

Chapter 2

Science-Based Industry Greenhouse Gas (GHG) Targets: Defining the Challenge



Sven Teske and Thomas Pregger

Abstract Background information is given on the Paris Climate Agreement and the role of nationally determined contributions and net-zero pledges. An overview of historical energy-related CO₂ emissions since 1750 and how they relate to economic development, measured in gross domestic product (GDP), is provided, together with the cumulative energy-related CO₂ emissions by region. The future energy demand if historical trends in energy efficiency and carbon intensity continue until 2050 is projected. The term ‘science-based target setting’ is defined, and how it relates to the carbon budget published in the Sixth Assessment Report of the IPCC is discussed. The energy-related CO₂ emission pathway required to achieve the 1.5 °C target is outlined.

Keywords Science-based GHG targets · GHG development · GDP · Population · Nationally determined contributions (NDCs)

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Paris Agreement—Article 2

1. *This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:*
 - (a) *Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change;*
 - (b) *Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and*
 - (c) *Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.*
2. *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.*

To understand the challenges involved in implementing the Paris Climate Agreement, it is helpful to look at historic trends in the world's population, its economic growth, its increasing energy demand, and—as a result of the energy sources chosen—the trajectory of energy-related CO₂ emissions. CO₂ concentrations are increasing in the global atmosphere, causing global warming (IPCC, 2021). The Paris Climate Agreement Goal is to limit this temperature increase to 1.5 °C above pre-industrial levels. In 2021, a new scientific report defined the remaining global carbon budget.

2.1 The Sixth Assessment Report of the IPCC: Climate Change Is Here

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations (UN) body that assesses the science related to climate change. In August 2021, it launched the Working Group I contribution to its Sixth Assessment Report (AR6) *Climate Change 2021: The Physical Science Basis*. The IPCC concluded that the emission of GHGs from human activities is responsible for approximately 1.1 °C of warming that has occurred since 1850–1900. Based on the improved observational datasets that are used to assess historical warming and the progress in scientific understanding of the climate system's response to anthropogenic GHG emissions, the IPCC expects that the increase in the global temperature will reach or exceed 1.5 °C (IPCC, 2021) (Table 2.1).

Table 2.1 Assumed population and GDP developments by region in 2020–2050

		Units	2019	2025	2030	2040	2050
OECD North America	Population	[Million]	499	524	543	575	599
	GDP	[Billion \$]	24,255	27,650	30,513	37,562	45,788
Latin America	Population	[Million]	526	552	571	599	616
	GDP	[Billion \$]	7415	8807	10,141	13,761	18,675
OECD Europe	Population	[Million]	579	587	592	598	598
	GDP	[Billion \$]	23,433	26,076	28,269	32,807	36,963
Africa	Population	[Million]	1321	1522	1704	2100	2528
	GDP	[Billion \$]	6865	9247	11,376	17,498	26,403
Middle East	Population	[Million]	250	276	295	331	363
	GDP	[Billion \$]	6120	7230	8857	12,112	17,587
Eurasia	Population	[Million]	346	347	346	343	339
	GDP	[Billion \$]	6685	7919	9081	11,853	15,025
Non-OECD Asia	Population	[Million]	1189	1269	1329	1428	1499
	GDP	[Billion \$]	11,101	14,577	17,794	25,876	34,234
India	Population	[Million]	1368	1452	1513	1605	1659
	GDP	[Billion \$]	10,816	17,084	22,652	37,966	54,074
China	Population	[Million]	1427	1447	1450	1426	1374
	GDP	[Billion \$]	26,889	37,997	47,427	64,986	84,825
OECD Pacific	Population	[Million]	208	208	208	204	198
	GDP	[Billion \$]	8761	9644	10,407	11,842	13,081
Global	Population	[Million]	7713	8185	8551	9210	9772
	GDP	[Billion \$]	132,339	166,230	196,516	266,263	346,656

The IPCC also identified the global carbon budget required to avoid exceeding 1.5 °C. Between 2020 and 2050, the global cumulative CO₂ emissions must not surpass 400 GtCO₂ if we are achieving this target with 67% likelihood. This likelihood decreases to 50% if total emissions reach 500 GtCO₂ (Table 2.2) between 2020 and 2050 (IPCC, 2021).

