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Climate Mitigation Policy in Türkiye

Ian Parry, Danielle Minnett, and Karlygash Zhunussova

WP/23/108

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Climate Mitigation Policy in Türkiye
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ABSTRACT: This paper discusses potential elements of a comprehensive strategy for making headway on Türkiye's net zero emissions pedge for 2053. These elements include: (i) aligning 2030 emissions commitments with long term neutrality; (ii) implementing a carbon price rising to an ilustrative $75 per tonne by 2030; (iii) enhancing acceptability through using carbon pricing revenues efficiently and equitably and including competitveness measures; (iv) introducing various feebate schemes (the fiscal analogue of regulations) to reinforce mitigation incentives in the power, industry, transport, building, forestry, and agricultural sectors. According to modelling results a phased revenue-neutral $75 carbon price reduces CO_2 emisisons 21 percent below baseline levels in 2030, raises revenues of 1.7 percent of GDP, avoids 11,000 air pollution deaths over the decade, while imposing an average burden on households of 3 percent of their consumption (before revenue-recycling). With revenues used for targeted transfers and labor tax reductions the overall policy is pro-poor and pro-equity (average household is better off by 0.4 percent).

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WORKING PAPERS

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1. Introduction

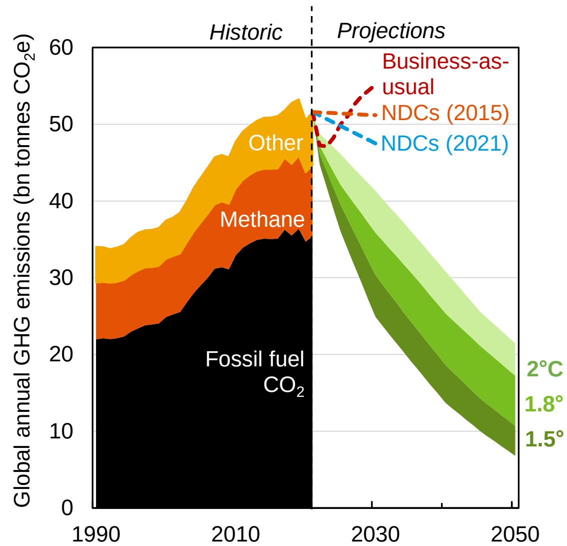
1. **Limiting global warming to 2°C or 1.5°C requires cutting global carbon dioxide (CO2) and other greenhouse gases (GHGs) 25 or 50 percent below 2019 levels by 2030, followed by a rapid decline to net zero emissions near the middle of this century (Figure 1).** Current national targets achieve only 13 percent emissions cuts below 2019 levels. If the needed emissions reductions are not achieved, this will likely put the Paris Agreement's temperature goals beyond reach. Indeed, without new mitigation policies, in the business as usual (BAU) case with no new or tightening of existing mitigation policies, global emissions are projected to continue rising.

2. **The world is not yet on track to net-zero on two fronts (Figure 2).**

- **There is a large global ambition gap.** 136 countries, representing 88 percent of global GHGs, have proposed, or set, net zero targets for around mid-century.[1] But even if intermediate pledges for 2030 in countries' Nationally Determined Contributions (NDCs) were fully achieved, they would only reduce global CO_2 emissions 13 percent below 2019 levels.
- **There is an even larger gap in policy implementation.** Keeping existing policies fixed would imply emissions well above targets and levels required by Paris' temperature goals.

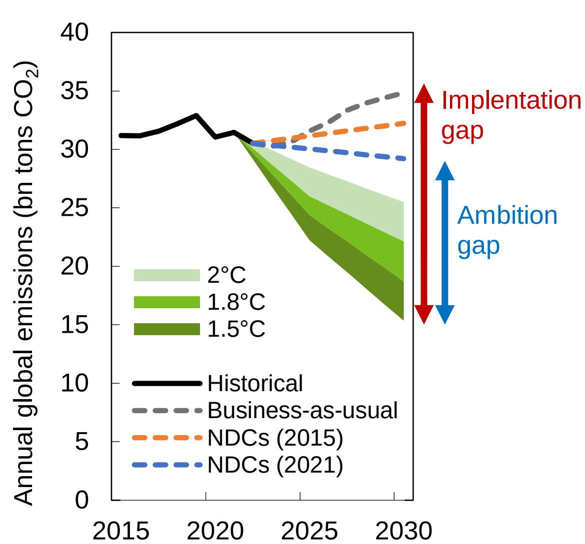
3. **Observed global warming to date of 1.2ºC is caused by human factors and warming is happening faster than previously expected.[2]** Warming is already causing a wide range of climate impacts including heatwaves, droughts, floods, hurricanes, higher sea levels, and swings

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



Sources: Black and others (2022a).
Note: Excludes land use and land use change

Figure 2. CO2 Emissions, Mitigation Ambition and Policy Gaps to 2030



Source. Black and others (2022a).

[1] See www.climatewatchdata.org/net-zero-tracker.
[2] This paragraph draws from IPCC (2018, 2021).

between climate extremes, and the frequency and severity of these impacts will rise as the planet heats up. Moreover, the risks of tipping points in the global climate system (e.g., runaway warming from release of methane and carbon in the permafrost, collapse of major ice sheets causing dramatic sea level rises, shutting down of ocean circulatory systems, destruction of the natural world) rise exponentially with warming above 1.5ºC. Türkiye will likely experience three accelerating trends: rising temperatures, dehydration, and rising sea levels which will cause more frequent and more severe weather conditions.

4. **Ambitious climate policy is potentially in Türkiye's own national interest.** A comprehensive mitigation strategy with carbon pricing[3] as its centerpiece can mobilize valuable government revenues, save lives by reducing local air pollution exposure, reduce poverty, and present Türkiye as a leader in combating the global climate challenge.

5. **Türkiye plans to complete a Climate Law laying out a net zero transition strategy in a revised Nationally Determined Contribution (NDC).** Türkiye ratified the 2015 Paris Agreement in October 2021 and set a net zero emissions target for 2053. Potential key elements of the strategy will include: (i) aligning intermediate emissions targets with long term neutrality; (ii) emissions pricing, likely in the form of trading; (iii) measures to enhance the acceptability of pricing; and (iv) supportive policies to reinforce responses like shifting from coal to renewables, and electrification of transportation.

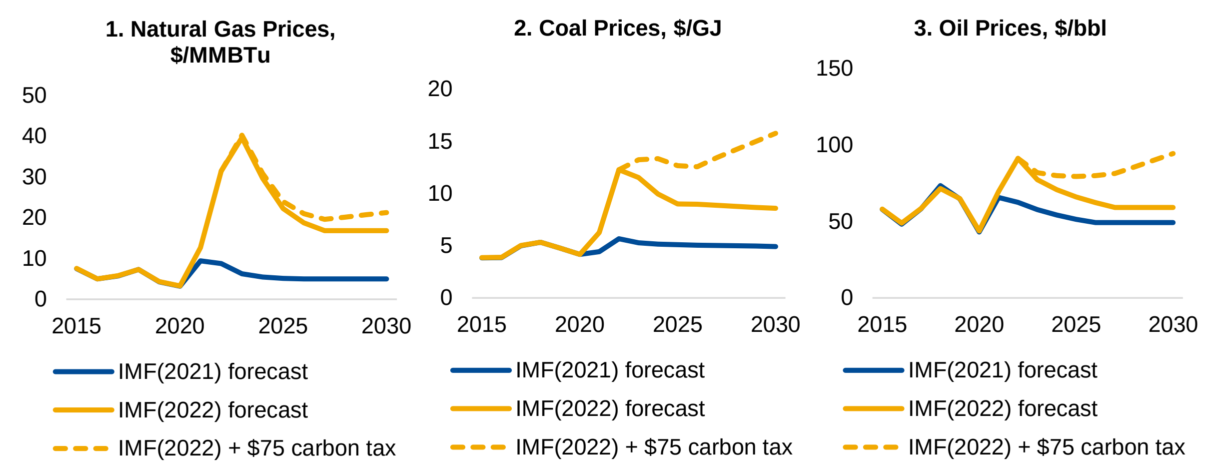
6. **In choosing a revised emissions target for 2030, Türkiye will need information on: (i) BAU emissions projections at economywide and sectoral level; and (ii) the costs of cutting emissions below BAU levels.** Both are sensitive to assumptions about key underlying factors (e.g., GDP growth, income elasticities for energy products, future BAU energy prices, fuel price responsiveness) that vary across different models. This paper presents analyses based on a spreadsheet tool that is approximately parameterized to the mid-range of the broader energy modelling literature and illustrates the implications of alternative assumptions.

