STAFF

CLIMATE

NOTES

Not Yet on Track to Net Zero

The Urgent Need for Greater Ambition and Policy Action to Achieve Paris Temperature Goals

Simon Black, Ian Parry, James Roaf, and Karlygash Zhunussova

IMF STAFF CLIMATE NOTE 2021/005

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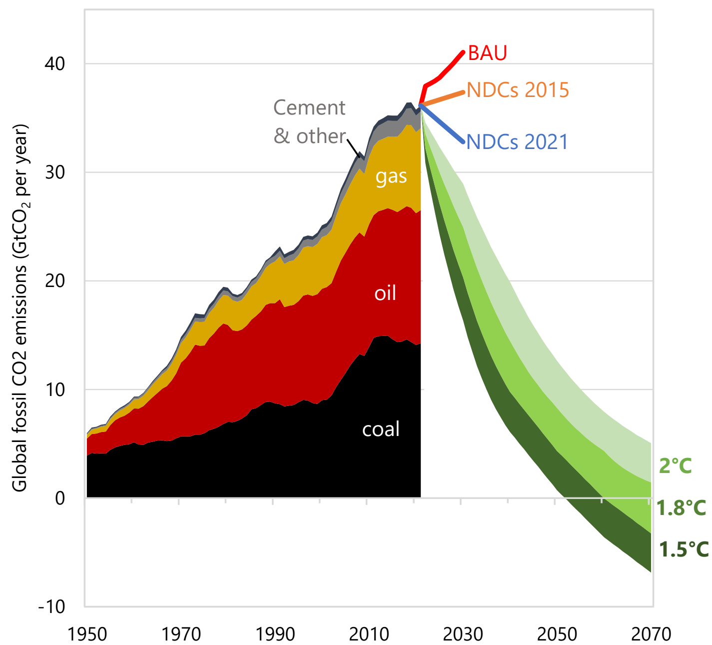
Summary

Achieving the Paris Agreement's temperature goals requires cutting global CO_2 emissions 25 to 50 percent this decade, followed by a rapid transition to net zero emissions. The world is currently not yet on track so there is an urgent need to narrow gaps in climate mitigation ambition and policy. Current mitigation pledges for 2030 would achieve just one to two thirds of the emissions reductions needed for limiting warming to 1.5 to 2ºC. And additional measures equivalent to a global carbon price exceeding \$75 per ton by 2030 are needed. This IMF Staff Climate Note presents extensive quantitative analyses to inform dialogue on closing mitigation ambition and policy gaps. It shows illustrative pathways to achieve the needed global emissions reductions while respecting international equity. The Note also presents country-level analyses of the emissions, fiscal, economic, and distributional impacts of carbon pricing and the trade-offs with other instruments—comprehensive mitigation strategies will be key.

Introduction

The key mitigation objective of the Paris Agreement is to limit future global warming to 'well below' 2ºC and ideally to 1.5ºC relative to pre-industrial levels. Limiting warming to this temperature range requires cutting global CO_2 emissions 25–50 percent below 2021 levels by 2030, followed by a steady decline to net zero emissions near the middle of this century (Figure 1). These reductions are equivalent to cutting CO_2 emissions 30–55 percent relative to IMF business-as-usual (BAU) projections in 2030.[1] Substantial cuts in coal, oil, and natural gas consumption are needed—in 2020 these fuels accounted for 39, 34, and 21 percent of global CO_2 emissions respectively. Additional action on greenhouse gases (GHGs) beyond CO_2 will also be needed, notably on methane (see annex).

Figure 1. Global CO_2 Emissions, Nationally Determined Contributions (NDCs) and Temperature Targets



Source: GCB (2021), IPCC (2018, 2021), UNFCCC (2021a) & IMF staff.
Note: BAU = business as usual; NDCs = nationally determined contributions.

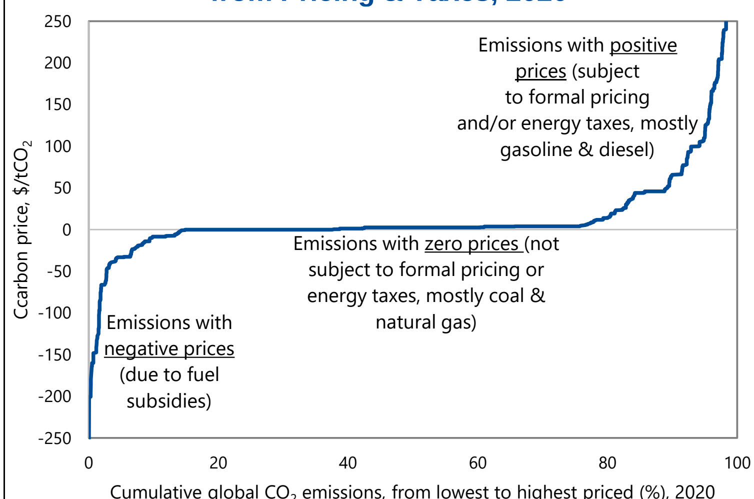
[1] BAU refers to a baseline without new, or tightening of existing, mitigation policies.

If these cuts are not achieved, warming will accelerate, and climate mitigation will require even more drastic reductions in the 2030s. Current global warming to date of 1.2ºC is already having a wide range of impacts.[2] This includes heatwaves, droughts, floods, hurricanes, sea level rise, and swings between climate extremes. The frequency and severity of these impacts is projected to rise as the planet continues to warm. Moreover, the risks of 'tipping points' in the global climate system (e.g., runaway warming from release of underground methane, collapse of major ice sheets causing dramatic sea level rises, shutting down of ocean circulatory systems) rise exponentially with warming above 1.5ºC. Delaying mitigation action would increase the risks of a disorderly and costly transition. Indeed, with a BAU scenario to 2030, emissions would then need to fall by an impractical 95 percent from 2030 to 2040 for a 1.5ºC pathway.

Despite countries variably committing to net zero emissions targets and strengthening 2030 targets, there remains a large near-term gap in *mitigation ambition* (i.e., emissions pledges)*…* 58 countries representing 61 percent of global GHGs have announced net zero targets for mid-century, and 67 of 195 countries have enhanced their 2030 targets in Nationally Determined Contributions (NDCs).[3] Second-round targets submitted ahead of COP26 in November 2021 imply a 20 percent reduction in 2030 emissions compared with BAU, up from a 9 percent reduction in first-round NDCs submitted for the 2015 Paris Agreement.[4] But even if these stronger pledges were achieved in 2030, they would achieve only one to two thirds of emission reduction pathways consistent with 1.5º–2ºC (Figure 1).[5] Some developing countries have pledged stronger ambition conditional on climate finance, though from a global perspective the extra reductions are modest.[6]

…And while carbon pricing is becoming more prevalent, and most countries have some energy taxes, there is still an enormous gap in *mitigation policy*. New measures equivalent to a global carbon price exceeding $75 per ton would be needed by 2030, in addition to existing energy taxes, to keep warming below 2ºC. In 2021, 30 national carbon pricing schemes were operating, new initiatives in China and Germany were launched, and prices in the EU Emissions Trading System (ETS) rose above $70.[7] Nonetheless, the average price from explicit carbon pricing across is only $3 per ton of CO_2. Energy taxes add another $9 to the global average price, mostly through road fuel taxes. Two thirds of global emissions however (largely coal and natural gas) are effectively unpriced, and 15 percent have a negative price due to explicit fuel subsidies (Figure 2).

Figure 2. Global Average Carbon Prices on Fossil Fuels from Pricing & Taxes, 2020



Source: IMF staff.
Note: Shows global average carbon price from carbon taxes/emissions trading systems plus fuel taxes/explicit subsidies by cumulative CO_2 emissions.

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[2] IPCC (2018, 2021)

[3] As of October 2021. See www.climatewatchdata.org/net-zero-tracker. All signatories of the Paris Agreement committed to update their NDCs with enhanced ambition ahead of COP26 in November 2021.

[4] Note for the remainder of the analysis it is assumed that 2030 targets above IMF baseline levels are nonbinding, i.e. countries do not grow their emissions above baseline to those levels. If this assumption is violated it would significantly reduce ambition in current NDCs to about 9 percent below BAU in 2030.

[5] UNFCCC (2021) estimates similar global ambition gaps.

[6] Current conditional and unconditional pledges would cut 2030 emissions 21 and 19 percent below BAU levels respectively—where applicable this Note averages over conditional and unconditional pledges.

[7] See WBG (2021) for details on carbon pricing schemes. All figures are expressed in real 2020 US$ or thereabouts.

Mitigation ambition needs to be scaled up globally, while accommodating the differentiated capabilities and responsibilities among countries—supportive international policy will be key. More countries will need to make long-term net zero commitments and governments will need to ensure intermediate targets for 2030 are aligned with these commitments. Differentiated responsibilities can be accommodated through proportionately lower ambition for developing countries (perhaps reflecting longer transition periods to net zero). Climate finance flows from developed to developing countries to accommodate enhanced ambition, and international coordination mechanisms to address obstacles that can hinder unilateral efforts to scale up mitigation policies, will need to be agreed.

And at the national level, the policy gap can be met by scaling up carbon pricing and/or other mitigation instruments—comprehensive domestic strategies are key. Countries will need to strike a balance between pricing and other instruments that are less efficient than pricing but may have greater political acceptability. Comprehensive strategies (as discussed in Box 2 below) can help improve acceptability by, for example, providing targeted assistance for vulnerable groups, ensuring the costs and revenue recycling benefits of mitigation policies are equitably distributed across households. Complementary public investments in enabling infrastructure, especially in the energy sector, and reinforcing sectoral policies may also be needed to accelerate low-carbon transitions.

Quantitative analysis informs dialogue on closing the global ambition and national policy gaps. This Climate Note presents an extensive quantitative assessment for both issues. The Note uses the Carbon Pricing Assessment Tool (CPAT), a streamlined spreadsheet-based model which projects, on a country-by-country basis for 175 countries, fossil fuel CO_2 emissions and the emissions, fiscal, economic, energy price, and distributional burden of carbon pricing and other commonly used mitigation instruments. CPAT is parameterized so that emissions projections, and the responsiveness of fuel use to pricing, are consistent with the broader climate/energy modelling literature (see the annex for a description of CPAT and caveats).

For this analysis, countries are grouped into three: Advanced Economies (AEs), higher-income (EMDE-H) and lower-income Emerging Market and Developing Economies (EMDE-L), with per capita income above or below $5,500. See Annex for countries in these groupings and discussion of for other country groupings with relevance for COP26. Results for individual G20 countries are also discussed in the following sections, while the full set of country results is available online.[8] The note focuses on fossil fuel CO_2 emissions, which are about three quarters of global GHGs.

<u>Key findings</u> of the analysis include:

- **There are large differences in mitigation commitments across country groupings.** AE/EMDE-H/EMDE-L countries have pledged to reduce their collective CO_2 emissions by 43/12/6 percent below BAU levels in 2030. While it is expected that AEs abate emissions more rapidly for reasons of equity and historical responsibility, without a significant increase in 2030 ambition among EMDEs, with corresponding support of the international community, temperature goals will rapidly become infeasible.

[8] See the online appendix at https://www.imf.org/en/Topics/climate-change/staff-climate-notes. The 19 individual G20 countries account for 80 percent of global BAU CO_2 emissions in 2030 (the other G20 member is the EU as a whole). CPAT, or earlier versions of it, have been used in a variety of multilateral and bilateral IMF reports on climate mitigation—see for example, Arregui and Parry (2020), Batini and others (2020), Black and others (2021), IMF (2019a and b), Parry, Mylonas and Vernon (2021).

- **Several options exist for enhancing ambition across countries in line with temperature targets.** Illustrative examples show different distributions of mitigation effort across the country groups, consistent with keeping temperatures below either 2ºC or 1.5ºC. Reaching the latter target will require much strong mitigation action by all country groups, however.

- **The emissions abatement costs associated with enhanced ambition allocations are generally manageable.** Abatement costs (primarily the annualized costs of investing in clean rather than fossil-based energy) are equivalent to around 0.2–1.2 percent of GDP across country groupings for a 2ºC emission pathway, though they range at 1.3–1.8 percent of GDP for AE and EMDE-Hs in a 1.5ºC pathway.

