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A Framework for Comparing Climate Mitigation Policies Across Countries

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Prepared by Simon Black, Danielle Minnett, Ian Parry, James Roaf, and Karlygash Zhunussova

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ABSTRACT: There is growing interest in international coordination over climate mitigation policy. Climate clubs or international carbon price floors could complement the Paris Agreement by helping to deliver the near-term cuts in global greenhouse gas emissions needed to contain global warming to 1.5 to 2ºC. To ensure inclusivity, these arrangements need to account for varying mitigation policies across countries, including carbon pricing, fuel taxes, subsidy reform, and non-pricing approaches like regulations. A transparent methodology is needed to compare and monitor mitigation effort by countries implementing diverse policy packages. This paper presents and illustrates a methodology for converting climate mitigation policies and targets into their carbon price equivalents and applies it to the Group of Twenty (G20) countries.

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WORKING PAPERS

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I. Introduction

Containing global warming to 1.5-2°C above pre-industrial levels—the central goal of the 2015 Paris Agreement—requires reducing global carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions 25 to 50 percent below 2019 levels by 2030.[1] Although about 140 countries, covering nearly 90 percent of global GHGs, have proposed, or set, net zero emissions targets for around mid-century[2], there remains a large gap in near-term global mitigation ambition. Even if fully achieved, emissions commitments would only cut global GHGs by about half of the needed reductions in 2030 (see Annex A, Table A 1 for current pledges among G20 countries). But there is an even larger gap in implementation of global mitigation policy—measures equivalent to a global carbon price exceeding $75 per tonne by 2030 are needed for staying below 2°C, whereas the current global average carbon price is only $5 per tonne.[3]

However, narrowing climate mitigation ambition and policy gaps can be difficult politically given policymakers' concerns about competitiveness impacts and relative implementation in other countries.[4] To scale up global action, an international mechanism is likely needed to reinforce the Paris Agreement. One possibility is an agreement to scale up ambition among large economies. This could include coordination over carbon pricing[5], with flexibility to accommodate countries using non-pricing instruments as long as they achieve equivalent emissions cuts.

Monitoring compliance with international arrangements requires a transparent methodology for comparing mitigation effort. This could be done through measuring emissions impacts and/or their *carbon price equivalen*t (CPE): the carbon price that would yield the same emissions reduction as non-pricing policies. The methodology needs to avoid double counting of emissions reductions where policies overlap, for example, where the power sector is subject to both carbon pricing and renewables policies.

For monitoring purposes, policy equivalence can be defined at the national level in terms of emissions reductions and/or pricing. For the latter, the *economywide carbon price equivalent* (ECPE) that would yield the same emissions reductions as the other policies under consideration is relevant.[6] Equivalence at the sectoral level can also be informative, for example, to compare carbon price equivalents across sectors. This could guide design of cost-effective mitigation strategies to limit cross-sectoral divergence in incremental abatement costs. In this case, the *sectoral carbon price equivalent* (SCPE) can be defined as the price on emissions in a particular sector that would yield the same emissions reduction within the sector as the policy under consideration.

[1] All figures in this paragraph are from Black and others (2022).

[2] See www.climatewatchdata.org/net-zero-tracker.

[3] All monetary figures are expressed in year 2021 US$ or thereabouts.

[4] Evidence on the competitiveness and emissions leakage impacts of mitigation policies remains mixed however (e.g., Keen and others 2021, Annex 3).

[5] See for example www.bundesfinanzministerium.de/Content/EN/Pressemitteilungen/2021/20210825-german-government-wants-to-establish-an-international-climate-club.html and Parry and others (2021a).

[6] The pattern of emissions reductions across sectors will vary between the ECPE and the other policies but the total emissions reduction in either case is the same.

Relatedly, there is debate about carbon price equivalence from the perspective of competitiveness and carbon leakage, spurred by recent proposals for border carbon adjustments (BCAs). Here the interest would be in the effects of different policies on the costs of trade-exposed firms, to understand whether imports from different countries or firms should have lower BCA charges in recognition of costs imposed by these mitigation policies. This would be a very different exercise, however: equivalence from a mitigation perspective (the subject of this paper) does not imply equivalence in costs or competitiveness—see Annex B.

This paper covers 19 country members of the G20, which collectively account for 80 percent of projected business as usual (BAU)[7] global CO_2 emissions in 2030. Estimates are provided for the CO_2 impacts and carbon price equivalence of policies and commitments to 2030. Where countries use a package of measures whose emissions impact is difficult to disentangle, the focus is on the sectoral targets these packages are intended to achieve, rather than individual instruments.

The analysis is limited to policies for the major energy-using sectors (power generation, industry, road transport, and buildings) since these account for the bulk of GHG emissions.[8] Additionally, mitigation policies for these sectors are more widespread and have received more attention in the literature than for other policies (e.g., for agriculture and forestry, to which the analysis could be extended subsequently). The analysis uses energy price projections as of mid-2021—prior to the rapid surge in energy prices in late 2021/early 2022, though it is currently unclear to what extent this surge reflects transitory versus permanent factors. Only policies that have been legislated with numerical targets are illustrated.

Some themes of the analysis include:

- Although many countries have explicit carbon pricing schemes, their projected ECPEs for 2030 are mostly modest, though in five cases (Canada, France, Germany, Italy, the UK) they are about $50 per tonne or more;

- At the sectoral level, in power generation, renewables targets and coal phaseout policies imply large sectoral carbon pricing equivalents. For seven countries, achieving these targets would cut sectoral CO_2 emissions by more than 50 percent below 2030 BAU levels, while SCPEs are upwards of $150 per tonne in ten cases;

- For industry, transport, and buildings, economywide emissions reductions are generally smaller. These sectors have smaller shares in economywide emissions and policies often (for buildings and transport) target new, rather than all, capital. However, one exception is aggressive building emissions targets in France, Germany, Italy, and Japan which apply to all buildings and imply SCPEs exceeding $150 per tonne;

- There is substantial divergence of SCPEs across sectors, suggesting scope for improving the cost-effectiveness of mitigation strategies;

[7] The BAU is a scenario with no new, or tightening of existing, mitigation policies. The other G20 member is the whole EU.

[8] The broader impacts of policies are beyond the paper's scope. See, for example, Black and others (2021) and IMF (2019a, b), on the fiscal, economic welfare, and distributional impacts of pricing and non-pricing policies and Chateau and others (2022) on the macro impacts of pricing regimes.

- ECPEs for all mitigation policies/targets combined in 2030 exceed $150 per tonne in six cases and are between $1 and $136 per tonne in the rest of the cases;

- Existing fuel taxes imply ECPEs of around $5-40 per tonne in most cases (and moderately negative in cases where fuels are subsidized), though fuel taxes were previously implemented for non-climate reasons leaving ambiguity about whether they should be included in ECPEs.

The following sections introduce the overall methodology, followed by its application to explicit carbon pricing, non-pricing policies, fuel taxes/subsidies, and all policies combined. The final section concludes.

II. Methodology

The methodology uses the Climate Policy Assessment Tool (CPAT), a modelling platform developed by IMF and World Bank staff, which is routinely used for cross-country, and individual country, assessments of mitigation policy (see Box 1).

Box 1. The IMF-WB CPAT Model

CPAT provides estimates for 170 countries of future fuel use and emissions by major energy sector as well as the emissions impacts of a diverse range of pricing and non-pricing mitigation approaches. CPAT is a highly flexible model because it can evaluate a diverse range of mitigation instruments. It also avoids a lot of structural detail (e.g., on micro-foundations or specific technologies) and is instead a streamlined, or ‘reduced form’, model parameterized to be approximately consistent with the mid-range of the empirical literature on income and fuel price elasticities and more detailed, country-specific energy models. CPAT will soon be made available for use by country authorities and the broader public.

Annex C provides details on emissions projections in CPAT, the parameterization of behavioral responses, caveats to the model, and procedures for calculating CO_2 reductions and carbon price equivalence of policies and targets. Fuel price responsiveness is decomposed into demand responses like changes in vehicle use and efficiency margins, like shifting to low emission internal combustion engine and electric vehicles—non-pricing policies are modelled as shadow prices on these latter margins. The main CPAT model is supplemented here with dynamic models of capital turnover for the building and vehicle sectors—lifespans of 15, 55 and 85 years are assumed for vehicles, commercial buildings, and residential buildings respectively.

One caveat is the increasing uncertainty associated with ‘large’ policy changes that might ultimately drive non-linear adoption of ‘breakthrough’ technologies, like carbon capture and storage (CCS) for large stationary emitters, power generation with biofuel energy and CCS, and direct air capture. These technologies might prove viable, but their future cost remains speculative.[9] Given these uncertainties, estimates of SCPEs above $150 per tonne are not reported for the power and industry sectors.

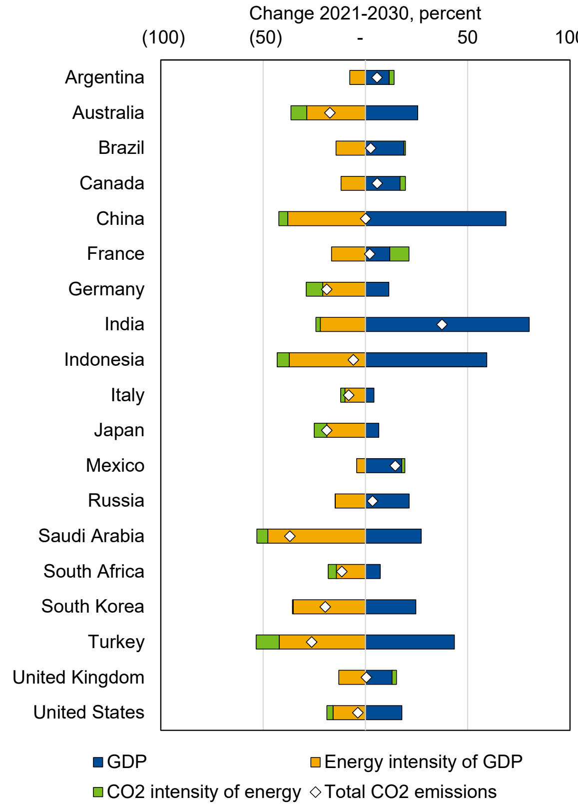
The first step is to establish a consistent set of BAU projections across countries, using CPAT—these projections account for pre-existing policies, whose impacts are already implicit in currently

[9] For example, direct air capture estimates are around $125 to $325 per ton of CO_2 abated but could fall below $100 by 2030—see IEA (2022)

observed fuel use and emissions, including carbon pricing, regulations, and fuel taxes/subsidies, with the current level or stringency of these policies held fixed.

BAU emissions projections depend on trends in three basic variables: (i) GDP; (ii) the energy intensity of GDP; and (iii) the CO_2 emissions intensity of energy. Under BAU conditions, GDP is projected to grow rapidly, by over 50 percent between 2021 and 2030 in China and India, but by a more moderate 5–25 percent in most other G20 countries—see Figure 1. On the other hand, the energy intensity of GDP is projected to decrease by about 5–40 percent across countries, primarily reflecting gradual improvements in energy efficiency (e.g., as newer capital replaces older) and the tendency of energy demand to grow less rapidly than GDP. Changes in the ratio of CO_2 emissions to primary energy are modest, principally because policies to advance renewables are frozen in the BAU.