7. **Achieving a substantial emissions reduction will likely require carbon pricing.** Comprehensive carbon pricing provides across-the-board incentives to reduce energy use and shift to cleaner energy sources and the critical price signal for redirecting investment to clean technologies. There are many technical issues however in the choice between and design of carbon pricing instruments, namely carbon taxes and emissions trading systems (ETS). This includes administration, price levels, relation to other mitigation instruments, use of revenues to address efficiency and distributional objectives, supporting measures to address competitiveness concerns, and extension to broader emissions sources. This paper discusses the main issues and presents an extensive quantitative assessment of the emissions, fiscal, and economic impacts of carbon pricing.

[3] Currently Türkiye is working on the establishment of an ETS in the country.

8. **A comprehensive strategy can enhance the acceptability of carbon pricing, especially given high energy prices.** Global gas, coal, and oil prices increased about 700, 180, and 110 percent respectively between mid-2020 and mid-2022 (Figure 3). This was in part due to the recovery in global energy demand, previously weak fossil fuel investment, and disruptions following the Russian invasion of Ukraine. These high prices are a key challenge for the political acceptability of carbon pricing. However, though subject to much uncertainty, projections suggest fuel prices will decline gradually over time as demand and supply adjust. This provides an opportunity to gradually increase carbon prices, while allowing the price of gas to decline below current levels. For illustration, phasing in a $75 carbon price on top of projected prices would imply 2030 gas prices that are 32 percent below mid-2022 levels, while oil and coal prices would be 3 and 28 percent higher respectively. Without carbon pricing (or related measures), the impact of higher baseline energy prices on decarbonization is limited, because: the relative increase in gas prices has caused switching to coal; price changes are seen as reversable; and higher market prices have increased the profitability of fossil fuel production.

Figure 3. Trends in International Fuel Prices



Source: Black and others (2022a).
Notes. Prices in real 2021 US$, deflated by respective IMF projections. Carbon tax starting at $10 in 2022 and rising to $75 in 2030 is assumed on top of IMF (2022b) baseline assuming elastic supply (this assumption is likely reasonable for coal and gas, although possibly less so for oil). Natural gas prices are a weighted average of natural gas in Europe, North America (Henry Hub) and LNG market (Japan). Coal prices are a weighted average of domestic sectoral coal prices in China, India, and the US. Oil prices are an average of Brent, Dubai Fateh, and West Texas Intermediate. The carbon tax is assumed to be fully passed forward into demand prices.

9. **Acceptability might be further enhanced through exploiting the revenue potential of pricing (e.g., by auctioning allowances in an ETS) and using the revenue in a way that boosts economic activity (e.g., through cutting labor taxes) and that addresses distributional concerns (e.g., by targeting some of the revenues to low-income households).** Also important is to address concerns about impacts on industrial competitiveness. The paper provides a quantitative analysis of the distributional burden of carbon pricing on households and firms under different scenarios for future energy prices, carbon pricing, and revenue recycling. It also discusses carbon border adjustment mechanisms (BCAs) in Türkiye and the EU and other measures to address competitiveness concerns.

10. **Reinforcing sectoral instruments can also help with hard-to-abate sectors and to the extent carbon pricing is subject to acceptability constraints.** Sectoral instruments are less efficient than carbon pricing (i.e., they promote a narrower range of mitigation responses) but they likely have greater acceptability as they avoid a significant increase in energy prices. This paper discusses the potential use of feebates, or similar instruments, for the power, industry, transport, building, forestry, and agricultural sectors. Feebates, which are a more novel approach, are the fiscal analogue of emission rate or energy efficiency regulations but can be more flexible in accommodating uncertainty over mitigation costs.

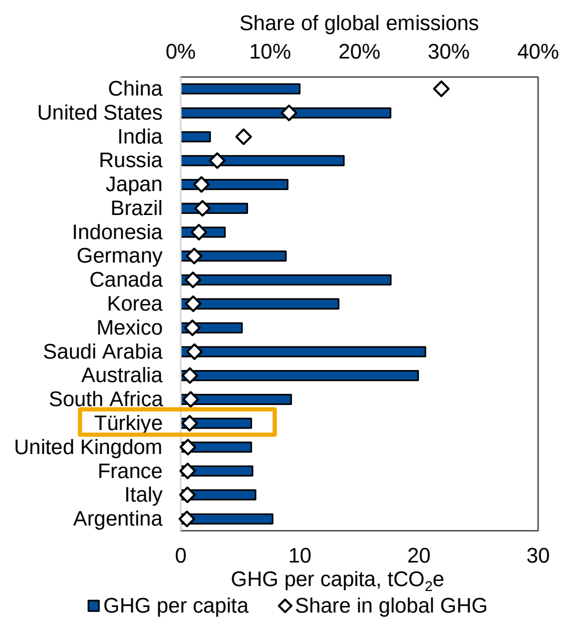
11. **The paper suggests potential elements of a comprehensive mitigation strategy for Türkiye and is organized as follows.**[4] The next section provides background on national emissions trends and targets in Türkiye and, for comparison, Group of Twenty (G20) countries. Section III discusses conceptual issues in the choice between, and design of, carbon pricing. Section IV presents estimates of the emissions, fiscal, and cost impacts of carbon pricing. Section V discusses the distributional impacts of pricing and measures to assist households and firms. Section VI discusses additional complementary instruments at the sectoral level. Section VII summarizes the main recommendations.

12. **The paper uses extensive quantitative analysis.** Most of this analysis is based on a flexible and transparent spreadsheet model—the Climate Policy Assessment Tool (CPAT)—developed by Fund and Bank staff. This model provides consistent cross-country projections for 200 countries of fuel use and CO_2 emissions by major energy sectors and the emissions, fiscal, economic, and distributional impacts of carbon pricing and other mitigation instruments. Although CPAT is based on central case parameter values, any modelling exercise involves inherent uncertainties over emissions projections and policy impacts. The model is described in Annex A.

2. National Emissions Trends and Targets

13. **In per capita terms, Türkiye's emissions are around the global average, but Türkiye remains a large global emitter in absolute terms** (Figure 4)**.** According to staff estimates, Türkiye's GHG emissions amounted to 5.9 tonnes of carbon dioxide equivalent (CO_{2e}) per capita in 2020,

Figure 4. Per Capita Emissions and Global Shares, 2020



Sources: UNFCCC (2022); EDGAR (2022); staff estimates

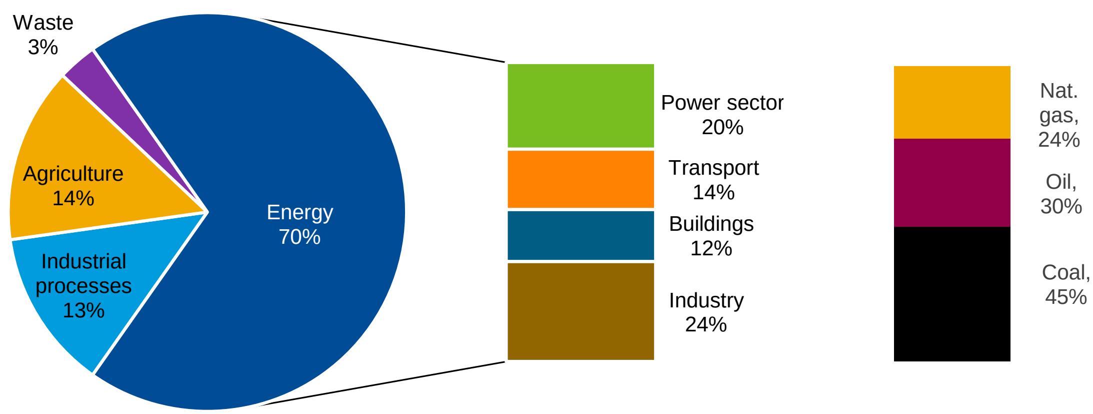
Note: GHGs exclude land use, land use change and forestry (LULUCF) emissions. World GHGs exclude international maritime and aviation.

[4] The policy recommendations are broadly in line with those in other recent IMF staff assessments of climate mitigation strategies (e.g., Arregui and Parry 2020, Black and others 2021a and b, Parry 2021). Some issues are beyond the scope of the paper including financial sector policies (see IMF 2022a, WBG 2022a) and technology-related market failures (see Dechezleprêtre and Popp 2017).

compared with a global average of 6.1 tonnes per capita, which is lower than OECD average (10.3 tonnes). At the same time, Türkiye was the eighteenth largest global emitter in absolute terms in 2020 producing GHG emissions of 495 million tonnes or 1 percent of the global total. Actions to mitigate emissions in Türkiye are therefore significant at the global level and could help to catalyze mitigation action among other emerging market economies.

