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Cutting Emissions, Securing Energy:

A Macroeconomic Assessment for COP30

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Prepared by Simon Black, Dora Benedek, Ian Parry, Nate Vernon and Sunalika Singh*

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ABSTRACT: Climate change poses significant macroeconomic challenges due to its impacts and the energy transition needed to address it. Despite the Paris Agreement's goal to keep global warming 'well below 2°C', and ideally to 1.5°C, the world is not on track. Temperatures are likely to pass 1.5°C this decade and would exceed 2°C by 2050, even if national targets are met. Limiting the 'overshoot' in peak temperatures by cutting global emissions of greenhouse gases would reduce climate risks. But current national emissions targets fall short, aiming for a 7 percent cut compared to the 30 to 45 percent needed by 2035. Using in-house models, we illustrate options and impacts of closing gaps to align emissions with temperature goals while minimizing climate risks. However, achieving these targets implies drastic changes in the energy system. Ensuring security of energy supply, which is critical for macroeconomic stability and growth, entails effective macroeconomic policies.

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WORKING PAPERS

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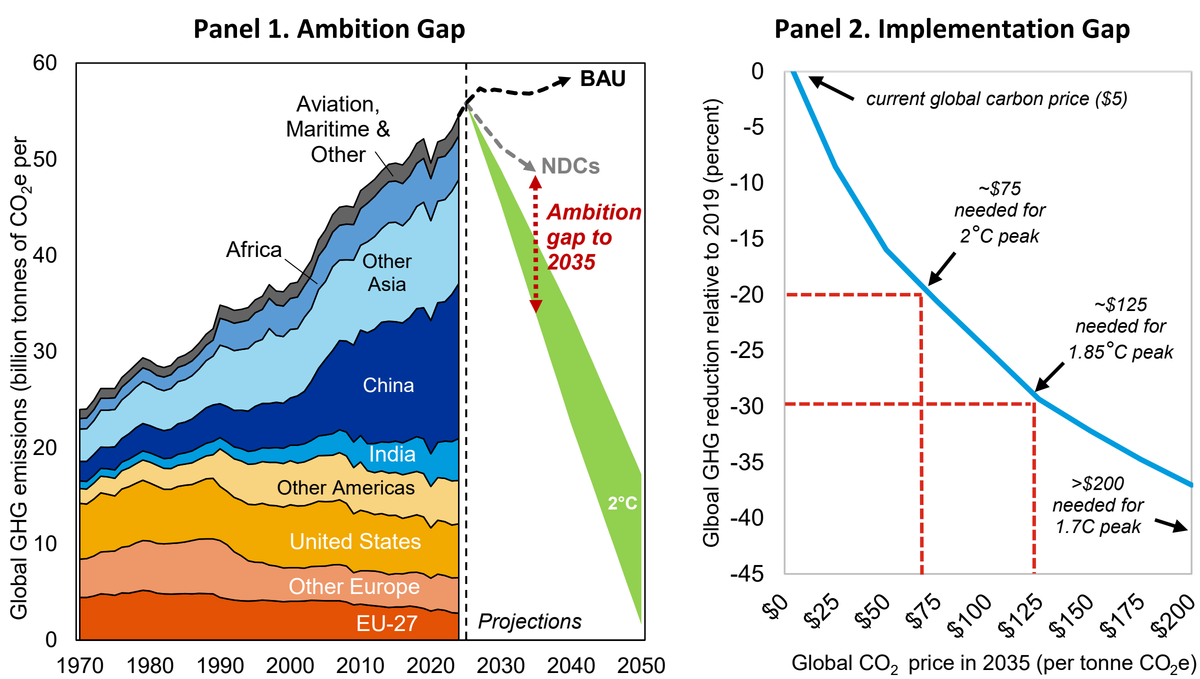
Contents

TABLES

Executive Summary

Climate change is macroeconomically critical due to both its impacts and the major structural adjustments required to address it (IMF 2021). For impacts, climate change is a systemic source of macroeconomic instability, simultaneously reducing potential output, straining fiscal and external balances, and complicating monetary and financial policy management. Through physical damages it amplifies volatility, weakens productivity, and heightens debt and balance-of-payments vulnerabilities (Mitra and others 2025). Climate change will also redistribute income across the globe, influencing trade patterns and exchange rate valuations. Exceeding 1.5°C warming could trigger multiple climate 'tipping points' with potentially disastrous macroeconomic implications (McKay and others 2022). For adjustments, achieving deep emissions cuts requires major structural changes, especially to economies' use of energy. Without effective macroeconomic policies, transition risks—the potential economic and financial disruptions triggered by decarbonization—could materialize. This includes asset stranding, fiscal stress, and inflationary pressures, creating potential trade-offs between price stability, growth, and financial stability. However, with effective macroeconomic policies, decarbonization holds the prospect of enhancing national energy security, improving energy efficiency, and yielding significant national welfare benefits (Parry and others, forthcoming). Lastly, climate mitigation is a global policy challenge falling under the IMF's mandate of multilateral surveillance, and hence it has an important role to play in assisting members by advising on policies and facilitating coordination.

Figure 1. Global GHG Emissions and Targets (in NDCs) and Temperature Goals (Panel 1) and the Global Mitigation Implementation Gap Expressed as a Carbon Price (Panel 2)



Sources: Intergovernmental Panel on Climate Change 2022; and IMF staff calculations using the IMF-World Bank Climate Policy Assessment Tool (CPAT). BAU = business as usual; CO_2e = carbon dioxide equivalent; GHG = greenhouse gas; NDC = nationally determined contribution. Note: Includes land use and land-use change emissions. In panel 1, NDCs shows the pathway global emissions would follow if country members of the Paris Agreement achieve their current 2030 and 2035 targets. Panel 2 shows the required global carbon price required to decrease GHG emissions versus 2019 and the current global average explicit carbon price.

With the signing of the Paris Agreement a decade ago, countries agreed to a common goal of limiting global temperature rise to 'well below' 2°C, ideally no more than 1.5°C, compared with preindustrial times. However, gaps in global climate ambition and implementation persist (Figure 1) and, as the United Nations Secretary-General just warned, passing 1.5°C is now inevitable.[1] Limiting global warming to well below 2°C requires cutting greenhouse gas (GHG) emissions by 30 to 45 percent by 2035 versus 2019 levels. Achieving this would entail major structural changes across economies, especially in energy. However, the world is not on track to achieving this goal. Even if current targets in 'nationally determined contributions' (NDCs) were achieved they would not achieve the Paris Agreement's temperature goals (Figure 1).

This Working Paper provides the following: (1) the authors' annual analysis of countries' climate mitigation ambition and fiscal policies supporting implementation; (2) illustrative options for aligning 2035 emissions targets with global temperature goals; and (3) analysis of the energy security implications of decarbonization. The Paper builds on earlier assessments (Black and others 2021, 2022a, 2023c, 2024)[2] by updating data sources, incorporating the latest set of NDCs (as of October 2025), updating illustrative options for getting global emissions on track, and discusses the ramifications of overshooting past the 1.5ºC long-term goal. The Paper uses the IMF-World Bank Climate Policy Assessment Tool (CPAT, see Annex I and Black and others 2023a), which is a model unique in allowing for comprehensive assessments of national climate mitigation targets and policies for over 180 countries.[3]

Key messages from the analysis include:

- **Despite recent updates to NDCs, the gap between current country ambition and the emissions goals implied by the Paris Agreement remains large (Figure 1).** Total global GHG emissions reductions of 30 or 45 percent below 2019 levels are needed by 2035 to be in line with limiting peak warming to 1.85ºC or 1.7ºC, respectively. But it is likely that updated pledges at COP30 will fall well short. Based on targets submitted so far, Paris Agreement members appear to be targeting just a 7 percent cut (Figure 1, Panel 1). In a business-as-usual (BAU) scenario, with no strengthening of mitigation policies, global emissions are projected to rise by 9 percent. Along with this ambition gap, there remains an implementation gap (Figure 1, Panel 2). Measures equivalent to a global average carbon price rising to $75 or $125 per tonne of CO_2e by 2035[4] would get GHG emissions on track to a peak of 1.85°C to 2°C (more for lower temperatures). But the current global average explicit carbon price is just $5 per tonne.

- **It is highly likely that global temperatures will 'overshoot' by rising above the 1.5°C target this decade, though in the long-term it could be temporary.** Every tenth of a degree beyond 1.5°C raises adaptation costs, climate risks, and hence macroeconomic risks. Overshooting does not mean '1.5 is dead' as it is a long-term goal which could still be achieved if temperatures return to that level by century's end. However, minimizing the magnitude and duration of overshoot entails: (i) reaching global 'net-zero' emissions as early as possible; (ii) thereafter, a long period of significant, costly, and uncertain negative global emissions, with ambiguous global distributional and macroeconomic implications.

- **Climate risks and adaptation costs depend on peak temperatures. However, the existing target under the Paris Agreement is ambiguous ("well below 2°C", ideally 1.5°C) which makes long-term**

[1] See https://www.theguardian.com/environment/2025/oct/28/change-course-now-humanity-has-missed-15c-climate-target-says-un-head
[2] See also UNEP (2024) and UNFCCC (2024) for similar findings on global mitigation ambition gaps.
[3] The model is available to government officials – see also www.imf.org/cpat for further information.
[4] All monetary figures are expressed in year 2024 US$.

economic planning difficult and hinders international climate negotiations to unlock further efforts. Seen through the lens of economics, Paris Agreements members' efforts to narrow the global climate ambition gap could be augmented by better specification and allocation of property rights. Having a commonly agreed global peak temperature goal would help identify the remaining global carbon budget (property rights specification). A global peak temperature target establishes a limit on how much can be emitted between now and when the world reaches net-zero global emissions. This would also clarify the global net-zero date—for example, assuming a linear emissions pathway, 1.7°C, 1.85°C, or 2.0°C would correspond to net-zero years of around 2045, 2055 and 2065, respectively.

- **Currently countries' climate objectives and policies are not consistent. Agreeing on 2035 targets (property rights allocation) while respecting countries' common but differentiated responsibilities could set the world on a path to limiting the peak in global temperatures**. Countries could raise ambition in their 2035 emissions targets cooperatively. We present scenarios for limiting global peak warming to 1.7°C, 1.85°C, or 2°C, providing illustrative emissions targets across countries and quantifying their macroeconomic impacts. Achieving such emissions targets requires effective macroeconomic policy packages though the costs appear manageable. For several developing countries national emissions reductions result in significant domestic welfare co-benefits, besides climate benefits.

- **Accelerating the adoption of domestic energy sources such as renewables can contribute to energy security, providing long-term macroeconomic benefits while cutting emissions.** Uninterrupted access to affordable energy remains a critical factor for economic stability and economic development. Sudden shocks to fossil fuel supply chains have driven price volatility leading to balance of payments crises, including debt crises, currency depreciation, and/or financial crises.

- **Electrification and decarbonization also offer significant improvements in terms of energy efficiency**. New technologies—such as electric vehicles, variable renewables and heat pumps—deliver energy services much more efficiently than conventional fuel combustion systems. This means that, due to improvements in conversion efficiency, the electrification of the economy requires much less primary energy than what is implied by current fossil-fuel based energy systems.

- **Overall, an accelerated decarbonization pathway aligned with peak warming at between 1.7°C to 2°C could enhance energy security, supporting countries' macroeconomic growth and stability.** But maximizing the benefits of decarbonization while minimizing risks requires optimal policy designs and, ideally, international coordination such as an international carbon price floor (ICPF; Parry and others 2021). Countries could benefit from putting in place a comprehensive strategy to promote both decarbonization and energy security jointly, especially storage and enhanced grid infrastructure. Grid stability will become a central issue as industrial, transport, and buildings sectors electrify, and demand rises to meet needs from artificial intelligence (AI; Bogmans and others 2025). Variable renewables (wind and solar) are intermittent and can be located far from population centers. So, beyond a comprehensive set of mitigation instruments, technology policies, and measures to assist vulnerable groups (see Parry and others forthcoming), energy storage and enhanced grid infrastructure are critical. This could include investments in batteries and long-term electricity storage, new or upgraded transmission infrastructure, and interconnections among countries' grids could also bolster electricity supply stability.

I. Introduction

Climate change is a macroeconomically critical challenge due to its profound impacts on economic and financial stability and its major ramifications for macroeconomic policy. Its widespread impacts[5] range from physical damages and productivity losses to heightened fiscal and financial vulnerabilities to potentially devastating 'tipping point' risks which rise with temperatures.[6] Addressing climate change through mitigation and adaptation requires effective macroeconomic policies—including fiscal, financial, and monetary—to minimize economic costs and manage risks.[7] In addition to mitigating and adapting to climate change, in 2023 members of the Paris Agreement have committed to "transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade." [8] Given the criticality of energy to the functioning of all economies, this will have profound ramifications for energy security, the macroeconomy, and macroeconomic policy.

This Working Paper aims to take stock of countries' climate mitigation ambition, providing quantitative analysis and illustrative options for aligning emissions targets with global temperature goals and of the energy security and economic implications of decarbonization. The first section examines recent trends in global emissions and temperatures, the gap in global climate ambition among members of the Paris Agreement, and quantitative estimates of the impacts of closing these gaps. The second section assesses the macroeconomic implications of energy security and transition, including quantitative and qualitative analysis of the threats and opportunities that decarbonization provides for both energy importers and exporters.

II. Cutting Global Emissions

Projected Emissions Pathways and Temperatures

Since the signing of the Paris Agreement a decade ago global GHG emissions have continued to rise (Figure 2). In 2015, members of the Paris Agreement set a target to limit global warming to "well below 2°C", ideally 1.5°C above preindustrial levels (known as the "long-term temperature goal", though "long-term" has never been defined).[9] To achieve this would require a significant cut in global emissions. However, since 2015 emissions of CO2 and other GHGs have continued to rise at the same rate as previous decades. Emissions of CO2 have risen from about 15 billion tonnes in 1970 to about 39 billion tonnes in 2024 (Figure 2, left panel),

[5] Rising temperatures entail growing physical risks, such as increasing duration and severity of extreme weather events; financial stability risks, as climate-shocks rapidly reprice risk across asset classes and could induce financial crises; balance of payments (BoP) and trade risks, as supply chains are disrupted from climate shocks; productivity risks, reducing labor productivity and increase health expenditures; and political risks, as climate shocks disproportionately affect low-income and informal workers, thus widening inequality and undermining social cohesion, leading to conflict, mass migration, or involuntary immobility.

[6] Tipping point risks are feedbacks in natural systems create irreversible changes, which could have devastating effects on economies. For example, though estimates are uncertain, a breakdown in the Atlantic Meridional Overturning Circulation (AMOC) might result in loss of up to 30 percent of global GDP, which is comparable to losses from the Great Depression (Nordhaus and Boyer 2000). Every tenth of a degree global temperatures rise above 1.5°C above preindustrial levels exacerbates these risks (McKay and others 2022).

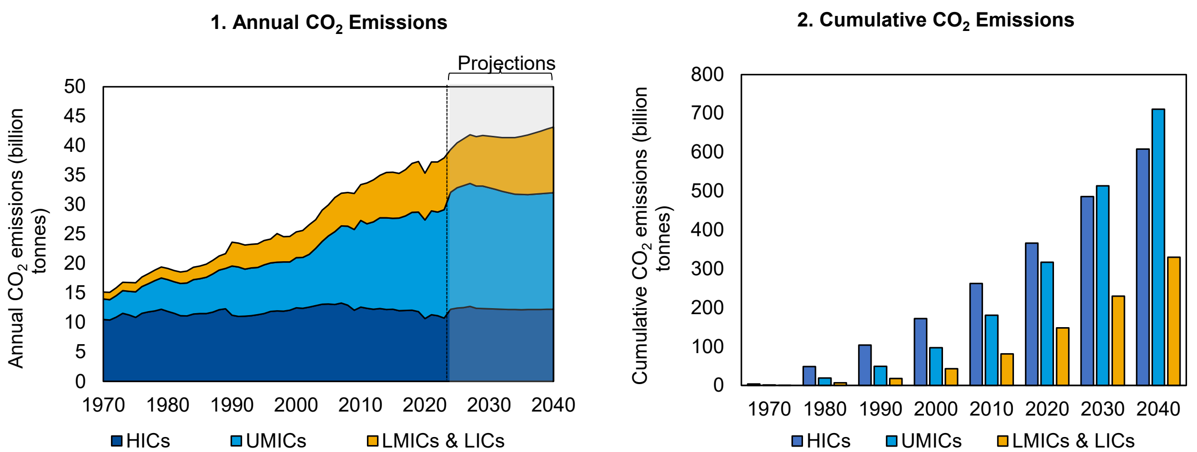
[7] See https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-16/

[8] At COP28, countries committed to accelerating the "phase-down on unabated coal power," scaling up "net zero emission energy systems," and "transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science." See https://unfccc.int/documents?f%5B0%5D=symboldoc%3AFCCC/SB/2023/9.

[9] See https://unfccc.int/process-and-meetings/the-paris-agreement

while total GHGs have risen from 24 billion tonnes of CO^2e to 55 billion tonnes of CO2e over the same period (Figure 1). A majority of the growth in emissions has come from developing countries: low, lower-middle, and middle income countries' share in CO2 emission grew from 31 percent in 1970 to 69 percent of annual emissions in 2024 (Figure 2, Panel 1). However, their share in historical emissions remains at just over half of historical emissions and in per capita terms high-income countries' share of annual and historical emissions remains higher (Figure 2, Panel 2).

Figure 2. Historical and Projected BAU Annual (Panel 1) and Cumulative (Panel 2) CO_2 Emissions for High-, Middle-, and Low-Income Countries, 1970–2040



Source: IMF staff calculations using CPAT. Note: BAU = business as usual; bn = billion; HICs = high-income countries; LICs = low-income countries; LMICs = lower-middle-income countries; UMICs = upper-middle-income countries.