- **GDP need not be significantly impeded, at least in the longer term, though design of mitigation policies is critical.** Models differ on GDP impacts of carbon pricing, although some indicate that a revenue-neutral shift from taxing labor to carbon could, after transitory losses, moderately increase GDP due to smaller negative fiscal multipliers for carbon pricing. Indeed, recent empirical studies suggest that carbon pricing reforms have not reduced GDP. Boosting green investment could also support GDP.

- **Differences in mitigation ambition, and in the costs of cutting emissions, can however imply large discrepancies in carbon prices or the stringency of other mitigation instruments.** This may hamper countries attempting to aggressively scale up mitigation.

- **Within groupings by development level, there is considerable variation in countries' mitigation pledges and in the responsiveness of emissions to pricing**. This underscores the need to consider individual country circumstances in assessing mitigation ambition and policies, subject to the overall cap on global emissions implied by temperature goals.

- **Carbon pricing, as well as being a key pillar of mitigation strategies, can mobilize substantial revenues, which can be used to support equity and other objectives.** Such revenues are timely not least because of fiscal pressures from the pandemic. Moreover, while the initial burden of price increases across household income groups varies, being somewhat regressive in some countries and progressive in others, recycling of carbon pricing revenues can result in reforms that support both equity and poverty objectives.

- **Climate mitigation can generate substantial domestic environmental co-benefits, most notably reductions in local air pollution mortality.** These co-benefits can more than offset abatement costs—before even counting climate benefits—especially in countries with severe air pollution exposure.

- **Beyond carbon pricing, policies vary in their effectiveness.** Carbon pricing schemes for electricity and industry, cross-sectoral packages of feebates and/or emission rate regulations, and in a few cases coal taxes can have reasonable effectiveness relative to comprehensive carbon pricing. Other policies like taxes on road fuels or electricity consumption have relatively low effectiveness.

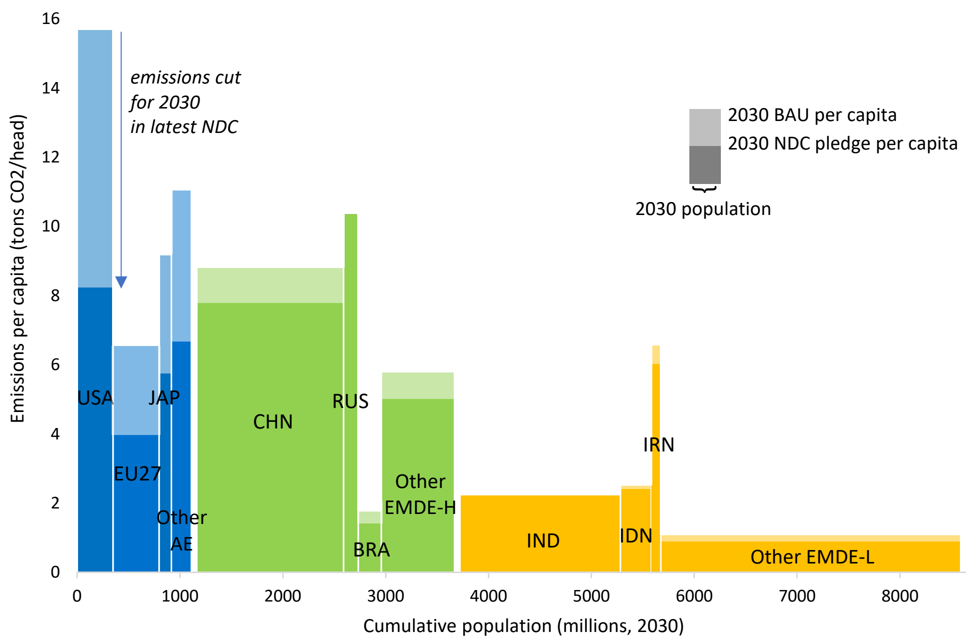
The rest of the Note is organized as follows. The next section discusses illustrative ambition allocations consistent with warming targets and their burdens across AEs, EMDE-Hs, and EMDE-Ls. The Note then presents extensive analysis of measures for closing national-level policy gaps. A final section offers concluding remarks.

Closing the Global Mitigation Ambition Gap

Globally, emissions are highly concentrated in a handful of major economies, with both emissions and ambition levels varying strongly across countries (Figure 3). In general, AEs have aggressive emissions reduction pledges. Large EMDE-Hs and EMDE-Ls have smaller—or in some cases nonbinding—pledges in their current NDCs. Some fast-growing EMDE-H countries are on track to match or exceed per capita emissions of some AEs by 2030, while most EMDE-Ls will still have much lower per capita emissions.

Figure 3. Top Emitters Emissions in 2030: Pledges vs BAU

Fossil fuel CO_2 emissions, top 3 emitters in each country grouping
Areas on chart represent total country emissions (emissions per capita x population)



Source: IMF staff.
Note: Shows the largest emitters in 2030 in the BAU scenario. BAU = business as usual; NDCs = nationally determined contributions; AEs = advanced economies; EMDE-H and EMDE-L = higher-income and lower-income emerging and developing economies.

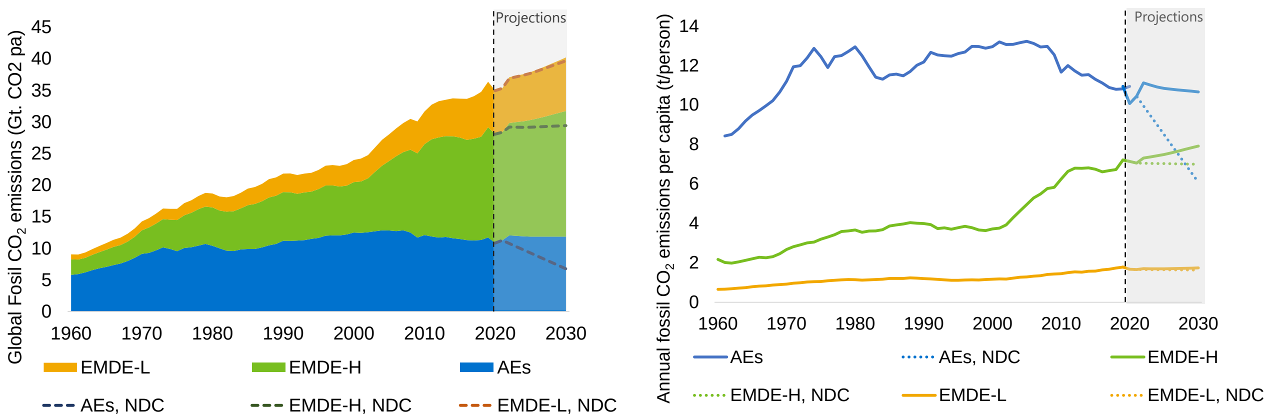
All countries must cut emissions rapidly to achieve the Paris Agreement's temperature targets, though capabilities vary and support for developing countries is needed. Under the Paris Agreement, unlike previous agreements, all countries committed to reducing emissions, subject to differentiated responsibilities, capabilities, and national circumstances.[9] Historically, developed countries have had higher annual, per capita, and cumulative emissions, but this has been changing gradually. EMDE annual emissions have grown from 36 percent (5 billion tons CO_2) in 1970 to 69 percent (24 billion tons) in 2020. AE emissions have stabilized at around 10–12 billion tons since 1970. AEs, EMDE-Hs, and EMDE-Ls account for 51, 35, and 14 percent, respectively of the cumulative stock of CO_2 in the atmosphere from 1860–2021 emissions. Per capita emissions remain higher in AEs, but have been falling since 2000, while rising rapidly in EMDE-Hs and more gradually in EMDE-Ls.[10] Under current pledges, AE average per capita emissions would be below those of EMDE-Hs by 2030 (Figure 4).

[9] Per the Paris Agreement: "common but differentiated responsibilities and respective capabilities, in the light of different national circumstances" UNFCCC (2016), Article 2.2

[10] Figures in this section are emissions-weighted averages for 39 AEs, 67 EMDE-Hs, and 89 EMDE-Ls.

Figure 4. Historical, Projected BAU and Targeted Fossil CO_2 Emissions by Country Grouping, Total (left) and Per Capita Emissions (right)

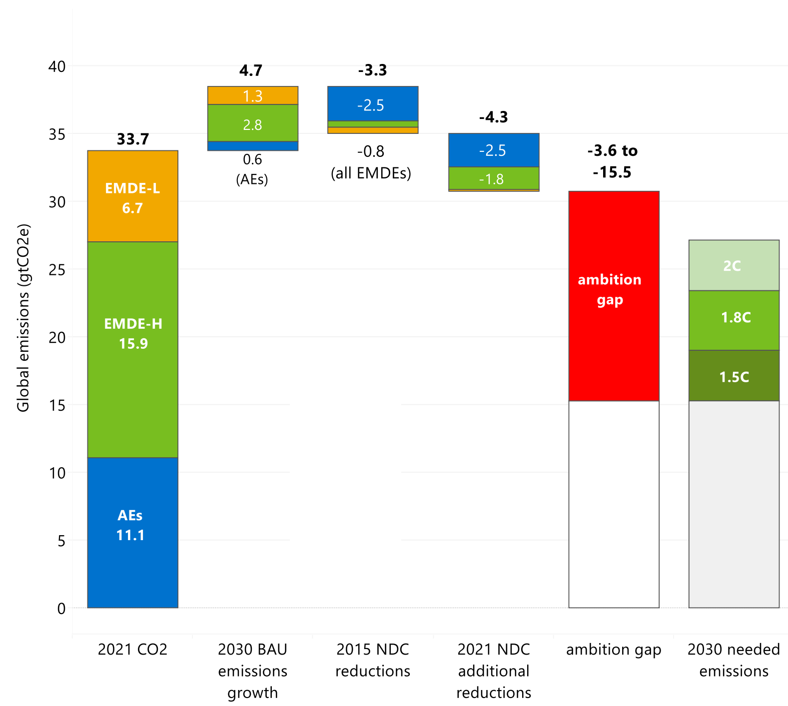
Panel 1. CO_2 emissions by country grouping **Panel 2. CO_2 per capita by country grouping**



Source: Global Carbon Budget (2021), UNFCCC (2021a), World Bank (2021) and IMF staff.
Note: NDC = nationally determined contributions; AEs = advanced economies; EMDE-H and EMDE-L = higher-income and lower-income emerging and developing economies.

Ambition gaps have narrowed since 2015 but remain large (Figure 5). Comparing ambition relative to future BAU levels better reflects countries' mitigation efforts. This is because it allows for rising total emissions in lower-income EMDEs over the next decade, though at a slower rate. In total, there is a global ambition gap in NDCs of 3.6 to 15.5 gigatons of CO_2 in 2030, requiring a tripling of ambition in the latter case. Aggregate AE/EMDE-H/EMDE-L ambition in revised NDCs corresponds to reductions in CO_2 emissions of 43/12/6 percent below BAU levels in 2030.[11] This compares to targets under the original 2015 NDCs of 21/3/4 percent below 2030 BAU levels. In total, current developing country NDCs imply their emissions in 2030 would be 6 percent higher than 2021 levels (4 and 12 percent in EMDE-H and EMDE-Ls, respectively).