14. **Energy-related CO_2 emissions accounted for 73 percent of Türkiye's (non-land use) GHGs in 2020. See Figure 5.** Power generation accounted for 21 percent of GHGs, industry fossil fuel CO_2 24 percent, transport 15 percent, buildings 13 percent, industrial process emissions (e.g., from cement) 11 percent, agriculture 13 percent, and waste 3 percent. By fuel type, combustion of coal, oil, and natural gas accounted for 45, 30, and 24 percent of fossil fuel CO_2 emissions. Land-use, land use change, and forestry (LULUCF) on net absorbed 82.3 million tonnes of emissions in 2020[5] (though measurement of these emissions is less accurate and more contentious than for energy-related CO_2 emissions).

Figure 5. GHGs by Sector and Fuel, 2020



Source. Turkish Statistical Institute (2022); IMF staff using CPAT
Notes. GHGs exclude LULUCF emissions. Buildings include emissions from residences, services, and fuel use in agriculture and forestry.

15. **GHG emissions in Türkiye increased 138 percent between 1990 and 2019 but, according to IMF staff estimates, BAU emissions[6] will decrease by 27 percent between 2019 and 2030.** Although GDP in Türkiye is projected to grow by approximately 44 percent in real terms between 2019 and 2030, the CO_2 emissions intensity of GDP declines 42 percent over this period, reflecting gradual improvements in energy efficiency (as older, less efficient capital is retired) and standard assumptions that the demand for electricity and fuels increase by less than in proportion to GDP. Aside from India, projected CO_2 emissions growth in other G20 countries over this period is around 0-20 percent. See Figure 6.

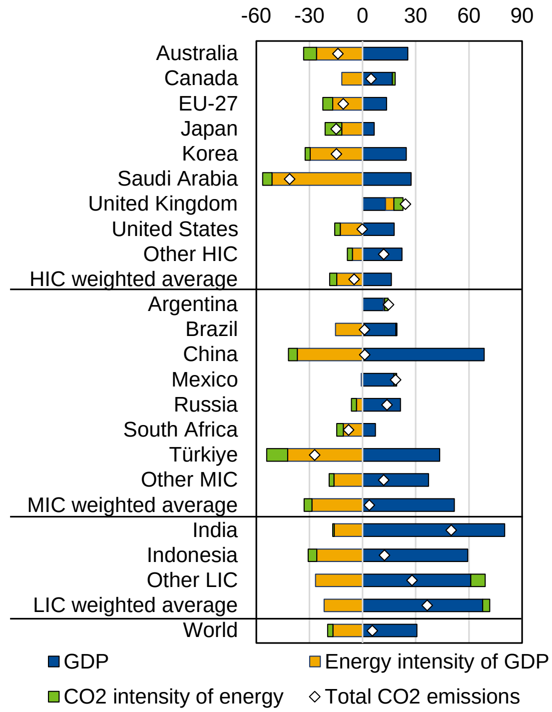
[5] WRI (2021). According to Turkish Statistical Institute, LULUCF absorbed 56.95 million tonnes of emission in 2020.
[6] BAU is estimated in the Climate Policy Assessment Tool, developed by the IMF and the World Bank staff. See Annex A for additional information

16. **Recent 2030 BAU emissions projections by the Turkish authorities are higher than in IMF staff projections.** Türkiye's Nationally Determined Contribution (NDC) submitted for the Paris Agreement projects BAU GHG emissions of 1175 million tonnes in 2030, or 175 percent higher than in the IMF BAU projections. The difference in part reflects growth in electricity demand which the government expects to double by 2030,[7] while the IMF projects growth of 16 percent.

17. **Baseline deaths from local air pollution are projected[8] to reach 9,700 a year by 2030, which brings approximately 2.7 bn USD of GDP loss, mostly from outdoor air pollution. See Figure 7.** Coal and diesel combustion causes emissions of fine particulates, both directly, and indirectly (through sulfur dioxide and nitrogen oxide emissions which react in the atmosphere to form particulates)—gas and gasoline combustion cause much smaller amounts of these pollutants. Fine particulates are small enough to enter the lungs and bloodstream and elevate mortality risks from various heart and lung diseases and strokes, especially for seniors with pre-existing conditions.

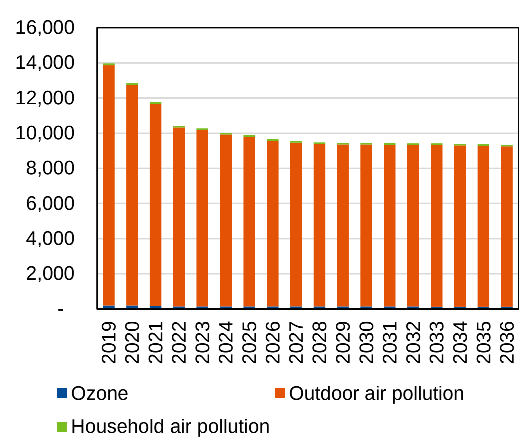
18. **Türkiye's current 2030 pledge is not aligned with net zero emissions in the long term—indeed according to IMF projections, the 2030 target will be met in the BAU without mitigation action.** For Türkiye, a linear emissions pathway to emissions neutrality between 2022 and 2053 would imply reducing GHGs 28 percent relative to 2021 levels to 292 million tonnes in 2030. In contrast, in its first NDC Türkiye pledged to limit emissions to 929 million tonnes in 2030, 21 percent below the authorities' own BAU projection. During COP27, Türkiye has announced new target reduction of 41 percent compared to BAU, approximately limiting the GHG emissions at 693 million tonnes in 2030.

Figure 6. Drivers of BAU CO2 Emissions 2021-2030



Source: IMF staff calculations using CPAT.

Figure 7. Annual projected local air pollution deaths to 2030



Source: IMF staff using CPAT

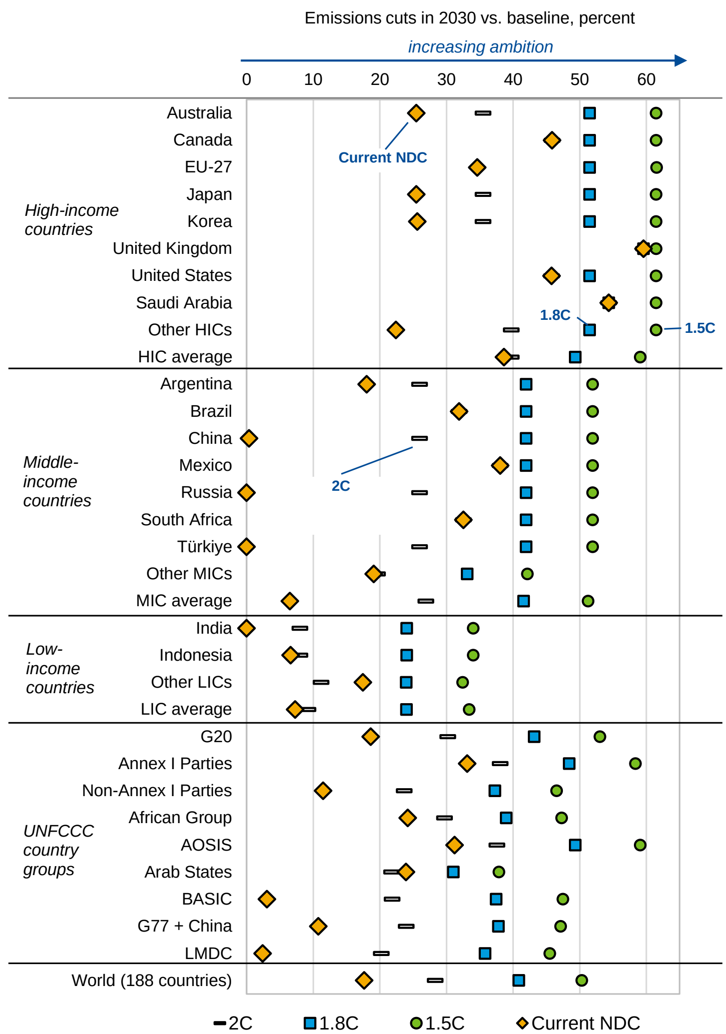
[7] Republic of Türkiye Ministry of Energy and Natural Resources (2019).