The IPCC media statement was unusually clear and unambiguous for a high-level scientific organization:

Stabilising the climate will require strong, rapid, and sustained reductions in greenhouse gas emissions, and reaching net zero CO₂ emissions. Limiting other greenhouse gases and air pollutants, especially methane, could have benefits both for health and the climate...
IPCC media release, Geneva 9 August 2021

2.2 The OneEarth Climate Model: The Context

The UN-convened *Net-Zero Asset Owner Alliance* is a *Program for Responsible Investment* and a United Nations Environment Programme Finance Initiative (UNEP FI)-supported initiative. The members of the Alliance have committed to transitioning their investment portfolios to net-zero GHG emissions by 2050, consistent with

Table 2.2 Estimates of remaining carbon budgets and their uncertainties—IPCC AR6, WG1, Technical Summary

Global surface temperature change: 2010–2019	Global surface temperature change: 1850–1900 ^{a(1)}	<i>Estimated remaining carbon budgets</i> —starting from 1 January 2020 and subject to variations and uncertainties quantified in the columns on the right				
°C	°C	Percentiles of TCRE ^{b(2)}				
		GtCO ₂				
		17th	33rd	50th	67th	83rd
0.43	1.5	900	650	500	400	300
0.53	1.6	1200	850	650	550	400
0.63	1.7	1450	1050	850	700	550
0.73	1.8	1750	1250	1000	850	650
0.83	1.9	2000	1450	1200	1000	800
0.93	2	2300	1700	1350	1150	900

Source: IPCC AR6, WG1, Technical Summary, Table TS.3, page 150

^{a(1)} Human-induced global surface temperature increases in 1850–1900 and 2010–2019 are assessed to be 0.8–1.3 °C, with a best estimate of 1.07 °C. Combined with a central estimate of the transient climate response to cumulative carbon emissions (TCRE) of 1.65 °C EgC-1, this uncertainty in isolation results in a potential variation in the remaining carbon budgets of ±550 GtCO₂. However, this is not independent of the assessed uncertainty of TCRE and is thus not fully additional

^{b(2)} TCRE: transient climate response to cumulative emissions of CO₂, assessed to probably be 1.0–2.3 °C EgC-1, with a normal distribution, from which the percentiles are taken

a maximum global temperature rise of 1.5 °C above pre-industrial levels. This requires intermediate targets to be established for 5-year intervals and regular reporting on progress.

The Alliance commissioned the Institute for Sustainable Futures (ISF) at the University of Technology Sydney (UTS) to utilize its pre-existing OneEarth Climate Model (Teske et al., 2019) to derive 1.5 °C decarbonization pathways for key high-emitting sectors, on a global level, to achieve net-zero emissions by 2050, and to inform the development of sector-based targets for decarbonization. This book presents the results of that research, undertaken between late 2019 and December 2021. We hope it will clarify investor expectations for decarbonization strategies for the sectors in which they invest.

2.2.1 Development of GHG Emissions: A Look Back

The global economy must decarbonize the energy system entirely within the next 30 years—in one generation. In historical terms, this means breaking the connection between population growth, steady economic development fuelled by fossil energy, and the increase in CO₂ emissions of the past 120 years and reversing those trends within the next 5 years. Between 2025 and 2030, global energy-related CO₂ must peak and start to decline to zero by 2050.