Figure 1. BAU CO_2 Emissions Projections, 2021-2030



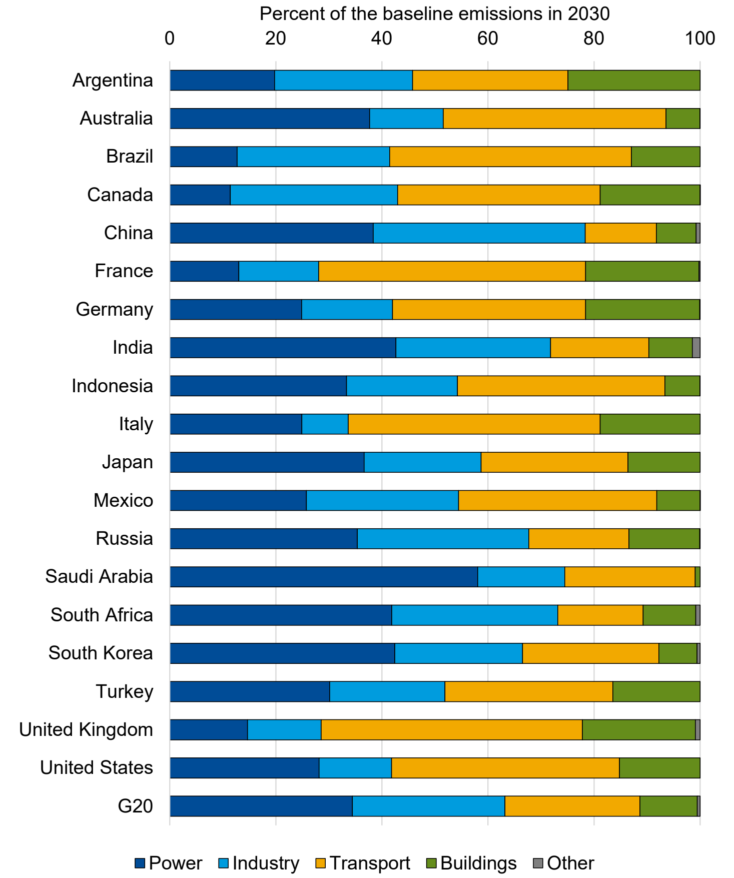
Source: IMF staff using CPAT.
Note. The percent change in CO_2 emissions is equivalent to the percent change in GDP, less the percent reduction in the CO_2 intensity of GDP, less the product of these two percentages.

Overall, CO_2 emissions growth is between about -20 and +10 percent in most cases. In the 2030 BAU scenario China accounts for 38 percent of G19 fossil fuel CO_2 emissions, the US 19 percent, India 12 percent, Russia 6 percent, and Japan 3 percent while other counties have emissions shares of 0.7-2.2 percent. Collectively, advanced economies are 33 percent of BAU G20 emissions, higher-income emerging market and developing economies (EMDEs) 52 percent, and lower-income EMDEs (India and Indonesia) 15 percent.

Figure 2 summarizes the direct contributions of different sectors to fossil fuel CO_2 emissions in the 2030 BAU. Power generation is the largest source of emissions, accounting on average for about 35 percent of emissions (typically around half or more of electric power is used in industry). Buildings (in the residential and commercial sector) have the smallest BAU emissions share—around 10 percent.

The second step is to model the sectoral and economywide emissions impacts from the planned tightening of existing policies, or new policies, to 2030 in different countries relative to BAU emissions. The following sections discuss which behavioral responses to reduce emissions are promoted by different policies.

Figure 2. CO_2 Emissions by Sector, 2030



Source: IMF staff using CPAT.
Note. Industry includes fuel use in industry, industrial buildings, construction, and agriculture.

The last step is to map the sectoral and economywide emissions impacts of policies into their SCPEs and ECPEs. This is done by: (i) reverting to the BAU and calculating the carbon price (in US$) at the sectoral level that achieves the same sectoral emissions reduction as the policy under consideration; and (ii) reverting to the BAU again and calculating the carbon price at the economywide level that achieves the same economywide emissions reductions as the policy under consideration.

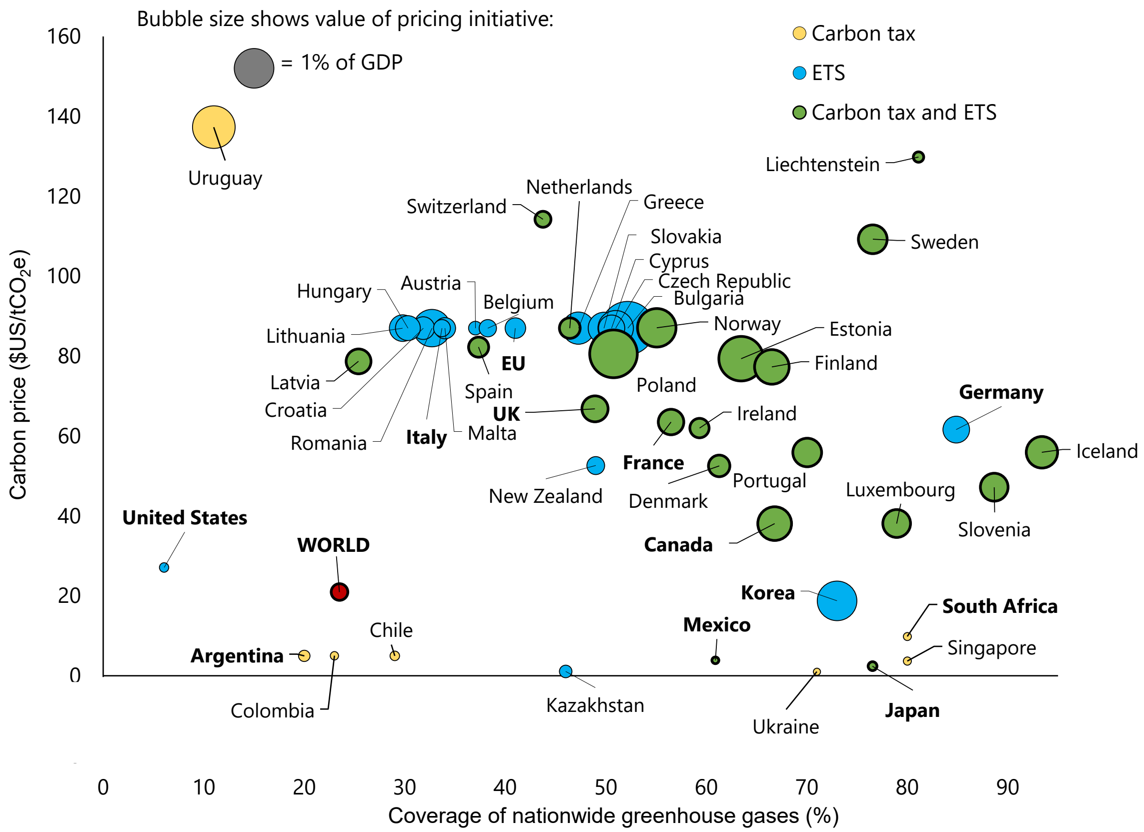
As noted above, this exercise does not attempt to translate specific non-pricing policies into emissions reductions or their carbon price equivalence where it is infeasible to disentangle the effects of overlapping policies. Instead, it assumes countries implement policies sufficient to meet their announced targets within each sector. If countries do not follow through with policy actions sufficient to meet these targets the analysis will overstate the emission reductions and carbon price equivalence. The credibility of sectoral targets would therefore be an important issue when applying this methodology to international agreements.

III. Explicit Carbon Pricing

Economywide carbon pricing is widely regarded as the most effective instrument for cutting emissions as it promotes a wide range of behavioral responses. This includes reducing energy use and shifting to cleaner energy sources across the power, industry, transport, and building sectors, as carbon prices are reflected in higher prices for carbon-intensive fuels and electricity. Pricing also strikes the cost-effective balance across these responses, as the cost of reducing emissions by an extra tonne—the carbon price—is equated.[10]

Carbon pricing schemes (at various levels of government) are now operating (see Figure 3) in 45 countries and twelve G20 countries.

Figure 3. Carbon Pricing Instruments as of April 2022



Sources: WBG (2022); IMF staff calculations; National sources.
Notes: Land use emissions are excluded. Prices are a weighted average between schemes. Country specific EU ETS values are calculated using sold auctions in 2020, and an average price for the period. Canada's price reflects the federal backstop. Mexico's subnational schemes are not included due to lack of data. China's national price is based on the opening price.

In eight G20 countries, pricing schemes cover more than 50 percent of national GHGs (Canada, France, Japan, Korea, Mexico, South Africa, Germany, and the UK). Canada, for example, requires provinces and territories to implement a minimum carbon price through a carbon tax or emissions trading system (ETS) for fuels used in power, transport, and buildings. Japan and South Africa have implemented carbon taxes midstream on fuel supply, while Korea has implemented an ETS downstream for large emitters in the power and industry sectors and midstream for suppliers of heating fuels. ETSs at the EU level and in the UK apply to emissions from power generation and industry. France and Germany also apply pricing systems (a tax and ETS respectively) midstream to

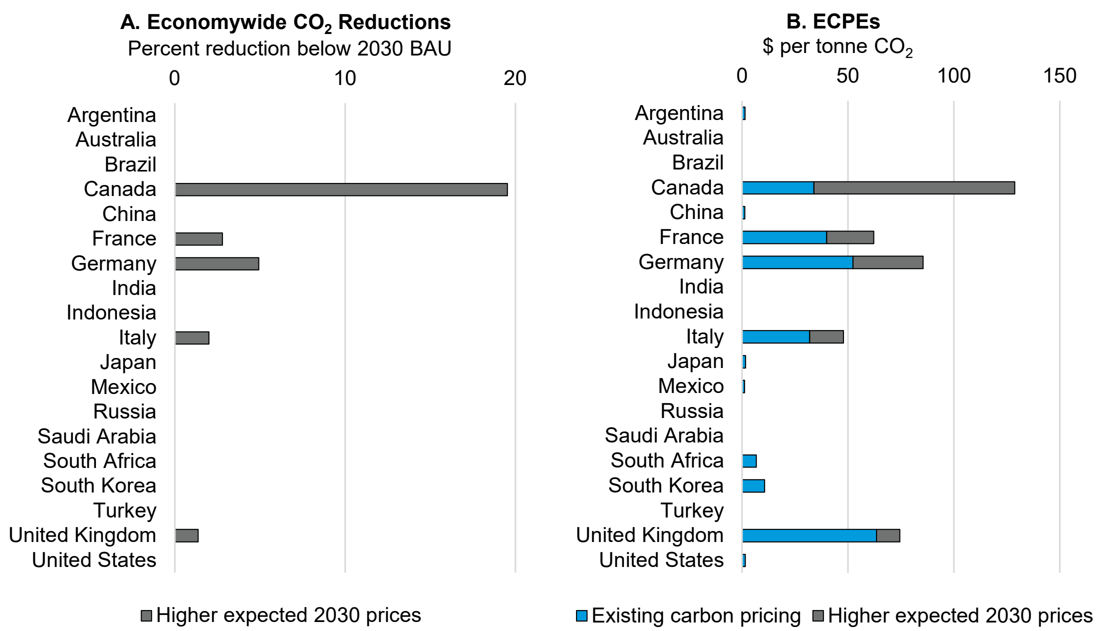
[10] The long-lived nature of energy-consuming capital assets (e.g., buildings and industrial equipment) and the presence of technology market failures (e.g., learning-by-doing spillovers and network effects) can inhibit the uptake of low-carbon technologies even under aggressive carbon pricing, hence additional policies for these sectors may be needed (but are beyond the paper's scope).

fuels used in the building and transport sectors. The US has regional ETSs, but these cover only 8 percent of nationwide emissions.[11]

Annex A, Table A2 provides more detail on pricing schemes in G20 countries. For example, as of April 2022 the EU ETSs' permit price was equivalent to $87 per tonne, while prices in the French and German national schemes were $49 and $33 per tonne, respectively. Prices are expected to rise in the EU, UK, and German ETS, and the Canadian system, and can be inferred from futures markets or from policy, but future price trajectories are not available for the other schemes.