[8] Using Climate Policy Assessment Tool (CPAT) – see Annex A. Lower band estimates as do not include the impact of air pollution on productivity and economic activity. For details, see Fu and others (2022), Dechezlepetre and others (2020), Chang (2016), Chang and others (2019) and Neidel (2012)

However, even the updated target is about 70 percent higher than the IMF BAU projections.

19. **Many G20 countries have pledged to cut CO_2 emissions around 25-50 percent below BAU levels in 2030.** This is the case for the EU, high-income countries, and some middle-income countries (Brazil, Mexico, South Africa). Indeed, many economies (notably the EU and US) strengthened 2030 commitments in their second-round NDCs submitted for COP26. In other cases, however, some middle- and low-income countries (e.g., China, India) currently have non-binding pledges (i.e., targets that are reached in the baseline) for 2030. See Figure 8.

Figure 8. Current and Illustrative CO2 Emissions Cuts for G20 Countries versus 2030 BAU



Source. Black and others (2022).

3. Carbon Pricing: Rationale, Instrument Choice, and Design Issues

A. Rationale

20. **Carbon pricing is the most cost-effective mitigation policy and ideally would be the centerpiece of Türkiye's mitigation strategy.** If comprehensively applied, pricing promotes (by reflecting the cost of carbon emissions in the prices of fuels, electricity, and goods) the full range of behavioral responses across households, firms, and sectors for reducing energy use and shifting toward cleaner energy sources. It also strikes the cost-effective balance across these responses as the incremental reward for reducing emissions by an extra tonne, the carbon price, is equated across responses. In contrast, other mitigation instruments by themselves, like emission rate standards and clean technology subsidies, promote a narrower range of behavioral responses. These other instruments could be combined in packages that could promote a wider range of responses from pricing—but not all responses (e.g., regulations cannot induce people to drive less or conserve on heating fuel). The policy combination would also be more administratively complex and potentially less cost effective. See Annex B.

21. **Carbon pricing has other attractions as it:**

- Provides the critical price signal for mobilizing innovation into, and deployment of, clean technologies;
- Mobilizes a valuable source of revenue, which can be used to help meet climate, social, or broader fiscal objectives; and
- Generates domestic environmental co-benefits, such as reductions in local air pollution deaths (though other mitigation instruments can produce similar benefits).

B. Instrument Choice and Design Issues

22. **Carbon taxes (generally under the purview of finance ministries) are easier to administer than ETSs (generally under the purview of environment ministries).** Carbon taxes can be integrated midstream (i.e., after fuel refining and processing) into collection procedures for existing fuel taxes and extended to other fossil fuels—fuel taxes are well established in Türkiye and are among the easiest of all taxes to collect. Rebates should be provided to downstream firms that adopt abatement technologies like carbon capture and storage, though these technologies are very rare at present. ETSs typically require more sophisticated administration as new capacity is required to monitor both downstream emissions and emissions trading markets.[9] ETSs may have more limited coverage as they have often been applied to large power and industrial firms (building off regulatory frameworks for local pollution),[10] though ETSs can also be extended midstream to transportation and building fuel suppliers (e.g., as in Germany's domestic ETS).

23. **In their pure forms, carbon taxes provide certainty over emissions prices while emissions are determined by market factors, and vice versa for ETSs.** Certainty over emissions is attractive if policymakers want to meet an emissions target in a future year but price uncertainty can deter private innovation in, and adoption of, clean technologies, especially those (e.g., renewables plants) with high upfront costs and long-range emissions reductions. Indeed, allowance prices in ETS schemes in California, the EU, and Korea have shown significant volatility to date—see Figure 9. ETSs can however be combined with price stability mechanism like price floors,[11] and carbon taxes may need periodic adjustment to maintain progress on emissions goals, so in practice differences in the time profile of prices between the two approaches may be less pronounced.

24. **Revenue mobilization for general government purposes is more robust under carbon taxes.** Revenues from carbon taxes accrue to finance ministries and can be used for fiscal priorities (e.g., reducing burdensome taxes on labor and capital, funding productive investment) and in ways that meet distributional objectives for the carbon tax reform (see below). Indeed, the fiscal case for carbon taxes is especially appealing when large informal sectors (about 30 percent of employment the economy in Türkiye)[12] hinder revenue mobilization from broader fiscal instruments. Under ETSs, in principle allowances could be auctioned with revenues transferred to the finance ministry though in practice free allowance allocation is common, and where allowances are auctioned revenues are frequently earmarked. A political motivation for free allowance

[9] Usually there is a pilot phase to establish emissions measurement, reporting and verification systems, allowances exchange platforms, and to simulate trading.

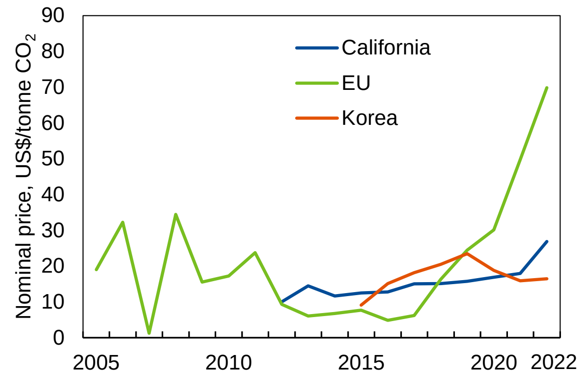
[10] For administrative reasons, small scale emitters are excluded, but their share in emissions is generally modest.

[11] These mechanisms can be implemented, for example, through minimum prices when allowances are auctioned (e.g., in the California ETS there is a reserve price for allowance auctions that rises annually at 5 percent in real terms while the Korea ETS links auction prices to historical prices). In the EU, the Market Stability Reserve withdraws allowances from the system during periods of downward pressure on allowance prices. See Flachsland and others (2018) for further discussion of price floor mechanisms.

[12] https://ilostat.ilo.org/topics/informality.

allocations is that they help to address concerns about industrial competitiveness, but a border carbon adjustment could be a more robust instrument for this (see below).

Figure 9. Allowance Price Volatility in ETSs



Sources: WBG (2022b), https://carboncredits.com/carbon-prices-today, http://data.krx.co.kr/contents/MDC/MDI/mdiLoader/index.cmd?menuId=MDC0201060301.

25. **Carbon taxes are more compatible with reinforcing mitigation instruments and variants of them may be more practical for broader emissions sources.** Overlapping instruments (e.g., feebates or in Türkiye's case feed-in tariffs for renewables) that reinforce some of the mitigation responses of pricing will be needed (see below). When combined with a carbon tax, these instruments reduce emissions without affecting the tax rate. In contrast, under a pure ETS with emissions fixed by the cap, overlapping instruments reduce the emissions price without affecting emissions. As discussed below, carbon taxes can also be extended to broader emissions sources (e.g., from extractives, forestry, and agriculture) building off existing business tax regimes in some cases, though sometimes proxy taxes of feebate variants may be needed.

26. **ETS may have their own appeal, however.** ETSs help achieve emissions targets with more certainty, are a more natural instrument where mitigation policy is under the purview of environment ministries, and free allowance allocation may help to garner industry support. See Table 1 for a summary comparison of carbon taxes and ETSs.

27. **Under a hybrid approach, an ETS could address emissions from the power and industry sector and the carbon tax emissions from the transportation and building sectors.** These hybrid approaches have been used elsewhere—for example, in the EU power and industry emissions are covered by the EU-wide ETS while several member states (e.g., Denmark, Finland, France, Ireland, Portugal, Sweden) have applied national carbon taxes to the transportation and building sectors. Cost effectiveness would require aligning carbon prices across the tax and ETS, for example by setting a trajectory of price floors under the ETS equal to the trajectory of carbon tax rate.