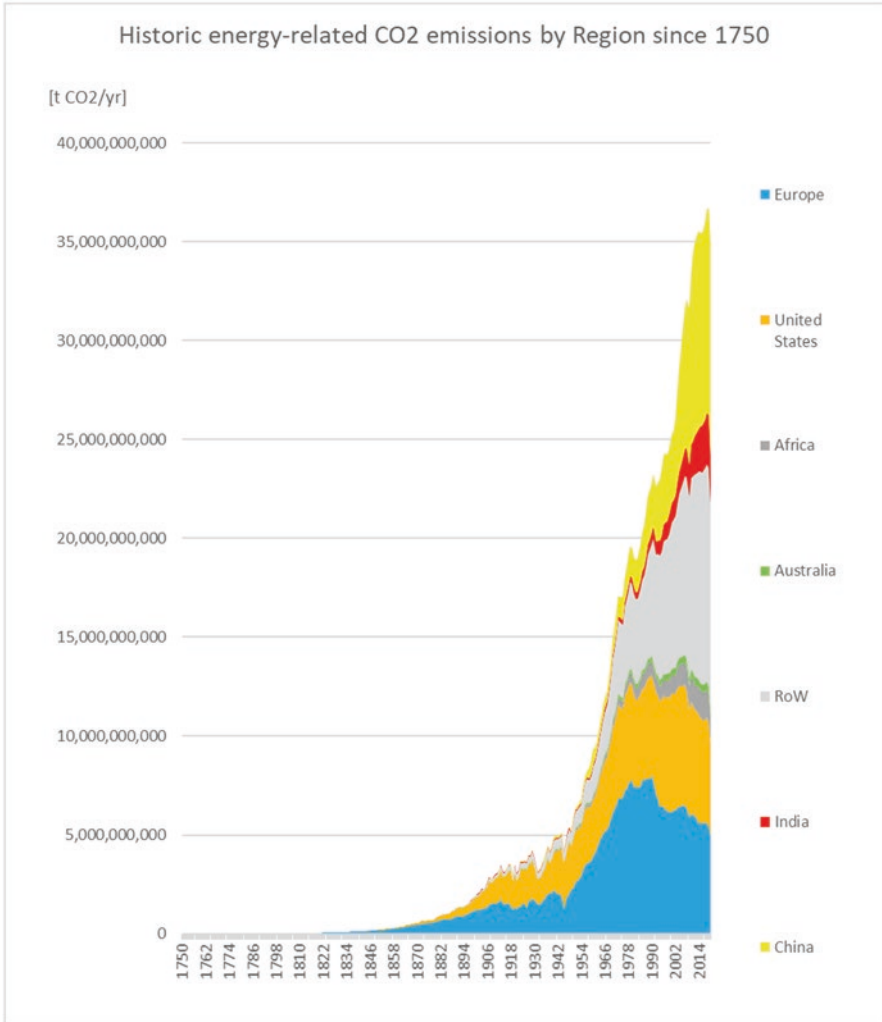


Fig. 2.1 Development of global energy-related CO₂ emissions by region in 1750–2020 (Ritchie & Roser, 2020)

Figure 2.1 shows the development of the annual energy-related CO₂ emissions between 1750 and 2020 based on data from the *Global Carbon Project* of the *Integrated Carbon Observation System* (Global Carbon Project, 2021). Global annual CO₂ emissions rose from 2 Gt in 1900 to 4 Gt 1935, to 6 Gt in 1950, and to 12 GtCO₂ in 1966. By 1966, global emissions had reached 24 GtCO₂—and only 10 years later, emissions increased by another 10 Gt. Since 2012, the increase in emissions has at least slowed, and in 2020, emissions were around 35 GtCO₂.

A closer look into regional emissions shows that Europe was responsible for 43% of all historic CO₂ emissions between 1750 and 1990, followed by the USA

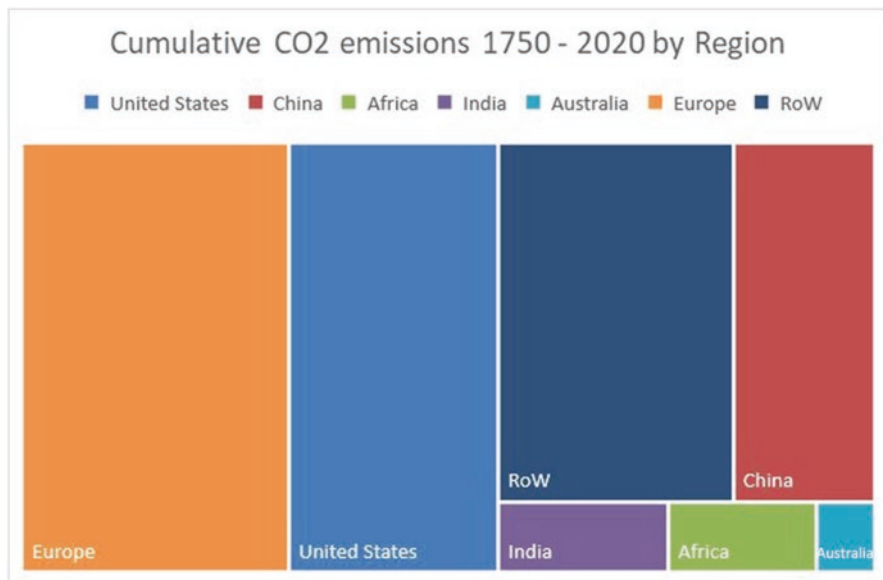


Fig. 2.2 Cumulative global energy-related CO₂ emissions by region in 1750–2020 (Ritchie & Roser, 2020)