Figure 4 shows the reductions in economywide CO_2 emissions below BAU levels from expected price increases (panel A) along with the ECPEs for existing and expected increases in carbon pricing (panel B). For the five countries where expected price increases for 2030 can be specified, projected emissions reductions from the price increases are 2-20 percent. For existing carbon pricing, ECPEs are below prevailing carbon prices, reflecting the incomplete coverage of the pricing schemes—for example, in Canada the ECPE is $30 per tonne compared with the formal carbon price of $40 per tonne. By 2030, EPCEs are about $50 per tonne or more in Canada, France, Germany, Italy, and the UK but are $10 per tonne or less in other cases.

Figure 4. Explicit Carbon Pricing, 2030



Source: IMF Staff using CPAT.

IV. Non-Pricing Sectoral Policies

This section discusses sectoral policies accounting for potential overlaps with carbon pricing, that is, additional emissions reductions from sectoral policies are measured relative to emissions in a 2030

[11] China has introduced separate tradable emission rate standards for coal and gas generators though it is not yet clear whether this will evolve into an ETS. Indonesia recently scheduled a carbon tax but it has been delayed.

baseline with carbon pricing (where relevant accounting for enhanced pricing) rather than the BAU. These overlaps have more significance for the power and industrial sector than for transport and buildings. ECPEs are reported for combined policy packages (see later) rather than individual sectoral measures.

A. Power

Renewable policies. As summarized in Annex A, Table A3 nearly all G20 countries have targets for the share of renewables (biomass, geothermal, hydro, wind, solar) in power generation and corresponding policies to make headway on these targets (though in four cases targets are met in the BAU projections). In 13 cases, targets are for 2030, varying from a share of renewables in the power generation mix from 30 percent (Korea) to 90 percent (Canada). As of 2021, actual renewable energy shares in generation varied between 0 percent (Saudi Arabia) and 83 percent (Brazil). Multiple instruments, which either explicitly or implicitly subsidize renewables relative to other generation technologies, are commonly used including:

- Feed-in tariffs (FIT), which guarantee above-market prices for renewable generation;
- Renewable portfolio standards (RPS), which specify requirements for the share of renewables in power generation;
- Tradable renewable energy certificates (RECs), which supplement RPSs but also promote a voluntary market for electricity consumers to buy renewable energy;
- Net metering, which allows households who generate some of their own electricity to use that electricity anytime, instead of when it is generated; and
- Investment or production tax credits for renewables.

These policies promote switching from coal/gas to renewables, but they do not involve the pass through of charges on remaining emissions (such as from a carbon tax) into electricity prices and therefore, at best, have limited impacts on reducing electricity demand in industry and buildings.

Additionally, non-pricing policies often overlap in the power sector, for example, of the ten countries with RPSs nine also have FITs. Country-specific policy instruments are not modelled here, given the impracticality of decomposing their individual impacts. Instead, countries are assumed to achieve their renewable generation targets for 2030 (or linearly interpolated shares for countries with target dates beyond 2030).[12]

Coal phaseouts. Eight G20 countries have pledged to phaseout or “phasedown” coal-fired power generation including, in five cases, a complete ban on or before 2030 (again see Table A3). When combined with a renewables target, two responses (fuel switching from coal to gas and coal/gas to renewables) are promoted.[13] In modeling these combinations, the CO_2 reduction from the combined policies is compared with that from the renewables target alone to infer the additional emissions reduction from the coal phaseout—this avoids double counting emissions reductions, but given the

[12] A ‘generic’ policy is modelled, which expands solar/wind generation with electricity demand kept at the same level as in the BAU.

[13] There is, however, no mechanism for ensuring that a cost-effective balance across these responses is achieved during the phaseout. A cost-effective alternative that also avoids significant increases in electricity prices would be a tradable emissions rate standard for power generators (though this policy has been uncommon to date).

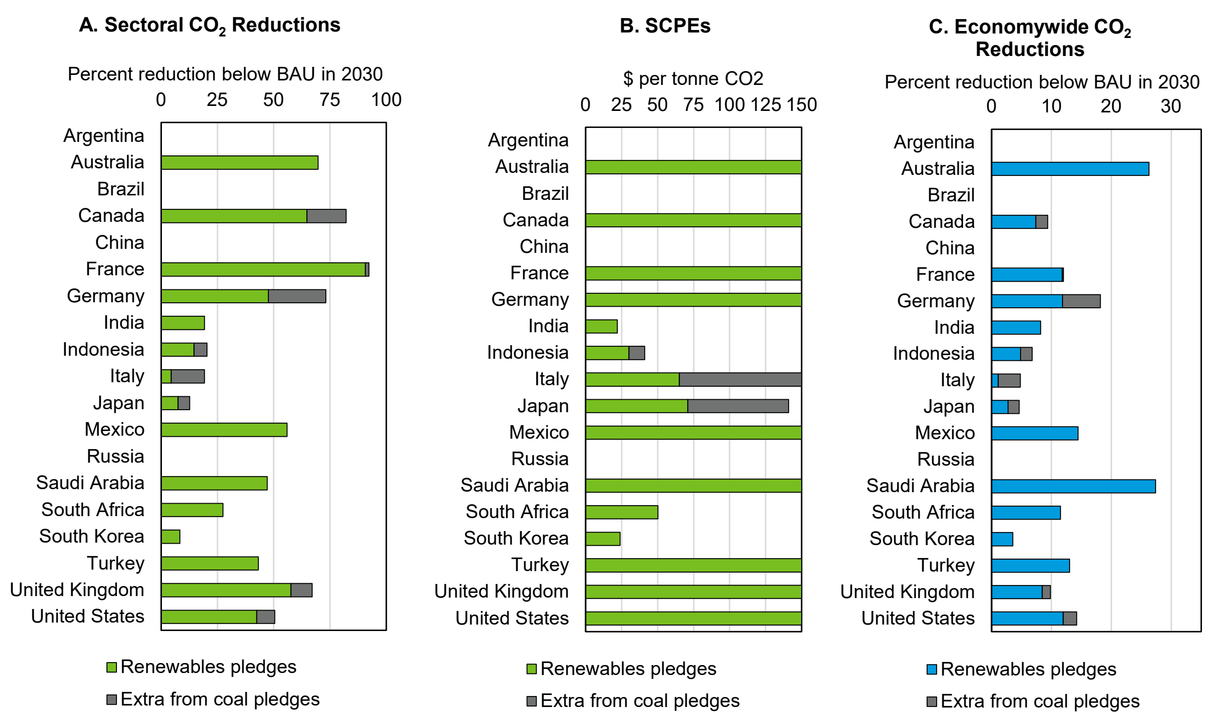
ambiguity in attributing CO_2 reductions to the individual targets the focus should be on the combined effect.[14]

Results. Figure 5 shows economywide and sectoral emissions reductions and carbon price equivalents for renewables targets and coal phaseouts (relative to the baseline with carbon pricing).

At the sectoral level, emissions reductions from renewable targets/coal phaseouts are 50 percent or more in seven cases but less than 25 percent in five cases, indicating large differences in ambition for countries with renewables targets (Figure 5, panel A). SCPEs for renewable/coal phase outs combined exceed $150 per tonne in ten cases but are $50 per tonne or less in eight cases (panel B)—SCPEs are higher the more stringent the target relative to BAU renewable shares and the greater the costs of increasing renewables.[15]

At the economywide level, achieving stated renewable/coal phaseout targets reduces CO_2 emissions by nearly 30 percent in Australia and Saudi Arabia, but the reductions are around 10 percent or less in most other cases (panel C).

Figure 5. Power Sector Targets, 2030



Source: IMF staff using CPAT.

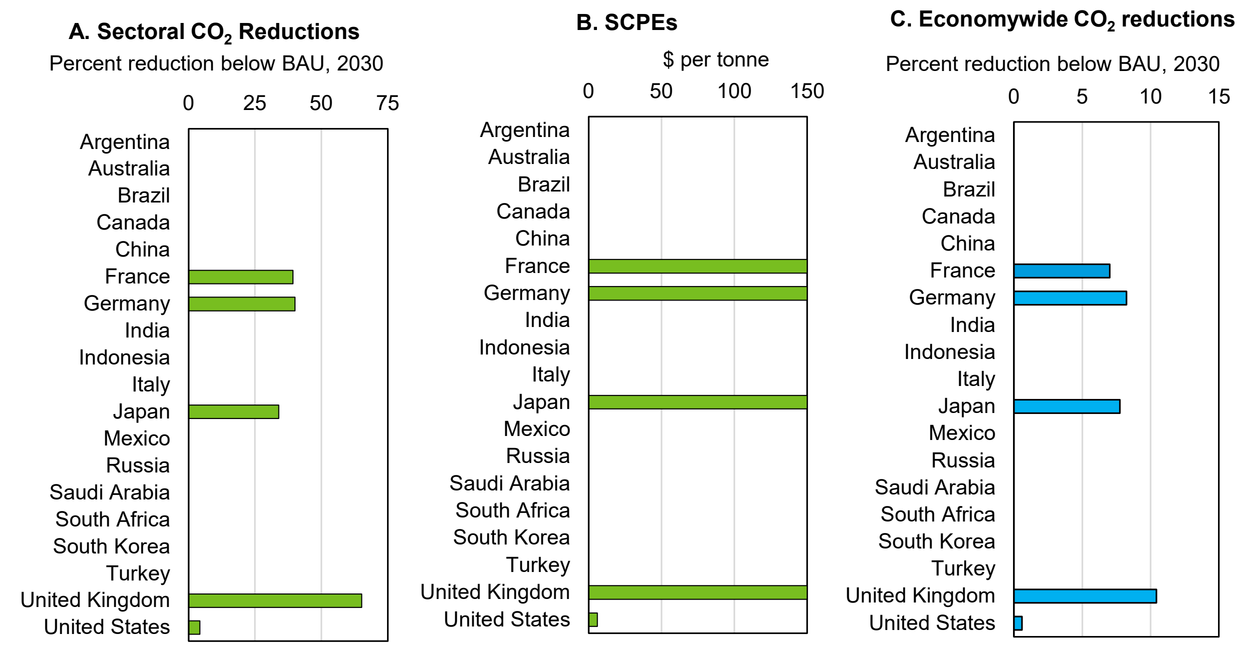
[14] Modelling the targets in the other order would change the attribution of emissions reductions to individual targets but the combined effect would be the same. In the cases of post-2030 coal bans, linear interpolations are used to infer 2030 targets.

[15] Costs are generally greater the larger the BAU renewables shares as this implies a larger share of low-cost opportunities are already exploited in the BAU.

B. Industry

There is generally less in the way of concrete policies for the industrial sector than for other sectors in G20 countries. Eight countries have targets for reducing CO_2 or energy intensity of industry (see Table Annex A, Table A4) though in four cases these targets overlap with explicit carbon pricing. Implementing industry emissions targets would reduce economywide CO_2 emissions most significantly in France, Germany, Japan, and the UK—indeed SCPEs in these cases exceed $150 per tonne and economywide CO_2 reductions are around 7 to 10 percent.

Figure 6. Industry Sector Targets, 2030



Source: IMF staff using CPAT.