28. **There is increasing momentum for carbon pricing globally, though there are large cross-country differences in coverage rates and prices.** See Figure 10 and (for further details on schemes) Annex C, Table C1. To date, 21 carbon taxes and 6 ETSs have been implemented at the national level while the EU ETS prices emissions in all EU (and 3 other) countries. There are also many sub-national pricing schemes, the largest being California's ETS. Major pricing initiatives were recently launched in China and Germany, prices in the EU ETS are currently around the equivalent of US $70 per tonne, and Canada has committed to an equivalent US$140 price by 2030. GHG emissions subject to (national and sub-national) carbon pricing however, vary, from below 30 percent in some cases to over 70 percent in others (e.g., Canada, Germany, Korea, Sweden) while economywide average prices in 2021 varied from below $5 to $115 per tonne (Sweden)—some differentiation in carbon prices is however consistent with the principle of Common but Differentiated Responsibilities and Respective Capabilities. Only 21 percent of global GHGs are formally

subject to pricing however (16 and 5 percent through ETSs and taxes respectively) and the global average carbon price is just $5 per tonne. At the same time, governments are implementing and scaling up a variety of non-pricing instruments (e.g., vehicle emission rate standards, incentives for renewables and electric vehicles, net zero requirements for new buildings).[13]

Table 1. Summary Comparison of Carbon Taxes and ETSs

Design issue	Instrument	
	Carbon tax	**ETS**
Administration	Administration is more straightforward (e.g., as extension of fuel taxes)	New capacity needed to monitor emissions and trading markets
Uncertainty: price	Price certainty can promote clean technology innovation and adoption	Price volatility can be problematic; price floors, and cap adjustments can limit price volatility
Uncertainty: emissions	Emissions uncertain but tax rate can be periodically adjusted	Certainty over emissions levels
Revenue: efficiency	Revenue usually accrues to finance ministry for general purposes (e.g., cutting other taxes, general investment)	Free permit allocation may help with acceptability but lowers revenue; tendency for auctioned revenues to be earmarked
Revenue: distribution	Revenues can be recycled to make overall policy distribution neutral or progressive	Free allowance allocation or earmarking may limit opportunity for desirable distributional outcomes
Political economy	Can be politically challenging to implement new taxes; use of revenues and communications critical	Can be more politically acceptable than taxes, especially under free allocation
Competitiveness	Border carbon adjustment more robust than other measures (e.g., threshold exemptions, output-based rebates)	Free allowances effective at modest abatement level; border adjustments (especially export rebate) subject to greater legal uncertainty
Price level and emissions alignment	Need to be estimated and adjusted periodically to align with emissions goals	Alignment of prices with targets is automatic if emissions caps consistent with mitigation goals
Compatibility with other instruments	Compatible with overlapping instruments (emissions decrease more with more policies)	Overlapping instruments reduce emissions price without affecting emissions though caps can be set or adjusted accordingly
Pricing broader GHGs	Amenable to tax or proxy taxes building off business tax regimes; feebate variants are sometimes appropriate (e.g., forestry)	Less amenable to ETS; incorporating other sectors through offsets may increase emissions and is not cost effective

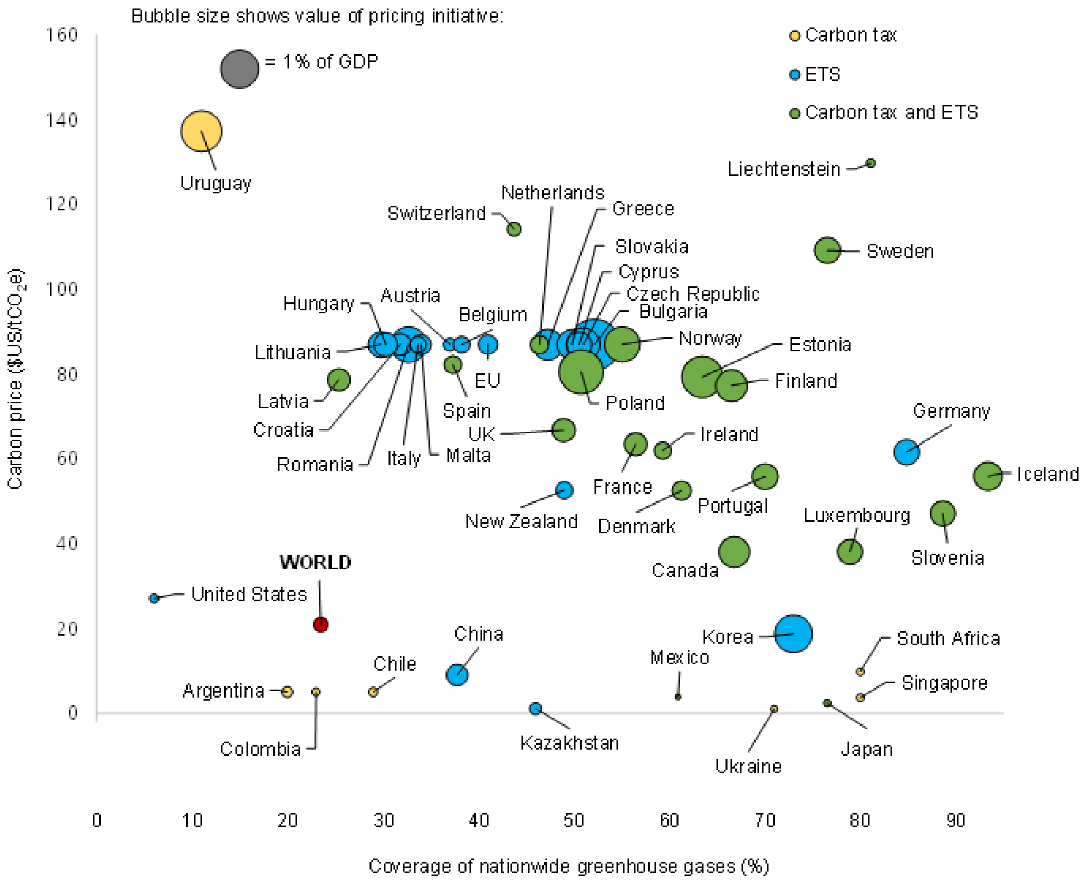
Source. IMF staff. Green indicates an advantage of the instrument; orange indicates neither an advantage or disadvantage; red indicates a disadvantage of the instrument.

29. **There is increasing momentum for carbon pricing globally, though there are large cross-country differences in coverage rates and prices.** See Figure 10 and (for further details on schemes) Annex C, Table C1. To date, 21 carbon taxes and 6 ETSs have been implemented at the national level while the EU ETS prices emissions in all EU (and 3 other) countries. There are also many sub-national pricing schemes, the largest being California's ETS. Major pricing initiatives were recently launched in China and Germany, prices in the EU ETS are currently around the equivalent of US $70 per tonne, and Canada has committed to an equivalent US$140 price by 2030. GHG emissions subject to (national and sub-national) carbon pricing however, vary, from below 30 percent in some cases to over 70 percent in others (e.g., Canada, Germany, Korea, Sweden) while economywide average prices in 2021 varied from below $5 to $115 per tonne (Sweden)—some differentiation in carbon prices is however consistent with the principle of Common but

[13] See Black and others (2022b) for a stocktaking of mitigation policies for Group of Twenty countries and their impact on future CO_2 emissions.

Differentiated Responsibilities and Respective Capabilities. Only 21 percent of global GHGs are formally subject to pricing however (16 and 5 percent through ETSs and taxes respectively) and the global average carbon price is just \$5 per tonne. At the same time, governments are implementing and scaling up a variety of non-pricing instruments (e.g., vehicle emission rate standards, incentives for renewables and electric vehicles, net zero requirements for new buildings).[14]

Figure 10. National or Regional Carbon Pricing Schemes, 2021



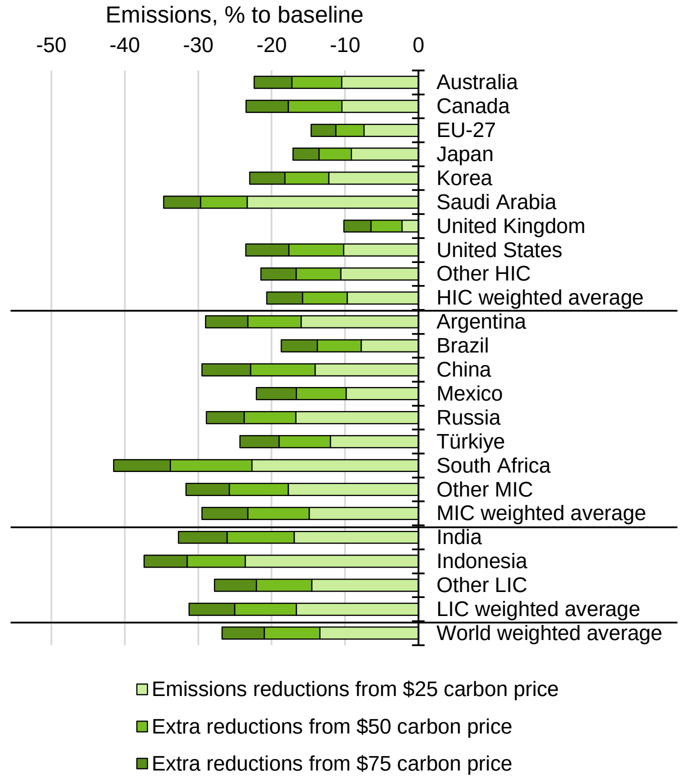
Sources: Parry and others (2022a).
Notes: EU ETS includes Norway, Iceland, and Liechtenstein. Prices are emissions weighted averages between schemes at national, sub-national and, if applicable, EU level. At present, China's system takes the form of a tradable emissions intensity standard with no fixed cap on emissions.