with 31%, whereas China emitted 5%, Africa 2%, and India only 1%. However, the regional distribution changed dramatically after 1990, with China’s double-digit economic growth over the past decades: China and Europe both contributed 21%, followed by the USA with 19%, India 5%, and Africa 4%. Figure 2.2 shows the cumulative CO₂ emissions by region between 1750 and 2020, based on data from Integrated Carbon Observation Systems (ICOS 2021). According to these data, Europe emitted 31% of all cumulative CO₂, followed by the USA (25%) and China (14%). The remaining 30% was distributed across all other regions and countries outside those three main economic hubs (the USA, Europe, and China).

2.2.2 Global Economic Development: A Look Back

On average, global economic development has steadily increased. Based on the World Bank data (World Bank, 2020), the global median GDP growth between 1970 and 2015 was 3.5%, although with significant regional differences. In 1966, the total global output of the world economy increased by over US\$20 trillion and then doubled within 20 years to \$40 trillion by 1986. Thirty years later—in 2006—this value surpassed \$80 trillion (Fig. 2.3). In 2020, the global GDP reached \$132 trillion. For this analysis, we follow the World Bank projection—which was also used for the World Energy Outlook 2017 and was the basis for the first OECM book published in 2019 (Teske et al., 2019) (Table 2.2).

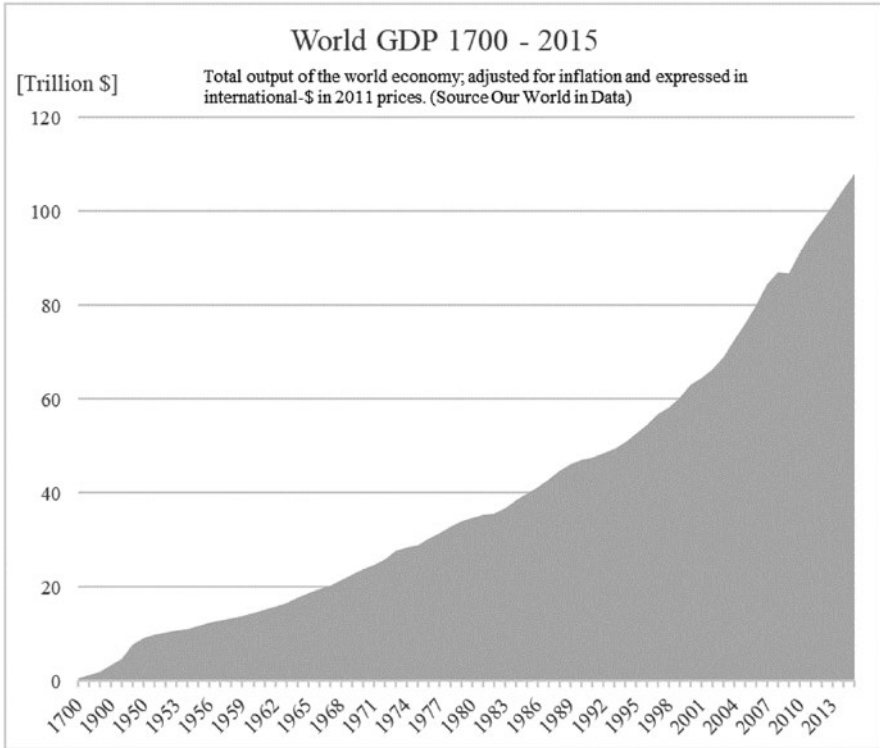


Fig. 2.3 Global GDP development in 1700–2015 (Ritchie & Roser, 2020)

2.2.3 *Socio-economic Assumptions for the OECM 1.5 °C Scenario*

The assumed development of regional populations is based on the projections of the United Nations Department of Economic and Social Affairs (UN DESA, 2019), whereas the regional GDP developments are based on World Bank projections. The global values for population and GDP are identical throughout the entire analysis, across all sectors. Regional values are used for the buildings and transport sectors, whereas for all other sectors, the resulting (summed) global values are used.