The 194 country members of the Paris Agreement are in the process of setting new emissions targets for 2035. The Paris Agreement was predicated on the need to ratchet-up ambition in countries' emission targets—in their 'nationally determined contributions' (NDCs)—over time.[10] In 2015, countries initially set targets for 2030 which did increase in ambition in subsequent negotiations. However, a large shortfall between those targets and what's needed to achieve the Paris Agreement's temperature goals remained (Black and others 2024a). This year, countries are due to set targets for 2035 that are '1.5C aligned'. At the time of writing (11 Nov 2025), 112 countries covering about 71 percent of global emissions have been announced or submitted.[11] Of these, 13 countries representing 36 percent of global emissions have announced new targets but are yet to formally submit them.[12]

Limiting global warming well below 2°C requires cutting greenhouse gas (GHG) emissions by 30 to 45 percent by 2035 versus 2019, but countries in total are currently targeting about a 7 percent cut (Figure

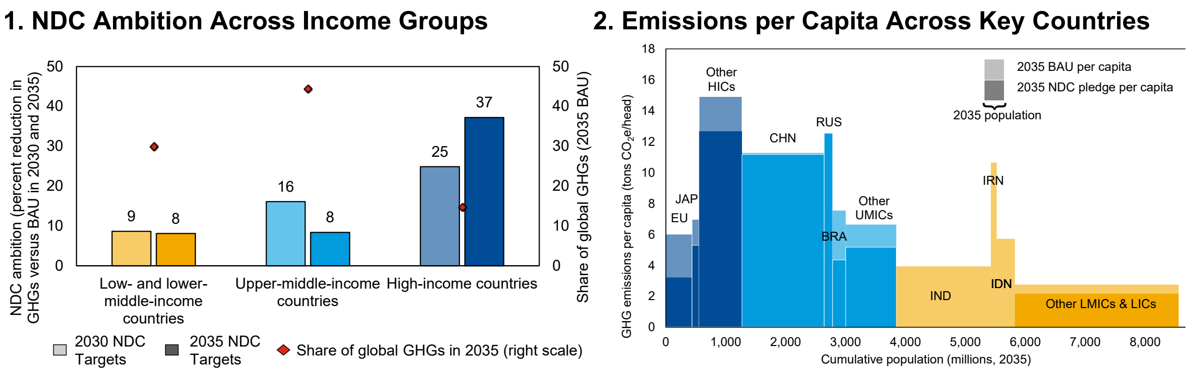
[10] During the Paris Agreement negotiations, it was known that emissions targets (in NDCs) would insufficient to keep global warming "well below" 2°C above pre-industrial levels, ideally to 1.5°C. It was envisioned that countries would ratchet up ambition on a five-yearly basis (the first in 2021), supported by periodic progress reviews (the "Global Stock Take," first concluded in 2023).

[11] This includes China (which announced its intension to cut emissions 7 to 10 percent below peak levels; we assume a target reduction of 8.5 percent compared to 2027 projected levels) and the EU (which intends to cut emissions by 66.25-77.5 percent versus to 1990 levels; we assume an average target reduction of 69.4 percent).

[12] In our analysis, for all countries that are yet to announce or submit new targets, we assume that the previously stated 2030 targets hold and 2035 targets are extrapolated from the trajectory 2022-2030 out to 2035. At time of writing, India, Iran, Indonesia, Korea, Russia, and Turkey had yet to update their targets while the United States announced its intention to withdraw from the Paris Agreement.

1). Of the NDCs submitted or announced to date, few appear aligned with a 1.5°C pathway. With about half of countries' submitting new targets for 2035 at time of writing, it appears that GHGs would fall by about 7 percent from 2019 levels if these targets were achieved (Figure 1, Panel 1). In addition, in a business-as-usual (BAU) scenario, with no strengthening of mitigation policies global emissions are projected to rise by 9 percent.

Figure 3. Distribution of NDC Ambition Across Income Groups and Emissions per Capita Across Key Countries in 2035



Source: IMF staff calculations using CPAT. Notes: For developing countries, unconditional and conditional NDCs are averaged. Where BAU and NDC are equal, the target is either nonquantifiable or nonbinding; that is, it is assumed to be achieved in the baseline. Data labels use International Organization for Standardization (ISO) country codes. BAU = business as usual; HICs = high-income countries; LICs = low-income countries; UMICs = upper-middle-income countries; LMICs = lower-middle-income countries; NDC = nationally determined contribution. Includes only members of the Paris Agreement. Of 182 countries analyzed, 37 had nonquantifiable NDCs, that is, do not have any targets or have targets that are not economy-wide. Of the 145 countries with quantifiable NDCs, 61 were considered nonbinding, that is, the target is met in the business-as-usual (BAU) scenario. These countries account for 14 percent of global GHGs. For countries with nonbinding NDCs, we do not assume that countries raise emissions above BAU by, for example, reversing current mitigation policies.

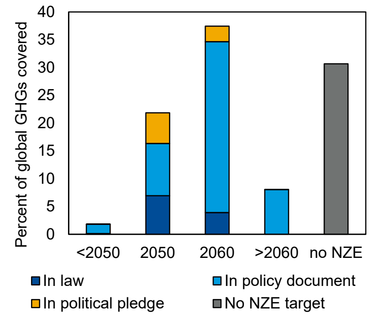
At present, countries' emissions targets for 2035 vary substantially across income groups (Figure 3). The IMF-World Bank Climate Policy Assessment Tool (CPAT) allows for quantification and comparison of mitigation ambition in NDCs for over 180 countries. By estimating countries' emissions in the business-as-usual and comparing to that implied by NDCs, countries can be compared in a transparent and consistent manner.[13] As a group high-income country (HICs)[14] (excluding the US[15]) are targeting a 25 and 37 percent cut versus 2030 and 2035 BAU, respectively (Panel 1). Upper-middle-income countries (UMICs) are targeting cuts of 16 and 11 percent, respectively. Lower-middle-income (LMICs) and low-income countries (LICs) are targeting cuts of 9 and 16 percent, respectively. Per capita GHG emissions vary also (Panel 2). For example, the EU is targeting about 3.2 tonnes of CO_2-equivalent (CO_2e) per capita per year by 2035, less than one quarter of that of other HICs, while China and Russia would have about double the per capita emissions of other UMICs.

[13] Comparing targets relative to business-as-usual (BAU) levels is a fairer measure of country ambition compared with absolute cuts, as for example, low-income countries could have targets implying emissions cuts versus BAU even while raising absolute emissions. BAU emissions projections by country authorities (using their own methodologies) may differ from those in the CPAT.
[14] IMF classifications are used – see https://www.imf.org/en/publications/weo/weo-database/2023/april/groups-and-aggregates#cee.
[15] In this Paper, where global emissions are needed – such as for projecting total global emissions and temperature trajectories – non-participating countries like the US are assumed to follow a business-as-usual emissions pathway.

In addition, though members of the Paris Agreement set a goal of net-zero global GHG emissions in the middle of century, countries are not universally aiming for this (see Figure 4). As of October 2025, 138 countries, accounting for about 69 percent of 2020 GHG emissions[16], have committed to net zero emissions by midcentury and intend to meet them with diverse strategies. Most of these commitments target 2050 or 2060, though some have made earlier or later commitments. Only 11 percentage points of these targets are enshrined in law; however, most are in policy documents and some in political pledges—see Figure 4. In addition, a total of 31 percent of current global emissions are not covered by a net-zero target. Major emitting countries under the Paris Agreement without a net-zero target include Iran, Mexico, Pakistan, and the Democratic Republic of Congo. Assuming targets for 2030, 2035 and net-zero are met, would suggest an illustrative global CO2 emissions trajectory (see Figure 6, Panel 1). With current targets, the world would not achieve net-zero at any point this century, with about 10 billion tonnes of residual emissions per year to the end of the century.

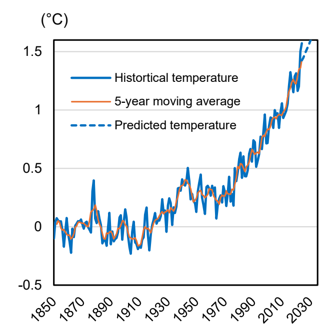
As a result of the continued growth in emissions, global temperatures also continue to rise and are highly likely to surpass 1.5°C soon (Figure 5), as the United Nations Secretary General (UNSG) noted in October 2025.[17] Since 2015, country members of the Paris Agreement have increasingly emphasized the need to keep warming at 1.5°C. However, in the last decade, emissions have continued to grow (albeit at a slower pace; Figure 2 Panel 1) leading to rising temperatures. The past ten years 2014-2024 were the warmest years on record. Last year, average temperatures were 1.55°C above preindustrial (1850-1900) averages (see Figure 5).[18,19] Using a 5-year average, global temperatures are already 1.42°C above preindustrial levels and, if the current trajectory continues, would pass 1.5°C around 2027.[20] This is much sooner than the 2040 date that the IPCC had previously predicted in 2021.[21], and according to the UNSG "humanity has failed to limit global heating to 1.5C" and it is now "inevitable" that the global temperatures will pass the target.

Figure 4. Net Zero Emissions (NZE) Targets by Target Year, Legal Status, and GHG Coverage



Sources: Net Zero Tracker; IMF staff. In law = target prescribed in legislation. In policy document = target in policy or planning document, e.g. NDC. In political pledge = announced (e.g. press release).

Figure 5. Global Temperatures (Land Surface Anomalies 1850-2025)



Source: IMF staff; HadCRUT 5 (1850-2024), NOAA GlobalTemp v6 (1850-2024), GISTEMP (1880-2024), Berkeley Earth (1850-2024). Shows land temperature anomalies above pre-industrial times (1850-1900).

[16] Total GHG emissions of countries include land-use, land-use change, and forestry.
[17] See https://www.theguardian.com/environment/2025/oct/28/change-course-now-humanity-has-missed-15c-climate-target-says-un-head
[18] See https://wmo.int/news/media-centre/wmo-confirms-2024-warmest-year-record-about-155degc-above-pre-industrial-level
[19] 1.5°C is not a threshold but rather a goal for long-term temperatures. However, countries have not agreed on the definition of the temperature target, including duration or target year, though the latter is generally defined as the end of the century.
[20] An ideal approach is using a climate model controlling for intra- and inter-annual fluctuations in temperatures.
[21] See https://www.ft.com/content/9a11b08c-4fb3-49ec-8939-9d853745bfce

'Overshoot'—passing 1.5°C before potentially returning to it through negative global emissions—appears inevitable. Limiting the duration and magnitude of overshoot would reduce macroeconomic risks and costs while reducing uncertainty in economic planning. Reducing the magnitude of overshoot entails reaching global net-zero emissions[22] sooner. This would help minimize economic risks. In addition, it would assist in economic planning for adaptation—peak warming, rather than long-term temperatures, determines national adaptation costs[23] and so uncertainty on peak temperatures creates uncertainty on the required investments in adaptation. Once temperatures have peaked, minimizing the duration of overshoot entails rapid removals of CO_2 from the atmosphere which are at present extremely costly, entail intertemporal tradeoffs, and would raise further issues with international and intergenerational burden sharing (see Box 1).

Box 1. Are Negative Emissions Economically and Politically Feasible

While the date of net-zero determines the magnitude of overshoot (how much temperatures rise above 1.5°C), the subsequent rate of carbon dioxide removal determines its duration. If the world were to achieve net-zero beyond midcentury, e.g. 2070, and still aim to stabilize temperatures at 1.5°C this would require extracting vast amounts of CO2, up to 45 billion tonnes per year in the 2080s which is more than peak annual emissions (currently 36 billion in 2024). Worse, the climate system may be asymmetric: one tonne of CO_2 emitted may add to temperatures by more than one tonne of CO_2 reduces temperatures (Zickfield and others 2021).

Extracting emissions from the atmosphere remains expensive and it is unclear who would pay for it. Negative net emissions require the use of highly expensive and uncertain negative emissions technologies (NETs). This includes direct air capture (DAC), which filters CO_2 from the air. Estimates of costs of DAC range from $90 to $600 per tonne of CO2.[24] The three simplified net-zero scenarios in Figure 6 imply peak removals of 11, 20, and 36 billion tonnes of CO2 per year. Assuming current technologies, scalability, and a flat marginal cost curve, this equates to peak costs ranging $1 to $21 trillion per year (about 0.9 to 19 percent of 2024 global GDP), orders of magnitude above current global climate finance. It is likely that costs for DAC will decline in coming years, but there is a floor to how much costs can decrease given their necessarily-high energy intensity.[25] In addition, there is also a global limit to how much CO_2 can be sequestered due to geological constraints,[26] let alone technical constraints. DAC uses vast amounts of electricity in the process, which could strain grids (see next section).[27] It is unclear who would pay for it. Some countries are committing to negative emissions in the long-run, such as the UK and EU. However, who is responsible for extracting CO_2 from the atmosphere after net zero remains unclear and is likely to become a contentious issue in international negotiations.

[22] Net zero allows positive emissions from some (hard-to-abate sectors) like agriculture so long as they are offset by negative emissions elsewhere, for example, through forest carbon sequestration or direct air capture.

[23] Local adaptation planning must focus on peak risk because: 1. many critical impacts are potentially irreversible or insensitive to declines in temperature; 2. there is a risk of transgressing adaptation limits i.e. where risks become intolerable; 3. adaptation strategies for peak warming may be more cost-efficient relative to strategies that consider the long-term temperature; and, 4. precautionary planning, given pervasive uncertainty on the severity and compounding nature of real-world climate hazards suggests that planning for maximum anticipated risk (peak warming) is preferable to planning for lower risk (declining temperatures) many decades into the future. See Theokritoff and others 2025.

[24] See https://www.rff.org/publications/issue-briefs/policies-for-scaling-up-carbon-dioxide-removal-in-the-united-states/. Afforestation also removes CO_2 from the atmosphere but is usually included under countries' emissions commitments and has limits on scalability. Challenges include the risk captured emissions will leak from storage sites, monitoring and verifying emissions capture, land-use trade-offs, and limits on reducing the technology costs due to high energy requirements.

[25] Assuming current global CO_2 atmospheric concentration of around 425 parts per million, DAC-based technologies would need to filter through 1 million molecules of air to extract just 425 molecules of CO_2. Because of the laws of thermodynamics, there is a strict lower bound on how much energy would be required.

[26] Median estimates put this at 1,460 billion tonnes of CO_2 (Giddens and others 2025). This compares to cumulative extraction needs in Figure 5 scenarios, assuming net-zero in 2045, 2055, or 2065, of 325, 550 and 750 billion tonnes of CO_2, respectively.

[27] There are other NETS beyond DAC such as forest sequestration and bioenergy with carbon capture and storage (BECCs) but there has been a surge of interest in DAC specifically.

III. Closing Ambition Gaps Through Property Rights: Illustrative Peak Temperature and Emissions Goals

Climate risks and adaptation costs depend on peak temperatures. However, the existing target under the Paris Agreement is ambiguous ("well below 2°C", ideally 1.5°C) which makes long term economic planning difficult, and hinders international climate negotiations to unlock further efforts. As a result, currently countries' policies and climate objectives are not consistent. This section discusses how countries' efforts to close the global climate ambition gap could be augmented by clarifying property rights and illustrates how the macroeconomic implications of doing so could be quantified. Members of the Paris Agreement are effectively engaging in allocation of property rights to the remaining finite global carbon budget (the maximum total cumulative emissions allowable to reach a given long-term temperature level). However, ambiguity over these property rights continues to stymie these efforts. The first section discusses how clarifying the current global temperature target by setting a peak temperature level would effectively specify the global carbon budget (property rights specification). Once a peak temperature level is set, countries need to agree on how to allocate that across all countries. The second section illustrates ways the budget could be distributed across countries (property rights allocation) and quantifies the macroeconomic implications of doing so.

Specifying Property Rights: Towards a Global Goal for Peak Temperatures?

Viewed through the lens of economics, climate change is a global commons and collective action problem. Countries face insufficient incentives to decarbonize unilaterally, hence the need for coordination. However, coordination is stymied by ongoing ambiguity on property rights, which are critical both for well-functioning markets and negotiations between agents. For any given temperature target, there is a finite global remaining carbon budget, i.e. total global emissions of CO2 that could be emitted to reach that goal. However, there is uncertainty over the finite global carbon budget given ongoing ambiguity over the Paris Agreement's temperature targets (per the Paris Agreement, "well below 2°C" and ideally 1.5°C). Due to the lack of clear property rights specification at present countries are effectively making overlapping claims on the carbon budget. Having an agreed peak temperature level would increase transparency and understanding of country level macroeconomic implications.

There is a strong link between the global carbon budget and temperatures. As a result, establishing a global target for peak temperatures would lead to specification of the remaining global carbon budget. Recent advances in climate science mean that specifying a peak temperature level would—with some uncertainty—pin down the remaining global carbon budget.[28] CO_2 emissions have a fast and near-permanent impact on temperatures, with most of the increase occurring within a year of emission (Ricke and Caldeira

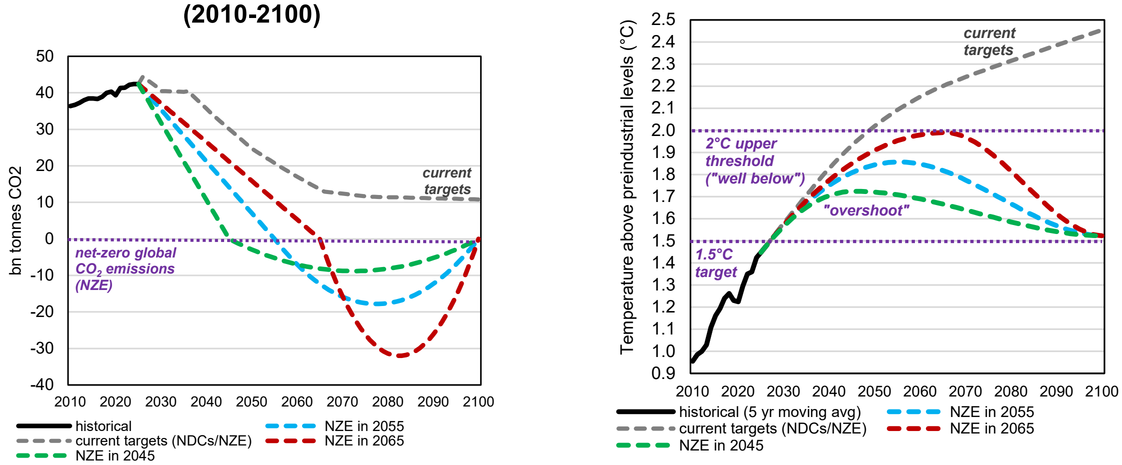
[28] The major source of uncertainty in climate science is the relationship emissions of greenhouse gases and temperatures ("climate sensitivity"). However, uncertainty on this key parameter has narrowed by about 40 percent over the last decade. As a result, estimating the impact that a given cumulative stock of CO2 will have on global temperatures – e.g. for calculating a global carbon budget – can now be done with a higher degree of certainty.