[14] See Black and others (2022b) for a stocktaking of mitigation policies for Group of Twenty countries and their impact on future CO_2 emissions.

4. Impacts of Carbon Pricing

30. **This section discusses the impacts of an illustrative carbon price rising to $75 per tonne in 2030. The calculations for this section were done in Climate Policy Assessment Tool (CPAT) – see Annex A.** The price (which could be either a carbon tax or ETS) starts at $35 per tonne in 2023 and rises progressively to $75 tonne in 2030, covering fossil fuel CO_2 emissions from the power, industry, transport, and building sectors. The price path is hypothetical (one of many possibilities) but is chosen for transparency and because it is just sufficient to achieve the recommended emissions target in 2030.[15]

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



Sources: IMF staff using CPAT.

A. Emissions and Energy System

31. **The responsiveness of emissions to pricing in Türkiye is broadly representative of that in other G20 countries.** Prices of $25, $50, and $75 per tonne in 2030 would cut Türkiye's fossil fuel CO_2 emissions by an estimated 15, 21, and 26 percent below BAU levels in 2030. Emissions price responsiveness in countries like China, India, and South Africa, is somewhat larger than in Türkiye due to the larger share of coal in CO_2 emissions (carbon pricing has a disproportionately large impact on increasing coal prices—see below) or lower BAU energy prices (which implies a large proportionate price increase from carbon pricing). See Figure 11.

32. **A $75 carbon price has a large impact on coal prices and intermediate impacts on prices for electricity, natural gas, and road fuels Türkiye.** Coal prices increase by a projected 120 percent above BAU levels in 2030, however coal is an intermediate input used by firms rather than directly consumed by

[15] For comparison, WBG (2022c) model a carbon price rising to either €20 or €100 per tonne by 2030 covering power, industry, wastewater, and air transport, combined with a phaseout of fossil fuel subsidies. This package achieves GHG emissions reductions of 27-36 percent below BAU levels in 2030.

households, and its consumption falls sharply due to switching to other fuels. Electricity, natural gas, and gasoline prices increase by 6, 34, and 18 percent above BAU levels in 2030. See Table 2.

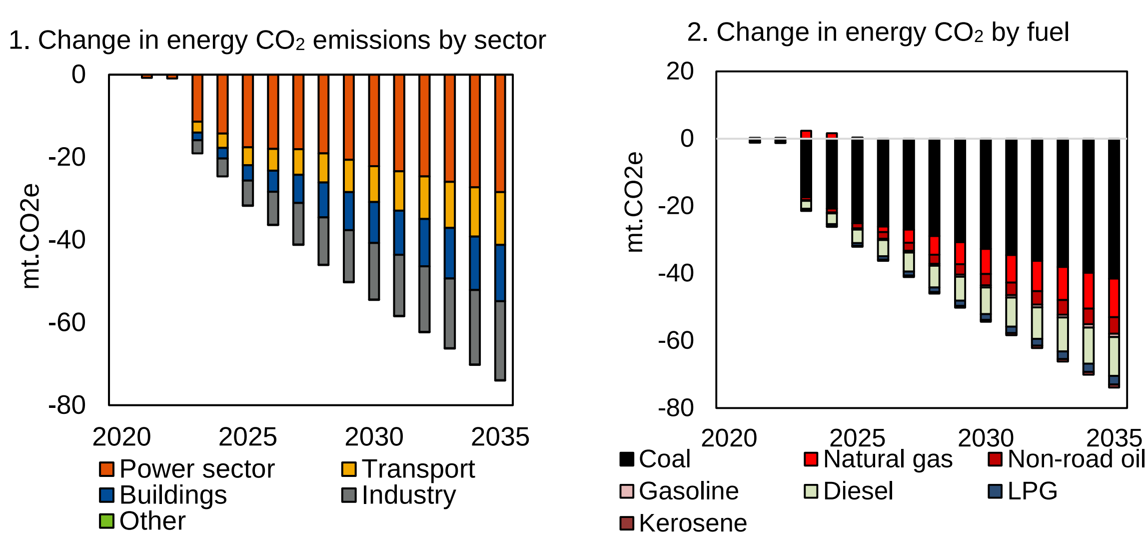
Table 2. Energy Price Increases from $75 Carbon Price, 2030

Fuel	Unit	Baseline price	Price with $75 carbon tax	% change	Share in energy-related CO_2 emissions in 2019
Gasoline	US$ per liter	1.19	1.40	17.5%	1.8%
Diesel	US$ per liter	1.09	1.33	21.8%	19.5%
LPG	US$ per liter	0.73	0.89	21.4%	3.6%
Kerosene	US$ per liter	0.82	1.04	27.0%	1.0%
Oil	US$ per barrel	57.39	92.60	61.3%	3.4%
Coal	US$ per gigajoule (GJ)	6.24	13.71	119.8%	46.1%
Natural gas	US$ per gigajoule (GJ)	14.58	19.58	34.3%	24.6%
Electricity	US$ per kwh	0.11	0.12	6.4%	0.0%

Source. IMF staff using CPAT.

33. **Under the $75 carbon price in Türkiye, 41 and 25 percent of the projected reduction in fossil fuel CO_2 emissions come from the power and industry sectors and 60 percent comes from the reduction in coal use. See Figure 12.** The contribution to emissions reductions from individual sectors depends on: (i) the sector's share in BAU emissions; and (ii) the responsiveness of emissions to pricing in that sector. In turn, the latter component depends on proportionate increases in fuel prices for that sector (as in Table 2) and fuel price responsiveness (which is broadly similar across fuels in CPAT).[16] Limiting the $75 carbon price to the power and industry sectors (as in a downstream ETS) would reduce economywide CO_2 emissions 17 percent, while limiting a carbon tax to coal only would reduce economywide emissions 12 percent (84 and 60 percent of the reductions under a comprehensive $75 carbon price respectively).

Figure 12. CO_2 Reductions under $75 Carbon Price by Sector and Fuel, 2030

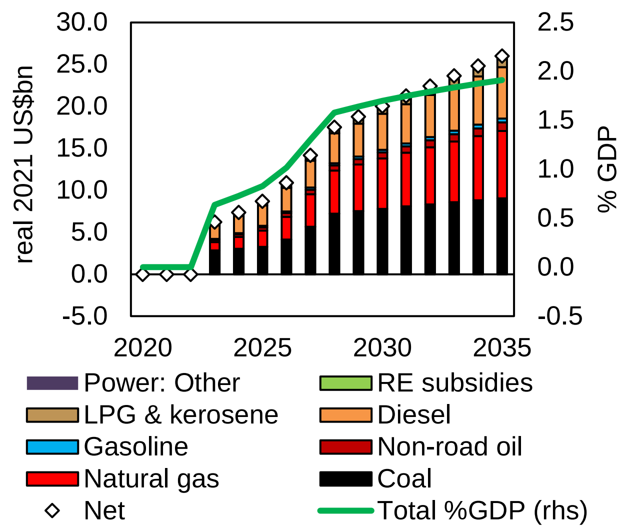


Source: IMF staff using CPAT.

[16] Fuel price elasticities in CPAT are typically around -0.5 to -0.8 based on other modelling and empirical literature.