Figure 5. Global Mitigation Ambition Gaps to 2030

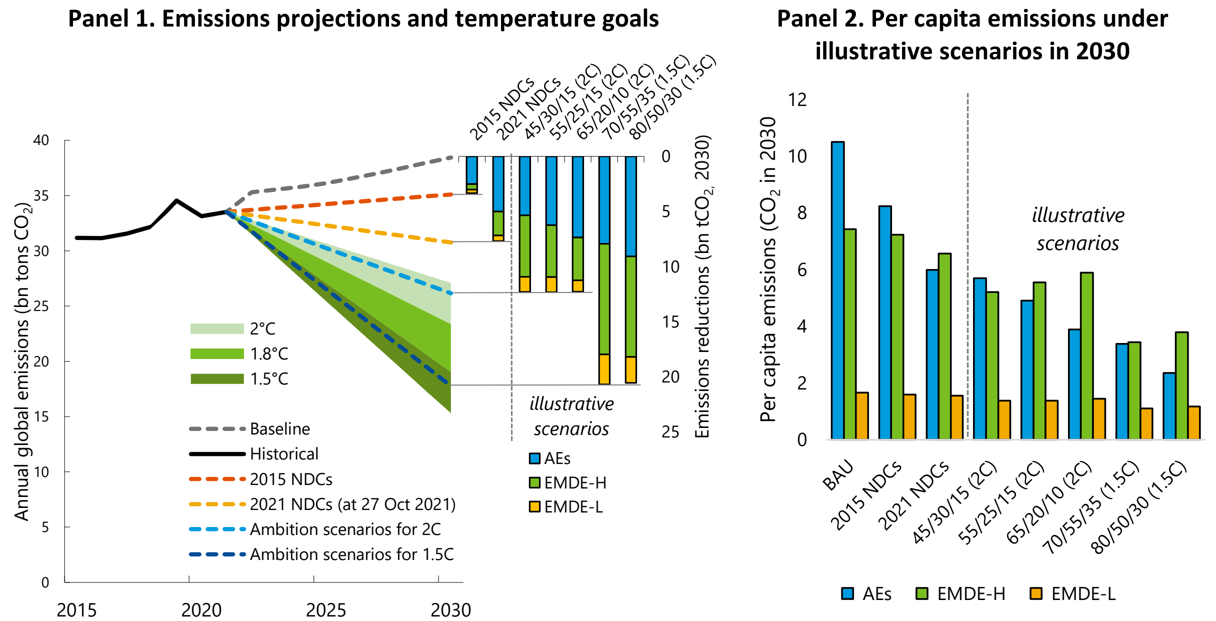


Source: IMF staff.
Note: NDC = nationally determined contributions; AEs = advanced economies; EMDE-H and EMDE-L = higher-income and lower-income emerging and developing economies.

[11] NDCs are as of October 2021. Reductions in CO_2 emissions are assumed to be proportional to pledged reductions in GHGs. It is assumed that countries with targets above forecast BAU do not increase emissions above that BAU.

Figure 6 presents illustrative scenarios for closing the global ambition gap, showing different allocations of mitigation effort across country groupings as well as uncertainty in needed emissions pathways. By way of examples, AE/EMDE-H/EMDE-L emissions reductions scenarios of 45/30/20, 55/25/15, or 65/20/10 percent below BAU would each put emissions within range for a 2ºC target, with varying levels of reductions in developed and developing countries.[12] Much more ambitious allocations of 70/55/35 or 80/50/30 percent would be in range for a 1.5ºC pathway (Panel 1). Under most of these scenarios, average per capita emissions would be higher in EMDE-Hs than in AEs in 2030, while average EMDE-L per capita emissions would remain below AEs and EMDE-Hs in all scenarios (Panel 2). Overall, to be on track with achieving the Paris Agreement's temperature goals, all country groups need to enhance their ambition from 2015 NDCs.[13]

Figure 6. Energy-Related CO2 Emissions Projections, Targets Aligned with Temperature Goals, and Illustrative Scenarios for Closing Ambition Gaps to 2030



Source: IMF staff and IPCC (2018, 2021).
Note: Shows energy-related CO_2 emissions (excluding international aviation and maritime). NDC = nationally determined contributions; AEs = advanced economies; EMDE-H and EMDE-L = higher-income and lower-income emerging and developing economies.

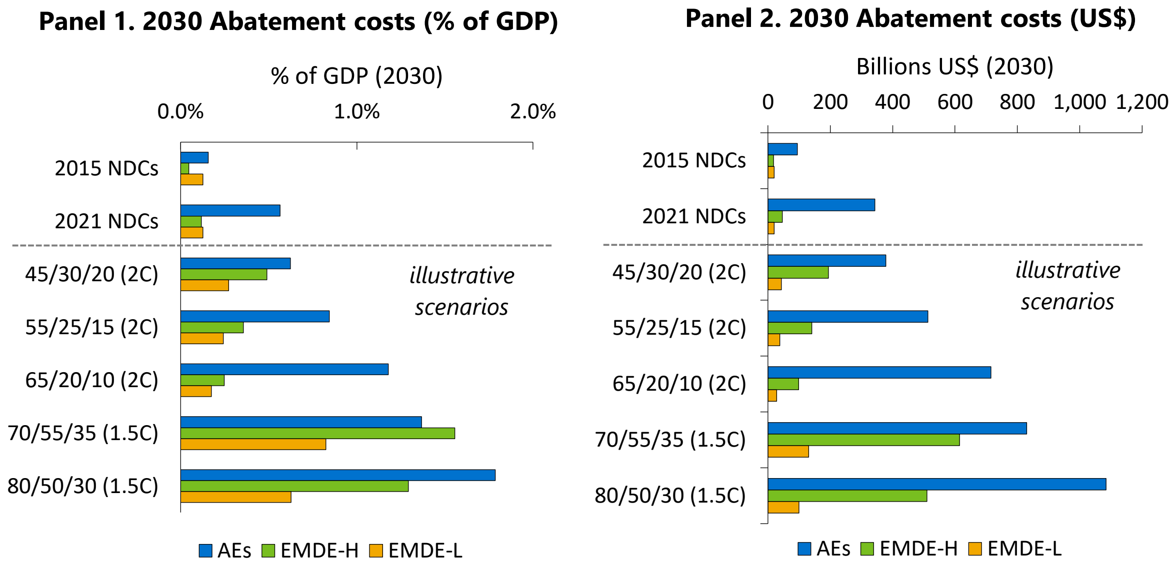
The economic burden implied by mitigation ambition—prior to counting global and domestic environmental benefits—can be measured by emissions abatement costs or by GDP impacts. Abatement costs measure the costs to households and firms from reducing their energy use and shifting to cleaner energy sources—they mainly reflect the annualized costs of investing in cleaner, rather than emissions intensive, technologies and products (net of any savings in lifetime fuel costs).[14] The estimates assume that emissions are reduced in the least-cost way. Policymakers also often focus on the (near term) GDP impacts of climate mitigation. These depend on how output and the demand components of GDP (including investment) respond to the change in mitigation policy.

[12] In the following calculations all countries in a group are assumed to increase their ambition from current levels to the enhanced amount or leave their current ambition unchanged if it already exceeds the enhanced amount.

[13] Notably, absent additional ambition by developing countries, AEs would need to (unrealistically) raise their 2030 ambition to 95 percent below BAU levels, even to meet the 2ºC pathway.

[14] To an approximation, abatement costs reflect integrals under marginal abatement cost schedules for reducing emissions and are approximately equivalent to losses in consumer and producer surplus in fuel markets.

Figure 7. Abatement Costs of Previous, Current and Temperature-Aligned Targets in 2030



Source: IMF staff.
Note: Abatement costs do not account for offsetting domestic and global environmental benefits. NDC = nationally determined contributions; AEs = advanced economies; EMDE-H and EMDE-L = higher-income and lower-income emerging and developing economies.

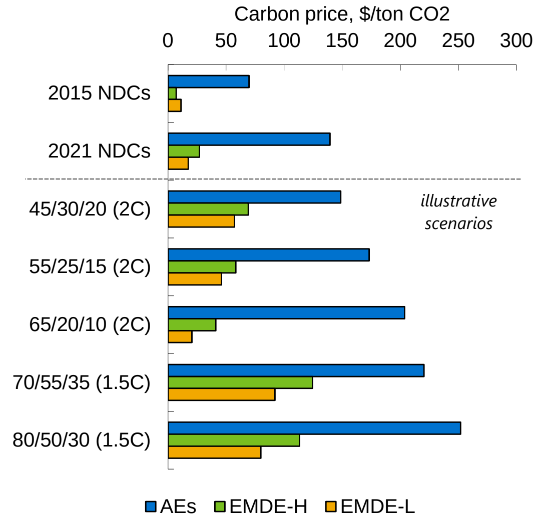
Abatement costs are manageable (equivalent to 0.2–1.2 percent of GDP) for a 2ºC target but are more considerable for a 1.5ºC target (Figure 7). Abatement costs rise disproportionately with deeper emissions reductions, as lower-cost mitigation opportunities are progressively exhausted. Costs are also larger—for a given percentage emission reduction below BAU and when expressed relative to GDP—for EMDE-Hs and EMDE-Ls than AEs due to the higher emissions intensity of GDP in the former countries, and therefore larger magnitude of emissions (relative to GDP) that need to be cut. Abatement costs for AE/EMDE-H/EMDE-Ls are equivalent to 0.6–1.2/0.2–0.5/0.2–0.3 percent of GDP under the illustrative allocations for 2ºC (Panel 1). For the illustrative 1.5ºC abatement costs are significantly larger at 1.4–1.8/1.3–1.6/0.6–0.8 percent of GDP respectively. For EMDE-Ls costs increase in absolute terms by $8-23 billion under the 2ºC scenarios relative to costs under their current mitigation pledges.

Cutting emissions need not come at the cost of GDP. Indeed, recent empirical studies suggest that previous carbon pricing reforms have not reduced GDP.[15] This could be, for example, due to findings that there are lower negative fiscal multipliers for carbon taxes than labor taxes.[16] Accordingly, some models indicate that a revenue-neutral tax shift from labor and onto carbon can, after transitory losses, moderately increase GDP. An increasing number of ex ante simulation-based studies have suggested potentially positive, albeit modest, impacts on GDP from environmental tax reforms, especially in developing countries, due to factors such as reductions in informality and tax evasion (as carbon taxes are harder to evade than income taxes).[17] Lastly, investments in renewable energy has larger fiscal multipliers than investments in non-renewables and that public investments in renewables could support GDP objectives.[18]

[15] See, for example, Bernard and Kichian (2021), Bretscher and Grieg (2020), and Metcalf and Stock (2020).
[16] Schoder (2021).
[17] See Heine and Black (2018).
[18] See Batini and others (2021).

There is considerable dispersion in carbon prices implied by ambition allocations. These are prices on CO_2 emissions that, if adopted by all countries within a grouping, would achieve the aggregate emissions reduction implied by ambition for that group. In practice, countries will rely at least to some extent on non-pricing policies but those would need to have the same impact on emissions as the carbon price. Under current ambition, 2030 implied carbon prices for AE/EMDE-H/EMDE-Ls are \$140/\$30/\$20 per ton. Such wide differences in needed carbon prices (or other instruments) will likely hinder country-level efforts to rapidly scale up mitigation[19] and in this regard, ideally, enhanced ambition allocations would if anything narrow, rather than compound, these price differences. For example, 2°C allocations would imply price ranges of \$150–205 per ton for AEs, \$40–70 for EMDE-Hs, and \$20–60 for EMDE-Ls. See Figure 8.

Figure 8. Implied Carbon Prices by Scenario, 2030



Source: IMF staff.
Note: Carbon prices weighted by baseline CO_2 emissions in 2030. NDC = nationally determined contributions; AEs = advanced economies; EMDE-H and EMDE-L = upper and lower-income emerging and developing economies.

In short, stronger commitments from the international community to support scaling up of ambition in developing countries will be needed to close a sizable portion of the ambition gap—international policy coordination will likely be needed to help achieve this. AEs can also play an important role in closing the ambition gap, building on their already stronger emissions commitments. To achieve ambition commitments, international agreement on policy coordination regimes to overcome obstacles to unilateral mitigation action will likely be needed. See Box 1.

External financing will be critical, given limited financing options in EMDEs for green projects, especially in the aftermath of the COVID-19 pandemic. Developed countries, however, are lagging on their current (let alone enhanced) commitments to global climate finance. AEs committed to mobilizing \$100 billion a year from 2020 onwards (or \$1 trillion over the decade) for climate mitigation and adaptation projects in developing countries, but so far there is a shortfall. The most recent stock-take put these flows at \$79.6 billion in 2019, with 43 percent from multilateral development banks, 36 percent from bilateral donations, and 18 percent from privately leveraged sources—about 75 percent of the flows are for mitigation and 25 percent adaptation.[20] Scaling up private financing for EMDEs will require overcoming their higher perceived risks, for example, through standardized measures of risk to provide better information for private investors.

[19] One issue is the potential loss, or fear of loss, of competitiveness from jurisdictions with relatively aggressive emissions pricing—in turn this can lead to emissions leakage if production activities are internationally mobile. However, carbon embodied in goods may be higher for traded products from EMDE-Hs and EMDE-Ls as for AEs (Keen and others 2021). Thus, AE industries may not suffer a loss in relative competitiveness even if they are subject to carbon prices that are higher than as those for EMDE-Hs and EMDE-Ls.

[20] See OECD (2021). Methodologies for measuring flows and to what extent they are additional are contentious, however. For example, some government donations might come at the expense of other overseas development assistance. See IMF (2021a), Ch. 3 for further discussion on the need for climate finance.