2.2.4 *Outlining the Task: Trend Reversals Until 2025*

The first step in the development of sectorial 1.5 °C pathways is to decide on the basic drivers of the future energy demand: population growth and economic development. To ensure that the OECM is transparent and comparable with other

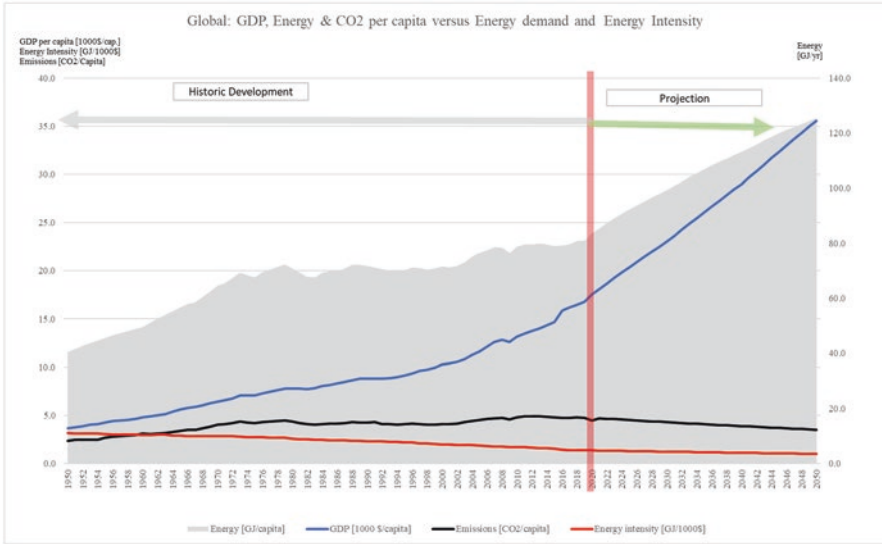


Fig. 2.4 Projection of global energy demand under the assumption that historic efficiency trends continue until 2050

scenarios, established projections of the UN and the World Bank were used. The OECM focuses on the development of energy-relevant parameters.

Figure 2.4 shows the global development of GDP per capita since 1950 and the projections from 2020 to 2050. Economic energy intensity is the average amount of energy units required for each dollar of economic value. In 1950, the energy intensity was around 11 GJ per US\$1000 GDP, on a global average. This value includes electricity and fuel demands, e.g. for heating and transport. Energy intensity decreased over time, which indicated the successful implementation of efficiency measures. Different economic sectors have very different energy intensities. A highly industrialized country with large manufacturing capacities, e.g. for steel production, has a significantly higher energy intensity than a service-based economy that is focused on tourism, for example. Therefore, a low energy intensity is not necessarily a sign of a very efficient economy, but could indicate an economy that is largely based on agriculture. However, on a global average, energy intensity is an important parameter reflecting advances in efficiency.

Between 1950 and 2020, the global energy intensity decreased by 1.2% annually, leading to an energy intensity of 4.8 GJ per US\$1000 GDP—about half the value in 1950. The projection of the energy demand shown in Fig. 2.4 was calculated under the assumption that the energy intensity will continue to decrease at 1% per year, while GDP continues to grow by 3.5%, on average, between 2020 and 2050.

The third relevant parameter is the average energy demand per capita, which is simply the overall primary energy demand divided by the population. The per capita energy demand doubled from 40.5 GJ per year in 1950 to around 80 GJ per year in