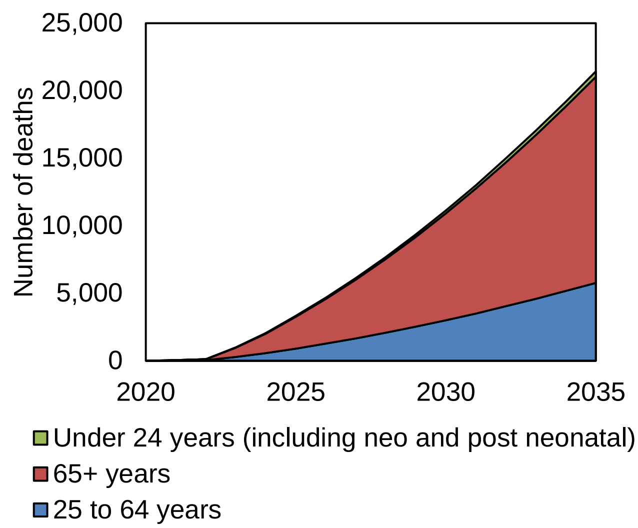
34. **A $75 carbon price could raise projected revenues of 1.7 percent of GDP ($20 billion) in 2030.** 39 percent of the additional revenues would come from charges on coal (despite its base being eroded due to fuel switching), 30 percent from natural gas, 31 percent from diesel and other oil products (see Figure 13). Carbon prices of $25 and $50 per tonne would raise revenues of 0.9 and 1.3 of GDP in 2030 respectively. Ultimately revenues from carbon pricing will need to be replaced by other sources, though this will not be an issue until the latter part of the clean energy transition.

Figure 13. Annual revenues from Phased $75 Carbon Price by Fuel Product, 2030



Source: Parry and others (2022a).
Notes: Calculations account for erosion of revenue from pre-existing fuel taxes.

Figure 14. Cumulative Averted Deaths from Reduced Air Pollution from Phased $75 Carbon Price



Source: IMF staff using CPAT.

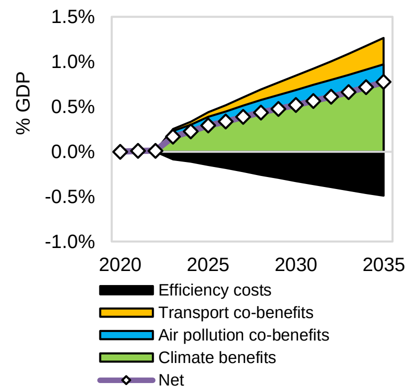
35. **Cumulated over 2021–30, a carbon price rising progressively to $75 per tonne by 2030 would save a projected 11,000 premature fatalities from local air pollution exposure.** See Figure 14. 71 percent of the avoided deaths are people over the age of 65 years (who are more likely to have pre-existing conditions) and 79 percent are in urban areas.

36. **Projected annualized mitigation costs from a $75 carbon price are relatively modest and are more than offset by domestic environmental co-benefits and swamped by global climate benefits.** Abatement costs reflect the annualized costs of adopting cleaner but more expensive technologies, net of any savings in lifetime energy costs and avoided investment in emissions-intensive technologies as well as the foregone benefits to households and firms from reduced energy use. These costs are 0.3 percent of GDP in 2030. Domestic environmental co-benefits however amount to 0.4 percent of GDP in 2030, implying a slight net economic gain (50 percent of the domestic environmental co-benefits reflect fewer local air pollution deaths and 50 percent reductions in other domestic environmental externalities including traffic congestion and accidents).

The global climate benefits, moreover—equivalent to 0.6 percent of GDP—would swamp these numbers. See Figure 15.

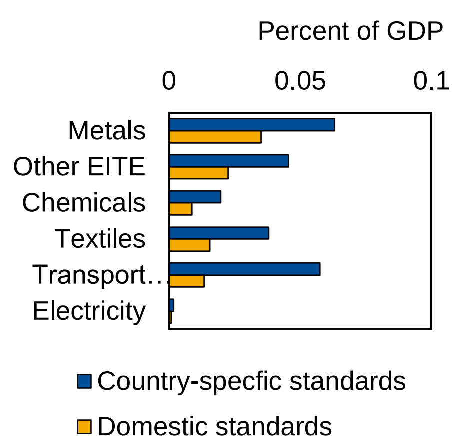
37. **Carbon pricing could avoid or reduce prospective payments under the planned EU carbon border adjustment mechanism (CBAM) which will apply to five energy-intensive, trade-exposed (EITE) industries.** The EU CBAM will phase in, from 2026 onwards, charges on the carbon content of steel, aluminum, cement, fertilizers, and electricity imported into the EU from trading partners.[17] The charge per tonne of CO_2 will likely be aligned with the EU ETS allowance price—currently equivalent to $70 per tonne—and country-specific estimates of carbon emissions for these industries, though another possibility is to use EU-wide emissions factors.[18] With the exception of electricity, payments under the EU BCA (in the absence of carbon pricing in Türkiye) would amount to a relatively modest 0.02-0.06 percent of GDP under country-specific factors and 0.1-0.03 under domestic emissions factors, given the small fraction of Türkiye's nationwide emissions embodied in traded products to the EU affected by the CBAM. See Figure 16. Payments from the electricity sector would be even lower. It should however be remembered that free allowance allocations for EU EITE industries will be phased out as the CBAM is introduced, which will partially ameliorate harmful competitiveness impacts for Turkish exporters.

Figure 15. Annual Abatement Costs and Domestic Environmental Co-Benefits from Phased $75 Carbon Price 2030



Source: IMF staff calculations.
Notes: Economic welfare costs are deadweight losses from the tax before revenue recycling. Global climate benefits are $185 per tonne CO_2 reduced from Rennert and others (2022).

Figure 16. Cost Increases for Turkish Exporters from the Prospective EU BCA, 2020



Source: IMF staff calculations.
Note: Country-specific standards use Türkiye's emissions intensities, whereas domestic standards use weighted average emissions intensities from EU countries, since the EU is the imposing party of the CBAM. Emission intensities are from 2015.

[17] https://ec.europa.eu/info/sites/default/files/carbon_border_adjustment_mechanism_0.pdf. See WBG (2022c) for further discussion of Türkiye's vulnerability to the EU CBAM—steel and aluminum in particular have high export values to the EU.
[18] Initially at least the CBAM will only charge for direct emissions from fuel combustion and not indirect emissions from electricity inputs.

5. Enhancing the Acceptability of Carbon Pricing

38. **Political acceptability of the carbon pricing is essential for successful reform.** Several factors, including regressivity of carbon taxation and its negative impact on competitiveness, lower the acceptability of carbon pricing in Türkiye (see Uyduranoglu and Ozturk, 2020)

39. **A comprehensive mitigation strategy could have carbon pricing as its centerpiece and a variety of other supporting measures to enhance effectiveness and acceptability.** Additional elements of a comprehensive strategy might include:

- robust assistance for vulnerable households, workers, and regions;
- recycling carbon pricing revenues to boost the economy while ensuring the overall reform package meets equity objectives;
- measures to address industrial competitiveness;
- feebates or regulations at the sectoral level to reinforce mitigation incentives;
- pricing of other emissions sources beyond energy-related emissions;
- public investment in clean energy infrastructure networks.

This and the next section take up the first five issues. The final issue is project specific and requires sound public investment management procedures.

A. Addressing Burdens on Households

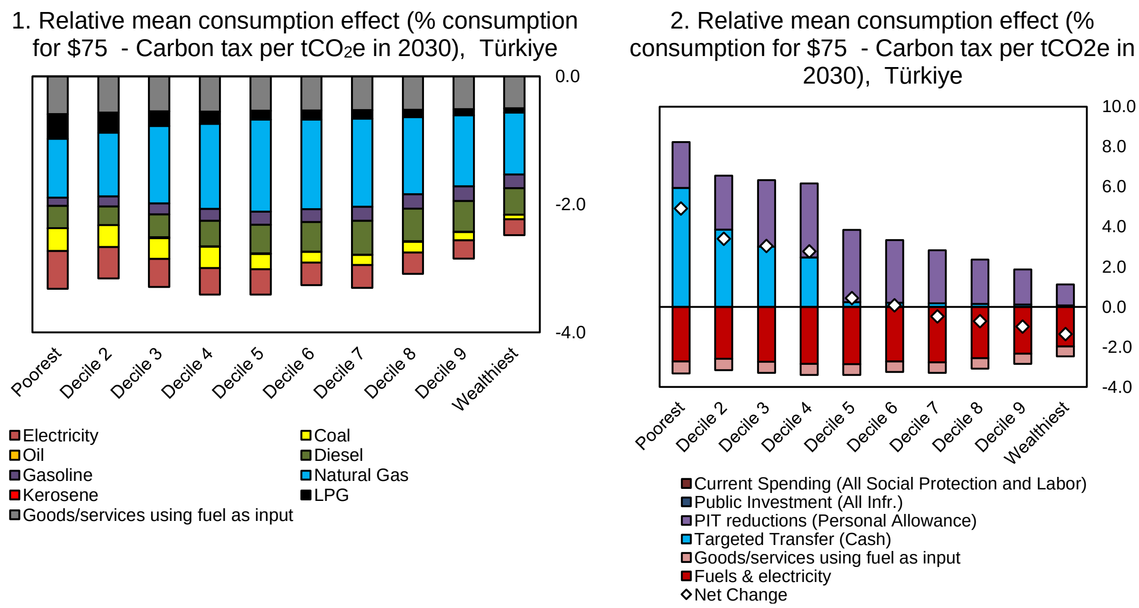
40. **A standard two-step approach is used here to assess the burdens on households from domestic carbon pricing in Türkiye.** First, an input-output table is used to calculate the effects on different categories of consumer goods (the table is adjusted for future trends in energy efficiency which reduce energy requirements per unit of output). Second, these price increases are mapped to data on budget shares for different goods by different household income groups using a household expenditure survey (budget shares are adjusted for behavioral responses to pricing at household and firm level).[19] Assessing the distributional burdens on households from carbon pricing, and measures that might counteract these burdens, is important to design reforms that meet distributional concerns—not least because voters and particular groups may oppose carbon pricing because of the burden of higher energy prices on households and if the burden is disproportionately borne by the poor.