Box 1. International Policy Coordination

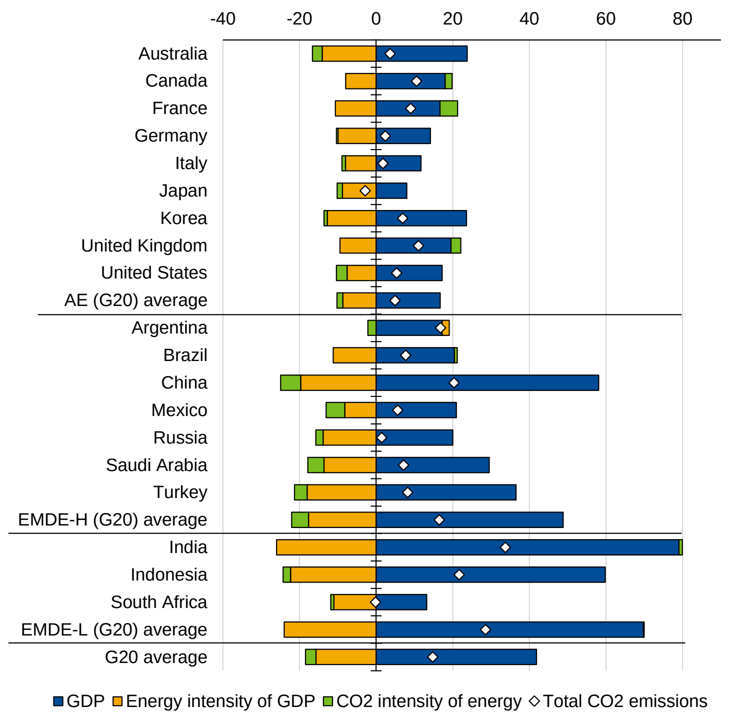
Though progress on ambition has been made since 2015, complementary 'mini-lateral' agreements may be needed to reinforce the Paris Agreement and deliver the needed global emissions reductions by 2030. Recent proposals for supplementary international regimes focus on coordinating carbon pricing since a carbon price is an efficient and easily understood parameter. Simultaneous action to increase in pricing across large emitters could be an effective way of addressing concerns about competitiveness and policy uncertainty in other countries. Proposals include a "Climate Club" suggested by Germany, an international carbon price floor suggested by IMF staff, and other forms of coordinated carbon pricing.[21]

An agreement between major emitters that increases ambition while addressing equity concerns could help narrow global ambition and policy gaps. Ideally, an agreement would include a small number of large-emitting countries to facilitate negotiation. For example, China, India, the EU, and US alone are nearly two-thirds of projected baseline emissions in 2030. It should also focus on concrete policy actions which, if implemented, would deliver the needed global emissions reductions by 2030. Critically, the agreement would need to consider the differentiated responsibilities. This might be accommodated through differentiating price (or quantity) targets based on development levels and financial or technological transfers. Additionally, it should accommodate countries pursuing other approaches to pricing so long as they achieve equivalent emissions outcomes through other policies.

Closing Country-Level Mitigation Policy Gaps

The starting point for assessing countries' domestic mitigation strategies is BAU emissions projections (Figure 9). In CPAT, BAU emissions projections depend on three basic trends, which are consistently estimated across countries: (i) GDP; (ii) the energy intensity of GDP; and (iii) the emissions intensity of energy. Under BAU conditions, GDP is projected to grow rapidly by 60–80 percent between 2021 and 2030 in China, India, and Indonesia, but by a more moderate 8–25 percent in most other G20 countries. On the other hand, the energy intensity of GDP is projected to decrease by 10–25 percent across countries reflecting, for example, improvements in energy efficiency (as newer capital replaces older) and the tendency of energy demand to grow less rapidly than GDP. Changes in the emissions intensity of energy are modest, principally because policies to advance renewables are frozen in the BAU scenario. On net, BAU emissions from G20 countries are projected to expand 15 percent.

Figure 9. Drivers of BAU CO_2 Emissions, 2021-2030



Source: IMF staff.

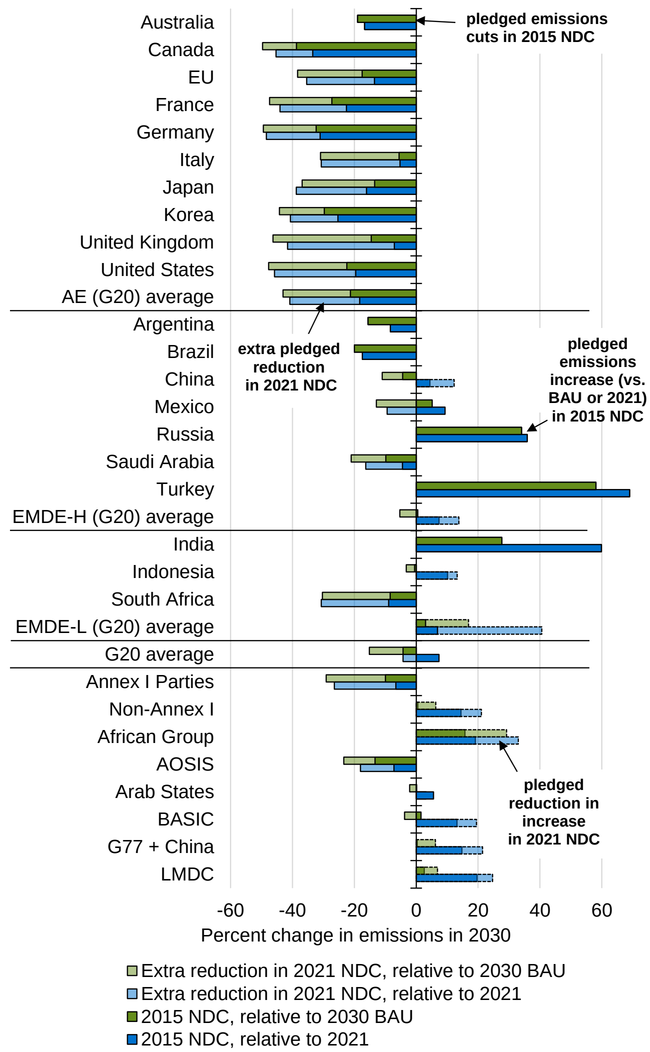
[21] See Parry, Black, and Roaf (2021), Nordhaus (2015), ICAP (2020), and www.bundesfinanzministerium.de/Content/EN/Pressemitteilungen/2021/20210825-german-government-wants-to-establish-an-international-climate-club.html.

Mitigation ambition can be difficult to compare across countries' nominal pledges. Mitigation commitments among G20 countries take the form of targets for emissions relative to historical or future BAU emissions, or for the emissions intensity of GDP (see Table A2 in the annex). These nominal pledges can be difficult to compare, not least because countries use different methodologies for assessing BAU emissions. CPAT converts all pledges into an absolute emissions target for 2030 and comparing these targets with the model's BAU emissions projections provides a consistent comparison of effective mitigation ambition across countries.[22]

There is notable heterogeneity in ambition across countries (Figure 10). Among G20 AEs, all but Australia have pledged GHG emissions[23] reductions of 30 percent or more below BAU levels, with significant increases in ambition. Average AE reductions are 43 percent vs. BAU. Six G20 EMDEs have pledged reductions of 15 to 30 percent, but three EMDE pledges (Russia, Turkey, and India) remain higher than BAU. EMDE-H average cuts are 5 percent below BAU while EMDE-L targets average above BAU.[24]

Additionally, ambition varies among Parties and negotiating groups within the UNFCCC, and about one third of Parties have enhanced their 2030 ambition. To date, Annex I (developed) countries as a group have enhanced their commitments significantly from 10 to 29 percent below BAU, whereas Non-Annex I (developing countries) commitments are roughly around BAU. Negotiating group AOSIS (Alliance of Small Island States) has enhanced its ambition moderately, Arab States and BASIC (Brazil, South Africa, India, and China) less so, while African Group, G77+China, and LMDCs (Like-Minded Developing Countries) have targets that remain above baseline. In total, 67 of 198 Parties to the UNFCCC have increased their 2030 mitigation ambition.

Figure 10. Pledged Changes in 2030 GHG Emissions (Absolute and vs. Business-As-Usual), G20 Countries



Source: IMF staff estimates and UNFCCC (2021).
Note: Positive values for bars indicate NDCs would allow emissions to increase in 2030 compared with BAU (green) and 2019 (blue) levels. Group averages weight by countries' 2030 BAU emissions. AOSIS = Alliance of Small Island States; BASIC = Brazil, South Africa, India, and China; LMDC = Like-Minded Developing Countries.

[22] In practice, most countries are planning mitigation policies, but these measures are highly country-specific, and their future stringency may change with economic and political factors. Using a BAU scenario provides a consistent comparison across countries and a clean benchmark against which policy options can be evaluated.
[23] This section focuses on GHGs excluding landuse, landuse change and forestry (LULUCF), and allows for emissions rises for countries whose targets are greater than BAU. Other sections focus on CO_2 and fix nonbinding pledges to BAU.
[24] Per footnote 5, in the rest of the analysis we assume that countries with targets above baseline levels do not grow emissions above BAU by, for example, reversing existing mitigation policies.

Least-Cost Mitigation Instruments and Their Impacts

Carbon pricing potentially achieves mitigation goals with lowest economic cost, but other mitigation instruments are needed due to likely constraints on the acceptability of pricing—and a comprehensive mitigation strategy contains several other key elements. As carbon prices, either in the form of a carbon tax or an ETS, are passed forward into higher prices for fossil fuels, electricity, and goods produced with energy, the full range of behavioral responses for reducing energy use and shifting to cleaner energy sources is promoted—and cost effectively, as the reward for reducing emissions by an extra ton (the carbon price) is equated across the responses. Due to constraints on the acceptability of higher energy prices however, policymakers may limit pricing, or not use it at all. In these cases, there is an important role for reinforcing instruments at the sectoral level like feebates and regulations (see the following section), which are less efficient but avoid significant impacts on energy prices. Indeed, a comprehensive approach with several key ingredients can enhance the effectiveness and acceptability of a mitigation strategy with carbon pricing as the centerpiece—see Box 2. Analyzing carbon pricing is still useful even for countries using other approaches as it indicates least-cost behavioral responses that ideally would be mimicked, insofar as possible, by other instruments.

Box 2. Key Elements of a Comprehensive Mitigation Strategy

Prospects for an effective and politically acceptable mitigation strategy can be enhanced by a comprehensive approach with several key elements.[25] These include:

- A balance between carbon pricing and other mitigation instruments—especially feebates or regulations—at the sectoral level that are less efficient than pricing but likely have greater acceptability;
- Recycling of carbon pricing revenues in ways that boost the economy (e.g., through lowering taxes on work effort or funding socially productive investments), making sure that benefits are equitably distributed across households;
- Public investments in clean technology infrastructure networks (e.g., electric vehicle charging infrastructure, grid updates to accommodate renewables) that would not be provided privately—estimates vary, but an additional 0.2 percent of GDP in public investment in energy could be needed per year to 2030[26], which is about one fifth of the revenues raised by a $75 global carbon tax;
- Basic research to advance critical technologies that are currently far from the market (e.g., energy storage, direct air capture and carbon capture and storage) and measures to address barriers to large-scale deployment of clean technologies;[27]
- Market reforms to enhance competition and investment in the main energy sectors;
- Just transition measures to assist vulnerable groups, such as stronger social safety nets or tax reliefs for low-income households, assistance programs for displaced workers and at-risk regions;
- Measures to limit impacts of carbon pricing on industrial competitiveness; and
- Pricing or similar schemes for GHG emissions beyond the energy sector.

Extensive upfront consultations with stakeholders and information campaigns to inform the public of the rationale for reform, can help build political support. Reforms should also be phased in progressively to give households and firms time to adjust. Recent increases in fossil fuel prices, while likely transitory in nature, are another reminder of the need for low-carbon energy transitions to shield the economy from recurrent fuel price shocks, but they also underscore the importance of a comprehensive and inclusive approach to reform.

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[25] See for example IMF (2019a, b, 2020 Ch. 3), Coady and others (2018).
[26] IMF (2021c).
[27] See Dechezleprêtre and Popp (2017) for an overview of technology policies—they recommend a gradual doubling of basic energy research (currently less than 0.1 percent of GDP in EU countries).