2014). As a result, the year of net-zero corresponds to the approximate year of peak warming.[29] In addition, assuming a linear global emissions pathway, the year of net-zero determines how much temperatures rise above 1.5°C. Therefore, clarifying the Paris Agreement's overall temperature goal by specifying a collective peak target temperature level within the current range (1.5°C to 2°C) would allow for specification of both the net-zero year and the remaining global carbon budget between now and then. This would aid countries in their efforts to negotiate and allocate rights to the global carbon budget. In addition, it would lead to an understanding of the level of cumulative negative emissions required to reach 1.5°C once temperatures have been peaked, which would aid in economic planning.

Figure 6. Global CO2 Emissions (Panel 1) and Warming Levels (Panel 2)

Panel 1. Emissions of CO_2: Global Example Pathways to Which Achieve 1.5°C at End-Century (2010-2100)

Panel 2. Temperatures: Corresponding Global Warming Trajectory (2010-2100)



Source: IMF staff calculations using CPAT; Forster et al (2025) which updates IPCC (2021). Carbon budgets are adjusted for projected 2025 emissions. 'Current targets' assumes countries without 2030, 2035 or net-zero targets decarbonize at 0.25 percent of 2019 emissions from 2040 onwards, countries with targets achieve them linearly if they are advanced economies and developing economies they achieve targets in a concave manner (smaller absolute cuts in initial years). Includes international maritime and aviation sectors which are assumed to meet their respective decarbonization and net-zero goals. Temperatures assume 67 percent probability of staying below that level. Excludes effects from non-CO2 GHGs such as methane, changes in which can have significant impacts on temperatures (although reductions in non-CO2 GHGs are assumed in carbon budgets).

For example, if countries set a global goal of peak warming level of 'no more than 1.85°C' it would correspond to global emissions cuts of 30 percent by 2035 and net-zero by 2055 (see Figure 6, panel 1 as well as Figure AIII.1 and Table AIII.1 in Annex III). Additionally, it would create the ability to monitor progress in the near-term since there would be a finite carbon budget from an assumed linear pathway.[30] Alternatively,

[29] Earlier, climate scientists thought temperature rise lagged emissions by a long period. Now, peak warming is believed to occur about a decade after emitting a ton of CO_2 (Ricke and Caldeira 2014). As the world nears net-zero, the impact of late emissions is small compared to the cumulative CO_2 stock. For example, in a 2050 net-zero scenario, emissions in the 2040s would make up only 12% of total emissions between 2025 and 2040. Under these assumptions, the year of net-zero likely marks peak warming.

[30] IPCC temperature scenarios tend to assume a convex emissions pathway, with large reductions in initial years and fewer cuts in later years. However, four trends create risks that drastic reductions in emissions in the next few years are unlikely: (1) recent geoeconomic fragmentation; (2) continued investment in fossil fuels which could lead to "carbon lock-in"; (3) growing climate-induced physical hazards as the world warms which could reduce resources available for mitigation as opposed to, for example, reconstruction; and (4) recent political backlash against mitigation policy in some countries. Additionally, although in later years marginal abatement costs increase as the world decarbonizes, both technology and political momentum may accelerate as the impacts of climate change become clear, meaning these two effects may cancel out. As a result, were net-zero to be achieved, global emissions may instead follow an approximately linear path with emissions reducing steadily and uniformly all the way to net-zero, which is what is assumed here. Results would be slightly different under convex of concave pathways.

setting a target date for global temperatures to achieve net-zero would also allow for peak temperatures to be estimated. Figure 6 provides current temperature trajectories alongside illustrative examples of potential net-zero emissions pathways, assuming linear emissions cuts.[31] Assuming current emissions targets for 2030, 2035 and net-zero are met, global temperatures would pass 1.5°C this decade, 2°C by 2050, and 2.5°C by 2100 (Figure 6, Panel 2). By contrast, if global CO_2 emissions get to zero by 2045 this would correspond to peak warming (roughly around that year) of 1.65°C. If net zero is reached by 2065 peak warming would be around 2.0°C (i.e. would not be 'well below 2.0°C'). However, for countries to be able to align their policies with their climate objectives, the remaining global carbon budget needs to be allocated among countries.

Allocating Property Rights: Illustrative Options for 2035

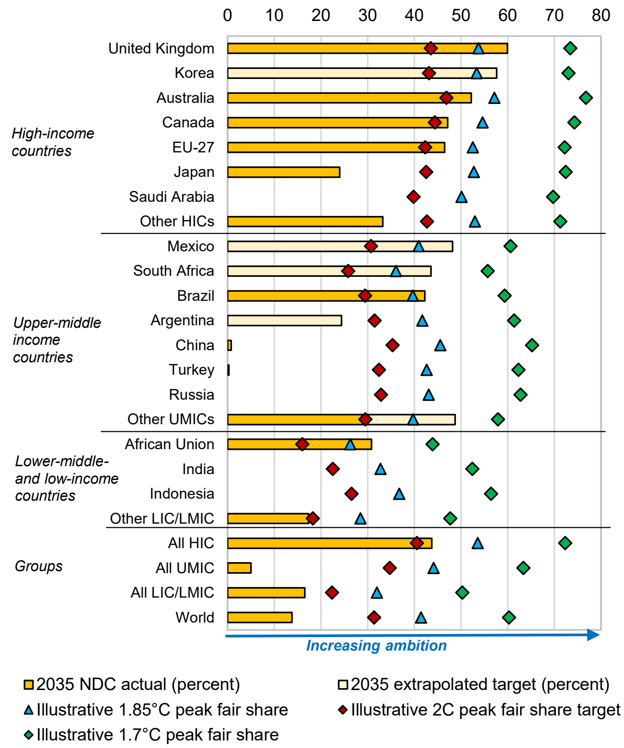
Near-term ambition could be aligned with temperature goals and the remaining global climate budget by raising collective ambition in 2035 emissions targets in a way that respects countries' common but differentiated responsibilities. Climate mitigation and international equity are intrinsically linked. The Paris Agreement sets out this requirement by referring to "common but differentiated responsibilities and respective capabilities." This has historically divided countries into two camps in the United Nations Framework Convention on Climate Change. Under the precursor to the Paris Agreement, the Kyoto Protocol, "Annex I" (mostly developed) countries were required to cut emissions, whereas "non-Annex I" countries (mostly developing countries) were not. Given that developing countries already accounted for a majority of annual emissions, and nearly half of historical emissions, when the Protocol came into force in 2012—and they account for over two-thirds of annual CO_2 emissions now (see Figure 2)—achieving a global emissions trajectory aligned with 1.5°C–2°C would not have been infeasible without them. Under the Paris Agreement, almost all countries are committed to cutting emissions, with high-income countries (HICs) going faster while providing financial and technological assistance to developing countries.

Economists have proposed six main approaches to share global emission cuts in line with common but differentiated responsibilities: (1) acquired rights, based on past emissions; (2) cost optimality, minimizing total global costs; (3) gradual convergence, aligning per capita emissions over time; (4) ability to pay, linking cuts to per capita income; (5) immediate convergence, equalizing per capita emissions immediately; and (6) greenhouse development rights, combining historical responsibility and capability. These yield very different emissions reduction outcomes—rich countries cut less under cost-based or historical approaches but far more under equity-based approaches. Annex III outlines these different analytical approaches to allocating emissions cuts across countries. For simplicity and illustration we average across these different approaches to generate allocations that are consistent with temperature targets. The methodology maintains that climate ambition is allocated based on the assumption that wealthier nations make steeper cuts.

[31] In this Note, aligned with the Intergovernmental Panel on Climate Change's 2°C scenarios, temperature goals are assumed to be achieved with 67-percent probability.

Using this methodology we provide illustrative allocations consistent with different temperature goals and resulting illustrative 2035 emissions targets for countries in the Paris Agreement. We show distributions for peak temperatures of 1.7˚C, 1.85˚C, or 2˚C (Figure 7). Different methodologies or peak temperature targets would yield different allocations, and it is for countries to agree on those details. These peak temperature targets correspond to cuts in GHGs in 2035 vs 2019 levels of 47, 30 and 20 percent. For 2°C peak, targets are achievable, with most developed countries cutting emissions by around 40 percent versus BAU and most developing countries cutting by 20 to 30 percent. For 1.85˚C peak, targets are more stringent but potentially manageable. A 30-percent global cut in 2035 versus 2019 means cuts around 50 percent compared to BAU for many developed countries and most developing countries would need to cut emissions by 30 to 40 percent versus BAU. For 1.7˚Cs peak, cuts are much more severe, with developed countries having to cut about 70 percent versus BAU and most developing countries cutting over 50 percent. It is questionable whether these cuts are achievable, and hence it appears likely that temperatures will peak somewhere above 1.7˚C. In all three scenarios, these cuts are approximately as progressive with respect to income as current NDCs (in that there is a similar relationship between ambition with respect to per capita income; see Annex III).

Figure 7. GHG Emissions Cuts for Countries Under Illustrative Proposals Versus Business as Usual (2035, G20 Paris Agreement Countries)



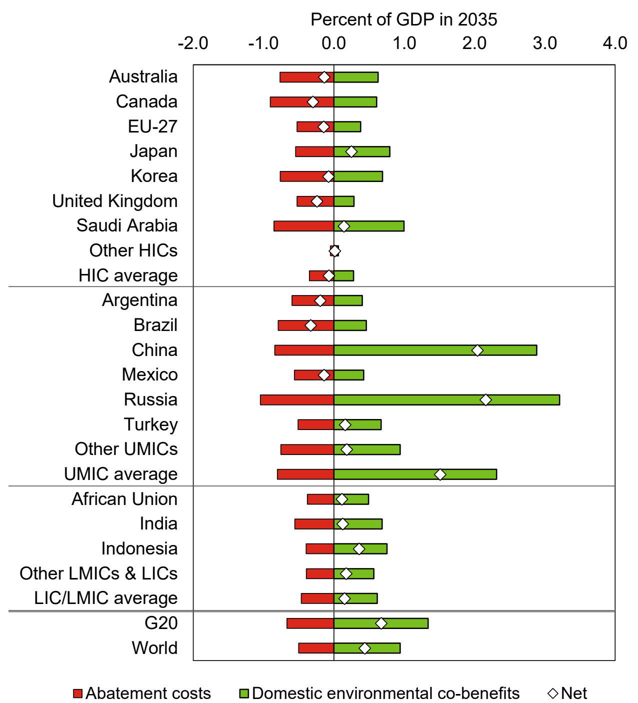
Sources: IMF Staff using CPAT.
Notes: excludes United States throughout. An average is taken of conditional and unconditional targets where both are specified. Where no NDC is shown, the target is nonbinding and is assumed achieved in the baseline or (for e.g. Saudi Arabia) nonquantifiable. Countries in light gold have yet to announce targets for 2035 at the time of writing and hence targets have been extrapolated assuming a linear emissions pathway from 2020 to 2030 NDC target continues to 2035 (though in some cases this is also nonbinding). EU = European Union; GHG = greenhouse gas. Income groups use the WB classification: HICs = high-income countries; LICs = low-income countries; UMICs = upper-middle-income countries; LMICs = lower-middle-income countries; NDC = nationally determined contribution.

Figure 7 also shows gaps between current national 2035 targets and illustrative targets. Shortfalls vary across income groups. Between income groups, shortfalls between current and illustrative targets are larger for UMICs and LIC/LMICs than for HICs. HICs as a group are aligned with a 2˚C and 1.85˚C peak, UMICs are 28 ppts away, and LIC/LMICs are 4 ppts away. For 1.85˚C, the respective distance is bigger, with the income groups being 4 ppts, 35 ppts, and 19 ppts away, respectively. For 1.7˚C, no income group is aligned currently, and cuts are severe, suggesting that this peak may not be feasible and temperatures will likely rise above this level. Figures and tables showing current 2035 ambition levels compared with these illustrative 1.7°C, 1.85°C, and 2°C peak temperature-aligned targets for all countries can be found in Annex V and Annex VI, respectively.

Ultimately, it is up to countries to decide how to allocate emissions cuts. As discussed in Annex IV, there are several different analytical approaches to allocating the global burden of mitigation, which can lead to vastly different allocations. However, having an agreed-upon methodology for allocating emissions cuts could aid countries in negotiations. This could be further assisted by setting a global peak temperature goal which would also imply a global carbon budget (see section above).

In addition, costs of these scenarios remain macroeconomically manageable, and in some cases domestic welfare benefits (excluding climate benefits) outweigh abatement costs (Figure 8). If these targets are implemented in least-cost ways then the mitigation costs for 1.85°C, are manageable and broadly equitable across countries. Mitigation costs (see Annex VII) reflect the annualized costs of switching to cleaner but more expensive inputs and technologies, net of any savings from lower lifetime energy costs, and lost benefits from other behavioral responses like people driving less than otherwise preferred. Mitigation costs relative to GDP depend on policy implementation, the emissions intensity of GDP, and the relative ease or difficulty of cutting emissions. But assuming countries achieve targets in a least-cost manner, Figure 8 shows their mitigation costs under the 1.85°C scenario. Costs are both manageable (about 0.7 percent of GDP for the G20 as a whole) and generally progressive (higher for advanced economies and lower for low-income countries). In addition, in many cases, especially emerging economies, domestic environmental co-benefits exceed mitigation costs, implying these countries could be better off on net from climate mitigation, before even counting global climate benefits. Co-benefits here include (most importantly) reductions in local air pollution morality from reduced use of fossil fuels (especially coal and diesel) and reductions in various side effects (like traffic congestion) from reduced vehicle use. GDP impacts differ from mitigation costs (for example due to changes in investment and trade balances) but also tend to be fairly modest with well-designed policies, or perhaps slightly positive with efficient use of carbon pricing revenues.[32]

Figure 8. Mitigation Costs and Domestic Welfare Benefits (2035) from 1.85°C Peak Scenario



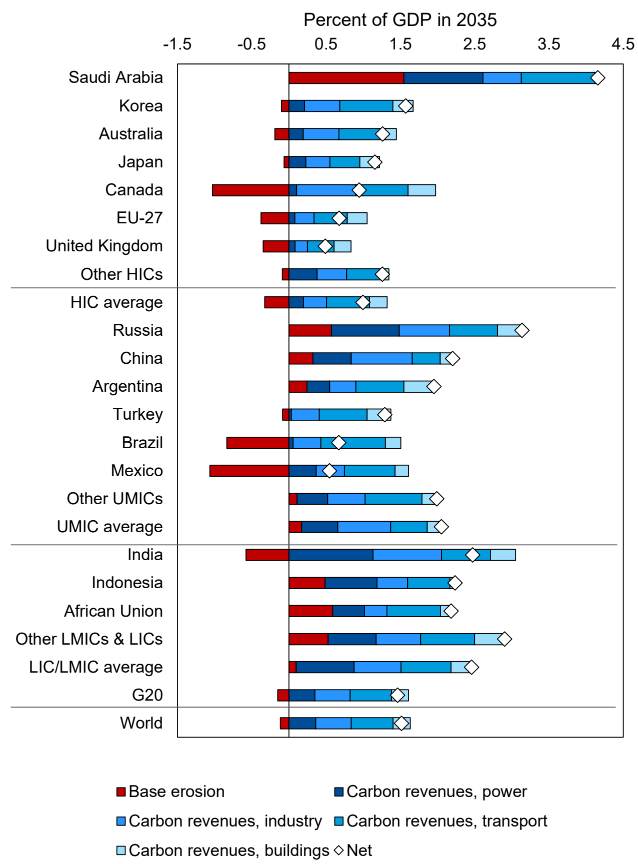
Sources: IMF Staff using CPAT.

If countries achieved these targets in a cost-effective approach using primarily carbon pricing, decarbonization could raise revenue in the near-term for most countries, but risks of base erosion emerge variably for countries (see Figure 9). Gross revenues from carbon pricing range from about 0.5 and 1.5 percent of GDP, and substantially more in some cases, with the contribution to revenue from different

[32] See for example Parry and others (forthcoming), Ch 5.

sectors varying significantly across countries. Erosion of fuel tax bases typically causes revenue losses of around 0.2 percent of GDP or less, though Saudi Arabia and Russia could gain significant revenues from reducing bases for fuel subsidies. Losses to revenue from fossil fuel production are typically small but exceed one percent of GDP for fossil fuel dependent countries.

Figure 9. Net Zero Emissions (NZE) Targets by Target Year, Legal Status, and GHG Coverage



Sources: IMF Staff using CPAT. Note: Revenue gains from critical mineral extraction are not captured. Losses from fossil fuel production are only captured for large oil and natural gas producers.

Beyond targets for temperatures and emissions, additional international mechanisms to complement the Paris Agreement could help overcome cross-country coordination issues on climate mitigation. Under the Paris Agreement the large number of parties can slow down negotiations and unilateral action can be hindered by concerns about competitiveness and policy uncertainties in other countries. Additional plurilateral agreements, that is, complementary agreements among a smaller group of countries (for example, large emitters, G20) could potentially accelerate ambition and align policies with reinforced targets, especially if they are concrete and transparent, and include monitorable actions such as an international carbon price floor agreement as proposed by the IMF staff.[33] It could also include an agreement on scaled-up, temperature-aligned, equitable emissions targets backed up by credible mitigation strategies to implement them. Including robust and transparent finance in agreements could encourage participation of large-emitting, lower-income countries.

