initiative (SBTi),[26] which is providing guidance for corporates and financial institutions on target setting, and verification of these targets, and in doing so encouraging them to demonstrate credible progress in line with climate science. For FIs, it is important to understand the transition plan (including emission reduction targets) set by the corporates they are financing to as well as understand the target setting guidance for their own financed emission. Box 4 below summarizes the SBTi's guidance on how to set targets for the corporates in general. For guidance specific to the financial industry, SBTi refer to PCAF's (Partnership for Carbon Accounting Financials) as a freely available approach to measure emissions related to financing activities[27].

Box 4: SBT method[28] for corporates to set targets based on scope 1 and 2 emissions[29] - comprises of three components:

1) A carbon budget;
2) An emissions scenario pathway (such as a pathway from the IEA sectoral pathway family described in Section 3.1.2);
3) An allocation approach, to allocate the remaining carbon budget to a company operating across various sectors or regions.



For individual companies setting targets, the primary focus is on sectoral pathways, which provide more relevant information such as required emissions reduction rates over time and allow a company to evaluate any key policy and technology constraints to achieving these. In terms of the allocation of emissions and required pathway of emissions reductions, there are three methods set out by SBTi: "absolute emissions contraction" (to set absolute targets), the "Sectoral Decarbonisation Approach" (SDA, to set physical intensity targets) and "Greenhouse Gas Emissions per Value Added" (GEVA, to set economic intensity targets)[30].

At this stage, many financial institutions are aligning with SBTi's Target Setting Protocol guidelines and referring to IEA or NGFS sectoral pathways as emission scenarios against which to assess the carbon footprint from their own physical operations (their scope 1 and 2 emissions) as well as their counterparties' and portfolios' alignment (scope 3 financed emissions) with a given global carbon budget or temperature outcome. A recent OECD report provides a summary of various methodologies used to assess the consistency of financial

[26] SBTi - Since its launch in 2015, there has been a significant surge in the number of companies committing to ambitious climate actions, especially in recent year. In 2021, the number of SBTi companies doubled to 2,253, including 1,082 companies with approved targets and 1,171 that committed to set science-based targets. These figures include 117 financial institutions that have made the commitment.
[27] SBTi Financial Sector Science-Based Target Guidance (Aug 2022): https://sciencebasedtargets.org/resources/files/Financial-Sector-Science-Based-Targets-Guidance.pdf
[28] This section is prepared based on SBTi Corporate Manual issued in Dec 2021.
[29] For those sectors, such as automotive, where certain scope 3 categories can be important in terms of emission magnitude, companies can apply similar allocation approaches on one or more scope 3 categories.
[30] GEVA allocation methodology is considered less robust and thus applicable for Scope 3 target-setting only.

institutions' portfolio alignment against their decarbonisation goals.

The focus of transition plan guidance is evolving in response to concerns around "paper decarbonisation", which relies on divestment policies that shift responsibility for, but do not reduce, emissions in the economy.[31]

For example, recent transition planning guidance from the Transition Plan Taskforce (TPT)[32] encourages financial institutions and corporates to take a 'strategic and rounded' approach to contribute to an early and orderly economy-wide transition – an approach that is inclusive of, and goes beyond, entity-level decarbonisation targets. It allows for a financial institution to consider other climate actions it can take to contribute to an economy-wide transition and provides space in its transition plan disclosure to outline potential trade-offs. For example, a core focus of an FIs transition strategy may be to support a company that is critical for the economy's transition to net zero but is a high-carbon asset (e.g., a copper or lithium mining company); this may not lead to a material reduction in the FI's GHG emissions in the short-term, but they will be materially contributing to the economy-wide transition.

The four financing strategies recommended by Glasgow Financial Alliance for Net Zero (GFANZ) offer guidance for FIs to prepare their own transition to support economy-wide decarbonisation, by financing: 1) climate solutions; 2) companies already aligned to net zero; 3) the transition of companies committed to aligning; and 4) the managed phase-out of high-emitting physical assets. A key element of a credible transition plan is having quantified and timebound metrics and targets that support the objectives and actionable steps of the plan.

Lastly, while target setting is generally informed by sectoral pathways, the TPT's guidance states that transition plans should be informed by national commitments as defined by countries' NDCs. For entities in the UK, this means that a transition plan should explain how the entity has taken into account the UK's legal commitment to reducing GHG by at least 100% of 1990 levels (net zero) by 2050 and the interim targets defined in the Sixth Carbon Budget. This reinforces the need to consider both national and sectoral decompositions of the carbon budget when undertaking target setting and transition planning.

3.3.2 What if we over-spend the global carbon budget? The importance of Climate Scenario Analysis

Climate scenario analysis extends the focus from one carbon budget and set of sectoral decarbonisation pathways to considering the risks and opportunities faced in multiple future states - or "scenarios" – that the firm could plausibly face.

As discussed earlier, the remaining carbon budget is depleting quickly. Even if we do achieve a transition to net zero as committed, the timing of policy action and technological advances to get there is inherently uncertain, as is the extent to which we may wish to rely on one sector more than the other. The timing of such developments will significantly impact the distribution of the remaining carbon budget over the coming years, which will have knock-on requirements for companies and financial institutions on their transition journey. These alternative futures will also result in different levels of climate transition risk (i.e. risks associated with the process of adjustment towards a low-carbon economy) and physical risks (i.e. arising from climate and weather-related events directly resulting from an increase in global warming).

Climate scenario analysis provides an approach to tackling this uncertainty. Financial institutions can use climate scenarios to assess the impact of physical and transition risks on their financing planning, balance sheet valuations and impairment expectations. The CFRF Scenario Analysis Working Group is aimed to provide guidance for financial institutions to identify use cases of climate scenario analysis, interpret the common climate scenarios developed by Central Banks and NGFS and leverage scenario analysis to understand their climate risk profile and to aid portfolio construction. Financial practitioners are encouraged to refer to their work for further details.

[31] 'Balancing on the net-zero tightrope' – Sarah Breeden's speech about the unintended consequences of paper decarbonisation

[32] TPT builds on existing Taskforce on Climate-related Financial Disclosures (TCFD) Guidance on Metrics, Targets and Transition Plans, as well as the International Sustainability Standards Board's (ISSB) Exposure Draft of IFRS S2 Climate-related Disclosures

4 Concluding remarks

The carbon budget has important implications for financial institutions.

As practitioners, we have started to measure our financed emissions, provide financing for climate solutions and manage the consequence of climate change on our risk profiles.

The discussions in this paper point to a number of priority areas for future work:

- Continue to collaborate with global initiatives and international standards setter to overcome the GHG data limitation and develop consistent methodology to measure financed emissions;
- Support the development in setting industry standard of assessing the credibility of transition plans to focus on companies' efforts in reducing their emissions;
- Enhance direct engagement with our clients to influence and support their business model changes to drive real-world emissions reduction;
- Incorporate carbon budget allocation into investment decisions and financing strategies, including financing climate solutions;
- Develop scenario analysis tools to understand the impact of not aligning with carbon budget on capital, portfolio and individual deal level; and
- Encourage public-private collaborations to promote incentive-based policies, including carbon price and other regulations, to support the transition at scale.