There is considerable variation in the responsiveness of emissions to pricing within AEs and EMDE-Hs (Figure 11). For illustration, a $75 carbon price reduces emissions around 25 percent in three AEs but only around 15 percent in three other AEs, while for EMDE-Hs a $50 carbon price reduces emissions around 25–30 percent in three cases and only about 15 percent in three others.[28] Ambition targets within country groupings might therefore take into account differences in the relative responsiveness of emissions to pricing across countries—if not, there could be considerable dispersion in emissions prices or incremental mitigation costs across those countries. For the whole G20, measures equivalent to a carbon price rising to over $75 per ton by 2030, on top of existing measures, are needed to cut emissions at least 30 percent below BAU levels, consistent with limiting warming to Paris temperature ranges.[29]

Figure 11. CO_2 Emissions Impacts from Carbon Pricing, G20 Countries 2030

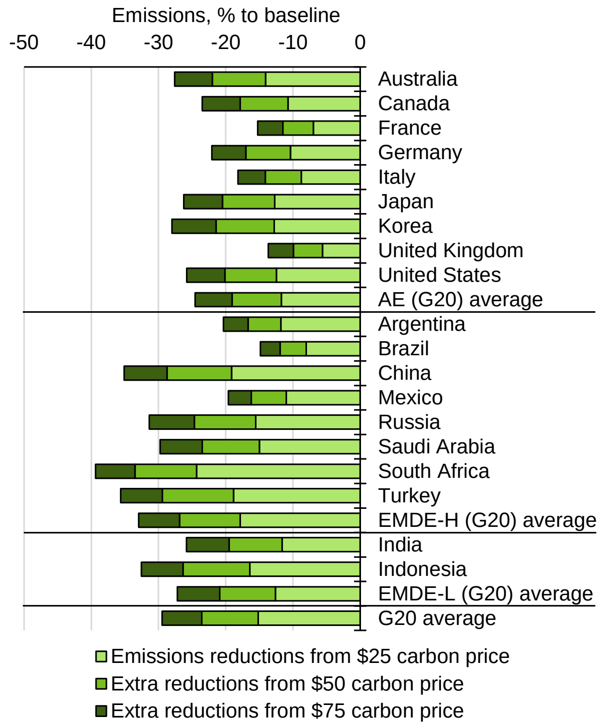
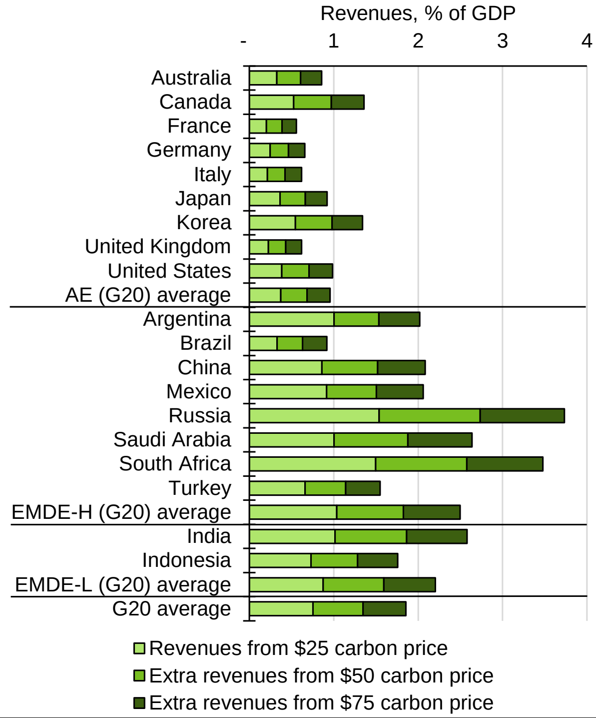


Figure 12. Revenues from Carbon Prices to Baseline, G20 Countries 2030



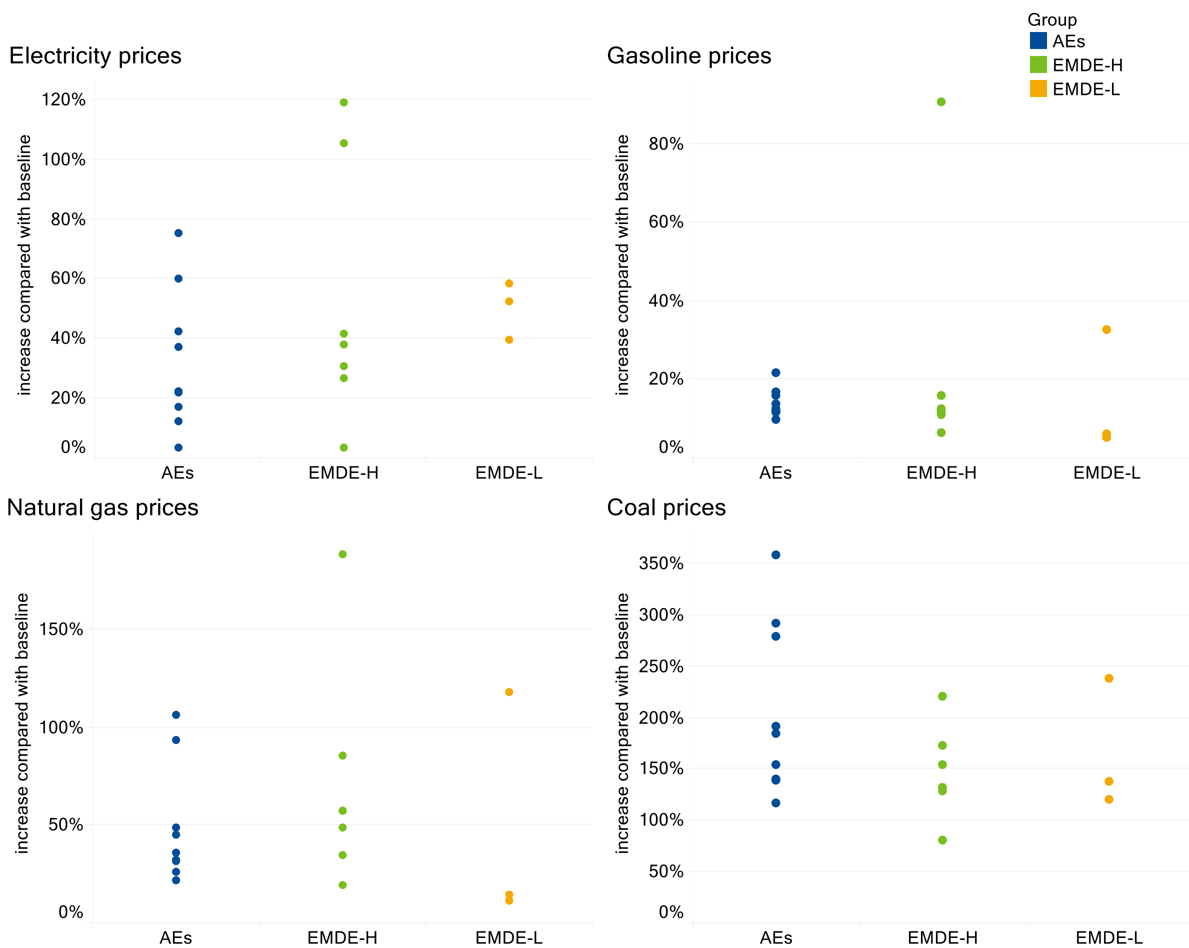
Source: IMF staff
Note: Group averages weight by countries' 2030 BAU emissions. Estimates impose carbon pricing on top of currently existing energy taxes or subsidies. Estimated revenues account for changes in revenues from pre-existing fuel taxes and subsidies.

Carbon pricing could mobilize a significant source of new revenue (Figure 12). Revenues average roughly 1 per cent of GDP for carbon prices of $75 in AEs, 1.5 per cent of GDP for $50 in EMDE-Hs and 1 per cent of GDP for $25 in EMDE-Ls, though again with significant variation among countries. For a given carbon price, potential revenues are higher for countries with higher CO_2 emissions intensity of GDP under BAU. Revenues increase less than proportionally to the carbon price, due to the progressive erosion of the tax base.

[28] Emissions price responsiveness tends to be relatively high in countries where a large share of emissions comes from coal and relatively low where a large share comes from petroleum products—this reflects the disproportionately high impact of carbon pricing on coal prices and its disproportionately low impact on petroleum product prices (see the following discussions).
[29] See also IMF (2019a) and Stiglitz and others (2017).

Carbon pricing has large impacts on coal prices, intermediate impacts on natural gas and electricity prices, and more moderate impacts on road fuel prices. Figure 13 shows impacts on energy prices in 2030 relative to BAU levels from carbon prices of $75/50/25 for AE/EMDE-H/EMDE-Ls (Table A3 in the annex shows impacts for individual G20 countries). Coal prices increase the most by far owing to its high emissions intensity per unit of heat produced, followed by natural gas, electricity and finally gasoline (which starts from a much higher base due to existing road fuel taxes). The absolute price increases from a given carbon price are similar across countries for coal, natural gas, and gasoline (the percent price increases vary with differences in BAU price levels, with a broad trend of higher percent increases in lower-income countries), while the absolute price increases for electricity vary according to the mix of generation fuels.

Figure 13. Impact of $75/$50/$25 Carbon Price on Energy Prices in G20 AE/EMDE-H/EMDE-Ls, 2030

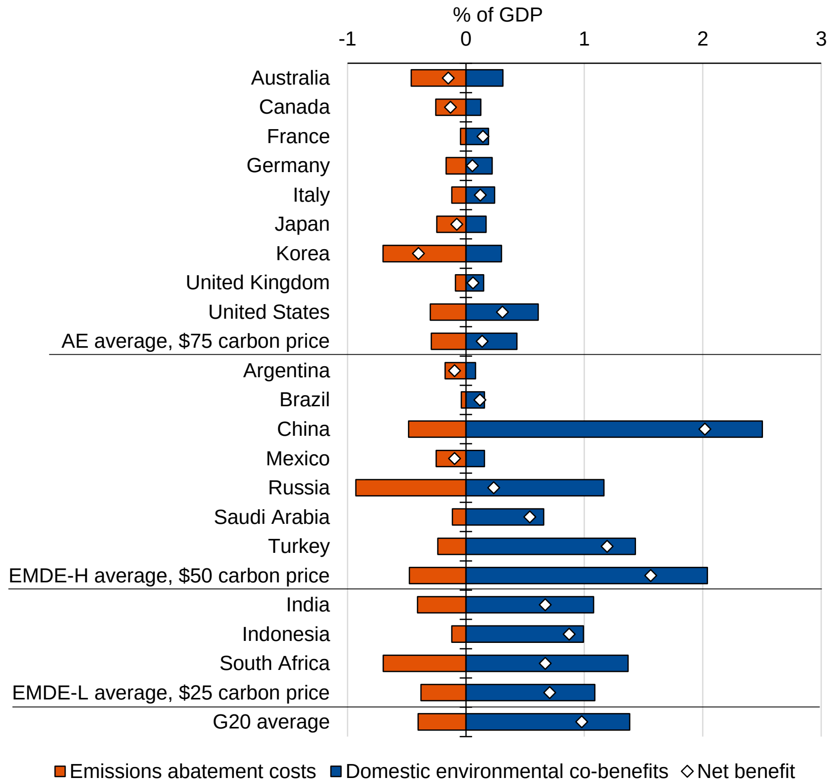


Source: IMF staff.

Note: AEs = advanced economies; EMDE-H and EMDE-L = higher-income and lower-income emerging and developing economies. Each dot represents a price in an individual country, which is a consumption weighted average across prices in different sectors within the country. Includes impact of $75/50/25 carbon prices for AE/EMDE-H/EMDE-Ls in 2030. Estimates impose carbon pricing on top of currently existing energy taxes or subsidies.

Emissions abatement costs are, in many countries, more than offset by domestic environmental co-benefits (Figure 14). Under carbon prices of $75/50/25 for AE/EMDE-H/EMDE-Ls in 2030 emissions abatement costs vary from 0.1 to 0.9 percent of GDP depending primarily on the price, their BAU emissions intensity of GDP, and the proportionate reduction in emissions induced by pricing. However, the blue bars in this figure indicate the domestic environmental co-benefits of carbon pricing—most importantly reductions in mortality from local air pollution. Net benefits (indicated by the diamonds) are approximately zero or moderately positive in most cases, and strongly positive in some cases (e.g., China, India, Turkey) where local air pollution benefits would be especially large.[30] These estimates suggest that unilateral carbon pricing might, up to a point, be in some countries' own national interests if the domestic environmental co-benefits are considered, before even counting the climate benefits they will share in.