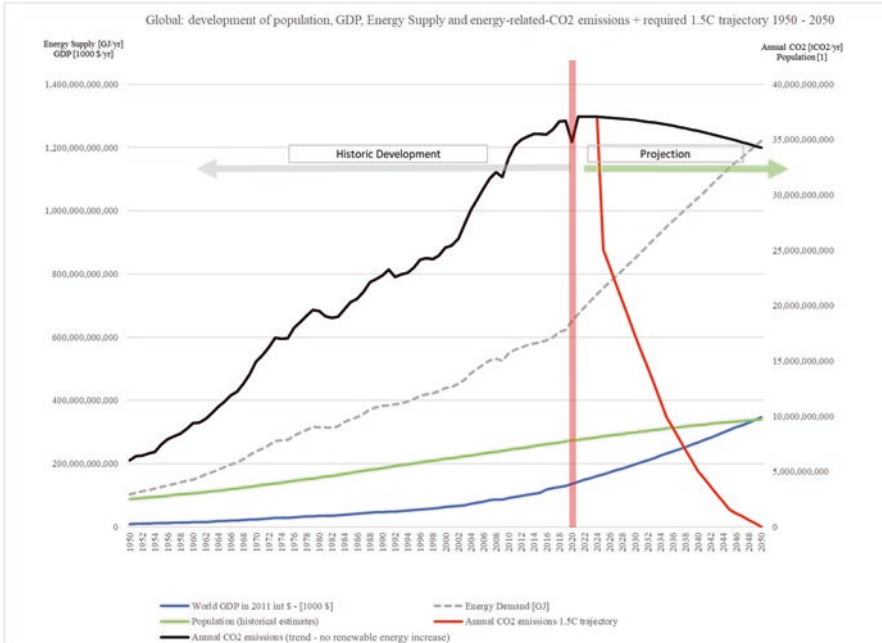


Fig. 2.5 Global development of key parameters

2020. With the assumed increase in economic energy intensity and the overall economic development, the per capita energy use should increase again by over 50% to 125 GJ per year in 2050. Finally, the emission intensity, or the average amount of energy-related CO₂ emissions per capita, results from the energy demand and the energy source selected. If coal is used to supply the entire energy demand, GHG emissions will steadily increase, whereas a supply of renewable energy will lead to a decarbonized economy.

Figure 2.5 shows the historic development of the global population, GDP, energy demand, and the resulting annual CO₂ emissions between 1950 and 2020 on the left side and the projected trend development until 2050 on the right side. Based on the projected population and economic growth until 2050 and under an assumed annual decline of 1% in both energy and emission intensities, the global energy demand will double, whereas CO₂ emissions will remain at around current levels.

The OECM does not question the development of the population or the global economy projected by international organizations, but focuses on technical measures to increase energy efficiencies and decarbonize the energy supply by a transition to renewable energies to achieve the 1.5 °C decarbonization trajectory (marked with the red line). This will require a bottom-up assessment of the energy demand combined with an alternative energy supply concept for power, heating, and transport, which are documented in the following chapters of this book.

2.3 Science-Based Target Setting

Science-based target setting has been discussed widely at the *United Nations Framework Convention on Climate Change* (UNFCCC) Climate Conferences and among stakeholders from industry, non-governmental organizations, and government departments. Although there is no official definition of ‘science-based target setting’, it basically means that global, regional, and sectorial carbon emission targets are set to achieve the goals of the Paris Climate Agreement based on the latest available scientific knowledge. Therefore, the overall target is to limit the global mean temperature rise to +1.5 °C with high probability.

The latest available scientific information is IPCC’s Sixth Assessment Report *Climate Change 2021: The Physical Science Basis* (Sect. 2.1). Table 2.2 shows the estimates of the remaining carbon budgets and their uncertainties published in the Technical Summary (IPCC, 2021). According to the IPCC definition, 67% likelihood is ‘good’, whereas 50% likelihood is ‘fair’.

The OECM aims to limit the global mean temperature rise to 1.5 °C with ‘good’ likelihood. Therefore, the ‘science-based target’ for the OECM 1.5 °C pathway in terms of the global carbon budget between 2020 and 2050 is set to 400 Gt CO₂.

The development of sectorial targets for the needs of specific countries or industries will ensure that the global sum of all energy-related CO₂ emissions for all countries or all industry sectors does not exceed the global budget. Therefore, any approach undertaken in isolation, such as for only a single industry sector, will involve the risk that one industry sector will claim a higher CO₂ budget and push the responsibility to reduce CO₂ emissions onto other sectors.

2.3.1 Science-Based Targets for the Finance Industry

Investment decisions for the decarbonization of investment portfolios are underpinned by highly complex considerations. In November 2020, the European Central Bank published a ‘Guide on climate-related and environmental risks’, which maps out a detailed process for ‘climate stress tests’ for investment portfolios. For the global finance industry to implement the Paris Climate Agreement, decarbonization targets and benchmarks for industry sectors are required.

The estimation of carbon budgets for specific industry sectors requires a holistic approach, and the interconnection of all sectors and regions must be considered. To estimate the carbon budget for a single industry sector in an isolated ‘silo approach’ based on current emission shares will inevitably lead to inaccurate results because this approach does not consider the possible technical developments in that sector or its interactions with other industry sectors. Therefore, the total of all sub-concepts for certain industries will exceed the actual CO₂ emitted, and/or the responsibilities for CO₂ reduction will be shifted to other areas.