C. Transportation

CO_2 emission rate (or fuel economy) standards. Aside from fuel taxes (see below), a common emissions abatement approach for light-duty vehicles are standards for the average CO_2 per kilometer (km) of producers' overall sales fleets, or for average fleet fuel economy (which have similar incentive effects). One or other of these policies apply nationally in nine G20 countries, and at the EU level, and have been progressively tightened over the last two decades. Standards in 2020 varied from the equivalent of around 100 grams CO_2 per km in EU countries and Korea to 140 grams CO_2 per km in South Africa and are scheduled to continue tightening (Figure 7).[16]

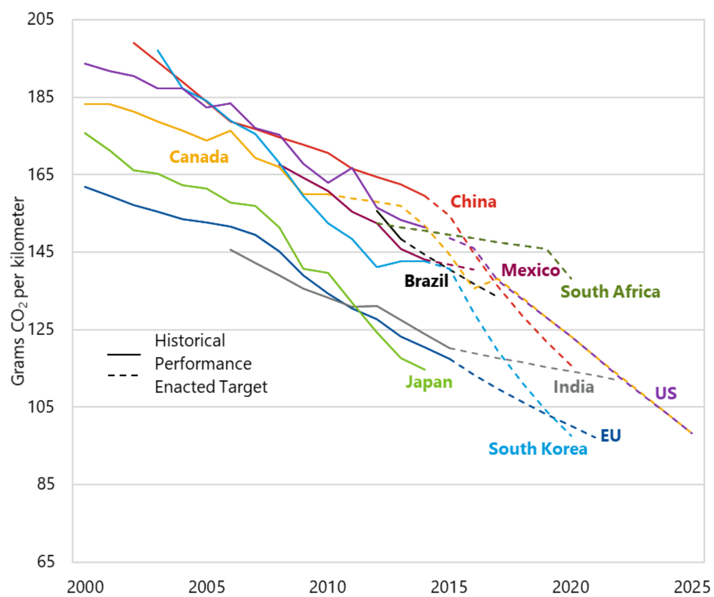
Standards apply to sales fleets averaging over both internal combustion engine vehicles (ICEVs) and electric vehicles (EVs) but only to first-time sales—they do not promote faster retirement of existing, high-emission vehicles. Standards also do not reduce vehicle km travelled—in fact, by

[16] Tighter standards are easier to meet in the EU because high fuel taxes and the predominance of small and more fuel-efficient vehicles imply a lower baseline CO_2 emission rate. Programs contain penalties for firms that are out of compliance, though do not typically include rewards for firms exceeding the standard.

lowering fuel costs per km they can encourage more driving, though this latter effect is ignored below.[17] Feebates—applying fees to the purchase of emissions-intensive vehicles and subsidies for relatively clean vehicles—promote similar behavioral responses as CO_2/km standards. Nine G20 countries include some form of feebates into initial vehicle purchase tax systems with EV subsidies varying between $2,000 (UK) and $7,500 (US) and fees for high emitters rising to between $3,000 Italy) and $12,000 (France)—see Annex A, Table A5.

Again, it is difficult to separate the individual impact of policies (regulations and feebates) on emissions. Instead, we consider the emissions impacts from countries achieving their specified reductions in future CO_2/km—for example, prospective EU standards will cut emission rates of vehicles 37.5 percent below 2020 levels by 2030.[18] Other transportation vehicles (for buses, trucks, trains, boats, planes, etc.) are not considered, as policies for these vehicles are less comprehensive than for light-duty vehicles (though these vehicles typically account for about a third of transport sector CO_2 emissions across G20 countries in the 2030 BAU).

Figure 7. CO_2 Emissions Rates Standards for Light-Duty Vehicle Sales for G20 Countries



Source: ICCT (2017), IMF staff estimates.

Notes: Miles per gallon data used to derive grams CO2/km are normalized to the US Corporate Average Fuel Economy test cycles (assuming 8,887 grams CO2 per gallon).

EV policies. 15 G20 countries have targets for phasing in EVs or phasing out ICEVs—indeed ten countries have pledged to fully phase out ICEVs in new vehicle sales by 2030 or 2035 (Annex A, Table A5). Emission rate standards, feebates, and EV sales requirements will all aid the transition to clean vehicle fleets, though again disentangling the contribution of individual measures to CO_2 reductions is difficult analytically.

The emissions impact of EV phase-ins are inferred from comparing CO_2 reductions from the CO_2/km and EV sales targets combined with that from the CO_2/km target only. EV targets are based either on those for 2030 or linearly interpolated shares for 2030 for countries with target dates beyond

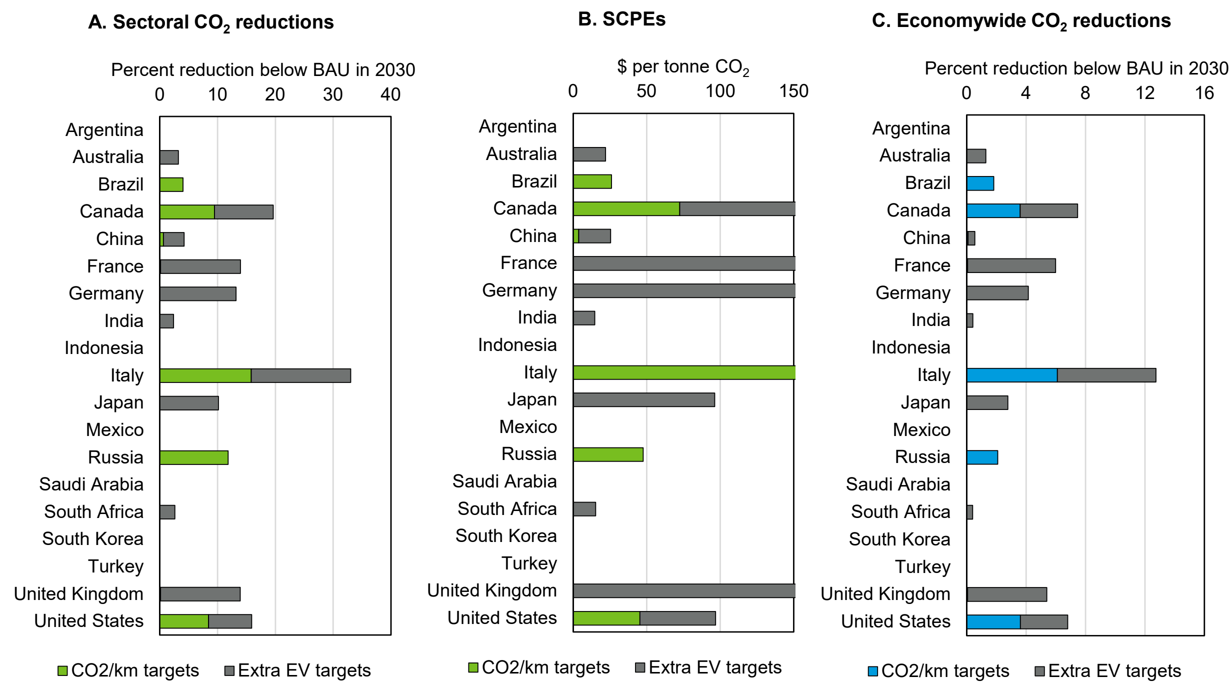
[17] For evidence on this rebound effect see, for example, Dimitropoulos and others (2018).

[18] Where future targets are not specified out to 2030, CO_2/km standards for new vehicles are fixed at the last year specified in legislation.

2030. In computing the emissions effects, partly offsetting indirect emissions from the additional electricity used by EVs are not considered.[19]

Results. Figure 8 shows the emissions reductions and carbon price equivalents for these targets. For the tightening of CO_2/km standards, sectoral emissions reductions from light-duty vehicles vary

Figure 8. Transport Sector Targets, 2030



Source: IMF staff using CPAT.

from 0.1 percent (UK and France) to 16 percent (Italy) below the 2030 baseline (with carbon pricing), with the average emissions reduction across the six countries with binding standards 8 percent (Figure 7, panel A). The gradual turnover of vehicles, and the gradual increase in standards, implies that emissions of the on-road vehicle stock are cut by around one-half of the reduction in new vehicle fleet emissions between 2020 and 2030. For countries with binding EV (or equivalent) targets, these promote additional emissions reductions in 2030 (beyond any reductions from CO_2/km standards) varying from 2 percent (India) to 17 percent (Italy).

Additional reductions are larger in countries with more aggressive EV targets relative to projected EV shares with CO_2/km standards only. SCPEs (panel B) for CO_2/km and EV sales shares combined vary from about $15 per tonne (India, South Africa) to over $150 per tonne (Canada, France, Germany, Italy, and UK).

Achieving both CO_2/km and EV share targets combined reduces economywide CO_2 emissions (panel C) below 2030 baseline levels by 8 percent or less in all but one case (Italy). These reductions are generally much smaller than those from the power sector, due to generally smaller

[19] This emissions offset varies across countries but to 2030 it is generally small. For example, according to IMF staff in Korea, which has relatively a carbon-intensive power sector, a slow decarbonization of power generation compared with a rapid decarbonization would offset about 20 percent of transport CO_2 emissions abatement benefits by 2030.

proportionate reductions in sectoral emissions and the smaller share of light-duty vehicles in economywide BAU emissions.

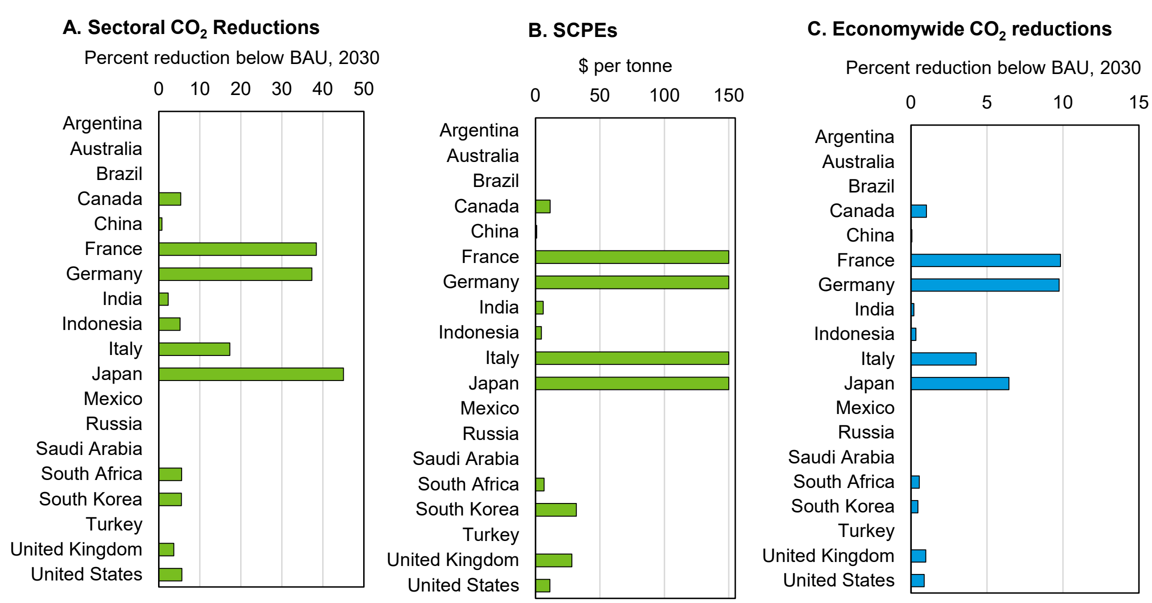
D. Buildings

Targets and policies. France, Germany, Italy, and Japan have targets for reducing energy use from the total building stock, by 25-44 percent between 2020 and 2030, while nine other G20 countries have targets for new buildings to produce approximately zero emissions by 2030[20] (in five cases) or later—see Annex A, Table A 6. Again, countries typically use multiple instruments to reduce energy use including:

- Building codes specifying design requirements to reduce energy needs for space heating and cooling;
- Retrofitting incentives such as fiscal incentives for insulation;
- Building certification programs for meeting energy, emissions, and other green criteria;
- Clean fuel requirements such as phasing out the use of fossil fuel heating systems in new buildings;
- Energy performance standards for household appliances; and
- Labelling schemes for appliances.