Figure 14. Emissions Abatement Costs and Domestic Environmental Co-Benefits from Carbon Pricing, 2030



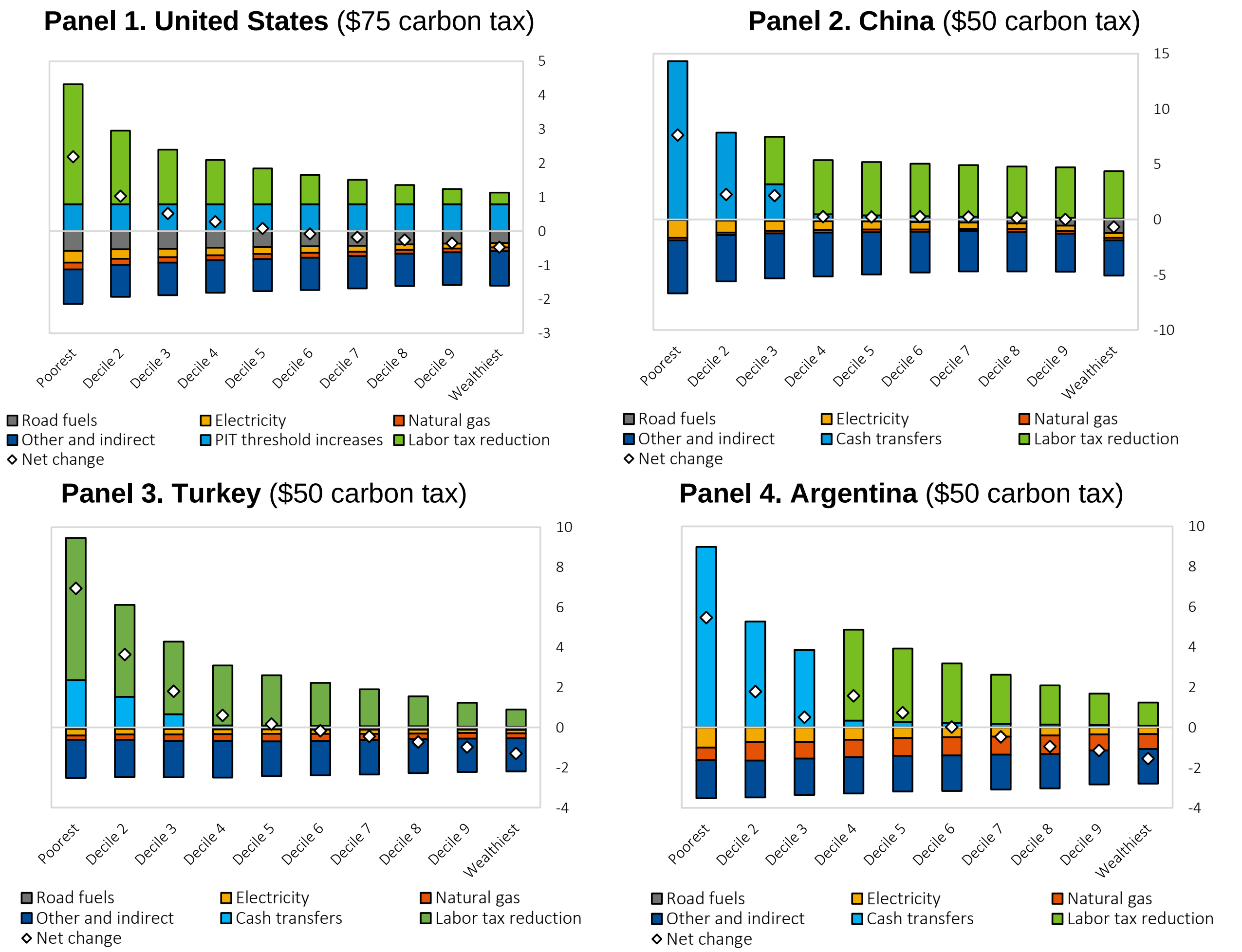
Source: IMF staff.
Note: Domestic environmental co-benefits include reductions in local air pollution mortality and road congestion and accident externalities.

In terms of distributional impacts, the first-round impacts on households from carbon pricing can be slightly regressive, progressive, or distributionally-neutral depending on country context.[31] Figure 15 illustrates the burdens on household income deciles in 2030 from carbon pricing of $75 per ton in the US and $50 per ton in China, Argentina, and Turkey. As indicated by the bars falling below the x-axis, the average household burdens vary from around 2 percent of household consumption in Turkey and the US to around 5 percent in China. Burdens are mildly regressive (imposing a larger burden relative to consumption for lower-income than higher-income households) in Argentina, China, and the US and approximately distribution-neutral in Turkey. Although higher electricity prices impose a disproportionately large burden on low-income households, this is a minor share of the total burden—indirect burdens from increases in the general price of consumer goods are the largest component and these are broadly distribution-neutral.[32]

[30] See Parry and others (2014, 2021) for a discussion of methodologies for measuring the domestic environmental costs of fossil fuel use. Local air pollution costs, for example, are measured using country-specific evidence on such factors as air pollution emission rates, population exposure to pollution, mortality rates for illness whose prevalence is increased by pollution exposure, and people's willingness to pay to reduce health risks.
[31] See also IMF (2019a).
[32] In some countries, with low rates of grid access and vehicle ownership among low-income households, the first-round impacts of carbon pricing are progressive (e.g., IMF 2019a).

However, recycling revenues can make carbon pricing reforms both equity-enhancing and pro-poor overall. In general, recycling carbon pricing revenues could offset about 90 percent of the average household burden across countries the four countries, while targeted recycling could support equity and poverty objectives.[33] If, for illustration, revenues are used to strengthen social safety nets for low income households, and the rest is used for labor tax reductions, the overall reform can be made progressive: lower income households would be better off on net (by around 3 to 8 percent of consumption), median households being left more or less neutral, while higher income households face manageable net burdens up to around 0.5–1.5 percent of consumption.

Figure 15. Household Burdens from Carbon Pricing in 2030, Selected Countries
(% Change in Household Consumption Relative to Pre-Policy)



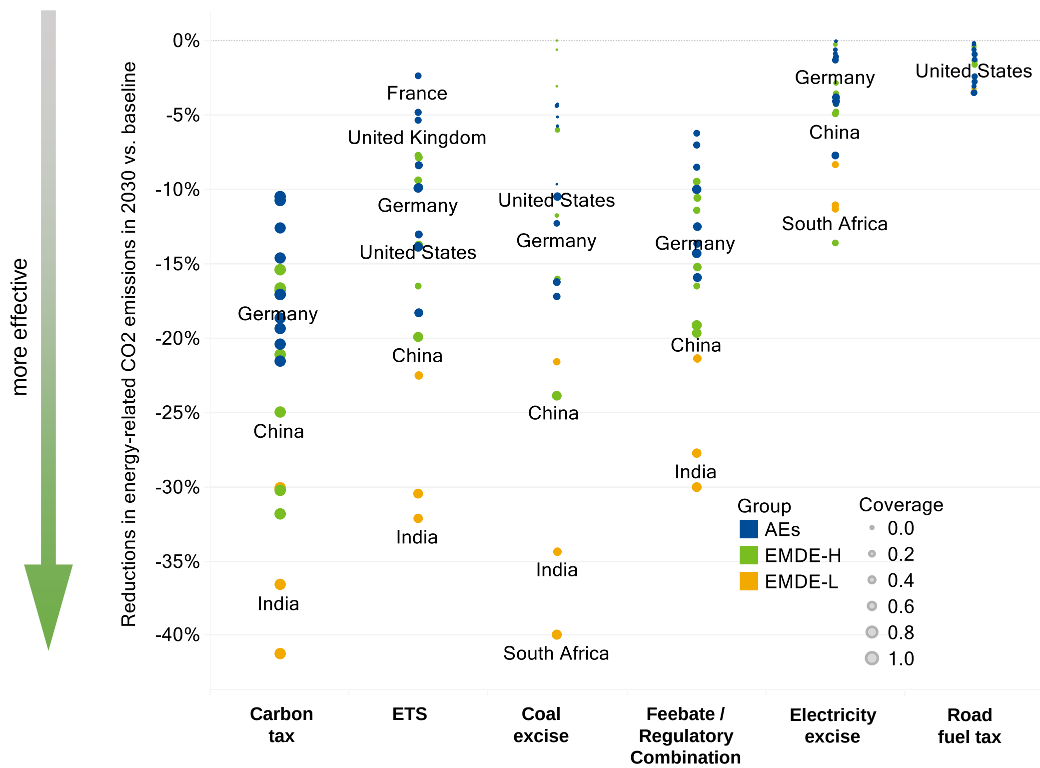
Source: IMF staff.
Note: Burden is the change in economic welfare or consumer surplus, that is, the benefit from revenue recycling through labor tax reductions and cash transfers, less extra household spending on energy and consumer products and the value of forgone consumption. For the US, revenues are recycled with 50 percent through labor tax reductions (via higher personal income tax thresholds) and 50 percent for a general labor tax reduction (proportionate to pre-policy tax burden). For China, 85 percent of revenues are used for a proportionate reduction in labor taxes (proportionate to pre-policy consumption) and 15 percent for a targeted transfer for the poorest 25 percent of households. For Turkey, 85 percent of revenues are used for labor tax transfers and 15 percent for a targeted transfer for the poorest 25 percent of households. For Argentina, 75 percent of revenues are used for labor tax reductions, and 25 percent for targeted transfers to bottom 30 percent of households.

[33] This fraction will decline with higher carbon prices and deeper decarbonization as the base progressively erode.

Alternative Mitigation Instruments

Policymakers have a wide range of other mitigation instruments at their disposal which might be used in place of, or in combination with, carbon pricing. For example, taxes on individual fuels or on emissions from specific sectors, may have a role if taxes on certain other fuels or sectors would be especially sensitive politically. Other policies like emission rate regulations, for example, on vehicles, or their fiscal analogue, feebates[34], may also have an important role on political acceptability grounds as they avoid a significant increase in energy prices. Unlike carbon pricing, these policies do not involve the pass through of pricing revenues or allowance rents in higher energy prices. Regulations and feebates are less efficient than carbon pricing on average (in that they do not promote a demand response—for example, they can encourage people to use cleaner vehicles but not to drive less). Ideally, regulations and feebates are designed to promote the full range of behavioral responses for reducing the emissions intensity of a particular sector. For example, in the power generation sector, regulations or feebates that reward any reduction in average CO_2 emissions produced per kilowatt hour of electricity reward shifting from coal to gas, to fossil generation with carbon capture, and then from these fuels to renewables.

Figure 16. Effectiveness of Alternative Mitigation Instruments



Source: IMF staff.
Note: $50 carbon price was modeled for all policies, that is, for all sources of emissions that are reduced by a policy the cost of the last ton reduced is $50 in 2030. Bubble sizes reflect the proportion of a countries energy-related CO_2 emissions covered by policies.

[34] Feebates provide a (revenue-neutral) sliding scale of fees on products or activities with above average emission rates and a sliding scale of rebates on products or activities with below average emission rates. See for example, IMF (2019a, Annex 1.5 and 1.5).

Emissions pricing confined to power and industry, and cross-sector combinations of regulations/feebates, promote many (but not all) behavioral responses for reducing emissions. Most ETSs have so far been limited to the power and industrial sectors. Across G20 countries these policies promote around 60-80 percent of the emissions reductions that would be promoted by comprehensive carbon pricing (that also covered transportation and buildings). A combination of regulations or feebates that promoted reductions in the emissions intensity of power generation and vehicles, and improvements in the efficiency of other energy using products promotes around 70 percent of the emissions reductions promoted by carbon pricing. In contrast, raising road fuel taxes or taxing electricity consumption has effectiveness of around 10 and 20 percent of that from comprehensive pricing. Coal taxes have relatively high effectiveness in coal intensive countries (e.g., China, India) but less so in other countries. See Figure 16 and, for individual country results, Table A4 in the annex.