2.3.2 *Nationally Determined Contributions (NDCs)*

The Paris Climate Agreement was adopted by 196 countries and regions (e.g. the European Union) in 2015 and came into force on 4 November 2016. It is a legally binding international treaty on climate change. Each signatory country must submit *nationally determined contributions* (NDCs). An NDC is basically a plan for a country that outlines specific measures that will be implemented to reduce GHG emissions. This usually includes an energy scenario but can also include targets for emissions related to land-use changes, such as in forestry and agriculture.

NDCs play a central role in the Paris Climate Agreement and are defined in Article 4, paragraphs 2, 3, and 4:

Paris Climate Agreement, Article 4 (UNFCCC, 2015)

§ 2. *Each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.*

§ 3. *Each Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.*

§ 4. *Developed country Parties should continue taking the lead by undertaking economy-wide absolute emission reduction targets. Developing country Parties should continue enhancing their mitigation efforts, and are encouraged to move over time towards economy-wide emission reduction or limitation targets in the light of different national circumstances.*

Nationally determined contributions must be submitted every 5 years. The first submission was in 2020, so the subsequent NDCs are required in 2025 and 2030. All NDCs are publicly available and collected at the 'NDC registry'. At the time of writing (December 2021), the modalities and procedures of the NDC registry were still under negotiation, and an interim NDC registry was in place.

All submitted NDCs are regularly analysed, and their targets are summarized in order to maintain an overview of the projected GHG emissions over the next 5-year period and to assess whether global emissions are on track to meet the 1.5 °C target. The estimated emissions are reported in CO₂ equivalents, in order to include all GHGs, not only energy-related CO₂ emissions.

There is a not-entirely-fixed template for NDCs, and each country structures its NDC differently. However, all NDCs are expected to cover the following five sectors:

1. Energy: Energy demand and supply scenarios and political measures for the country or region.
2. Industrial Processes and Product Use (IPPU): Projection of industry-related emissions, such as from the cement and steel industries and the planned development of feedstock for the chemical industry.

3. Agriculture: Emissions especially from land-use changes, including agriculture, forestry, and other land-use (AFOLU) emissions (see Chap. 11).
4. Land Use, Land-Use Change, and Forestry (LULUCF): This sector mainly focuses on activities that increase the removal of GHGs from the atmosphere or reduce emissions by halting the loss of carbon stocks.
5. Waste: Aims to reduce emissions, such as methane (CH₄), from water treatment plants, but also emission from food waste and other disposal substances.

NDCs should include not only CO₂ emissions but also CH₄, nitrous oxide (N₂O), and gases and aerosols that fall under the Montreal Protocol (see Chap. 11).

2.3.3 *Net-Zero Pledges*

To support the NDC process, the UNFCCC started the ‘Race to Zero’ campaign, with the aim of obtaining ‘net-zero pledges’ in the run-up to and during COP26 in November 2021. The target group for these pledges were industry sectors and/or industry companies, finance sectors, and/or finance institutions, but also countries, which would submit pledges in addition to NDCs. The campaign received significant positive feedback. An analysis by the International Energy Agency (IEA) in November 2021 concluded that all the pledges announced by 3 November 2021 will—under the assumption that they will be implemented by 2050—reduce annual global CO₂ emissions from around 35 Gt currently to just over 20 Gt. Although this is already a notable reduction, it will not limit the global temperature increase to 1.5 °C, but instead to around 2.0 °C (Biol, 2021).

According to the UNFCCC Race to Zero website (UNFCCC, 2021), the *net-zero pledge* consists of four steps (see Box 2.1):

Box 2.1: Race to Zero Criteria

1. Pledge: Pledge at the head-of-organization level to reach (net) zero in the 2040s or sooner, or by mid-century at the latest, in line with global efforts to limit warming to 1.5 °C.
2. Plan: In advance of COP26, explain what steps will be taken towards achieving net zero, especially in the short to medium term. Set an interim target to achieve in the next decade, which reflects a fair share of the 50% global reduction in CO₂ by 2030 identified in the IPCC Special Report on Global Warming of 1.5 °C.
3. Proceed: Take immediate action towards achieving net zero, consistent with delivering interim targets specified.
4. Publish: Commit to report progress at least annually, including via, to the extent possible, platforms that feed into the UNFCCC Global Climate Action Portal.

The OneEarth Climate Model aims to support the development of NDCs and Net-Zero Pledges. The following chapters document the detailed bottom-up assessment of the energy demand, the energy supply concept, and the changes in land-use required to achieve the Paris Agreement goals.

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