Combinations of the above policies reduce building emissions, but less effectively to the extent they apply only to new as opposed to all capital, especially given the very gradual turnover of the building

Figure 9. Buildings Sector Targets, 2030



Source: IMF staff using CPAT

[20] That is, any net electricity used by buildings (after buying/selling to the grid) needs to be provided by renewable sources like solar panels.

stock. The scenarios below focus on the emissions impacts of achieving countries stated sectoral energy reduction targets (again modelling individual, overlapping policies is impractical).

Results. At the sectoral level, emissions reductions from energy targets for buildings (Figure 9, panel A) exceed 30 percent below baseline levels in 2030 in France, Germany, and Japan but are around 5 percent or less where standards apply only to new buildings (as less than 2 percent of the building stock is replaced each year and new buildings are already more energy efficient than existing buildings). SCPEs are over $150 per tonne in the three EU countries and Japan but less than $25 per tonne in six cases (panel B).

At the economywide level, CO_2 emissions cuts from targets for buildings (panel C) for France, Germany, Italy, and Japan are 4-10 percent below BAU levels, but they are less in the other cases.

V. Fuel Taxes and Subsidies

Table 1. Excise Taxes by Fuel and Sector in 2020, G20 Countries

(converted to taxes per tonne CO_2)

	power			industry			transportation[b]		buildings[c]	
	coal	natural gas	oil	coal	natural gas	oil	gasoline	diesel	natural gas	oil
Argentina	0	-31	19	5	0	33	105	45	-41	1
Australia	0	0	79	6	24	96	157	99	-54	68
Brazil	5	106	20	42	106	23	149	42	203	65
Canada	5	-34	14	5	-45	90	157	83	-9	97
China	3	70	6	4	70	35	168	65	-24	49
France	-7	113	79	29	111	192	377	262	93	208
Germany	14	-22	31	-3	-18	167	364	218	-60	213
India	4	-99	101	4	-99	50	232	130	0	-2
Indonesia	0	33	-7	0	11	-10	38	-11	-65	-93
Italy	-11	-51	7	16	-3	191	396	278	-120	201
Japan	0	-25	21	3	80	98	270	148	218	178
Mexico	0	-16	8	1	0	44	112	103	-71	18
Russia	0	-34	2	0	-33	2	49	5	-158	-25
S. Arabia	0	-68	-13	0	-68	-26	-46	-159	0	-88
S. Africa	0	79	90	0	79	107	204	101	0	75
S. Korea	0	39	12	24	78	92	296	175	-43	108
Turkey	0	20	0	5	14	43	219	74	-133	111
UK	20	-35	53	37	73	176	341	285	-103	93
US	0	0	10	0	0	39	71	46	-19	33
weighted average[d]	**2**	**19**	**20**	**5**	**25**	**47**	**158**	**74**	**-18**	**44**

Sources: IEA (2021c), IEA (2021a), Enerdata (2021), Global Petroleum Prices (2021), European Commission (2021), IIASA emission factors (2021), IMF staff calculations.

Notes: [a] Tax rates include fuel excises and subsidies (VAT is excluded). [b] For light-duty vehicles. [c] For fuels used in residential buildings.

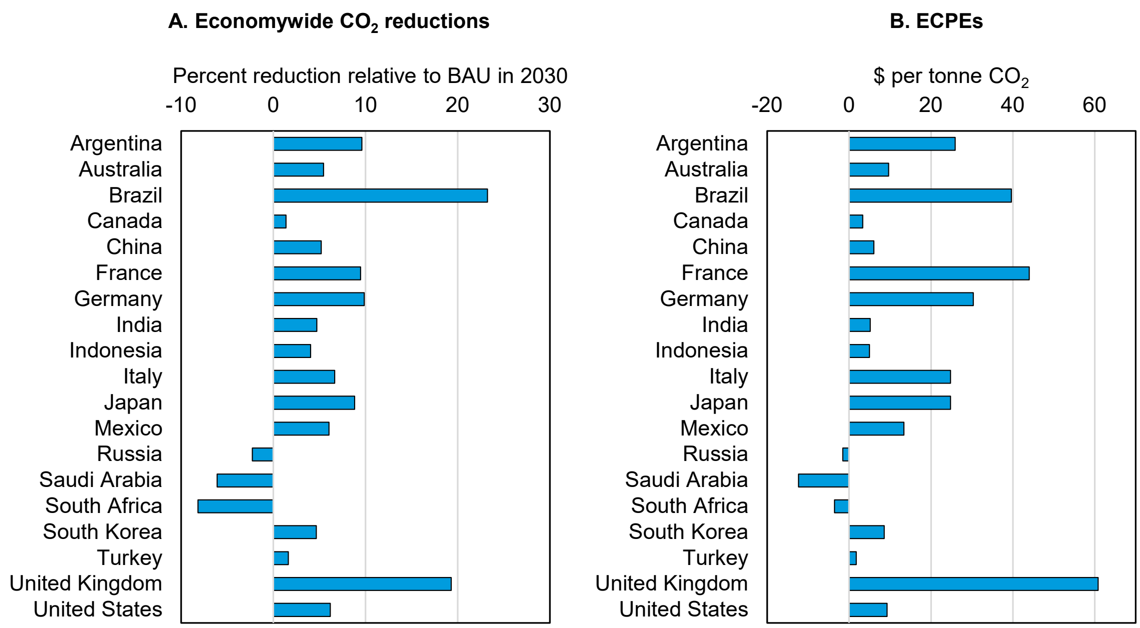
[d] Weighted by total GHG emissions.

Tax policies. Fuel taxes and subsidies have been implemented historically for many reasons, usually unrelated to climate mitigation. For example, in the case of road taxes to raise revenue (given their relatively unresponsive tax base) or address (albeit bluntly) local externalities like air pollution and traffic congestion. In other cases, fuels are subsidized, for example, through price controls or relief from general consumer taxes in the case of household fuels.

Whether fuel taxes should be included in an assessment of countries' current ECPEs is unclear. The impact of these taxes is already implicit in currently observed emissions, and if taxes remain unchanged, they will not contribute towards cutting future emissions. On the other hand, fuel taxes are transparent and raise fuel prices in the same way that carbon pricing does, albeit not in proportion to carbon content. If fuel taxes are included in measures of countries' current ECPEs, then of course the needed carbon price equivalent to align global emissions with Paris temperature goals would be correspondingly larger than noted in the Introduction.

Table 1 summarizes fuel excise taxes or subsidies by fuel type and within the four energy sectors for 2020, excluding general consumption taxes and expressed in terms of their emissions-weighted charges per tonne of CO_2. Tax rates and subsidies vary considerably across fuels, sectors, and countries. For example, coal remains relatively untaxed across all countries and sectors, gasoline and diesel account for much larger taxes relative to other fuels, while natural gas varies from -$158 per tonne of CO_2 (buildings in Russia) to $218 (buildings in Japan). The behavioral responses to fuel taxes are straightforward, for example, road fuel taxes will promote all responses for reducing emissions from light-duty vehicles (reducing vehicle km travelled, shifting among new and used ICEVs with differing fuel economy, and from ICEVs to EVs) while taxes on natural gas in power generation will partially promote shifting to renewables generation but could also perversely increase coal generation.

Figure 10. CO_2 Reductions and Economywide Carbon Price Equivalence of Existing Energy Taxes and Subsidies



Source: IMF staff using CPAT.

Scenarios for increasing individual fuel taxes are not considered below because countries have not made specific commitments to significantly increase them (or reduce subsidies) over the next decade. Rather, the focus is on the ECPE implied by each country's set of fuel taxes or subsidies, which gives a sense of how a proportionate scaling up or down of these tax/subsidy schemes might enhance, or offset, the effect of an explicit carbon pricing scheme.

Results. Figure 10 provides estimates of economy-wide CO_2 reductions implied by existing fuel taxes compared with a baseline of removing those fuel taxes by 2030, along with corresponding

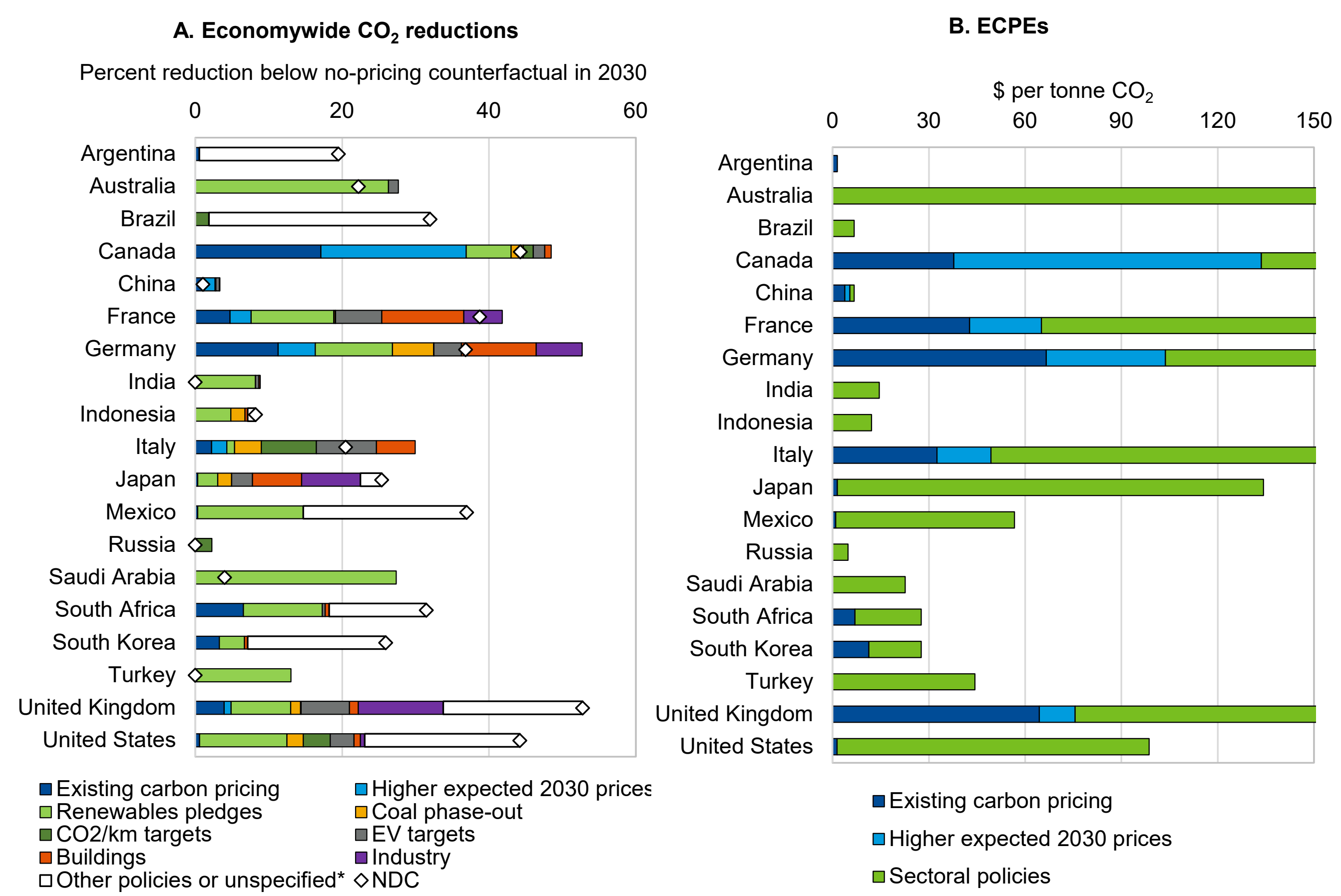
ECPEs (panel B). It gives a sense of the relative impacts and hence stringency of pre-existing fuel taxes. In most cases, fuel tax systems reduce economywide CO_2 emissions by around 5-20 percent

or, where there are subsidies, increase them by 2-8 percent (panel A). ECPEs are mostly in the range of $5-40 per tonne (panel B). These estimates, however, should not be confused with planned policies and targets of countries, since this exercise estimates emissions reductions and ECPEs based on the removal of existing policies rather than from new, additional policies and targets.