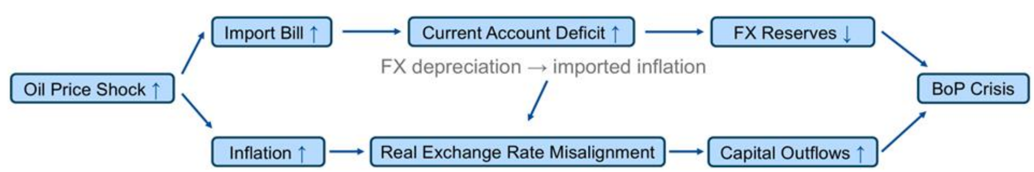
Lastly, limiting global temperatures to well below 2°C, and especially minimizing peak temperatures, would only be possible through cutting emissions beyond energy-related CO_2. Methane emissions—predominately from coal, oil, and gas extraction, agriculture, and waste—can have an outsized impact on warming. Cutting methane emissions earlier would reduce the level of peak warming, potentially by up to 0.3°C by 2045,[34] requiring specific measures (see Annex II). In addition, forestry and agricultural sectors are major sources of non-energy CO2 and methane but limited progress has been made cutting their emissions.

[33] See Parry and others (2021).
[34] See https://www.unep.org/news-and-stories/press-release/global-assessment-urgent-steps-must-be-taken-reduce-methane

IV. Securing Energy While Cutting Emissions

Energy security – the universal, uninterrupted availability of energy sources at affordable prices – is a macroeconomically critical concern. For energy-importing economies, the reliability and affordability of supply are closely tied to price stability and external balance. Given the dominance of fossil fuels in the current global energy mix, the price of oil, gas, and coal is critical to the macroeconomy. Indeed, key macroeconomic indicators like CPI, fiscal balances, and output, can be highly sensitive to energy-prices volatility (Cevik 2022; Rabbi 2022). Fossil fuels can provide energy security benefits, for example, the security of supply from large domestic coal reserves. Nonetheless, fuel prices constitute a systemic vulnerability to domestic price stability, with cost shocks propagating through the economy (Weber et al. 2024). Recent geopolitical tensions (most notably Russia's war in Ukraine) exposed the long-standing vulnerabilities of fossil-fuel dependence and unsettled global energy markets.

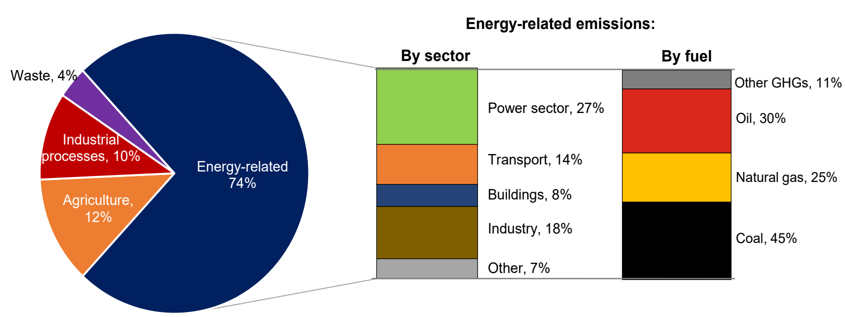
Figure 10. Oil Price Shocks and Balance of Payments (BoP) Crises – Transmission Mechanisms



Source: IMF staff illustration. Stylized link linking oil price shocks to BoP crises through import bills, reserves, and capital flows.

Countries with greater fossil-fuel import dependence systematically face stronger balance-of-payments and fiscal pressures when global energy prices rise. This can escalate into external-financing crises (see Figure 10).[35] Such shocks are typically exogenous and supply-driven, making them difficult for authorities to manage with standard policy tools. There is substantial heterogeneity in countries' vulnerability to fossil fuel price shocks and hence energy security. Developing economies generally exhibit more vulnerability than advanced economies due to fewer fiscal resources, and this gap has widened over the past decade (Shen et al. 2024). Among European economies, those that have reduced oil dependency and expanded investment in alternative energy sources are better positioned to absorb fossil-price shocks (Piłatowska et al. 2025). Globally, vulnerability is especially pronounced where structural exposure to fossil fuel imports coincides with high energy intensity (Gatto et al. 2020).

Figure 11. Global CO2 Emissions by Sector and Fuel (2024)



Sources: IMF staff using CPAT.

35 As seen during the 2022 energy shock, which led to significant GDP-growth downgrades across Europe (Ari et al. 2022, cited in Kim et al. 2025; IMF 2022, cited in Kim et al. 2025).

As the world decarbonizes, maintaining a reliable and affordable energy supply will be important for global macroeconomic stability. There are potential benefits of decarbonization from an energy security and affordability standpoint (Dolphin and others 2024) but also potential challenges that need to be managed. Energy makes up most of global CO2 emissions (see Figure 11, and hence decarbonization at the rate implied by the Paris Agreement's temperature goals would therefore entail major changes to the energy system, with ramifications for energy intensity, security, and efficiency. This in turn would have pervasive impacts on the availability, accessibility, and affordability of the world's energy supply, which will remain crucial to addressing the world's development goals. This section provides an overview of these positives and challenges also looking at lessons about policy options that help maximize the benefits and minimize the costs and risks of energy transition.

Table 1. National Energy Security: General Considerations and Relevance of Decarbonization

Dimension	Energy Security in Business-As-Usual	Energy Security in Global Decarbonization Scenario
Availability	Supply risks driven by geopolitical shocks, depletion, or underinvestment.	Fossil fuel risks decline, but renewable intermittency problematic primarily at high shares and in the absence of complementary investments (Schwerhoff 2024; Kim 2025)
Accessibility	Reliance on pipelines, refining/processing infrastructure and ports, with risks from disruptions.	Grid stability, distribution networks, digital resilience, and a suite of flexibility options—including demand-side management, energy storage (batteries, pumped hydro, green hydrogen), and advanced grid technologies—become core priorities (IEA 2024; Schwerhoff 2024).
Affordability	Exposure to fossil fuel price spikes and inflation.	Renewables have the potential to lower electricity prices but, absent complementary investments or market design, create variability in short-run prices (Weber 2024; Andaloussi 2022).
Sustainability	Environmental and health externalities from fossil fuel combustion.	Decarbonization is the way to mitigate climate change so climate damages are minimized.
Resilience	Fossil fuel shocks spill over to inflation and growth.	Grid modernization and storage required to offset intermittency risks alongside potential regional grid integration (Kim 2025).

Source: IMF staff and cited sources.

The challenges of energy security in general and in the relevance of decarbonization are in Table 1. Energy security is often defined based on availability, accessibility, affordability, sustainability and resilience of the energy system. Decarbonization has relevance for all of these aspects. For example, under availability, fossil fuel dependence risks decline with decarbonization but the challenges of intermittency of variable renewables and hence reliability of the grid become more salient.

The Opportunity of Decarbonization for Energy Security

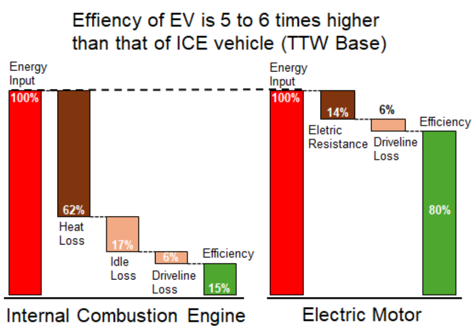
Climate mitigation and strengthening energy security is the "dilemma or opportunity of the century" (Cevik 2022). Global decarbonization could significantly enhance energy security for many countries by reducing trade dependency and increasing system resilience. Global decarbonization at the rate discussed above would radically lower global fossil fuel consumption while entailing widescale adoption of renewables, transmission infrastructure, batteries, potentially nuclear (if done safely and with prudent waste management), and green hydrogen for hard-to-abate sectors. For non-fossil producers, fuels must be continuously imported since they are combusted, while renewables are indigenous energy sources with very low marginal prices as there are no or low fuel costs, long-lived technologies (like wind turbines) with one-off import needs and potential for recycling ('circular economy') thereafter.

Decarbonization generally improves the current account balance of fossil fuel importers from reduced consumption and lower exposure to international fuel prices. This could reduce vulnerability to BOP shocks from unexpected changes in fossil fuel prices (Espagne and others 2023). As a result, according to International Energy Agency (IEA), renewables "inherently strengthen energy supply security" (IEA 2025). For example, a recent study of 39 European countries found that, during 1980 to 2019, a 10-percentage point increase in the share of nuclear, renewables and other non-hydrocarbon energy reduced long-run energy imports by 6 percentage points while lowering CO2 emissions (Cevik 2022). For example, deep decarbonization in Japan (where 80 percent of energy is imported) could reduce import dependency to less than a half of the total primary energy supply by 2050.[36] According to the International Energy Agency (IEA), renewables have already cut fossil fuel imports for more than 100 countries.[37]

Additionally, there are potentially large energy efficiency benefits from shifting away from fuels to renewables which could have productivity benefits. Fossil fuels are a wasteful source of energy since the majority of potential energy is dissipated in the combustion process, notably through heat loss. For example, in 2011 more energy was wasted than used. Of the 532 exajoules of energy input, over half (290 exajoules) were 'rejected' or wasted energy, mostly through heat loss.[38] By contrast, renewable energy production, transmission and end-use electric technologies contain much lower losses in energy. For example, electric vehicles are about 5 times more efficient than internal combustion engines at making use of energy (see Figure 12). Decarbonizing the transport sector would reduce total energy consumption in transport. Using a technoeconomic transportation model, fully electrifying the global road transport system could cut total energy use by between 40 to 60 percent, leading to a more efficient use of energy (Figure 13). Similarly, replacing gas or oil-based furnaces with electric heat pumps would yield large energy efficiency gains. As a result, fossil fuel based energy does not need to be substituted for renewable energy at a 1-to-1 scale (known as the 'primary energy fallacy'). [39]

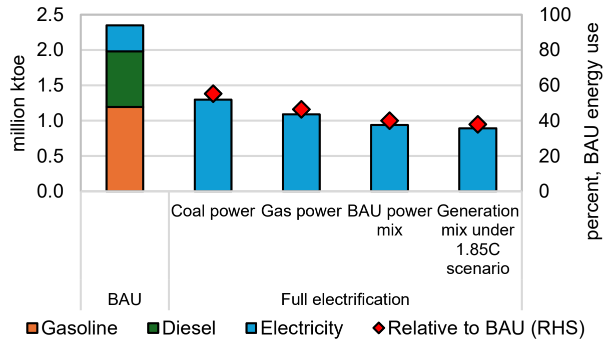
[36] Cherp and others (2012), cited in Oshiro and others (2016).
[37] Without new renewables, for example, more than half of (59 percent) of the UK's electricity would have been based on imported fossil fuels, whereas in reality wind and solar helped cut to less than one quarter (23 percent). See https://www.carbonbrief.org/iea-renewables-have-cut-fossil-fuel-imports-for-more-than-100-countries/
[38] See https://flowcharts.llnl.gov/sites/flowcharts/files/styles/orig/public/ENERGY_2011_WORLD.png?itok=EJi8nkIQ.
[39] From a welfare maximization perspective, there is a debate as to whether the gains from reduced energy intensity of transport are fully internalized by vehicle owners. If so, efficiency alone is not a justification for policy intervention and if not then it is. One recent study found that fuel economy standards raised welfare with 85 percent of the welfare benefits coming from households undervaluing energy efficiency (Leard and others 2023) though this 'energy efficiency paradox' remains unresolved in environmental economics.

Figure 12. Relative Efficiency of Electric Vehicles (EVs) vs. Internal Combustion Engine (ICE) Vehicles



Source: US Environmental protection Agency (EPA). Note: TTW = Tank to Wheel.

Figure 13. Change in Total Energy Consumption from Electrifying Road Transport Sector (World, 2035)



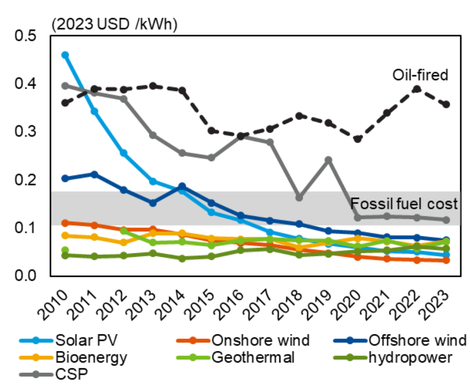
Source: IMF Staff. Note: Shows transport sector total energy use under a business as usual (BAU) and scenarios with full electrification of the vehicle stock. Electrification scenarios vary the source of electricity by generation technology. Energy use includes fuel used to produce electricity. Ktoe = thousands of tons of oil equivalent.

By decarbonizing and electrifying energy-consuming sectors, especially transport, industry, and buildings, much less primary energy from fossil fuels would be wasted, leading to lower carbon intensive economies and potentially productivity gains. Several studies have found that increasing energy efficiency leads to productivity gains at the macro level (Montalbano and others 2022, Romero-Jordán and others 2025). These benefits may outweigh the small but manageable costs from the transition and these benefits tend to not be accounted for in ex ante models (Heine and Black 2019). In addition, from an energy security perspective, countries that are less energy intensive in general are also less macroeconomically vulnerable to shifts in energy prices (Gatto and Busato 2020).

Domestic Challenges: Grid Stability

Meanwhile, renewables continue to decline in cost, with solar photovoltaics (PV) becoming the "cheapest source of energy ever". Solar and wind technologies have seen rapid cost declines over the last decade, declining by about 80 to 90 percent since 2010 (see Figure 14). Onshore wind and solar PV are now the cheapest sources of new electricity generation, with 91 percent of renewable projects being cheaper than the cheapest fossil fuel alternatives in 2024. In 2024 solar PV projects were, on average, 41 percent cheaper than the

Figure 14. Levelized Cost of Electricity Generation (Global Average, New Capacity)



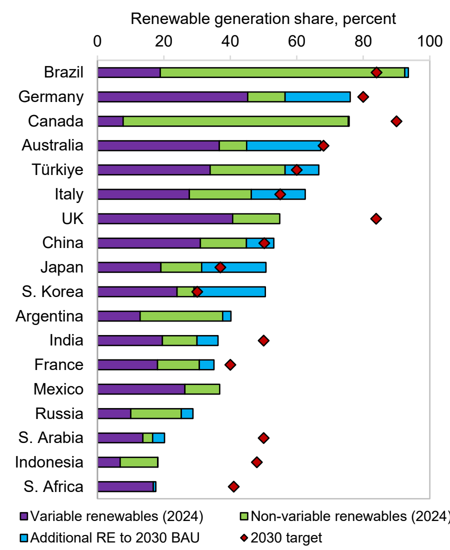
Source: IRENA (2024). Renewable Power Generation Costs in 2023. Note: Solar PV = Solar photovoltaic; CSP = Concentrated Solar Power.

lowest-cost fossil fuel alternatives, while onshore wind projects were 53 percent cheaper.[40] Other renewable technologies such as concentrating solar power (CSP), bioenergy, hydropower, and geothermal are cost-competitive with fossil fuels. Additionally, batteries used for long- and short-term storage of electricity continue to decline in cost. In 2024, the cost of lithium-ion batteries fell by 20 percent in a single year.[41]

As a result, renewables are growing rapidly, even in the business-as-usual case (Figure 15). Among G20 countries, renewables grew from 32 percent in 2022 to 37 percent in 2024 as a share of electricity supplied. Globally, renewables accounted for 93 percent of total capacity expansion in 2024.[42] In the BAU case, without additional mitigation policies, renewables are expected to continue growing to 47 percent of G20 electricity supply by 2030. In eight of 19 countries this would achieve countries' national targets for renewable energy share, including Turkey, Italy, China, Japan, South Korea, Argentina, India, and Mexico . In several notable cases countries rely on hydroelectric power (Brazil, Canada, Argentina) which is non-variable but in most cases most renewable generation comes from variable sources such as solar and wind.

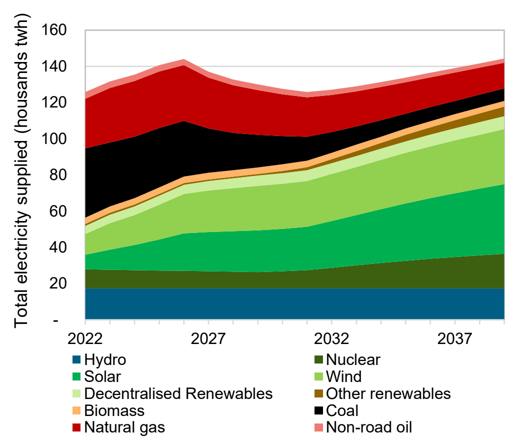
Under a 1.85C peak scenario, renewables would penetrate the global power system even more rapidly, more than tripling as a share of electricity generation by 2040 (Figure 16). Assuming the world decarbonizes using carbon pricing – which reduce electricity demand and hence less power would be needed overall compared with subsidization or regulatory policies – renewables would rise from about 20 percent of total electricity generation in 2022 to about 60 percent by 2030 and 71 percent by 2040 (see Figure 16). Almost all of the increase will be in intermittent sources (also known as 'variable' renewable energy, VRE), notably solar and wind.

Figure 15. Renewables as a Share of Electricity and National Targets (G20, 2024 & 2030)



Source: IMF staff using CPAT; US Environmental protection Agency (EPA). Variable renewable energy (RE) includes solar, onshore/offshore wind, and other renewables. Non-variable includes hydro and biomass. Both exclude nuclear. Renewable targets for China and UK are for 2060 and 2035 respectively and are interpolated to 2030.

Figure 16. Global Supply of Electricity Under a 1.85C Peak Scenario (2022-2040)



Source: IMF staff using CPAT. Assumes global carbon price rising from $10 in 2026 to $100 in 2035. Twh=terawatt hour.