Conclusion

Over the next decade, getting on track to net zero emissions to achieve the temperature stabilization goals of the Paris Agreement will require addressing a large gap in mitigation ambition and an even larger gap in mitigation policy. Despite recent updates to countries' emissions commitments, pledged reductions for 2030 would achieve only one to two thirds of reductions consistent with 1.5º–2ºC pathways. Many countries have not yet made longer term net zero emissions commitments, and greater transparency is needed to compare near term commitments. Moreover, many countries continue to fall short of identifying and implementing needed mitigation policies. Measures having the equivalent effect of a global carbon price of at least $75 per ton by 2030—on top of existing energy taxes and other measures—are needed to be on track with containing global warming below 2ºC. So far, global carbon pricing averages just $3 per ton.

An equitable scaling up of near-term global mitigation ambition can be achieved through differential emissions reductions for developed and developing countries and enhanced climate finance commitments for lower income countries. The costs of achieving the global emissions reductions needed to keep warming below 2ºC should be manageable and in many cases these costs are offset by the domestic environmental co-benefits from reducing fossil fuel use. If developing countries are to accelerate decarbonization, it will require national policies as well as international support—developed countries, however, are lagging on their current (let alone enhanced) commitments to global climate finance—and policy coordination to address obstacles to unilateral action.

The most effective way to reduce use of fossil fuels is to raise their price, although this can be difficult politically. Countries will need to strike a balance between carbon pricing and other (often less efficient or effective but politically less challenging) instruments that promote some of the key behavioral responses of carbon pricing. Countries will also need comprehensive approaches that address concerns about equity, impacts on vulnerable groups, and provide the complementary public investment in clean technology infrastructure, to enhance the overall acceptability and effectiveness of the mitigation strategy.

Without an urgent narrowing of ambition and policy gaps on climate mitigation, a potentially dangerous cliff-edge for emissions reductions for 2030–2040 will be set up, greatly increasing transition costs, and potentially putting temperature goals beyond reach. An orderly, internationally cooperative, and timely transition is strongly preferable to a disorderly, uncooperative, and late transition.

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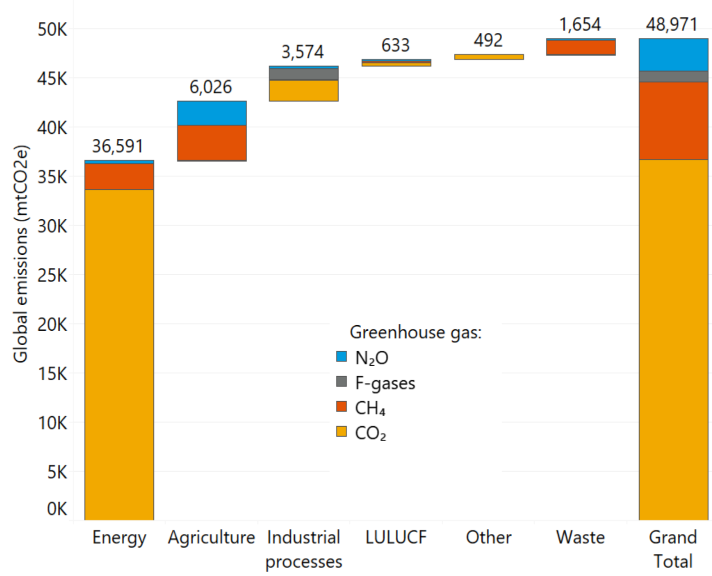
Annex

This annex discusses broader sources of GHGs, describes the Carbon Pricing Assessment Tool (CPAT) tool used for the quantitative analyses in this note and presents various supplementary tables and figures.

Broader Sources of GHGs

CO_2 is the largest among the long-lived climate pollutants and most analyses of climate mitigation focus on this gas.[35] Other GHGs have varying levels of warming potential and lifetime in the atmosphere. Although methane (CH_4) has a much larger impact on warming than CO_2 per ton of emissions (28 times over a 100-year time horizon) it decays rapidly in the atmosphere. According to the IPCC methane will need to be cut by 40-45 percent by 2030 relative to 2020 levels to be on track to 1.5C (IPCC 2018). Indeed, cutting methane emissions 45 percent by 2030 could help avoid almost 0.3 degrees of warming in the 2040s,[36] thereby limiting risks of crossing tipping points in the climate system. In 2020, fossil fuel CO_2 emissions accounted for 72 percent of global GHGs (expressed on a lifetime warming equivalent basis), methane from agriculture, extractive activities, and waste 16 percent, nitrogen oxide (N_2O) from agriculture 5 percent, and CO_2 and fluorinated gases from industrial processes 7 percent. See Figure A1.

Figure A1. Global Greenhouse Gases by Sector and GHG, 2020



Source: UNFCCC (2021a); WRI (2021), national sources, and IMF staff.

Pricing or proxy pricing schemes could play a role in mitigating broader sources of GHGs. Methane emissions from extractive industries might be priced based on production levels and default leakage rates (with rebates for firms demonstrating lower emission rates). Process emissions have been priced in ETSs covering the industrial sector—they might also be priced based on production levels and default emission rates. Forest carbon sequestration might be promoted through feebate systems that reward or penalize landowners depending on whether they increase or decrease stored carbon over time relative to storage in a baseline year.[37] Agricultural emissions are challenging to mitigate, given difficulties in monitoring emissions but proxy pricing schemes might be feasible, based on farm level outputs or inputs and default emission rates.

[35] IPCC (2021).
[36] UNEP (2021).
[37] See Parry (2020). Forest carbon storage is measured using a mix of satellite imagery, aerial photography, and on the ground tree sampling.

The Carbon Pricing Assessment Tool (CPAT)

This annex describes the Carbon Pricing Assessment Tool (CPAT) tool used for the quantitative analyses in this note and presents various supplementary tables and figures. CPAT provides, on a country-by-country basis for 175 countries, projections of fuel use and CO_2 emissions by major energy sector.[38] This tool starts with use of fossil fuels and other fuels by the power, industrial, transport, and residential sectors[39] and then projects fuel use forward in a baseline case using:

- GDP projections;[40]
- Assumptions about the income elasticity of demand and own-price elasticity of demand for electricity and other fuel products;
- Assumptions about the rate of technological change that affects energy efficiency and the productivity of different energy sources; and
- Future international energy prices.

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: (i) their proportionate impact on future fuel prices in different sectors; (ii) a simplified model of fuel switching within the power generation sector; and (iii) 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 (IEA) on recent fuel use by country and sector.[41] GDP projections are from the latest IMF forecasts.[42] 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 IEA (which are rising) and IMF (which are flat) 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 IEA. The domestic environmental costs of fuel use are based on IMF methodologies.[43]

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

[38] CPAT was developed by IMF and World Bank staff and evolved from an earlier IMF tool used, for example, in IMF (2019a and b). For descriptions of the model and its parameterization, see IMF (2019b Appendix III, and Parry, Mylonas and Vernon 2021) and for further underlying rationale see Heine and Black (2019).

[39] International aviation and maritime fuels are excluded from the model and from computations of fossil fuel subsidies.

[40] GDP projections exclude the negate growth effects of global climate change.

[41] IEA (2021). Any fuel consumption that could not be explicitly allocated to a specific sector was allocated apportioned based on the relative consumption by sector in a given country.

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

[43] See Parry, Black and Vernon (2021).

highly uncertain.[44] In addition, fuel price responsiveness is approximately similar across countries—in practice, price responsiveness may differ across countries with the structure of the energy system and regulations on energy prices or emission rates. The model also does not explicitly account for the possibility of upward sloping fuel supply curves, general equilibrium effects (e.g., changes in relative factor prices that might have feedback effects on the energy sector), and changes in international fuel prices that might result from simultaneous climate or energy price reform in large countries. Parameter values in the spreadsheet are, however, 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 sorts of factors.

Finally, while the emissions abatement costs are broadly in line with those from many sophisticated 'general equilibrium' models there are two limitations. First, they do not account for interactions between carbon pricing and distortions in the economy created by the broader fiscal system—a large literature shows that these interactions can on net decrease policy costs if the carbon pricing revenues are used to reduce an especially distortive tax.[45] Second, the costs above do not account for changes in international fuel prices from global mitigation which can result in transfers from energy producing countries to energy consuming countries.

[44] Marginal abatement costs are linearized beyond prices of $75 per ton—for example, if $75 reduces emissions in a country by 30 percent below BAU levels then a 50 percent reduction implies a marginal cost of $75 times 50/30. Alternative assumptions moderately affect the abatement cost and carbon price calculations for AEs.

[45] Parry (2021).

Supplementary Tables

Table A1s and A2 shows classifications of countries by AE/EMDE-H/EMDE-L grouping and withing UNFCCC negotiating groups. Tables A3 and A4 show, for G20 countries, formal mitigation commitments in NDCs, and the impacts of carbon pricing on energy prices. Table A5 shows the effectiveness of alternative mitigation instruments at reducing CO_2.

Table A1. Country Classifications

AE	EMDE-H		EMDE-L	
Australia	Argentina	Malaysia	Afghanistan	Kiribati
Austria	Bahamas, The	Maldives	Albania	Kyrgyz Republic
Belgium	Bahrain	Mauritius	Algeria	Lao P.D.R.
Canada	Belarus	Mexico	Angola	Liberia
Cyprus	Bosnia and Herzegov	Montenegro	Armenia	Madagascar
Czech Republic	Botswana	Oman	Azerbaijan	Malawi
Denmark	Brazil	Panama	Bangladesh	Mali
Estonia	Brunei Darussalam	Peru	Belize	Moldova
Finland	Bulgaria	Poland	Benin	Morocco
France	Chile	Qatar	Bolivia	Mozambique
Germany	China	Romania	Burundi	Myanmar
Greece	Costa Rica	Russia	Cambodia	Namibia
Iceland	Croatia	Saudi Arabia	Cameroon	Nepal
Ireland	Dominica	Serbia	Central African Repul	Nicaragua
Israel	Dominican Republic	St. Lucia	Chad	Niger
Italy	Ecuador	St. Vincent and the	Colombia	Nigeria
Japan	Equatorial Guinea	Grenadines	Comoros	Pakistan
Korea	Gabon	Suriname	Congo, Democratic F	Paraguay
Latvia	Grenada	Thailand	Congo, Republic of	Philippines
Lithuania	Guyana	Trinidad and Tobago	Côte d'Ivoire	Rwanda
Luxembourg	Hungary	Turkey	Djibouti	Samoa
Malta	Kazakhstan	Turkmenistan	Egypt	São Tomé and Príncipe
Netherlands	Kuwait	United Arab Emirates	El Salvador	Senegal
New Zealand	Macedonia, FYR	Uruguay	Eritrea	Sierra Leone
Norway			Ethiopia	South Africa
Portugal			Gambia, The	South Sudan
Singapore			Georgia	Sri Lanka
Slovak Republic			Ghana	Sudan
Slovenia			Guatemala	Tajikistan
Spain			Guinea	Tanzania
Sweden			Guinea-Bissau	Togo
Switzerland			Haiti	Tonga
United Kingdom			Honduras	Tunisia
United States			India	Uganda
			Indonesia	Ukraine
			Iran	Uzbekistan
			Iraq	Vietnam
			Jamaica	Yemen
			Jordan	Zambia
			Kenya	Zimbabwe

Source: IMF staff.
Note: EMDE-Ls are defined as countries with per capita GDP below $5,500 in 2020.