VI. Combined Effects of Mitigation Policies

Across countries, the combined effect of specified policies and targets (avoiding double counting of CO_2 reductions where policies overlap) varies substantially. CO_2 reductions below levels with no carbon pricing are less than 20 percent in eight countries and range from 20 to about 50 percent in the other 11 (Figure 11, panel A).

Figure 11. Policies and Sectoral Targets Combined



Source: IMF staff using CPAT.
Note: *'Other policies or unspecified' includes policies not quantified in this exercise or not yet specified by the authorities.

Additionally, countries vary significantly in their choice of instrument and relative contribution of sectoral targets. Renewables targets make a significant contribution to reductions in the policy mix in 15 cases and explicit carbon pricing contributes substantively in eight cases. As noted above however, the attribution of emissions reductions to individual policies and targets is ambiguous where they overlap (e.g., for carbon pricing of power emissions and renewable generation targets) hence the total CO_2 reductions (and ECPEs) should be considered more than the relative contribution of specific policies and targets. ECPEs for combined policies exceed $150 per tonne in six cases and are below $60 per tonne in ten cases (panel B).

Countries vary in the extent to which policies considered here achieve economy-wide mitigation pledges (NDCs). Three countries (India, Russia, Turkey) do not currently have binding emissions targets. Some countries over-achieve binding NDCs with sectoral policies (Australia, Canada, China, France, Germany, Italy, Saudi Arabia)—economywide targets could be enhanced in these cases by bringing them in line with existing sectoral targets. However, this relies on sectoral targets being met, which may not be the case if the actual pricing and non-pricing policies are not strong enough. In seven cases the economywide emissions reductions from specified policies and sectoral targets fall well short of the reductions needed for NDCs. All counties are implementing, or have announced, additional measures that are not included here (see Annex A, Table A 7), which may narrow the gap, however their emissions impacts are difficult to quantify (not least given their overlapping nature).

Lastly, as noted above, even if existing targets were met for all countries, a large gap between emissions reductions in 2030 and reductions needed to achieve the Paris Agreement's temperature goals would remain (see Black and others 2022). Stronger emissions targets and additional, concrete policies to achieve them, will be needed.

VII. Conclusions

This paper discusses and operationalizes a methodology for quantifying the emissions impacts and carbon price equivalence of pricing policies, non-pricing sectoral targets, and pre-existing fuel taxes for G20 countries to 2030.

Carbon pricing and other price-based policies like energy excise taxes promote a wide range of behavioral responses for reducing emissions. However, non-pricing sectoral policies such as clean technology subsidies, coal phaseouts, fuel economy standards, emission rate regulations, and feebates are often used by countries to complement, or instead of, pricing. Hence for policymakers seeking internationally cooperative approaches to complement the Paris Agreement—such as carbon price floors or climate clubs—metrics like the carbon price equivalence can help promote effective and inclusive participation. This approach is generalizable in that it can be implemented with any transparent and consistent multi-country mitigation model.

The results from an application using the IMF-WB CPAT suggests that current national policies vary significantly in strength, sectoral composition, and adequacy to achieve targets. Packages of pricing and non-pricing approaches are aligned with existing national mitigation targets (in NDCs) for 2030 in some cases but not others. In addition, existing targets themselves fall well short of what's needed to be on track to the Paris temperature goals.

Other findings include that accelerating renewables while phasing out coal in the power sector can significantly cut emissions, and that buildings efficiency regulations would be much more impactful if they applied to existing as well as new buildings. Pre-existing fuel taxes can have significant carbon price equivalence but whether they should count towards comparisons of mitigation effort remains unclear since these policies were implemented for mostly non-climate reasons.

While uncertainties are inherent in this type of exercise, the model used here is parameterized to be approximately consistent with midrange estimates of emissions projections and policy responsiveness from the broader energy modelling literature and econometric evidence. However, the analysis is confined to fossil fuel CO_2 emissions from the power, industry, transport, and buildings sectors. Future work could integrate other sectors (including emissions from extractives, forestry, agriculture, waste) and gases (including methane). A comprehensive comparison across policies and countries against a broader range of metrics would also be useful, including fiscal, economic welfare, and macroeconomic impacts, as well as distributional burdens on households and industries.

Annex A. Background Information on Mitigation Targets and Policies

Table A 1. Economywide Mitigation Pledges for the Paris Agreement, G20 Countries

Country	Submission Round[a]	Latest Mitigation Pledge for Paris Agreement[b]	Year for Net Zero Target
Argentina	Second	Net emissions cap of 359 $MtCO_2e$ in 2030	2050[d]
Australia	Second	Reduce GHGs 43% 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	2070
Indonesia	First	Reduce GHGs 29%(41%) below BAU in 2030	2060
Italy	Second	Reduce GHGs 55%[c] below 1990 by 2030	2050[c]
Japan	Second	Reduce GHGs 25.4% below 2005 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]
South Korea	Second	Reduce GHGs 40% below 2017 by 2030	2050
Turkey	First	Reduce GHGs 20% (25%) below BAU by 2030	2053
United Kingdom	Second	Reduce GHGs 68% below 1990 by 2030	2050
United States	Second	Reduce GHGs 50-52% below 2005 by 2025	2050

Sources: UNFCCC (2021).

Notes: [a]'First' and 'second round' refers to whether nationally-determined contribution was submitted in 2015/16 or has been updated in 2020/21/22. [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 A 2. Explicit Carbon Pricing Policies, G20 Countries

	Instrument/coverage (April 2022, 2030 prices, US $/ton)[a]
Argentina	Carbon tax for all emissions (5,5)
Canada	Carbon tax/ETS for power, industry, transport, buildings (40, 140)[b]
China	ETS for electricity to be expanded to industry (9, 9)[c]
France	EU ETS for power/industry (87,140), domestic tax for industry/buildings/transport (49,
Germany	EU ETS for power/industry (87,140), domestic ETS for buildings/transport (33,55)
Italy	EU ETS for power/industry(87,140)
Japan	Carbon tax for all emissions (2,2), Subnational ETS schemes
Mexico	Carbon tax for all emissions (0.42-4,0.42-4), [d]ETS for power/industry (4,4), Subnational
South Africa	Carbon tax for all emissions (10, 10)
South Korea	ETS for power/industry/buildings (19, 19)
UK	ETS for power/industry (99,130), domestic tax for power (24,24)
US	Subnational ETS schemes

Sources: WBG (2022), IMF staff, and national sources.

Notes. [a]Where prices, or caps in ETSs, are not specified in legislation for 2030 they are based on 2022 prices or, as in Germany, the last available year where a price is specified. For the EU ETS, the 2030 price is an estimate based on CPAT. [b]For some provinces and territories industry is covered by a tradable emission rate standard rather than carbon pricing. [c]China's ETS takes the form of a tradable emission rate standard. [d]Mexico's carbon price on additional $CO2$ emission content compared to natural gas.

Table A 3. Sector-Specific Targets and Policies for Power Generation, G20 Countries

	Renewables							Coal	
	Generation shares, %		Regulatory and fiscal policies					Generation shares, %	
	2021	Future target (year)	Feed in tariff	Renewable portfolio standard	Tradable renewable energy credits	Net-metering	Investment or production tax credits	2021	Future target (year)
Argentina	27	20 (2025)[a]	●	●		●	●	1	
Australia	20	68 (2030)	○	●	●	○		51	
Brazil	83	[b]				●	●	5	
Canada	68	90 (2030)	○	○	●	○	●	4	0 (2030)
China	28	80 (2060)	●	●			●	56	
France	22	40 (2030)[c]	●		●		●	1	0 (2022)
Germany	41	80 (2030)	●		●		●	17	0 (2030)
India	22	50 (2030)	○	●	●	○	●	64	
Indonesia	17	48 (2030)	●	●			●	51	30 (2025)[f]
Italy	41	55 (2030)	●			●	●	5	0 (2025)
Japan	21	36-38 (2030)	●		●			36	19 (2030)
Mexico	18	35 (2024)				●	●	5	
Russia	18	20 (2020)	●					9	
Saudi Arabia	0	50(2030)				●		0	
South Africa	6	41(2030)		●				87	
South Korea	5	30 (2030)		●	●	●	●	30	0 (2050)
Turkey	44	60(2030)[d]	●			●		19	
UK	39	100 (2035)	○	●	●			2	0 (2024)
US	19	28(2030)[d]	○	○	○	○	●,○	12	

Sources: REN21(2021); Government websites; and IMF staff estimates.

Notes: [a]Argentina's target excludes large hydro, which is included in its generation share. [b]Brazil's latest NDC no longer includes a renewable target. [c]EU wide target. [d]Inferred from numeric targets. ●= national. ○=subnational.

Table A 4. Sector-Specific Emissions Targets for the Industrial Sector, G20

	Target
Australia	Reduce the energy intensity of industry 30 percent between 2015 and 2030.
China	Peak aluminium and steel CO_2 emissions by 2025, and reduce them 40 and 30 percent, respectively from that peak by 2040.
France	Reduce (all GHG) emissions from industry 37 percent by 2030 relative to 2019.
Germany	Reduce CO_2 emissions 49-51 percent below 1990 levels by 2030
Japan	Reduce CO_2 emissions 38% below 2013 levels by 2030
South Africa	Reduce energy consumption of manufacturing 16 percent below 2015 levels by 2030.
Turkey	Reduce energy intensity by at least 10 percent in each sub-sector by 2023 (2011 baseline)
UK	Reduce CO_2 emisisons 67 percent below 2018 levels by 2035.

Sources: Climate Transparency; Climate Action Tracker: IEA; Government Websites.

Table A 5. Sector-Specific Targets and Policies for Vehicles, G20 Countries

	CO2/km		% EVs in vehicle sales		
	2020	Target (year)	2021	Target (year)	Additional incentives in registration fees (in US$)
Argentina					
Australia			1	30 (2030)	EV luxury car tax threshold at $56,800 compared with ICE threshold of $49,370.
Brazil	125	119 (2022)	<1		
Canada	123	100 (2026)	4	100 (2035)	Feebate: $4,000 subsidy for EVs, taxes on ICEVs rising to $3,200.
China	116	72 (2030)	6	100 (2035)	Feebate: $4,000 subsidy for EVs, taxes on ICEVs risng to 40% of base prices. 10% sales tax exemption for EVs.
France	100	61 (2030)	11	100 (2030)[a]	Feebate: $7,000 subsidy for EVs, taxes on ICEs rising to $12,000.
Germany	100	61 (2030)	14	100 (2030)[a]	Feebate: $7,000 subsidy for EVs, taxes on ICEVs rising to $5,000.
India	114	112 (2022)	<1	30 (2030)[b]	Subsidy up to $137/kWh for EVs <$20,455, general sales tax reduced 28% to 5%.
Indonesia			<1	numeric (2025)[c]	EV luxury tax exemption.
Italy	100	61 (2030)	4	100 (2030)[a]	Feebate: $4,600 subsidy for EVs, taxes on ICEs rising to $3,000.
Japan	106	92 (2030)	<1	100(2035)	Feebate: $7,000 subsidy for EVs, rising environmental performance tax on ICEVs.
Mexico	114	85 (2025)	<1	n/a[e]	
Russia				production (2030)[f]	5% purchase price subsidy on Russian-made EV up to maximum of $8,570.
Saudi Arabia				30 (2030)	
South Africa	138	n/a	<1		
South Korea	98	84 (2030)	3	numeric (2025)[d]	EV subsidy up to $17,000; excise tax reduction up to $2,700; acquisition tax reduction up to $1,200.
Turkey				numeric (2030)[g]	Special consumption tax reduced from 45%-160% to 10%- 60% for ZEVs.
UK	100	61 (2030)	11	100 (2030)	Feebate: $2,000 EV subsidy, taxes on ICEs rising to $3,870.
US	123	100 (2026)	2	50 (2030)	$7,500 producer subsidy for EVs (for first 20,000 vehicles sold).