[40] See https://www.irena.org/News/pressreleases/2025/Jul/91-Percent-of-New-Renewable-Projects-Now-Cheaper-Than-Fossil-Fuels-Alternatives

[41] See https://about.bnef.com/insights/commodities/lithium-ion-battery-pack-prices-see-largest-drop-since-2017-falling-to-115-per-kilowatt-hour-bloombergnef/

[42] See https://www.irena.org/News/pressreleases/2025/Mar/Record-Breaking-Annual-Growth-in-Renewable-Power-Capacity

As the share of variable renewable energy (VRE) rises, challenges to grid stability and domestic energy security become more pronounced—but these are not inherent to VRE itself. Intermittency is problematic mainly when VRE shares are high and complementary investments in flexibility options are lacking. To ensure grid stability, investments in VRE would need to be paired with a comprehensive suite of flexibility measures, including short- and long-term electricity storage (batteries, compressed air, pumped hydro), energy demand management systems, green hydrogen for storage and grid balancing, and advanced grid technologies. Grid development—such as new or upgraded transmission infrastructure—remains important, especially for connecting renewables located far from population centers, but it is not sufficient on its own to ensure grid stability. A holistic approach, drawing on the IEA's six-phase framework (IEA 2024) and reviews of flexibility options (Schwerhoff 2024), would help ensure grid stability. Country experiences, such as Lithuania and Denmark, demonstrate that with the right complementary investments, VRE shares exceeding 60% can be achieved without grid stability issues. In addition, while grid development—such as expanding transmission networks—can help decouple energy generation across space and connect renewables to demand centers, it does not automatically ensure grid stability. Grid stability requires a broader set of complementary investments, including flexibility options like storage, demand management, and green hydrogen. Renewables' ability to be deployed off-grid also presents opportunities for rural areas, but may not address grid instability in larger systems.

Integrating VRE into the grid requires investment in transmission infrastructure and energy storage, that can be supported by fiscal policies. Investing in enhanced grid infrastructure would facilitate deeper penetration of renewables and could enhance grid stability through regional integration of grids (Oshiro and others 2016). Lack of permitting reform is one of the biggest obstacles to renewables' growth—both off-grid and in utility-scale renewable projects—in many countries alongside powerful lobbies supporting fossil fuels. Ensuring a diversified mix of clean energy sources (renewables, hydropower, and, where possible and safe, nuclear energy) enhances resilience (Rabbi and others 2022).

Fiscal policies used for integrating VREs into the grid often involve a combination of pricing mechanisms, direct incentives, and targeted public investments in grid infrastructure (Andaloussi and others 2022). They can also include Feed-in Tariffs (FITs) – which fix the price of electricity for power generators, thereby reducing price risk costs of capital – and Contracts-for-Difference (CfDs).[43] In addition, in the context of limited fiscal space globally, revenue-neutral options are available. This could include charging fees on high-emission generation such as from coal, revenues from which are then used to fund rebates on low-emission generation ("feebates"). Additionally, many developing countries have high cost of capital in the power sector, which hinders investment in low carbon generation. Addressing the underlying cause of high economy-wide borrowing costs, such as currency and political risks, and power sector specific issues, such as insolvent state-owned utilities that create significant counterparty risk and weak land tenure, helps unlock low carbon investment (World Bank 2024b).

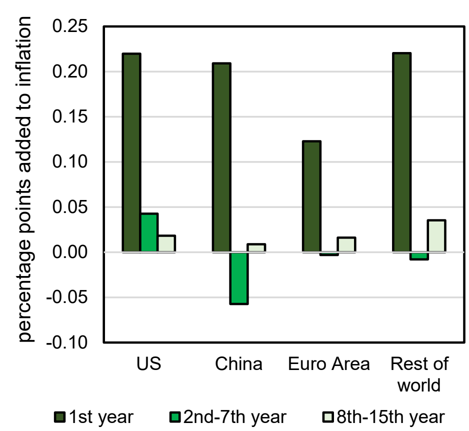
[43] Two-sided CfDs are becoming a key instrument in Europe, guaranteeing a fixed strike price to producers. If market revenues fall below the strike price, the government pays the shortfall; if revenues exceed the strike price, the surplus is transferred to the government. This design stabilizes investor returns while protecting consumers from excessive costs. These and other instruments such as renewable energy certificates are beyond the scope of this Paper.

Macroeconomic Risks from Energy Security

Decarbonization implies significant structural changes. The near-term macroeconomic costs of the energy transition are manageable with carefully designed policies. Balance of Payments (BoP) impacts are asymmetric. Fossil fuel importers benefit from reduced import bills and improved current accounts positions, while fossil exporters face declining hydrocarbon revenues (Puyo and others 2024). The accelerated transition pathway consistent with global mitigation goals often involves significant changes that occur during the unstable "mid-transition" period, where fossil-based and low-carbon energy systems coexist.[44] The rapid transition requires large-scale policy changes (Andaloussi and others 2022). In several model simulations, policy changes such as environmental tax reform and carbon pricing or similar policies can be positive for GDP and employment, notably from productivity gains.

Inflationary impacts of the energy transition are likely to be muted (see Figure 17), though they are difficult to estimate and contingent on the future path of energy costs and policies used by governments. On the cost side, renewables continue to decline in cost relative to fossil fuels and so as the share of renewables increases, the overall cost of generation should decrease.[45] Similar cost declines from electrification such as EVs could yield savings, though some hard-to-abate sectors – for example steel and cement – are not yet cost competitive with fossil fuel incumbent technologies. On the policy side, carbon pricing is the most effective single policy tool for accelerating the energy transition but has impacts on inflation in the near-term. Simulations suggest the inflationary impacts of carbon pricing are modest and short-lived, assuming they are implemented effectively. For example, simulations with the IMF Global Macroeconomic Model for the Energy Transition (GMMET; see Carton and others 2023) suggest inflationary impacts of a carbon price rising to $50 per tonne for China, Euro Area, US and rest of the world adds around 0.05-0.2 percentage points to annual inflation in year 1 but would gradually decline in subsequent years (see Figure 17). Lastly, it should be noted that there are potential inflationary impacts from climate shocks, which could be mitigated through global energy transition alongside adaptation.[46]

Figure 17. Inflation Impacts of Carbon Price in 15 Years Following Implementation (Rising to $50 per Tonne of CO_2)



Source: IMF staff using GMMET. Note: Carbon price starts at $20 per tonne in 2025, rising to $50 in 2030, and is flat thereafter. 70 percent of revenue is used labor income tax reductions and 30 household transfers.

Revenues from carbon pricing may be used to reduce taxes on labor and capital which could help to boost production over the longer term and possibly lower prices. Feebates, emission rate standards, and other mitigation instruments that have weaker impacts on energy prices may be used instead of carbon pricing

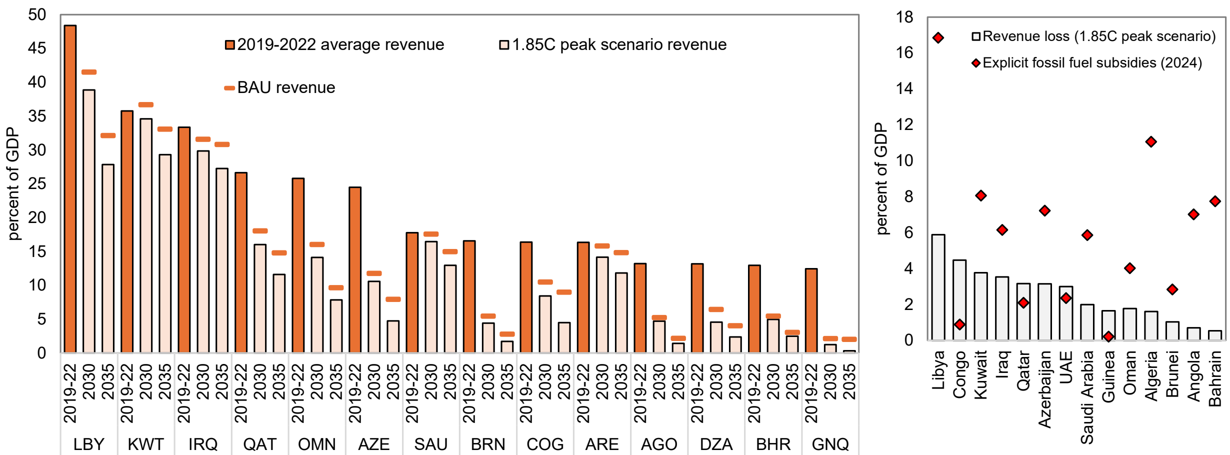
[44] See Espagne and others (2023).

[45] For example, one study in the US finds that moving to a renewable-dominated grid would lower power prices by 20 to 80 percent, leading to an aggregate real wage of 2 to 3 percent (Arkolakis and Walsh 2024).

[46] To the extent there are inflationary pressures, this raises equity concerns and the need for adjusting social safety nets to protect vulnerable households (see Amaglobeli and others, 2022).

but at the same time they are less efficient as (unlike carbon pricing) they do not strike the cost-effective balance across all mitigation responses—which instruments cause the larger increases in production costs at the economywide level is not entirely clear.

Figure 18. Revenues from Fossil Fuel Exports: Current Compared with a Global 1.85C Peak Scenario (Panel 1) and Losses Compared with Explicit Subsidies (Panel 2, Percent of GDP)



Source: updated from IMF (2023b), IMF staff calculations using CPAT, and Parry and others (forthcoming). Note: revenue estimates use country-level data on fossil fuel production, prices, and costs to estimate net cash flows. These flows are then split between the government and investor according to a country's fiscal regime (such as royalties and production sharing arrangements). The framework uses the Fiscal Analysis of Resource Industries (FARI) library of fiscal regime parameters and project-level financial models as well as CPAT. See IMF (2023b), Annex I for details.

However, revenue losses for fossil fuel exporting countries from the transition are potentially large (see Figure 18). Some countries are heavily dependent on oil, gas and coal exports, including as major contributor to government revenues. Figure 18 (Panel 1) illustrates impacts on fossil fuel producers under a 1.85C peak scenario with falling prices. Under the 1.85C scenario, fuel exporting countries face large revenue declines of over 3 percent of GDP per year by 2035 compared with BAU (e.g. Libya, Kuwait, Qatar, Congo). Some countries facing major losses in revenue and sources of dollar reserves are prone to economic and political stability. For countries dependent on fossil fuel exports, the main challenge is to diversify economically and fiscally (see Box 2 for elements of a revenue diversification strategy). One option is to gradually remove explicit fossil fuel subsidies, which in 2024 exceed projected revenue losses from a 1.85C scenario in 2035 in 10 out of the 14 countries in Figure 18 (Panel 2).[47] Using revenue gains from subsidy removal for public investment, reductions in distortionary taxes, and mitigating impacts on vulnerable households and firms can support growth and development (Lee and others 2025).

As a result, decarbonization could lead to economic, fiscal, and political instability in some vulnerable fuel exporting countries. Large fuel importing blocs (e.g. the EU) could consider the external ramifications of decarbonization on these countries. One way to provide support from advanced economies to vulnerable countries could be to do preferential purchases of fuel from vulnerable countries in exchange for reforms, including to their fossil fuel subsidies. For example, advanced importers could agree to purchase fuels from

[47] Libya, Kuwait, Iraq, Qatar, Oman, Azerbaijan, Saudi Arabia, Brunei Darussalam, Republic of Congo, United Arab Emirates, Angola, Algeria, and Bahrain.

vulnerable exporting countries at a price above market rates (like a power purchasing agreement). This could be done in exchange for the exporting country accelerating its economic and fiscal diversification (see Box 2), which would reduce its vulnerability, as well as decarbonization efforts which would contribute to global decarbonization. This could include: eliminating domestic fossil fuel subsidies; carbon pricing; liberalizing domestic energy prices; deregulating energy supply; and other supportive policies. Such ‘first-generation’ structural reforms could help reduce energy and emissions intensity of output (Budina and others 2023).

Box 2. What are the Elements of a Revenue Diversification Strategy for Fuel Exports-Dependent Countries?

Appropriate policy packages and sequencing of reforms will vary with national circumstances, including which main fuel a country exports and current diversification away from the extractive sector. Elements might include:[48]

- *Adjustments to fiscal regimes* such as shifting the mix from production-based to profit based taxes if countries wish to extend the life of fossil fuel reserves (this shifts risks from investors to the government), after a robust assessment of the impacts on revenue and investment.
- *Strengthening fiscal resilience* through building fiscal buffers and frameworks to better manage resource wealth (for example through sovereign wealth funds).
- *Enhancing resilience of the financial sector to energy price volatility* through strong regulatory, supervisory, and macro-prudential frameworks.
- *Pro-growth regulatory and institutional frameworks* such as removing regulatory barriers to competition, trade integration, and labor market flexibility.
- *Promoting an enabling public sector* through, for example, infrastructure investments for growth sectors and limiting the size of the public sector workforce and premiums over private sector wages.
- *Promoting a diverse economy* for example, through streamlining tax structures and lowering entry requirements to mobilize foreign direct investment; deepening integration in global value chains through enhancing production efficiency, improving technological capacity, and ensuring wage competitiveness; and enhancing vertical diversification in existing sectors by shifting to higher value-added products.
- *Targeting green technologies* for example green hydrogen production might be attractive, as existing export infrastructure could be used.

Lastly, the low-carbon technologies needed for the transition increases demand for Transition-Critical Materials (TCMs; e.g., lithium, copper, nickel, REEs). TCM supply and processing capacity is often geographically concentrated, raising risks of bottlenecks, price volatility, and financial risk (Miller and others 2023). Global prices for these critical mineral prices could become more volatile and rise substantially, about 90 percent to 2030 according to IMF estimates. Under NGFS ‘Net Zero by 2050’ projections, lithium demand could exceed 360 percent of current supply by 2040. (Miller and others 2023). If supply-demand imbalances lead to competition for resources between economic sectors (inter-sectoral shifts in demand), this would result in higher commodity prices, potentially jeopardizing the financial viability of low-carbon technology projects. Commodity prices in transition-critical sectors could therefore be viewed as systemically significant, requiring close monitoring to prevent inflation and instability (Weber and others 2024; Miller and others 2023).

[48] See IMF (2016).

Annex I. Climate Policy Assessment Tool (CPAT)

The IMF-World Bank Climate Policy Assessment Tool (CPAT) provides, on a country-by-country basis for over 180 countries, projections of fuel use and carbon dioxide emissions by major energy sector.[49] For key attributes of CPAT, see Table AI.1.

This tool starts with the use of fossil fuels and other fuels by the power, industrial, transport, and residential sectors and then projects fuel use forward in a baseline case using (1) GDP projections, (2) assumptions about the income elasticity of demand and own-price elasticity of demand for electricity and other fuel product, (3) assumptions about the rate of technological change that affects energy efficiency and the productivity of different energy sources, and (4) future international energy prices.

Table AI.1. Attributes of CPAT

Desirable modelling feature	How CPAT addresses feature
Country coverage	Over 200 countries with full set of data (for example, on fuel use, emissions, energy prices) for each country. Provides consistent cross-country comparisons of baselines and policy effects.
Baseline projections and NDCs	Projections based on most recent observed emissions and projected forward by fuel/sector using latest data on GDP projections, income elasticities for energy products, trend rates of efficiency improvements, and future energy price scenarios. NDC pledges are mapped to emissions reductions below baseline/historical levels.
How mitigation policies work	Behavioral responses to mitgation policies are approximately in the mid-range of those from broader energy modelling literature and empirical evidence on fuel price/income elasticities.
Mitigation policies	Potential policies include carbon taxes, ETSs, energy efficiency/emission rate regulations, feebates, clean technology subsidies/mandates, electricity/fuel taxes, fossil fuel subsidies, energy price liberalization, removals of preferential VAT for fuels, combinations of policies. Baseline includes energy taxes/subsidies and carbon pricing regulations are implicit in observed fuel use.
Sectors and gases	Main module covers power, industry, transport, and buildings. Supplementary models cover agriculture, extractives, forestry, and waste. All GHGs are included.
Metrics for policy evaluation	Impacts on energy production/consumption, prices, trade; GHG and local emissions; GDP and economic welfare; revenue; incidence across households (income deciles, within deciles, urban/rural); incidence across industries; domestic environmental co-benefits (e.g., local air pollution mortality).
Transparency, sensitivity, accessibility	Key model parameters and inputs are easily adjusted in the dashboard. Results presented rapidly via a chart-driven interface, allowing for experimentation in designing policy reforms. Spreadhseet model has user-friendly dashboard.

Source: IMF Staff.
Note: CPAT = Climate Policy Assessment Tool ETSs = emissions trading systems; GHG = greenhouse gas; NDC = nationally determined contributions; VAT = value-added tax.

In these projections, current fuel taxes/subsidies and carbon pricing are held constant in real terms. The impacts of carbon pricing on fuel use and emissions depend on (1) their proportionate impact on future fuel prices in different sectors, (2) a model of dispatch and investment in the power generation sector, and (3)

[49] For more details on the model, its parameterization, and key caveats, see Black and others (2023b).

various own-price elasticities for electricity use and fuel use in other sectors. For the most part, fuel demand curves are based on a constant elasticity specification.

The basic model is parameterized using data compiled from the International Energy Agency on recent fuel use by country and sector (IEA 2024b). GDP projections are from the latest IMF forecasts.[50] Data on energy taxes, subsidies, and prices by energy product and country is compiled from publicly available and IMF sources, with inputs from proprietary and third-party sources. International energy prices are projected forward using an average of World Bank and IMF projections for coal, oil, and natural gas prices. Assumptions for fuel price responsiveness are chosen to be broadly consistent with empirical evidence and results from energy models (fuel price elasticities are typically between about −0.5 and −0.8).

Carbon emissions factors by fuel product are from the International Energy Agency. The domestic environmental costs of fuel use are based on IMF methodologies (see Black and others 2023a).

One caveat is that the model abstracts from the possibility of mitigation actions (beyond those implicit in recently observed fuel use and price data) in the baseline, which provides a clean comparison of policy reforms to the baseline. Another caveat is that, while the assumed fuel price responses are plausible for modest fuel price changes, they may not be for dramatic price changes that might drive major technological advances, or rapid adoption of technologies like carbon capture and storage or even direct air capture, though the future viability and costs of these technologies are highly uncertain. The model does not explicitly account for full general equilibrium effects (for example, changes in relative factor prices that might have feedback effects on the energy sector), changes in international fuel prices that might result from simultaneous climate or energy price reform in large countries, or cross-country linkages through trade. Some of these effects may be of relatively minor importance however—for example, trade-sensitive sectors account for a minor portion of emissions, trade impacts depend on mitigation policies in other countries, and countries usually implement measures (like free allowance allocations) to limit the competitiveness impacts of their own mitigation policies. Moreover, parameter values in the spreadsheet are, chosen such that the results from the model are broadly consistent with those from far more detailed energy models that, to varying degrees, account for these factors.