Table A2. UNFCCC Parties – Part 1 – Party Type

Annex I	Non-Annex I		
Australia	Afghanistan	Guatemala	Papua New Guinea
Austria	Albania	Guinea	Paraguay
Belarus	Algeria	Guinea-Bissau	Peru
Belgium	Andorra	Guyana	Philippines
Bulgaria	Angola	Haiti	Qatar
Canada	Antigua and Barbuda	Honduras	Congo, Republic of
Croatia	Argentina	India	Rwanda
Cyprus	Armenia	Indonesia	St. Kitts and Nevis
Czech Republic	Azerbaijan	Iran	St. Lucia
Denmark	Bahrain	Iraq	St. Vincent & Grenadines
Estonia	Bangladesh	Israel	Samoa
Finland	Barbados	Côte d'Ivoire	San Marino
France	Belize	Jamaica	São Tomé and Príncipe
Germany	Benin	Jordan	Saudi Arabia
Greece	Bhutan	Kazakhstan	Senegal
Hungary	Bolivia	Kenya	Serbia
Iceland	Bosnia and Herzegovina	Kiribati	Seychelles
Ireland	Botswana	Kuwait	Sierra Leone
Italy	Brazil	Kyrgyz Republic	Singapore
Japan	Brunei	Lao P.D.R.	Solomon Islands
Latvia	Burkina Faso	Lebanon	Somalia
Liechtenstein	Burundi	Lesotho	South Africa
Lithuania	Cambodia	Liberia	Korea
Luxembourg	Cameroon	Libya	South Sudan
Malta	Cabo Verde	Madagascar	Sri Lanka
Monaco	Central African Republic	Malawi	Sudan
Netherlands	Chad	Malaysia	Suriname
New Zealand	Chile	Maldives	Swaziland
Norway	China	Mali	Syria
Poland	Colombia	Marshall Islands	Tajikistan
Portugal	Comoros	Mauritania	Tanzania
Romania	Cook Islands	Mauritius	Thailand
Russia	Costa Rica	Mexico	Bahamas, The
Slovak Republic	Cuba	Moldova	Gambia, The
Slovenia	Congo, Dem. Republic	Mongolia	Togo
Spain	Djibouti	Montenegro	Tonga
Sweden	Dominica	Morocco	Trinidad and Tobago
Switzerland	Dominican Republic	Mozambique	Tunisia
Turkey	Timor-Leste	Myanmar	Turkmenistan
Ukraine	Ecuador	Namibia	Tuvalu
United Kingdom	Egypt	Nauru	United Arab Emirates
United States	El Salvador	Nepal	Uganda
	Equatorial Guinea	Nicaragua	Uruguay
	Eritrea	Niger	Uzbekistan
	Ethiopia	Nigeria	Vanuatu
	Micronesia	Niue	Venezuela
	Fiji	Northern Macedonia	Vietnam
	French Polynesia (France)	Oman	Yemen
	Gabon	Pakistan	Zambia
	Georgia	Palau	Zimbabwe
	Ghana	Palestine	
	Grenada	Panama	

Source: UNFCCC (2021b)

Table A2. UNFCCC Parties – Part 2 – Selected Negotiating Groups

African Group	AOSIS	Arab States	G77+China		
Algeria	Antigua and Barbuda	Algeria	Afghanistan	Indonesia	Solomon Islands
Angola	Bahamas, The	Bahrain	Algeria	Iran	Somalia
Benin	Barbados	Comoros	Angola	Iraq	South Africa
Botswana	Belize	Djibouti	Antigua and Barbuda	Côte d'Ivoire	South Sudan
Burkina Faso	Cabo Verde	Egypt	Argentina	Jamaica	Sri Lanka
Burundi	Comoros	Iraq	Bahrain	Jordan	Sudan
Cabo Verde	Cook Islands	Jordan	Bangladesh	Kenya	Suriname
Cameroon	Cuba	Kuwait	Barbados	Kiribati	Swaziland
Central African Republic	Dominica	Lebanon	Belize	Kuwait	Syria
Chad	Dominican Republic	Libya	Benin	Lao P.D.R.	Tajikistan
Comoros	Fiji	Mauritania	Bhutan	Lebanon	Tanzania
Congo, Democratic Republic	Grenada	Morocco	Bolivia	Lesotho	Thailand
Congo, Republic of	Guinea-Bissau	Oman	Bosnia and Herzegovina	Liberia	Bahamas, The
Côte d'Ivoire	Guyana	Palestine	Botswana	Libya	Gambia, The
Djibouti	Haiti	Qatar	Brazil	Madagascar	Togo
Egypt	Jamaica	Saudi Arabia	Brunei	Malawi	Tonga
Equatorial Guinea	Kiribati	Somalia	Burkina Faso	Malaysia	Trinidad and Tobago
Eritrea	Maldives	Sudan	Burundi	Maldives	Tunisia
Ethiopia	Marshall Islands	Syria	Cambodia	Mali	Turkmenistan
Gabon	Mauritius	Tunisia	Cameroon	Marshall Islands	United Arab Emirates
Gambia, The	Micronesia	United Arab Emirates	Cabo Verde	Mauritania	Uganda
Ghana	Nauru	Yemen	Central African Republic	Mauritius	Uruguay
Guinea	Niue		Chad	Mongolia	Vanuatu
Guinea-Bissau	Palau		Chile	Morocco	Venezuela
Kenya	Papua New Guinea	**LMDCs**	China	Mozambique	Yemen
Lesotho	Samoa	Algeria	Colombia	Myanmar	Zambia
Liberia	São Tomé and Príncipe	Argentina	Comoros	Namibia	Zimbabwe
Libya	Seychelles	Bangladesh	Costa Rica	Nauru	
Madagascar	Singapore	Bolivia	Cuba	Nepal	
Malawi	Solomon Islands	China	Congo, Dem. Rep. of	Nicaragua	
Mali	St. Kitts and Nevis	Cuba	Djibouti	Niger	
Mauritania	St. Lucia	Ecuador	Dominica	Nigeria	
Mauritius	St. Vincent and the Grenadine	Egypt	Dominican Republic	Oman	
Morocco	Suriname	El Salvador	Timor-Leste	Pakistan	
Mozambique	Timor-Leste	India	Ecuador	Palestine	
Namibia	Tonga	Indonesia	Egypt	Papua New Guinea	
Niger	Trinidad and Tobago	Iran	El Salvador	Paraguay	
Nigeria	Tuvalu	Iraq	Equatorial Guinea	Peru	
Rwanda	Vanuatu	Jordan	Eritrea	Philippines	
Senegal		Kuwait	Ethiopia	Qatar	
Seychelles	**BASIC**	Malaysia	Micronesia	Congo, Republic of	
Sierra Leone	Brazil	Mali	Fiji	Rwanda	
Somalia	China	Nicaragua	Gabon	St. Kitts and Nevis	
South Africa	India	Pakistan	Ghana	St. Lucia	
South Sudan	South Africa	Saudi Arabia	Grenada	St. Vincent and the Grenadines	
Sudan		Sri Lanka	Guatemala	Samoa	
Swaziland		Sudan	Guinea	São Tomé and Príncipe	
Tanzania		Syria	Guinea-Bissau	Saudi Arabia	
Togo		Venezuela	Guyana	Senegal	
Tunisia		Vietnam	Haiti	Seychelles	
Uganda			Honduras	Sierra Leone	
Zimbabwe			India	Singapore	

Source: Carbon Brief (2015) and UNFCCC (2021b)

Table A3. Mitigation Pledges for the Paris Agreement, G20 Countries

Country	Submission Round[a]	Latest Mitigation Pledge for Paris Agreement[b]	Net Zero Target
Argentina	Second	Net emissions cap of 359 $MtCO_2e$ in 2030	2050[d]
Australia	Second	Reduce GHGs 26-28% below 2005 by 2030	2050[d]
Brazil	Second	Reduce GHGs 43% below 2005 by 2030	2050
Canada	First	Reduce GHGs 30% below 2005 by 2030	2050
China	First	Reduce CO2/GDP 65% below 2005 by 2030	2060
France	Second	Reduce GHGs 55%[c] below 1990 by 2030	2050[c]
Germany	Second	Reduce GHGs 65% below 1990 by 2030	2045
India	First	Reduce GHG/GDP 33-35% below 2005 by 2030	na
Indonesia	First	Reduce GHGs 29%(41%) below BAU in 2030	na
Italy	Second	Reduce GHGs 55%[c] below 1990 by 2030	2050[c]
Japan	Second	Reduce GHGs 25.4% below 2005 by 2030	2050
Korea	Second	Reduce GHGs 40% below 2017 by 2030	2050
Mexico	Second	Reduce GHGs 22% (36%) below BAU in 2030	2050[d]
Russia	First	Reduce GHGs to 70% of 1990 level by 2030	2060[d]
Saudi Arabia	Second	Reduce GHGs 278 MtCO2e below BAU by 2030	2060[d]
South Africa	Second	Reduce GHGs to 350-420 MtCO2e in 2025 and 2030	2050[d]
Turkey	First	Reduce GHGs 20% (25%) below BAU by 2030	na
United Kingdom	Second	Reduce GHGs 68% below 1990 by 2030	2050
United States	Second	Reduce GHGs 50-52% below 2005 by 2025	2050

Source: UN Framework Convention on Climate Change (2021).

Notes: BAU = business as usual; CO2 = carbon dioxide; GHG = greenhouse gas; na = not applicable; NDCs = nationally determined contributions.

[a] 'First' and 'second round' refers to whether mitigation pledge in latest nationally determined contribution (NDC) was submitted in 2015/16 or has been updated in 2020/21, respectively.

[b] Targets conditional on international support are in brackets.

[c] EU-wide target.

[d] Target has been announced but is not yet featured in policy documents.

Table A4. Energy Price Impacts of $75/50/25 per ton Carbon Price in AE/EMDE-H/EMDE-Ls, 2030

Country	Coal		Natural Gas		Electricity		Gasoline	
	Baseline Price, $/GJ	Price Increase, percent	Baseline Price, $/GJ	Price Increase, percent	Baseline Price, $/kWh	Price Increase, percent	Baseline Price, $/liter	Price Increase, percent
Argentina	2.9	172	7.6	57	0.12	27	1.33	11
Australia	2.9	291	13.4	49	0.22	60	1.28	16
Brazil	3.9	132	7.1	19	0.17	4	1.65	6
Canada	2.1	358	5.2	107	0.11	22	1.17	17
China	5.9	80	11.0	49	0.11	42	1.09	12
France	6.5	116	18.5	26	0.15	3	1.86	12
Germany	4.2	191	17.1	32	0.27	17	1.85	11
India	1.8	137	5.0	118	0.13	40	1.25	5
Indonesia	2.6	119	10.4	15	0.10	59	0.49	33
Italy	4.4	183	16.8	36	0.24	22	1.93	12
Japan	5.3	139	20.0	22	0.20	37	1.48	14
Mexico	3.3	154	5.1	86	0.12	31	1.14	12
Russia	2.1	220	3.7	188	0.13	105	0.86	16
Saudi Arabia	8.7		8.7	57	0.10	119	0.41	91
South Africa	0.9	237	11.5	11	0.06	52	1.03	5
Korea	5.5	138	12.8	45	0.11	75	1.40	13
Turkey	3.8	127	9.6	34	0.10	38	1.18	12
United Kingdom	5.1	153	14.2	32	0.22	12	2.24	10
United States	2.8	278	5.3	94	0.12	42	0.91	22
Simple Average	3.9	170	10.7	57	0.11	39	1.29	17

Source: IMF staff.
Note: Baseline prices are retail prices estimated in Parry, Black and Vernon (2021) and include preexisting energy taxes. Impacts of carbon taxes on electricity prices depend on the emissions intensity of power generation. GJ= gigajoule; kWh= kilowatt-hour.

Table A5. CO_2 Reductions from Alternative Mitigation Instruments Relative to BAU, 2030

Country	Carbon tax	ETS	Coal excise	Electricity excise	Road fuel tax	Feebates / regulations
Argentina	-17	-8	-1	-3	-1	-11
Australia	-22	-18	-17	-8	-1	-16
Brazil	-12	-6	-4	0	-1	-11
Canada	-20	-8	-6	-1	-1	-14
China	-25	-20	-24	-5	0	-19
France	-11	-2	-4	0	-4	-6
Germany	-17	-10	-12	-1	-3	-12
India	-37	-32	-34	-11	0	-28
Indonesia	-30	-23	-22	-8	-3	-21
Italy	-11	-5	-4	-1	-2	-7
Japan	-15	-10	-11	-4	0	-10
Mexico	-15	-9	-3	-5	-1	-10
Russia	-30	-14	-12	-4	0	-20
Saudi Arabia	-32	-17	0	-14	-4	-17
South Africa	-41	-30	-40	-11	0	-30
Korea	-19	-14	-16	-4	0	-14
Turkey	-21	-14	-16	-4	0	-15
United Kingdom	-13	-5	-5	-1	-3	-9
United States	-19	-13	-10	-4	-1	-14
Simple average	**-21**	**-14**	**-13**	**-5**	**-1**	**-15**
Weighted (emissions) average	**-24**	**-18**	**-19**	**-5**	**-1**	**-18**

Source: IMF staff.

Note: All policies impose the same explicit or implicit $50 price on the CO_2 emissions they reduce. The combination policy reduces emissions intensity in the power and vehicle sector and improves the efficiency of other energy using products (but does not promote demand responses like less driving).

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