Sources: IEA (2021b); ICCT (2017); Government websites

Notes: [a]EU wide target. [b]Target is for private cars. Target for commercial vehicles=70%, buses=40%, two and three-wheeler sales=80%. [c]Target of 2 million EVs in the passenger vehicle stock by 2025. [d]Target of 1.13 million EVs in the passenger vehicle stock by 2025. [e]No federal target but Jalisco, Mexico committed to 100(2030). [f]Annual EV production target of 220,000 units by 2030. [g]Target of 1 million EVs in the vehicle stock by 2030.

Table A 6. Sector-Specific Targets and Policies for Buildings, G20 Countries

	Targets	Policies					
	Target	Building Energy Codes for all Building Types	Retrofitting Incentives	Building Certification	Clean fuel requirements	Performance standards for household appliances	Appliance Labelling Scheme
Argentina				●^{v}		●	●
Australia		●		●^{m,v}		●	●
Brazil				●^{v}		●	●
Canada	All new buildings net zero emissions by 2030.	●	●	●^{v}		●	●
China	Green buildings to account for 50% of new urban buildings.	●	●	●^{m,v}		●	●
France	Reduce building sector emissions 44% below 2020 emisisons by 2030; EU legislation requires all new buildings to be nearly zero energy.	●	●	●^{m,v}	●	●	●
Germany	Reduce building sector emissions 43% below 2020 emisisons by 2030; EU legislation requires all new buildings to be nearly zero energy.	●	●	●^{m,v}	●	●	●
India	Reduce energy use for new commercial buildings 50% by 2030.			●^{v}		●	●
Indonesia	Reduce energy intensity ≥ 1% per year till 2025.*			●^{v}		●	●
Italy	Reduce building sector emissions 25% below 2020 emisisons by 2030; EU legislation requires all new buildings to be nearly zero energy.	●	●	●^{m,v}	●	●	●
Japan	Reduce building sector CO_2 emissions 66% below 2013 levels by 2030. All new houses net zero emissions by 2030.	●		●^{m,v}		●	●
Korea	All new buildings net zero emissions by 2030.	●	●	●^{v}		●	●
Mexico	Reduce energy consumption for all buildings 3.7% a year 2031-2050.	●	●	●^{v}		●	●*
Russia		●	●	●^{m,v}			●
Saudi Arabia		●	●	●^{v}		●	●
South Africa	All new buildings net zero emissions by 2030.	●	●	●^{m,v}		●	●
South Korea	All new buildings net zero emissions by 2030.	●	●	●^{v}		●	●
Turkey		●	●	●^{v}		●	●
UK	Reduce CO2 emisisons for all new buildings 75-80% by 2030.	●	●	●^{m,v}	●	●	●
US	All new buildings net zero emissions by 2030.	●		●^{m,v}		●	●

Sources: Climate Transparency (2021); IEA (2020); Government Websites

Notes: ●= national policy.●^{v}=widely voluntary. ●^{m,v}= Partially mandatory, widely voluntary.

Table A 7. Some Broader Mitigation Measures Excluded from the Analysis

Argentina	Congress passed a climate change law that establishes minimum standards for climate change. This includes the implementation of a National Climate Change Response Plan, a National System for GHG Inventory, and monitoring of mitigation initiatives. Argentina will also invest US $16.6 billion to reactivate railway lines by 2030.

Australia	The 2021-22 budget funds clean hydrogen, CCS, payments to farmers through the national soil carbon innovation challenge, the Climate Active framework, and businesses introducing energy efficiency measures. Australia also has an emissions reduction fund, where entities can voluntarily sell carbon credit to the government, a small-scale Renewable Energy Scheme, national energy efficiency measures, a National Energy Productivity Plan, a National Food Waste Strategy, legislated phase-down of HFCs, and state-implemented renewable targets. Other policies have also been announced, including the National Reconstruction Fund to support mitigation technologies, the Regions Fund, a new Driving the Nation Fund, and electric car tax incentives.
Brazil	Brazil has sectoral plans to reduce emissions, such as, the Mitigation and Adaptation to Climate Change for a Low-Carbon Emission Agriculture (ABC Plan), the Steel Industry Plan, the Low Carbon Emission Economy in the Manufacturing Industry Plan, the Sectoral Transport and Urban Mobility Plan and the Low-Carbon Emission Mining Plan. Brazil's National Energy Plan (2050) sets the strategic direction of energy expansion.
Canada	Canada passed the Canadian Net-Zero Emissions Accountability Act, legislating its 2050 net-zero GHG emissions into law and released their 2030 Emissions Reduction Plan, which targets emission reductions by sector. The federal government is developing a GHG offset system for activities not covered by carbon pricing and has announced funding of CAD $7 billion to support nature-based solutions, and CAD $1.72 billon to clean up inactive oil and gas wells. The country maintains a series of other targets including planting two billion trees over ten years, and to update methane emission reduction targets in the oil and gas sector for 2030 and 2025 beyond the current targets.
China	In 2022, China released its 14th Five-Year Plan on energy. China also has issued medium-term regulatory climate targets such as reducing energy and carbon intensities by 13.5 percent and 18 percent, respectively, while increasing nuclear power generation to reach 70GW by 2025. The country also aims to increase forest stock volume by 6 billion cubic meters from 2005 levels by 2030. Meanwhile, the nationwide trading system is expected to expand to cover seven industrial sub-sectors.
France	France's 2022 Climate and Resilience Law enforces higher standards on consumption, work, travel, housing, food and legal development. France's National Energy and Climate Plan (2020-2030) includes a National Low Carbon Strategy, aiming to be carbon neutral by 2050 while the Multiannual Energy Programme establishes the country's energy policy.
Germany	The Climate Action Plan 2050 aims to reach GHG neutrality by 2050. The German government is developing an increasing number of detailed sectoral plans to reach their ambition. The Ministry of Economic Affairs and Climate has been established to uphold climate policy. The new "Easter Package" is promoting renewable energy, the government is increasing funding for efficient buildings, and the economics ministry developed a plan to further economic efficiency, which is not yet binding.
India	India's Perform, Achieve and Trade mechanism sets intensity-based energy targets. In addition, India aims to introduce a pilot carbon market mechanism for small and medium enterprises as well as waste. The Faster Adoption and Manufacturing of Electric Vehicles (FAME) scheme incentivizes EVs and charging infrastructure. The Ministry of Power aims to have at least one charging station per $3km^2$. India has a plan for energy storage and grid integration of renewable energy, with a role for hydrogen. Several initiatives, including the National Urban Transport Policy and the Smart Cities Mission, aim to improve transport efficiency. The government plans to blend 20 percent ethanol in petrol by 2025. Railways are targeted to have net-zero emissions by 2030, after electrification of the systems by 2023. The National Mission for Sustainable Agriculture aims to reduce emissions in the agricultural sector.
Indonesia	Indonesia has a national energy plan, an electricity sector plan, and a National Medium-Term Development Plan 2020-2024 which guides the country's growth. The country imposed a biofuel mandate and aims to produce biodiesel from palm oil. Biofuel suppliers are subject to the Indonesian Sustainable Palm Oil certification scheme. Indonesia plans for the forestry sector to be a net sink by 2030.

Italy	Italy's 2019 Climate Decree contains several measures for improving air quality. In 2021, there was a ministerial reshuffle and now climate action sits under the Ministry of Ecological Transition. Italy's national recovery and resilience plan earmarks €62 billion, including funds for low-carbon public transit and rail infrastructure.
Japan	Japan has approved several plans relating to climate change, including the Sixth Basic Energy Plan, the Global Warming Prevention Plan, and a long-term growth strategy based on their NDC. Japan's Outlook for Energy Supply and Demand in FY2030 sets detailed energy efficiency and CO_2 reduction targets and plans across sectors and programs. Japan also aims to promote the development of CCS technologies by 2050. Japan's main energy efficiency law is the Energy Conservation Act. Recently, the government has announced plans to improve coal-fired power plants' efficiency standards and revisions to the FIT scheme by moving it to a feed-in-premium. Improved fuel economy standards were also announced for trucks and buses by 2025.
Mexico	Mexico's climate policy is guided by the General Climate Change Law, which hosts plans to achieve climate targets, including Mexico's first NDC. Under the law, there are two imposed frameworks, the National Strategy on Climate Change, which focuses the long-term (last published in 2013), and a Special Programme on Climate Change, which focuses on the short term (last published in 2021). In 2022, the country committed to investing US $2 billion to reduce methane and signed the forestry pledge at COP26. Their NDC aims to reach zero deforestation by 2030.
Russia	In 2021, Russia announced its long-term climate strategy, showing projections until 2050. The country also released its Draft Energy Efficiency Action Plan in 2021, which includes sectoral targets.
Saudi Arabia	Saudi Arabia's Vision 2030 aims to reduce fossil fuel subsidies. Meanwhile, the country is promoting a circular carbon economy and interconnecting their grid with neighboring countries. The government has also increased insulation standards for new buildings and air conditioners and has committed to plant 450 million trees by 2030, with a longer-term commitment of 10 billion trees.
South Africa	South Africa's Climate Change Bill commits to establishing a national GHG emissions trajectory and introduces a Ministerial Committee on Climate Change who would be responsible for working with the Minister of Environmental Affairs to set sectoral emission targets every five years. Carbon budgets would be established for large emitters, ultimately capping emissions. The Bill is under consideration of the National Assembly.
South Korea	South Korea has legislated their climate neutrality target under the Framework Act on Carbon Neutrality and Green Growth. The Act inaugurates an impact assessment strategy for public projects, integrates targets into the budgeting process, and introduces a climate response fund. The Green New Deal (2020) invests US $31 billion to green projects. The energy sector policy is driven by the 3rd Energy Master Plan (2019) and the 9th 15-year Basic Plan for Electricity Supply and Demand (2020). In 2021, the country revised their Renewable Energy Act and joined the Global Methane Pledge.
Turkey	Turkey's climate policies are defined by the National Climate Change Strategy (2010-2023), the National Climate Change Action Plan (2011-2023), the 10th Development Plan (as the 11th Development Plan focuses on energy security), and the National Renewable Energy Action Plan. The National Energy Efficiency Plan introduces schemes to increase efficacy in the industrial sector. The country also commits to increase forest cover to 30% by 2023, is expecting to reduce GHGs from the waste sector through a series of policies and aims to produce its own EVs.
UK	In 2020 the UK released the Ten Point Plan for a Green Industrial Revolution. Later that year, the Energy White Paper was published which committed to further reductions through additional measures. In 2021, the UK introduced their Net Zero Strategy, hydrogen and building strategies. Overall, the government has announced several plans targeting all sectors of the economy.
US	President Biden issued the Infrastructure Investment and Jobs Act, investing $1.2 trillion in EV charging infrastructure and improving efficiency in the power grid and building sector. The 2022 Inflation Reduction Act also aims to reduce emissions, mostly through subsidies and tax credits. Passenger vehicle emission standard rollbacks have been reversed for model years 2023-2026, and a bill on hydrofluorocarbons has been introduced to reduce production over the upcoming 15 years.