The CPAT converts all mitigation pledges into a single, comparable metric: required emissions reductions against future business-as-usual or historical baseline emissions. It also accommodates a diverse range of mitigation policies such as carbon pricing, fossil fuel subsidy reform, energy price liberalization, electricity subsidy and tariff reform, renewable subsidies, removal of favorable VAT treatment of fuels, and combinations of these and other policies. It also has full coverage of sectors and gases, including CO_2 and non-CO_2 greenhouse gases (GHGs), as well as local air pollutants (including those with an effect on warming and others).

For each policy, CPAT assesses impacts on all the metrics noted previously and some others (household and industry incidence is available for all almost 100, but not all, countries). The model also includes a country-specific database on prices, taxes, and subsidies by fuel product/sector.
The CPAT's core is a macro-energy model distinguishing 17 fossil and non-fossil fuels and four sectors—power, industry, transport, buildings, with transport and industry split into various subsectors consistent with the classifications provided by the United Nations Framework Convention on Climate Change.

[50] A modest adjustment in emissions projections is made to account for partially permanent structural shifts in the economy caused by the coronavirus pandemic.

In CPAT, the user interacts with the “Dashboard,” which is a chart-driven, user-friendly interface. The user selects the country, mitigation policy (for example, carbon or energy taxes), the stringency of the policy over time and its sectoral/fuel coverage, and complementary policies (for example, fossil fuel subsidy reform, energy price liberalization, and feed-in subsidies for renewables). Revenues from mitigation policies can be recycled in broader tax reductions, public spending or investment, or transfers. The user then sees the main results in key charts (for example, impacts on emissions, revenue, GDP, households by income group, local air pollution mortality, and economic welfare) and numerous more detailed charts. CPAT does not require any external data, but users can adjust various inputs including data and key assumptions (such as domestic energy prices, fuel price responsiveness).

Given the importance of power generation in the early stages of decarbonization, CPAT includes a technology-based model of the sector which the user can select as an alternative to the power model based on fuel price elasticities. The technology-based model is grounded in observed generation technologies and forward-looking investments in new capacity, as well as dispatch from existing technologies, based on projections of levelized technology costs, assumptions about capital retirement rates, capacity factors, the increasing need for storing intermittent power, and possible constraints on expansion rates for renewables.[51] The technology-based model provides more accurate baseline projections of the power generation mix, though it tends to be less responsive to mitigation policies than implied by empirical evidence on the price responsiveness of generation fuels.

Lastly, it should be noted that there are many other models that can quantify and project energy consumption, emissions, and other impacts of climate mitigation policy. This includes, for example, macroeconometric models such as the Macro-Fiscal Model (Burns and others 2019), computable general equilibrium models like IMF’s ENVISAGE (Chateau and others 2022), sectoral models such as the Future Technology Transformations models (Mercure and others 2012), the IMF’s Fiscal Analysis of Resource Industries model (Luca and Mesa Puyo 2016), and others. Each model has varying strengths and weaknesses, and no model can provide all answers to questions relating to climate mitigation policy.

Overall, CPAT can be a useful tool for governments setting revised and new NDC targets and assessing the policies to achieve them. It is being made available exclusively to governments.[52]

[51] In default settings, hydroelectric capacity is fixed on the assumption opportunities have already been exploited, while nuclear power can gradually ramp up in countries with fission reactors, adequate safety measures, and waste management practices.
[52] For more details, see www.imf.org/cpat.

Annex II. Coordination Mechanisms for Methane

The discussion here draws on Black and others (2022b), which discusses policies to decarbonize methane. Several factors are favorable in establishing an international policy coordination mechanism to cut methane emissions:

- Participants: Signatories to the Global Methane Pledge, or representatives from blocs of signatories, could potentially negotiate an agreement.[53]
- Initial coverage: An initial agreement could focus on extractives which (1) account for most low-cost opportunities for cutting methane and (2) are already covered administratively through business tax regimes.
- Parameters: The agreement could focus on simple parameters like a minimum methane price or emission rate standards.
- Competitiveness: Concerns might be addressed through implementing revenue-neutral fees for industries, or other policies like feebates that avoid new tax burdens on the average producer, though competitiveness impacts are modest anyway.
- International equity: Equity issues are less challenging than for CO_2 as methane mitigation costs are much smaller. Again, equity issues might be dealt with through stricter requirements for advanced economies and transfer of know-how on monitoring and mitigation technologies to developing countries.
- Flexibility: The choice of mitigation instrument could be left to national governments as countries should be able to agree on methodologies for mapping instruments to emissions reductions.

The arrangement would need to encompass mutually agreed procedures for measuring methane emissions. A tricky issue is whether the agreement should be supported by a border methane adjustment, charging for embodied methane in fuel imports from nonparticipants. This adjustment would, however, complicate the agreement's initial set up and may not be needed if competitiveness concerns are addressed through other measures (like revenue-neutral fees or regulations).

[53] The Global Methane Pledge seeks to cut global methane emissions 30 percent by 2030 relative to 2020 levels—more than 150 countries have so far signed the pledge (notable large emitting exceptions include China, India, and Russia, although China has released a national action plan to control methane emissions). See www.globalmethanepledge.org.

Annex III. Global Carbon Budgets Remaining for Temperature Goals

Table AIII.1 provides updated estimated global carbon budgets from 1 January 2026 onwards for limiting temperatures given different levels of probability.

Table AIII.1. Global Carbon Budgets Remaining for Different Global Temperature Levels (Cumulative Billions of Tonnes of CO_2, 2026 Onwards)

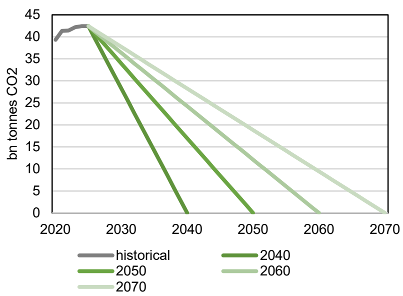
Temperature	Avoidance probability (TCRE uncertainty only)						
(°C)	10%	17%	33%	50%	67%	83%	90%
1.5	418	278	158	88	38	-12	-32
1.55	598	428	268	178	118	53	28
1.6	778	578	378	268	198	118	88
1.65	963	723	488	358	273	183	148
1.7	1,148	868	598	448	348	248	208
1.75	1,328	1,013	708	543	428	318	268
1.8	1,508	1,158	818	638	508	388	328
1.85	1,693	1,308	933	728	588	453	383
1.9	1,878	1,458	1,048	818	668	518	438
1.95	2,063	1,603	1,158	913	748	583	498
2	2,248	1,748	1,268	1,008	828	648	558
2.05	2,433	1,893	1,378	1,103	908	713	618
2.1	2,618	2,038	1,488	1,198	988	778	678
2.15	2,803	2,183	1,598	1,293	1,068	843	738
2.2	2,988	2,328	1,708	1,388	1,148	908	798
2.25	3,173	2,473	1,818	1,483	1,228	973	858
2.3	3,358	2,618	1,928	1,578	1,308	1,038	918
2.35	3,543	2,763	2,038	1,673	1,388	1,103	978
2.4	3,728	2,908	2,148	1,768	1,468	1,168	1,038
2.45	3,913	3,053	2,258	1,863	1,548	1,233	1,098
2.5	4,098	3,198	2,368	1,958	1,628	1,298	1,158
2.55	4,283	3,343	2,478	2,053	1,708	1,363	1,218
2.6	4,468	3,488	2,588	2,148	1,788	1,428	1,278
2.65	4,653	3,633	2,698	2,243	1,868	1,493	1,338

Source: IMF Staff calculations using Forster and others (2025) which updates IPCC (2021). Notes: TCRE = Transient Climate Response to Cumulative Carbon Emissions, also known as 'climate sensitivity'. Table shows maximum remaining cumulative CO_2 emissions from 2026 onwards to achieve different temperature levels given uncertainty on climate sensitivity. Budgets are adjusted for estimated 2025 emissions. Temperatures between decimal points (e.g. 1.75°C) are interpolated while temperatures from 2°C onwards are extrapolated, as is aligned with IPCC (2021), assuming linearity in climate response to cumulative stock of CO_2.

Figure AIII.1 provides illustrations of what these carbon budgets mean in practice, using the example of net-zero achievement dates of 2045-2070 and corresponding peak warming.

Figure AIII.1 Illustrative Example of Global CO_2 Emissions Pathways to Net Zero (Panel 1) and Corresponding Peak Warming Levels by Year of Net Zero (Panel 2)

Panel 1. Example Global CO_2 Emissions Pathways to Net Zero (2020-2070)



Panel 2. Corresponding Cumulative CO_2 Emissions and Peak Warming

Year of net zero	*2045*	*2050*	*2055*	*2060*	*2065*	*2070*
Cumulative CO_2 emissions (2026-year of net zero; 'carbon budgets')	403	509	615	721	827	933
Peak warming (°C, 67 percent chance)	1.75	1.8	1.85	1.95	2.00	2.05

Source: IMF Staff calculations using Forster et al (2025) which updates IPCC (2021). Carbon budgets are adjusted for projected 2025 emissions and corresponding budgets for temperatures between decimal points (for e.g. 1.75°C) are interpolated linearly. Temperatures assume 67 percent probability of staying below that level.

Annex IV. Allocating Property Rights Over Emissions: An Illustrative Example

Climate mitigation and international equity are intrinsically linked. The issue of equity (known as "common but differentiated responsibilities and respective capabilities") has historically divided countries into two camps in the United Nations Framework Convention on Climate Change. Under the precursor to the Paris Agreement, the Kyoto Protocol, "Annex I" (mostly developed) countries were required to cut emissions, whereas "non-Annex I" countries (mostly developing countries) were not. Given that developing countries already accounted for a majority of annual emissions, but less than half of historical emissions, when the Protocol came into force in 2012—and they account for two-thirds of annual CO_2 emissions now (see Figure 2)—achieving a global emissions trajectory aligned with 1.5°C–2°C would have been infeasible. Under the Paris Agreement, all countries are committed to cutting emissions, with high-income countries (HICs) going faster while providing financial and technological assistance to developing countries.

Economists have proposed various ways to distribute the burden of global emissions cuts equitably. The various approaches (as identified by a team of researchers from developing and developed countries—see van der Berg and others 2020) can be ordered roughly from least to most "equitable" in terms of the emissions cuts versus BAU[54]:

1. **Acquired rights** ("grandfathering"): Under this approach, countries cut emissions proportionate to their historical (for example, 2010) annual emissions.
2. **Cost optimality**: Emissions are cut at their least-cost location to minimize global costs.
3. **Gradual convergence**: Per capita emissions converge linearly over time.
4. **Ability to pay**: Emissions cuts are based on annual per capita GDP, with lower reductions calculated based on the poverty of a country and considering that costs increase with larger emissions reductions.
5. **Immediate convergence**: Per capita emissions converge immediately.
6. **Greenhouse development rights (GDR)**: Emissions cuts are based on a mixed measure of historical responsibility and capability, which includes GDP per capita and carbon intensity.

These six approaches lead to markedly different impacts on emissions cuts for key countries (see Annex Figure 2.1 in Black and others 2024b). For example, acquired rights and cost-optimal paths lead to fewer emissions reductions in HICs compared with other methods, since HICs' historical per capita emissions and marginal abatement costs are both relatively high compared with middle-income countries and LICs. Gradual convergence and ability to pay lead to intermediate solutions, with all countries required to cut emissions compared with baseline and larger cuts (in absolute terms) in HICs than middle-income countries and LICs. Lastly, "immediate convergence" and "GHG development rights" lead to large cuts in HICs (for example, more than 100 percent for Japan under GDR, that is, requiring annual carbon removals) and much smaller reductions in developing countries (for example, India grows its emissions to be above even BAU in 2030 under the GDR approach).

[54] In this narrow definition, an approach leading to more emissions cuts in developed countries is considered more "equitable."

Figure AIV.1. Current Country Emissions Targets in NDCs for 2035 by per Capita Income

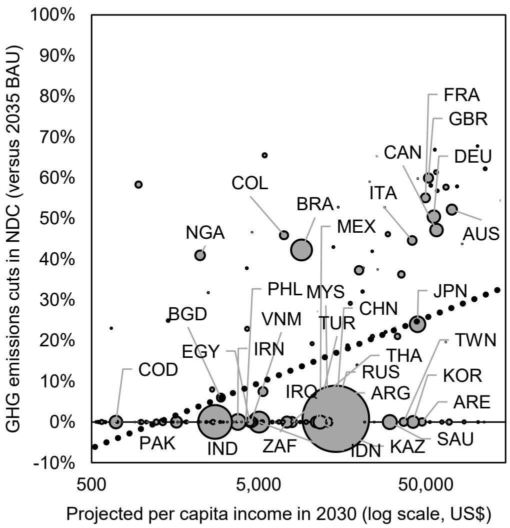


Figure AIV.2. Illustrative 2°C-Peak Aligned GHG Emissions Targets for 2030

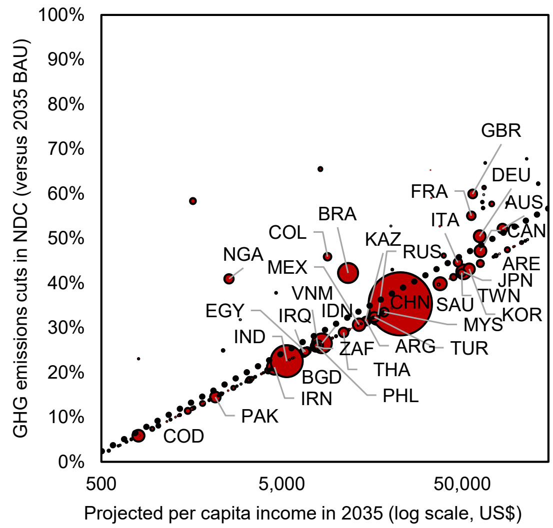


Figure AIV.3. Illustrative 1.85°C-Peak Aligned GHG Emissions Targets for 2030

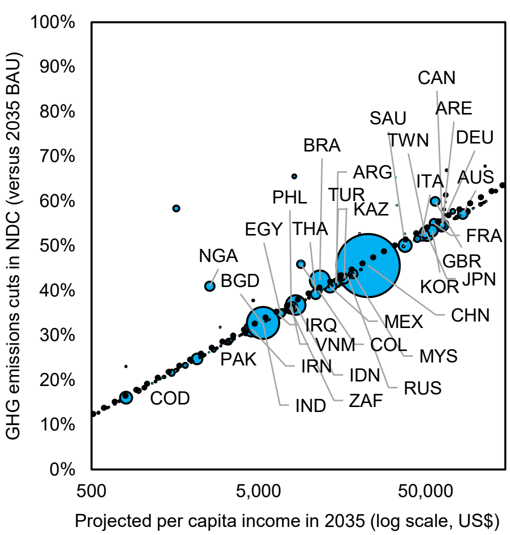
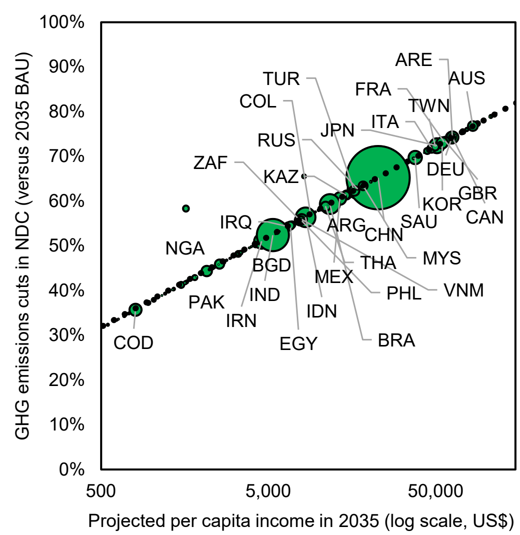


Figure AIV.4. Illustrative 1.7°C-Peak Aligned GHG Emissions Targets for 2030



Source: IMF staff calculations using CPAT.
Note: Bubble sizes reflect 2023 GHG emissions. Data labels are for major emitting countries and use International Organization for Standardization (ISO) codes. For countries with a nonbinding target (achieved in the BAU) it is assumed to be zero. An average is taken of conditional and unconditional targets where both are specified. A trend line is shown for all countries. BAU = business-as-usual; GHG = greenhouse gas; NDC = nationally determined contribution.