Annex B. Policy Equivalence from the Perspective of Implementing Border Carbon Adjustments

The EU plans to phase in a BCA, while other jurisdictions with aggressive emissions pricing are considering it. Charges on embodied carbon in products imported into a jurisdiction with a BCA should be reduced to the extent that the foreign country applies carbon pricing to those emissions. This Annex discusses whether BCAs should be adjusted for alternative mitigation policies.

Alternative policies with similar effects on emissions can have very different impacts than carbon pricing on production costs, and vice versa. Generally, carbon pricing places higher private costs on firms than equivalent non-pricing policies because their remaining emissions (after abatement measures) also face a charge. This charge on remaining emissions is generally larger than the cost of abatement measures—indeed, this is the charge the BCA seeks to equalize. Some regulations could place higher private costs on firms than emissions-equivalent carbon pricing, for example, in cases of very high emissions reductions (when charges on remaining emissions are a relatively small part of firms' compliance cost) or when regulations are inefficiently designed. In either case, non-pricing policies reduce the charges foreign firms pay under the BCA, simply because they reduce the assessed emissions intensity of their products—no further adjustment is needed because there is no charge on remaining emissions.

Equivalence from a BCA perspective would also require a granular approach, focusing on energy-intensive, trade-exposed (EITE) sectors like steel, aluminum, and cement. These sectors and the emissions embodied in their tradeable goods are a minor share of global emissions,[21] and hence not the focus of global mitigation efforts.

Countries might implement BCAs to encourage mitigation in other countries. The country imposing the BCA might choose to exempt an entire country from the BCA on grounds that it is doing its "fair share" of mitigation effort overall, for example as a member of a carbon club. In this case a mitigation-based equivalence could be the appropriate metric for exemption. Arguably the arrangement would address concerns about carbon leakage (since the emissions of both countries are effectively agreed in the context of the carbon club), but it would not necessarily be a remedy for concerns about EITE competitiveness. Such an arrangement might also be challenged at the WTO if a firm from a non-exempted country could show its product had lower embodied emissions than an equivalent product from an exempted country.

[21] Keen and others (2021), Figure 12.

Annex C. The IMF-WB Climate Policy Assessment Tool (CPAT)

(i) Model description and caveats

The Climate Policy Assessment Tool is a climate mitigation policy modelling platform developed jointly by the IMF and World Bank. Covering over 170 countries, CPAT provides projections of fuel use and CO_2 emissions for the four major energy sectors—power, industry, transport, and buildings. The tool starts with recently observed use of fossil fuels and other fuels by sector and then projects fuel use forward in a BAU using:

- GDP projections;
- Assumptions about the income elasticity of demand and the price responsiveness of fuel use in different sectors;
- 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 carbon pricing, non-pricing policies, and fuel taxes are held fixed in real terms at their 2021 levels or stringency.

The impact of carbon pricing on fuel use and emissions depends on: (i) the proportionate impact on future fuel prices; and (ii) the price responsiveness of fuel use in different sectors. Proportionate price increases depend on BAU prices, carbon emissions factors for fuels, and the pass through of carbon charges into fuel user prices which, for the most part, is taken to be 100 percent.[22]

In the power sector,[23] results are averaged over two models. One is a simplified model of fuel generation choices, parametrized to match the fuel price responsiveness of more complicated energy supply and integrated assessment models. The other is a technology-explicit, hybrid economic-engineering model where forward-looking agents choose dispatch and investment decisions to minimize levelized costs (e.g., capital, operational, and fuel costs). In the latter case, carbon prices reduce dispatch from fossil fuel plants and shift investment towards now-cheaper (in levelized terms) renewable generation. As new renewable plants become more cost competitive relative to new coal and gas, an increasing share of investment is shifted to renewables (subject to constraints, notably a maximum increase in annual scale-up of renewables). Additionally, they also accelerate retirement of coal plants, that is, coal plants are scrapped before the end of their natural lifetimes starting with the oldest plants. For the engineering model, a functional form is adopted which accounts for inertia both in decision making (e.g., the time taken to alter investment decisions)

[22] That is, fuel supply curves are perfectly elastic, which can be a reasonable approximation when fuel prices are determined on world markets or, in the longer term, there are large reserves. In countries with state-owned enterprises (SOEs) or regulated fuel pricing, pass through rates for fossil fuels are estimated based on historical relationships and taken to be 0.25, 0.5, or 0.75 (for example on petroleum, see Abdallah and others 2020), though most are estimated at 1.0. In power generation, carbon charges, including from ETSs with free allowance allocation, are assumed to be fully reflected in higher electricity prices (see, e.g., Sijm and others 2012). These assumptions might still be reasonable for countries with SOEs if there is significant energy market liberalization over the next decade.

[23] This sector also includes district heating.

and the distribution of costs within generation sources (e.g., that coal and renewables plants have costs that vary around that generation source's mean levelized cost). As a result, the switching between sources for dispatch and investment are gradual rather than immediate.

The industrial sector is disaggregated into eight industries (e.g., iron and steel, machinery, cement). In each industry, carbon pricing reduces the emissions intensity of production (e.g., through adoption of cleaner or more energy efficient technologies) and reduces production levels as carbon charges are reflected in higher consumer prices.

In the transport sector, fuel consumption from gasoline and diesel vehicles declines in response to higher prices as individuals switch to more fuel-efficient vehicles and reduce vehicle miles travelled. Fuel consumption in railways, domestic aviation, and domestic shipping are modelled in an equivalent manner.[24] In the buildings sector, fuel and electricity demand are decomposed into responses reflecting changes in energy and CO_2 intensity (e.g., insulation upgrades, shifting from fossil to electric heating, adoption of energy-efficient appliances) and behavioral changes (e.g., economizing on use of lighting, heating).

To analyze policies affecting only new investment in the transport sector, CPAT is supplemented with dynamic models of capital turnover. In the light-duty vehicle sector, the dynamic model distinguishes ICEVs and EVs in the vehicle stock in any future period, as determined by the previous history of purchases of these vehicle types before that period[25] and vehicle fleet turnover rates (6.7 percent a year based on an assumed 15-year life). In the building sector, commercial and residential buildings are distinguished with 1.8 and 1.2 percent of these stocks replaced annually (based on assumed building lives of 55 and 85 years respectively). The initial split electricity use in, and direct CO_2 emissions from, commercial and residential buildings is from UNFCC data.[26] The CO_2 and electricity intensity of new buildings is initially assumed to be 30 percent of that of the existing building stock (which implies consistency with rates of energy efficiency improvement in CPAT), though new building policies progressively reduce that (usually to 0 percent by 2030).

CPAT is populated using energy consumption data by country and sector compiled from the International Energy Agency (IEA)[27] and other sources (the latest data is for 2019). GDP projections are from the latest IMF forecasts.[28] Data on energy taxes, subsidies, and prices by energy product and country is compiled from publicly available and IMF and World Bank sources, with inputs from proprietary and third-party sources.[29] International prices for coal, oil, and natural gas (at the global level for oil and regional level for coal and gas) are projected forward using IMF price projections as of 2022. Fuel and electricity price responsiveness is parameterized to be broadly consistent with empirical evidence and results from energy models (fuel and electricity price elasticities over the

[24] The analysis here excludes both emissions from industrial processes (e.g., CO_2 from cement production) and international aviation and shipping (emissions for the latter are the responsibility of the United Nations bodies governing the industries).

[25] Based on country-specific IEA (2021b) projections.

[26] See UNFCCC (2022). This data is available for Annex 1 countries. For non-Annex 1 countries the split is based on a simple average of that across Annex 1 G20 countries.

[27] See IEA (2021a).

[28] IMF (2022a). Projections are extrapolated beyond five years assuming GDP growth rates in the last year persist till 2030, assuming gradual convergence among developing countries.

[29] See Parry and others (2021b) for details.

longer term are generally between -0.5 and -0.8). Carbon emissions factors by fuel product are from IIASA (2021), and emissions in 2019 are calibrated to match those of implied by UNFCCC GHG and emissions in 2020-1 calibrated to match those of EC-JRC (Crippa and others 2018), Global Carbon Budget (Friedlingstein and others 2021), and various sources.[30]

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 (). 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 mitigation ambition across countries. For our purposes, pledged proportionate reductions in CO_2 emissions below BAU are assumed equal to those for total GHGs.

One caveat (see text) is that fuel price responses become very uncertain for large policy changes that might ultimately drive non-linear adoption of technologies, like CCS and direct air capture.[31] In addition, fuel price responsiveness is approximately similar across countries—in practice, price responsiveness may significantly differ across countries with the structure of the energy system and regulations on energy efficiency and emission rates. CPAT implicitly accounts for general equilibrium effects such as the (modest) feedback effect on energy demand from policy-induced changes in GDP, but does not explicitly account for international feedback effects (e.g., changes in trade patterns) and changes in international fuel prices that might result from simultaneous climate or energy price reform in large countries. The model is parameterized, however, such that emissions projections and the price responsiveness of fuel use and CO_2 emissions is broadly consistent with that from far more detailed energy and computable general equilibrium models that, to varying degrees, account for these sorts of factors.[32]

(ii) Calculating CO_2 reductions and carbon price equivalence for alternative mitigation approaches

The economywide CO_2 reductions of alternative approaches are obtained by subtracting economywide emissions in 2030 under the policy or target from economywide BAU CO_2 emissions in 2030. The ECPE and SCPE of the other policy is then obtained by modelling in CPAT the equivalent carbon price at economywide and sectoral level respectively required to achieve the equivalent CO_2 reduction. Economywide pricing involves applying new charges on all fossil fuel use across the four energy sectors in proportion to their carbon content, while partial pricing limits these new charges to a subset of sectors.[33]

Renewables targets in CPAT are modelled by a renewable generation subsidy funded by a tax on electricity consumption (this promotes shifting towards renewables while approximately neutralizing

[30] For more details on model specification and parameters see Black and others (2023).

[31] Some recent assessments put the projected costs for CCS and direct air capture in the ballpark of $75 and $175 per ton of CO_2 reduced, respectively (e.g., Gillingham and Stock 2018, Keith and others 2018) though estimates remain highly speculative.

[32] The BAU emissions projections are broadly consistent with other models when the same international energy price scenarios (from IEA) are used.

[33] ETSs applied downstream to power generators and industry are assumed to cover 90 percent of emissions as small scale emitters are excluded from these schemes.

any impact on overall electricity production). The subsidy is set to achieve a given target for the future renewable generation share. Similarly, the coal phaseout is modelled by a tax on coal use with impacts on electricity demand approximately neutralized through using revenues used to subsidize electricity consumption.

Policies to reduce the (direct) CO_2 intensity of industrial production are modelled by a charge on the carbon content of fuel inputs with revenues returned in output-based subsidies (again this reduces the emissions intensity of production while approximately neutralizing output effects). Charges are set to achieve a given reduction in the CO_2 intensity of production.

CO_2/km standards for new vehicles are modelled by a ‘virtual’ or ‘shadow’ price that cost-effectively promotes reductions in CO_2/km through both shifting to more efficient ICEVs and from ICEVs to EVs without any change in fleet turnover rates. The shadow price is set to achieve target reductions in CO_2/km. Additional emissions reductions from EV targets are calculated from the supplementary dynamic model of vehicle turnover. The supplementary building model is used to calculate (direct and indirect) reductions in CO_2 emissions from emissions targets for new and existing buildings emissions.

Lastly, the ECPE of countries’ pre-existing fuel tax/subsidy systems is computed by first setting the tax/subsidy on all fossil fuels across different sectors gradually to zero by 2030, which in most cases increases economywide emissions. An economywide carbon price is then imposed to equal the emissions reductions sufficient to achieve the original BAU level (the BAU with pre-existing fuel taxes/subsidies kept fixed at 2021 levels).

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