There are thus many ways to think about equity in global mitigation. However, one simplifying, illustrative way is to average across approaches and link to per capita incomes. Current NDCs and their relationship to per capita incomes are shown in Figure AIV.1. As can be seen there is a positive but weak relationship between current country ambition (defined in terms of emissions cuts versus BAU) and per capita income. The implied illustrative emissions reductions targets compared with BAU in 2030 can be inferred for key countries across the six different identified approaches (for details see Annex 2 in Black and others 2024b). Then, by plotting these illustrative targets relative to per capita incomes, a linear relationship can be inferred between emissions cuts and (log) per capita income levels with the slope determining the relative level of effort required across the income distribution (see Figure AIV.3). Lastly, assuming countries achieve the maximum of the illustrative target (in percentage reduction versus BAU given their per capita income) and their current NDC, this line can be scaled upward or downward (in percentage points) to achieve different peak temperature targets (for example, 2°C or 1.85°C).[55]

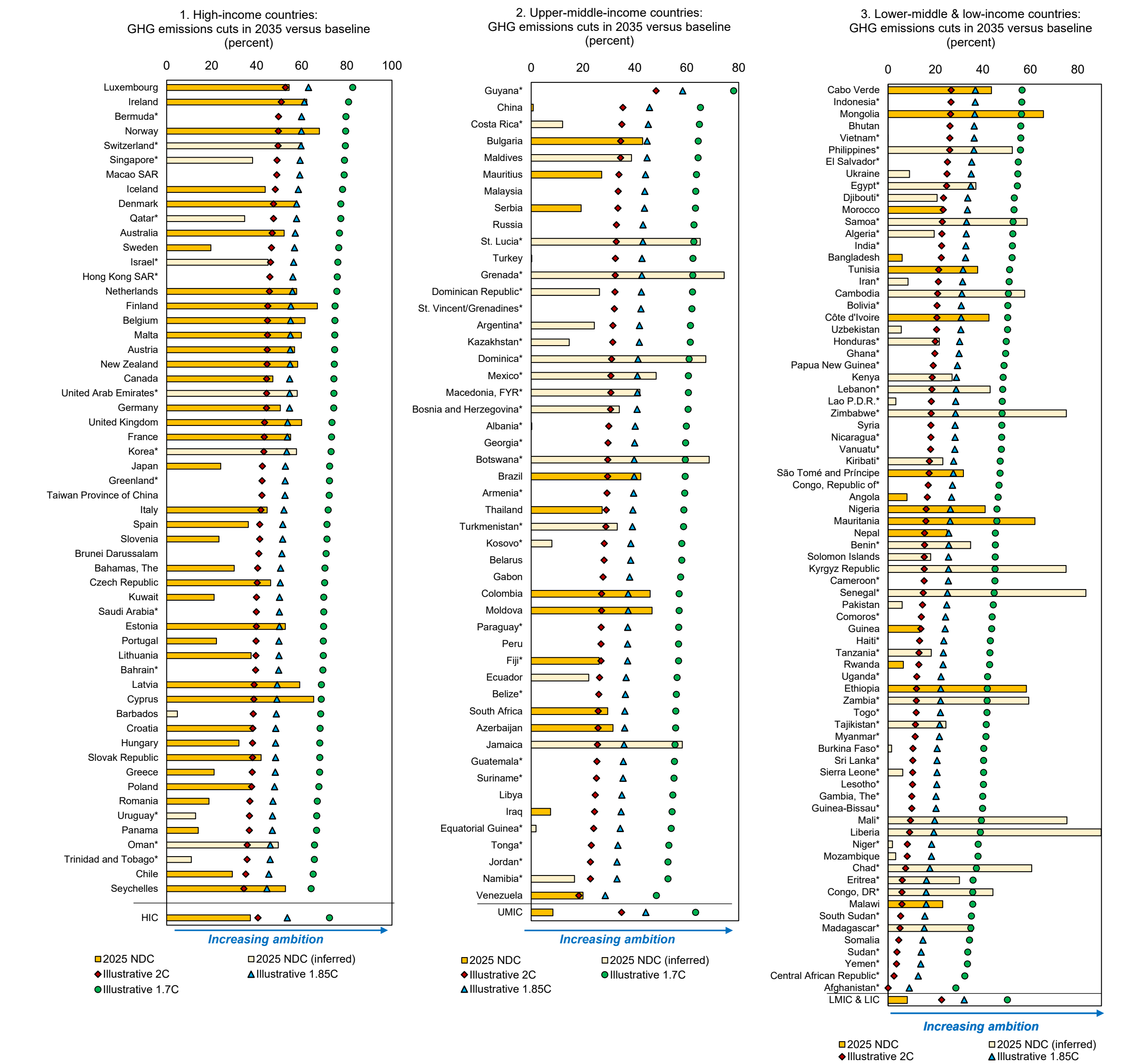
This illustrative example yields targets as or even more progressive that current NDCs (slope is similar or steeper) while delivering the needed emissions reductions for a peak temperature aligned global pathways. Figures AIV.1 to AIV.4 shows what enhanced, 2°C, 1.85°C, and 1.75°C-aligned 2035 targets would be under the approach described in the previous section. Ambition would be raised substantively for most countries, but cuts remain broadly progressive, with a positive relationship between projected 2035 per capita income and country ambition.[56]

[55] This approach is similar to the third most equitable approach listed ("'ability to pay"') but draws upon all approaches to determine a relationship between emissions cuts and projected per capita incomes.

[56] For further discussion of equitable sharing of emissions reductions see, for example, NGFS (2025), UNFCCC (2016), Art. 4.3.

Annex V. Illustrative Temperature-Aligned Targets by Country (Paris Agreement members)

Figure AV.1. Mitigation Ambition (in NDCs) and Illustrative Targets for All Countries (as of 11 Nov 2025)



Source: IMF staff calculations using CPAT. Note: Within groups countries are ordered in descending order of per capita incomes. Countries with an asterisk (*) do not have 2035 targets, including countries with unquantifiable targets. Countries in light gold have yet to announce targets for 2035 at the time of writing and hence targets have been extrapolated assuming a linear emissions pathway from 2020 to 2030 NDC target continues to 2035 (though in some cases this is also nonbinding). NDCs for EU countries are inferred using national allocations for non-ETS sectors (in effort-sharing regulations) and an assumed similar reduction in EU ETS sectors. NDCs average over conditional and unconditional targets where both are specified. ETS = emissions trading system; EU = European Union; FYR = former Yugoslave Republic; GHG = greenhouse gas; LIC = low-income country; LMICs = lower-middle-income countries; NDC = nationally determined contribution; PDR = People's Democratic Republic; SAR = Special Administrative Region; UMICs = upper-middle-income countries.

Annex VI. Illustrative Temperature-Aligned Targets by Country (2035)

Table AVI.1. Illustrative Emissions Targets in 2035 Aligned with 1.85°C and 2°C Peak in 2035

Country	Baseline GHG emissions in 2035, $MtCO_2e$	Illustrative 2C aligned target in 2035, $MtCO_2e$	Percent cut vs. (negative = increase)			Illustrative 1.85C aligned target in 2035, $MtCO_2e$	Percent cut vs. (negative = increase)			Baseline per capita GHG emissions in 2035, tCO_2/person	Illustrative 2C aligned per capita GHG emissions in 2035, tCO_2/person	Illustrative 1.85C aligned per capita GHG emissions in 2035, tCO_2/person
			1990	2005	2010		1990	2005	2010			
Afghanistan	35.9	35.9	-252.5	-128.5	-32.5	35.9	-252.5	-128.5	-32.5	0.6	0.6	0.6
Albania	8.7	6.1	47.5	10.5	11.4	5.2	55.2	23.6	24.4	3.4	2.4	2.0
Algeria	282.9	218.7	-60.6	-34.9	-19.8	189.8	-39.3	-17.0	-4.0	5.4	4.2	3.6
Angola	112.6	94.0	-61.1	21.4	25.2	82.5	-41.4	31.0	34.4	2.2	1.8	1.6
Argentina	414.2	283.8	5.9	33.2	33.9	241.4	19.9	43.2	43.7	8.8	6.0	5.1
Armenia	12.6	8.9	63.3	-19.8	-25.0	7.6	68.6	-2.5	-7.0	4.6	3.2	2.8
Australia	429.2	205.3	67.2	66.3	66.0	184.1	70.6	69.8	69.5	14.6	7.0	6.3
Austria	61.0	26.3	60.6	64.5	59.4	26.3	60.6	64.5	59.4	6.8	2.9	2.9
Azerbaijan	61.7	45.8	32.5	-6.4	-6.1	39.5	41.8	8.2	8.5	5.7	4.2	3.6
Bahamas, The	1.9	1.2	14.7	2.4	28.3	1.0	29.3	19.1	40.6	4.7	2.8	2.3
Bahrain	63.0	38.1	-31.1	7.4	21.1	31.7	-8.9	23.1	34.4	33.9	20.5	17.1
Bangladesh	385.5	299.1	-101.7	-62.4	-37.0	259.6	-75.1	-41.0	-18.9	2.0	1.5	1.3
Barbados	1.0	0.6	31.1	31.5	41.8	0.5	42.5	42.9	51.5	3.4	2.1	1.8
Belarus	40.4	29.1	74.9	44.6	36.4	24.9	78.5	52.5	45.5	4.8	3.5	3.0
Belgium	102.4	39.6	72.3	72.5	70.3	39.6	72.3	72.5	70.3	8.6	3.3	3.3
Belize	4.7	3.5	51.1	11.1	15.7	3.0	57.9	23.4	27.4	9.9	7.3	6.3
Benin	32.5	27.6	-41.8	-45.1	-23.3	24.2	-24.7	-27.5	-8.4	1.8	1.5	1.3
Bhutan	2.9	2.2				1.9				3.5	2.6	2.2
Bolivia	110.3	87.6	22.5	8.8	28.0	76.3	32.5	20.6	37.3	7.8	6.2	5.4
Bosnia and Herzegovina	25.3	17.6	46.5	25.3	38.9	15.0	54.4	36.3	47.9	8.8	6.1	5.2
Botswana	44.1	31.1	38.2	39.1	39.1	26.6	47.1	47.9	47.9	14.9	10.5	9.0
Brazil	1644.9	950.0	44.9	55.8	57.9	950.0	44.9	55.8	57.9	7.5	4.4	4.4
Brunei Darussalam	13.0	7.7	-6.2	17.6	31.3	6.4	12.2	31.8	43.2	26.3	15.5	12.8
Bulgaria	29.1	16.6	79.9	63.8	65.0	16.1	80.5	64.9	66.1	4.7	2.7	2.6
Burkina Faso	58.5	52.4	-115.7	-42.6	-29.8	46.4	-91.1	-26.3	-15.0	2.0	1.8	1.6
Burundi	10.1	10.1	-27.7	-60.7	-38.1	10.1	-27.7	-60.7	-38.1	0.6	0.6	0.6
Cabo Verde	1.4	1.1		-42.8	-18.3	0.9		-22.9	-1.8	2.6	1.9	1.7
Cambodia	85.6	67.7	-136.3	-86.9	-64.3	59.0	-105.7	-62.8	-43.0	4.3	3.4	3.0
Cameroon	78.9	66.9	19.9	8.5	7.4	58.9	29.6	19.5	18.6	2.1	1.8	1.6
Canada	757.1	400.0	23.7	45.0	41.5	343.5	34.4	52.7	49.8	17.6	9.3	8.0
Central African Republic	45.6	44.5	-11.0	10.2	5.3	39.8	0.6	19.6	15.3	6.1	5.9	5.3
Chad	133.9	124.1	-363.8	-127.7	-90.9	110.4	-312.5	-102.6	-69.8	4.8	4.5	4.0
Chile	70.2	45.5	-9.1	18.5	32.4	38.3	8.1	31.4	43.1	3.4	2.2	1.9
China	15475.3	10005.4	-183.4	-27.3	8.5	8422.1	-138.6	-7.1	23.0	11.3	7.3	6.1
Colombia	297.5	161.0	29.2	32.5	36.4	161.0	29.2	32.5	36.4	5.2	2.8	2.8
Comoros	1.0	0.8	-115.8	-46.4	-44.1	0.7	-90.1	-28.9	-27.0	0.9	0.8	0.7
Congo, Democratic Republic of the	503.8	474.4	-12.0	-10.9	-9.5	422.9	0.2	1.1	2.4	3.3	3.1	2.8
Congo, Republic of	33.9	28.2	-43.1	0.6	8.3	24.7	-25.5	12.9	19.6	4.2	3.5	3.0
Costa Rica	10.8	7.0	41.8	38.2	46.2	5.9	51.0	47.9	54.7	2.0	1.3	1.1
Côte d'Ivoire	68.6	54.5	22.4	-24.5	-19.6	47.5	32.4	-8.5	-4.2	1.7	1.3	1.2
Croatia	19.5	12.0	52.1	45.1	43.4	10.0	60.1	54.2	52.8	5.4	3.3	2.8
Cyprus	8.7	3.0	44.0	66.3	67.0	3.0	44.0	66.3	67.0	6.0	2.1	2.1

Country	Baseline GHG emissions in 2035, $MtCO_2e$	Illustrative 2C aligned target in 2035, $MtCO_2e$	Percent cut vs. (negative = increase)			Illustrative 1.85C aligned target in 2035, $MtCO_2e$	Percent cut vs. (negative = increase)			Baseline per capita GHG emissions in 2035, tCO_2/person	Illustrative 2C aligned per capita GHG emissions in 2035, tCO_2/person	Illustrative 1.85C aligned per capita GHG emissions in 2035, tCO_2/person
			1990	2005	2010		1990	2005	2010			
Czech Republic	94.8	51.1	73.2	63.7	61.6	46.9	75.3	66.6	64.7	9.2	5.0	4.6
Denmark	44.1	18.6	76.4	74.9	72.9	18.6	76.4	74.9	72.9	7.2	3.0	3.0
Djibouti	2.9	2.2	-19.4	-14.3	-9.7	1.9	-3.5	0.9	4.9	2.2	1.6	1.4
Dominica	0.1	0.1	35.4	21.4	33.0	0.1	44.9	33.0	42.9	2.0	1.4	1.2
Dominican Republic	55.3	37.4	-273.6	-34.7	-15.7	31.8	-217.2	-14.4	1.8	4.5	3.0	2.6
Ecuador	98.8	72.8	2.4	13.9	24.3	62.7	15.9	25.9	34.8	5.0	3.7	3.2
Egypt	487.3	367.1	-149.3	-43.5	-25.7	317.2	-115.4	-24.0	-8.7	3.6	2.7	2.3
El Salvador	16.2	12.1	-46.4	8.9	3.7	10.5	-26.4	21.4	16.9	2.5	1.8	1.6
Equatorial Guinea	11.6	8.8	-118.4	54.9	53.4	7.6	-89.0	60.9	59.7	4.8	3.6	3.1
Eritrea	8.1	7.6	-48.5	-28.4	-26.8	6.8	-32.4	-14.4	-13.0	1.8	1.7	1.5
Estonia	11.5	5.5	85.1	66.7	65.1	5.5	85.1	66.7	65.1	9.1	4.3	4.3
Eswatini	.											
Ethiopia	253.9	105.8	-18.4	12.4	29.7	105.8	-18.4	12.4	29.7	1.5	0.6	0.6
Fiji	1.4	1.0		-78.3	-87.5	0.9		-53.3	-61.2	1.5	1.1	0.9
Finland	40.6	13.4	70.3	67.4	72.9	13.4	70.3	67.4	72.9	7.3	2.4	2.4
France	372.4	167.4	68.0	66.7	64.4	167.4	68.0	66.7	64.4	5.5	2.5	2.5
Gabon	25.7	18.6	22.0	36.5	22.4	16.0	33.0	45.4	33.4	8.2	5.9	5.1
Gambia, The	2.8	2.5	-49.6	-25.6	-1.8	2.2	-32.6	-11.4	9.8	0.8	0.7	0.7
Georgia	24.8	17.4	58.3	-125.8	-105.1	14.9	64.4	-93.0	-75.3	6.6	4.6	4.0
Germany	520.3	257.8	80.0	74.0	72.3	236.5	81.6	76.2	74.6	6.4	3.2	2.9
Ghana	41.4	33.2	-62.8	47.5	52.3	29.0	-42.1	54.2	58.4	1.0	0.8	0.7
Greece	64.3	39.9	60.8	70.1	65.6	33.3	67.3	75.0	71.3	6.8	4.2	3.5
Grenada	0.2	0.1	-39.9	-8.0	23.4	0.1	-18.8	8.4	35.0	1.6	1.1	0.9
Guatemala	56.7	42.3	-42.4	-4.1	-0.5	36.5	-22.9	10.2	13.2	2.6	2.0	1.7
Guinea	45.5	39.2	-111.8	-60.6	-33.1	34.6	-86.6	-41.6	-17.3	2.5	2.1	1.9
Guinea-Bissau	4.7	4.2	-22.9	-9.0	4.9	3.7	-8.9	3.4	15.7	1.7	1.5	1.4
Guyana	19.8	10.3	-11.2	16.2	19.7	8.2	10.7	32.7	35.5	22.4	11.6	9.3
Haiti	14.7	12.8	-72.8	-23.5	-6.8	11.3	-52.5	-8.9	5.8	1.1	1.0	0.9
Honduras	31.7	25.4	-68.2	-15.9	-5.9	22.1	-46.7	-1.1	7.6	2.5	2.0	1.7
Hong Kong SAR	36.8	19.9	49.1	58.1	57.7	16.2	58.8	66.1	65.7	5.2	2.8	2.3
Hungary	52.8	32.6	64.4	54.0	47.1	27.2	70.3	61.6	55.9	5.7	3.5	2.9
Iceland	11.6	6.0	55.0	56.3	58.7	4.8	63.9	64.9	66.9	27.3	14.1	11.3
India	6211.5	4812.1	-313.0	-126.2	-74.3	4176.6	-258.4	-96.3	-51.3	3.9	3.0	2.6
Indonesia	1740.4	1278.9	-19.7	-13.2	-18.8	1100.8	-3.1	2.6	-2.3	5.7	4.2	3.6
Iran	1039.6	819.6	-162.4	-35.0	-13.2	713.3	-128.4	-17.5	1.5	10.6	8.4	7.3
Iraq	375.0	283.4	-64.9	-72.1	-34.6	245.0	-42.5	-48.8	-16.4	6.6	5.0	4.3
Ireland	64.7	24.4	60.3	69.1	65.1	24.4	60.3	69.1	65.1	11.4	4.3	4.3
Israel	81.6	43.9	-5.2	38.8	47.1	35.6	14.8	50.4	57.1	7.5	4.0	3.3
Italy	322.3	178.5	65.5	68.0	62.9	154.5	70.2	72.4	67.9	5.7	3.2	2.7
Jamaica	8.7	6.5	32.3	34.2	0.3	5.6	41.6	43.2	14.0	3.2	2.3	2.0
Japan	808.0	464.6	61.5	63.9	62.2	381.9	68.3	70.4	68.9	7.0	4.0	3.3
Jordan	41.1	31.7	-161.3	-27.9	-21.2	27.5	-126.6	-11.0	-5.2	3.1	2.4	2.0
Kazakhstan	329.0	225.6	40.7	39.1	40.8	192.0	49.5	48.2	49.7	14.2	9.8	8.3
Kenya	133.6	108.7	-219.1	-60.2	-16.1	95.1	-179.0	-40.0	-1.5	1.9	1.6	1.4
Kiribati	0.2	0.1	-278.5	-50.2	-46.6	0.1	-231.6	-31.6	-28.5	1.0	0.8	0.7
Korea	574.6	326.8	-15.6	36.3	45.9	268.0	5.2	47.8	55.6	11.4	6.5	5.3
Kuwait	166.9	100.3	-98.6	16.4	20.3	83.2	-64.8	30.6	33.9	30.0	18.0	14.9
Kyrgyz Republic	22.1	18.8	43.8	-57.8	-33.1	16.5	50.6	-38.8	-17.1	2.7	2.3	2.0
Lao P.D.R.	50.5	41.3	-96.7	-56.2	-29.6	36.1	-72.1	-36.7	-13.4	5.7	4.7	4.1

Country	Baseline GHG emissions in 2035, $MtCO_2e$	Illustrative 2C aligned target in 2035, $MtCO_2e$	Percent cut vs. (negative = increase)			Illustrative 1.85C aligned target in 2035, $MtCO_2e$	Percent cut vs. (negative = increase)			Baseline per capita GHG emissions in 2035, tCO_2/person	Illustrative 2C aligned per capita GHG emissions in 2035, tCO_2/person	Illustrative 1.85C aligned per capita GHG emissions in 2035, tCO_2/person
			1990	2005	2010		1990	2005	2010			
Latvia	12.5	5.1	62.4	-1.5	47.8	5.1	62.4	-1.5	47.8	7.3	3.0	3.0
Lebanon	22.0	17.9	-130.8	11.9	27.9	15.7	-101.9	23.0	37.0	3.5	2.8	2.5
Lesotho	3.0	2.7	-28.4	-0.1	1.7	2.4	-13.8	11.3	12.9	1.2	1.0	0.9
Liberia	15.3	13.9	8.7	13.2	16.4	12.3	19.0	22.9	25.8	2.2	2.0	1.8
Libya	117.3	88.3	-1.4	15.4	16.7	76.3	12.3	26.9	28.0	14.2	10.7	9.2
Lithuania	15.1	9.1	78.7	50.2	12.3	7.6	82.3	58.7	27.2	5.8	3.5	2.9
Luxembourg	8.5	3.9	69.5	68.7	67.5	3.2	75.2	74.6	73.6	11.5	5.2	4.3
Macao SAR	3.6	1.8	-81.9	13.9	-1.8	1.5	-45.5	31.2	18.6	5.0	2.5	2.0
Macedonia, FYR	11.5	8.0	44.6	35.5	32.1	6.8	52.8	45.0	42.1	6.8	4.7	4.0
Madagascar	50.0	47.5	9.5	1.4	6.0	42.4	19.2	12.0	16.1	1.2	1.2	1.0
Malawi	32.2	24.8	-74.1	-41.0	-22.3	24.8	-74.1	-41.0	-22.3	1.1	0.9	0.9
Malaysia	400.0	265.9	-32.5	19.4	27.3	225.0	-12.1	31.8	38.5	10.0	6.7	5.7
Maldives	3.5	2.3	-1592.4	-198.6	-95.8	1.9	-1328.4	-152.0	-65.2	6.4	4.2	3.5
Mali	62.7	56.8	-284.6	-169.7	-112.4	50.4	-241.1	-139.3	-88.4	1.9	1.7	1.5
Malta	2.5	1.0	61.6	66.4	66.2	1.0	61.6	66.4	66.2	4.5	1.8	1.8
Mauritania	21.7	18.2	-158.4	-68.4	-54.4	16.0	-127.0	-47.9	-35.6	3.2	2.7	2.3
Mexico	867.3	601.1	-29.3	-7.3	0.5	512.3	-10.2	8.6	15.2	6.1	4.3	3.6
Moldova	17.5	9.4	75.0	8.9	10.9	9.4	75.0	8.9	10.9	6.5	3.5	3.5
Mongolia	88.9	30.7	37.9	36.4	50.5	30.7	37.9	36.4	50.5	22.9	7.9	7.9
Morocco	135.6	104.1	-177.1	-57.6	-36.9	90.2	-140.2	-36.6	-18.7	3.3	2.5	2.2
Mozambique	101.6	93.4	-23.6	-9.5	-1.6	83.0	-9.9	2.7	9.7	2.2	2.0	1.8
Myanmar	193.2	171.2	21.7	26.6	31.7	151.4	30.7	35.1	39.6	3.4	3.0	2.6
Namibia	22.8	17.6	-2.9	16.4	14.0	15.3	10.7	27.5	25.4	6.2	4.8	4.2
Nepal	71.3	53.5	-83.7	-67.0	-47.8	53.0	-82.1	-65.5	-46.5	2.2	1.7	1.7
Netherlands	142.1	60.1	73.6	72.7	72.6	60.1	73.6	72.7	72.6	7.5	3.2	3.2
New Zealand	62.9	26.3	40.9	53.3	45.2	26.3	40.9	53.3	45.2	11.4	4.8	4.8
Nicaragua	37.7	30.9	-3.8	18.9	21.0	27.1	9.1	29.0	30.9	4.8	3.9	3.5
Niger	57.5	52.9	-218.9	-148.6	-115.4	47.0	-183.4	-120.9	-91.4	1.5	1.4	1.3
Nigeria	507.2	299.5	8.3	30.2	23.6	299.5	8.3	30.2	23.6	1.8	1.0	1.0
Norway	34.7	11.2	72.6	67.2	64.0	11.2	72.6	67.2	64.0	6.0	1.9	1.9
Oman	143.4	92.1	-163.4	-48.1	-20.5	77.4	-121.4	-24.5	-1.3	22.0	14.1	11.9
Pakistan	641.5	548.6	-161.8	-63.6	-42.7	483.0	-130.5	-44.0	-25.6	2.1	1.8	1.6
Panama	29.0	18.3	-42.4	-9.9	4.3	15.4	-19.3	7.9	19.8	5.7	3.6	3.0
Papua New Guinea	35.9	29.1	-9.3	16.9	7.6	25.4	4.5	27.4	19.3	2.9	2.3	2.0
Paraguay	81.2	59.3	7.1	28.7	36.3	51.0	20.1	38.7	45.3	10.5	7.6	6.6
Peru	159.6	116.6	-11.5	8.7	17.8	100.3	4.1	21.5	29.3	4.2	3.1	2.7
Philippines	360.5	266.9	-157.5	-74.9	-61.8	230.0	-121.9	-50.8	-39.5	2.9	2.1	1.8
Poland	259.7	161.7	63.7	54.1	56.8	135.2	69.7	61.7	63.9	7.2	4.5	3.7
Portugal	47.0	28.3	57.5	68.5	55.0	23.5	64.7	73.9	62.6	4.6	2.8	2.3
Qatar	175.5	92.2	-250.9	-40.4	1.6	74.3	-182.6	-13.1	20.8	50.0	26.3	21.2
Romania	69.1	43.5	81.0	63.1	51.3	36.5	84.0	69.1	59.2	3.9	2.4	2.0
Russia	1754.4	1178.0	61.9	17.7	10.8	998.5	67.7	30.2	24.4	12.5	8.4	7.1
Rwanda	11.8	10.3	-27.9	-47.9	-28.8	9.1	-12.9	-30.5	-13.6	0.7	0.6	0.5
Samoa	0.8	0.6	-53.7	-19.5	-7.7	0.5	-33.3	-3.6	6.6	3.4	2.6	2.3
São Tomé and Príncipe	0.5	0.4	-289.6	-116.9	-73.4	0.4	-289.6	-116.9	-73.4	1.8	1.2	1.2
Saudi Arabia	863.3	519.2	-119.5	-13.6	13.9	430.9	-82.2	5.7	28.6	21.6	13.0	10.8
Senegal	42.6	36.3	-136.0	-61.7	-40.3	31.9	-107.6	-42.3	-23.5	1.8	1.5	1.4
Serbia	63.4	42.2	50.5	-14.6	42.1	35.8	58.1	3.0	51.0	10.2	6.8	5.7
Seychelles	1.4	0.7	-114.2	34.4	31.7	0.7	-114.2	34.4	31.7	10.1	4.8	4.8

Country	Baseline GHG emissions in 2035, $MtCO_2e$	Illustrative 2C aligned target in 2035, $MtCO_2e$	Percent cut vs. (negative = increase)			Illustrative 1.85C aligned target in 2035, $MtCO_2e$	Percent cut vs. (negative = increase)			Baseline per capita GHG emissions in 2035, tCO_2/person	Illustrative 2C aligned per capita GHG emissions in 2035, tCO_2/person	Illustrative 1.85C aligned per capita GHG emissions in 2035, tCO_2/person
			1990	2005	2010		1990	2005	2010			
Sierra Leone	10.9	9.8	-31.9	-16.5	-8.4	8.7	-16.8	-3.2	4.0	1.0	0.9	0.8
Singapore	85.4	43.5	-29.1	13.5	25.0	34.8	-3.2	30.8	40.0	13.9	7.1	5.7
Slovak Republic	31.9	18.5	71.2	59.6	54.3	16.5	74.4	64.1	59.3	6.0	3.5	3.1
Slovenia	10.8	6.3	56.1	52.9	49.9	5.2	63.7	61.1	58.7	5.2	3.0	2.5
Solomon Islands	32.7	27.7	-556.2	-1164.8	-1116.4	24.3	-477.0	-1012.1	-969.6	31.4	26.6	23.4
Somalia	56.3	53.7	-25.2	-11.2	-13.6	48.0	-11.8	0.7	-1.4	2.1	2.0	1.8
South Africa	490.9	364.1	12.0	34.6	38.2	313.9	24.2	43.6	46.7	6.9	5.1	4.4
Spain	224.6	131.7	48.1	66.6	57.6	108.8	57.1	72.4	65.0	4.8	2.8	2.3
Sri Lanka	25.5	22.8	10.7	29.4	31.7	20.2	20.9	37.5	39.5	1.1	0.9	0.8
St. Lucia	0.3	0.2	-2103.0	-91.8	-19.3	0.2	-1767.6	-62.6	-1.2	1.6	1.1	0.9
St. Vincent and the Grenadines	0.1	0.1	-234.6	14.5	34.1	0.1	-184.3	27.4	44.0	1.6	1.1	0.9
Sudan	0.1	0.1	99.8	99.9	99.9	0.1	99.8	99.9	99.9	0.0	0.0	0.0
Suriname	10.6	7.9	-46.1	-23.3	-18.8	6.8	-26.2	-6.5	-2.5	15.4	11.5	9.9
Sweden	7.8	4.2	83.4	81.9	70.3	3.4	86.6	85.4	76.0	0.7	0.4	0.3
Switzerland	40.6	20.5	61.4	61.4	60.9	16.4	69.2	69.2	68.8	4.4	2.2	1.8
Syria	47.6	39.1	37.8	54.5	55.6	34.2	45.5	60.1	61.2	1.5	1.2	1.1
Taiwan Province of China	286.9	165.5	-12.9	51.7	47.2	136.2	7.1	60.2	56.6	13.0	7.5	6.2
Tajikistan	25.1	22.2	-0.8	-93.7	-92.7	19.6	10.8	-71.3	-70.4	2.0	1.7	1.5
Tanzania	174.6	151.9	-73.2	-36.5	-30.0	134.0	-52.8	-20.4	-14.7	1.9	1.6	1.5
Thailand	510.6	362.8	-56.8	-7.7	3.9	310.5	-34.2	7.8	17.8	7.2	5.1	4.4
Togo	15.5	13.6	-126.5	-109.1	-63.2	12.0	-100.2	-84.8	-44.3	1.3	1.1	1.0
Tonga	0.3	0.3	-37.7	-15.6	-12.2	0.2	-19.4	-0.2	2.7	3.4	2.6	2.3
Trinidad and Tobago	36.0	23.2	-44.9	44.4	52.0	19.5	-21.8	53.3	59.6	24.1	15.5	13.0
Tunisia	43.3	26.9	-20.8	19.7	30.6	26.9	-20.8	19.7	30.6	3.4	2.1	2.1
Turkey	511.9	345.9	-126.1	-30.1	-5.8	293.5	-91.8	-10.4	10.2	5.7	3.8	3.3
Turkmenistan	102.3	72.8	-18.8	10.1	17.9	62.4	-1.7	23.0	29.7	12.0	8.5	7.3
Uganda	80.7	70.9	-139.8	-87.3	-42.4	62.7	-111.9	-65.5	-25.9	1.2	1.1	1.0
Ukraine	290.1	218.0	76.1	49.7	45.3	188.3	79.3	56.6	52.7	7.9	5.9	5.1
United Arab Emirates	312.8	174.0	-118.8	-11.8	17.0	142.0	-78.6	8.7	32.3	24.2	13.5	11.0
United Kingdom	386.7	155.0	81.0	78.0	74.9	155.0	81.0	78.0	74.9	5.3	2.1	2.1
Uruguay	39.9	25.3	-57.2	9.1	12.6	21.2	-31.8	23.8	26.7	11.9	7.5	6.3
Uzbekistan	259.0	206.1	-25.3	-25.6	-13.7	179.6	-9.2	-9.5	1.0	6.0	4.8	4.2
Vanuatu	0.8	0.6	-36.8	-19.1	4.5	0.6	-19.7	-4.3	16.4	1.9	1.6	1.4
Venezuela	212.5	173.6	43.7	47.5	50.1	151.8	50.8	54.1	56.3	7.1	5.8	5.1
Vietnam	654.9	484.3	-1426.4	-97.5	-54.9	417.3	-1215.2	-70.1	-33.5	6.1	4.5	3.9
Yemen	44.2	42.6	-143.5	3.5	19.5	38.1	-117.7	13.7	28.1	0.8	0.8	0.7
Zambia	76.4	67.4	-28.7	-21.7	-8.4	59.5	-13.7	-7.5	4.2	2.7	2.4	2.1
Zimbabwe	99.5	81.4	-81.1	-112.2	-110.0	71.2	-58.4	-85.7	-83.7	4.9	4.0	3.5

Source: IMF staff calculations using CPAT.

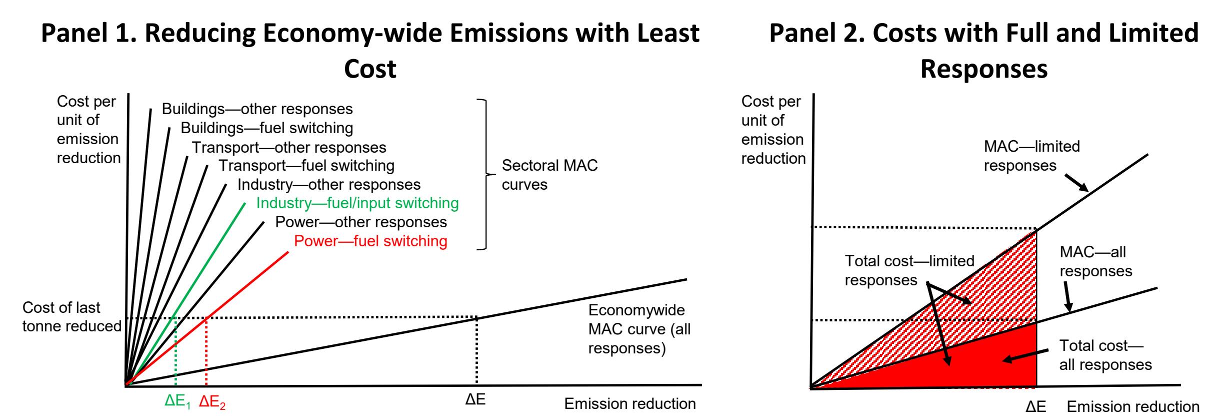
Note: The terms "country" and “economy” do not in all cases refer to a territorial entity that is a state as understood by international law and practice. The terms also cover some territorial entities that are not states. GHG = greenhouse gas; $MtCO_2e$ = million tonnes of CO_2 equivalent; tCO_2 = tonnes of CO_2.

Annex VII. Understanding Mitigation Costs

Cutting economy-wide emissions at least cost involves equating the cost of the last tonne reduced across responses and sectors. This is illustrated in Annex Figure VII.1, Panel 1 where the economy-wide marginal abatement cost (MAC) curve is the envelope, or horizontal summation, of MAC curves at the sectoral level for switching to clean fuels and other responses (like improving energy efficiency, conserving on energy-using products). Reducing economy-wide emissions by ΔE at least cost involves emissions reductions of ΔE_1 and ΔE_2 from fuel/input switching in industry and power generation respectively, and so on. If instead, only a limited range of behavioral responses is exploited, total mitigation costs—the integral under the relevant MAC curve over the range of emissions reductions—will be higher for a given total emissions reduction as indicated in Annex Figure AVII.1, Panel 2, because the narrower policy pushes along a steeper MAC schedule.

Economists generally measure the costs of environmental and other regulations, government investments, taxes, and other policies using the concept of welfare costs. In the context of climate mitigation, the welfare cost of the CO_2 reductions from reducing a particular fuel with no prior tax or subsidy is just the mitigation cost, or integral under the marginal abatement cost schedule, while costs would be larger or smaller if there were a pre-existing tax or subsidy on the fuel. The costs from carbon pricing can therefore be approximated by adding up the mitigation costs from the CO_2 reductions for each fuel in each sector, accounting for any pre-existing fuel tax or subsidy. The domestic environmental co-benefits (like reductions in local air pollution deaths) are netted out from mitigation costs to give the overall economic welfare impacts of carbon mitigation policies.[57]

Figure AVII.1. Minimizing Mitigation Costs



Source: Authors.
Note: The relative position of sectoral MAC curves will vary with country circumstances. MAC = marginal abatement cost.

Where fuels are subject to preexisting taxes this effectively causes the MAC curve for reducing the fuel to start out with a positive (rather than zero) intercept and conversely where fuels are subsidized the MAC for reducing them starts out with a negative intercept. The Climate Policy Assessment Tool takes these effects into account in calculating mitigation costs using a country-specific database of fuel taxes and subsidies (that is, costs are measured relative to a baseline with current price distortions in fuel markets, including from carbon pricing).

[57] See Black and others (2023d) and Parry and others (forthcoming), Ch. 8. On the measurement of domestic environmental co-benefits.

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