41. **Prior to recycling, a $75 carbon price in 2030 imposes a projected average burden of 3 percent of consumption …** For the average household, the direct effect of higher prices for electricity, natural gas, and transport fuels accounts for about a third of the burden and the indirect effect (as higher prices for fuels and electricity used by firms is passed forward into higher prices for general consumer products) about two-thirds. See Figure 17.

[19] Input-output tables used are those from Global Trade Analysis Project and the household survey is from 2018.

42. **…after recycling the average household is better off by 0.4 percent and with revenues used for targeted transfers and labor tax reductions the overall policy is pro-poor and pro-equity.** Figure 16 illustrates a case where 25 percent of the revenues are used for a targeted, unconditional cash transfer aimed at the bottom four consumption deciles and 75 percent for raising the basic income tax threshold.[20] On net, the bottom four deciles are better off from the reform with net benefits amounting to about 3-5 percent of consumption. The next three deciles are approximately no better or worse off, while wealthier households are worse off on net but by a modest 1.4 percent of consumption.

Figure 17. Burden on Households from $75 per tonne Carbon Price before and after Revenue Recycling, 2030



Source: IMF staff calculations using CPAT.
Note: Panels show relative to consumption impact of the carbon price on consumption deciles before (left) and after (right) revenue recycling. Revenue recycling assumes 25 percent of carbon pricing revenues are used for a targeted transfers (assumed targeting bottom 4 deciles with a 90 percent coverage and 10 percent leakage rate) and 75 percent for reducing labor taxes by raising lower income thresholds.

43. **There are however sharp trade-offs between equity and efficiency objectives in how revenues are used.** If revenues are used to cut labor taxes this boosts the economy by strengthening incentives for labor force participation and work effort and discouraging black market (informal economy)[21] and tax-sheltering activity—in contrast, using revenues for lumpsum transfers forgoes these beneficial effects.[22]

[20] The scenario assumes a coverage rate (i.e., proportion of targeted that receive the transfer) of 90 percent and leakage rate (i.e., proportion of non-targeted wealthier households that erroneously receive the transfer) of 10 percent.

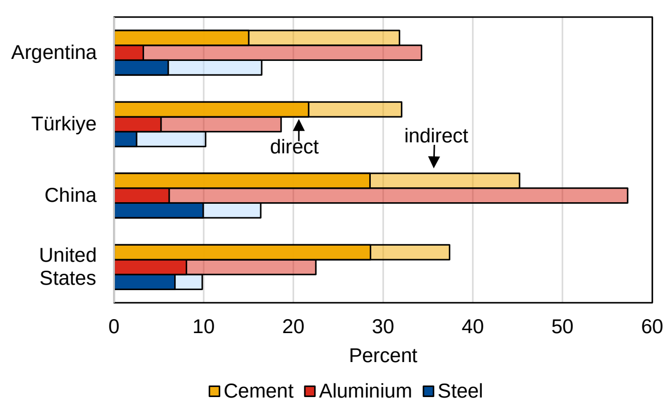
[21] See Timilsina et al (2021) for details on the impact of carbon taxation on informality.

[22] See IMF (2019) for further discussion.

B. Addressing Burdens on Firms

44. **Domestic carbon pricing increases firms' production costs and a particular concern is EITE industries. Production cost increases have three components.** First, industrial firms will incur a direct charge, or allowance purchase requirement, for emissions they continue to emit directly. Second, they incur an indirect charge for carbon charges on emissions embodied in their inputs, especially electricity. Third, firms will incur abatement costs to the extent they cut emissions or electricity use, for example, by switching to cleaner (but costlier) technologies and fuels. At more modest abatement levels, the direct and indirect charges would be expected to be much higher than the abatement costs, though this is less likely at deeper levels of decarbonization.[23]

Figure 18. Production Cost Increases for Selected EITE Industries and Countries from $75 Carbon Price in 2030



Source: Black and others (2022c)
Notes: Excludes abatement cost (which is relatively modest at modest abatement levels).

45. **Proportionate cost increases under carbon pricing for EITE industries in Türkiye would be similar to those for high-income trading partners and less than that in large emerging market trading partners.** See Figure 18. For example, a $75 carbon price would increase production costs for steel and aluminum by 10 and 20 percent in Türkiye respectively accounting for direct and indirect charges whereas production cost increases in China would be more than twice as large.

46. **CBAMs are one possible instrument for maintaining competitiveness as jurisdictions moving forward with carbon pricing, but their design should be kept simple.** A CBAM is a charge on embodied carbon in products imported into a jurisdiction with carbon pricing, potentially matched by rebates for embodied carbon in exports.[24] Limiting the CBAM to EITE industries would focus it on the sectors most vulnerable to carbon pricing and competition from foreign producers. It would also contain administrative costs by limiting the range of products that need to be charged; measurement complexities (embodied carbon is more readily measured for EITE industries than other sectors); and may limit risks of legal challenge under World Trade Organization (WTO) rules as, with targeted coverage, the CBAM is more credibly defended as an environmental (rather than protectionist) measure. Rebates for exporters should be based on industry (rather than firm level) emission rates to avoid undermining mitigation incentives for these firms. Ideally embodied carbon for imports would be based on country-specific emission rates, but there might be a pragmatic case for

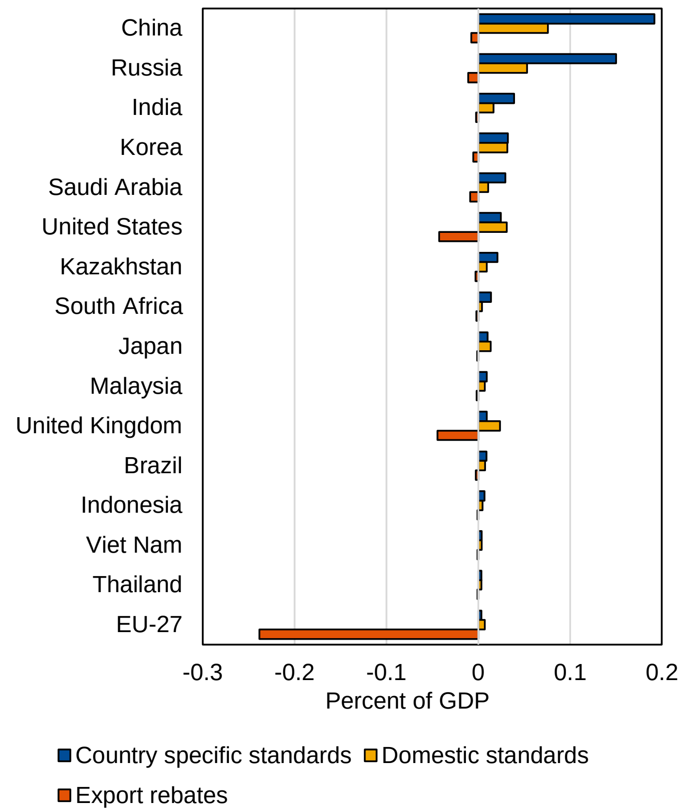
[23] See Keen and others (2021) for further discussion.

[24] For countries with ETSs (rather than carbon taxes) BCAMs can take the form of an allowance purchase requirement for foreign exporters, with rebates for allowance purchases from domestic exporters.

initially basing it on domestic industry emissions rates to avoid undue burdens on developing country trading partners that may have significantly higher emissions intensity of production. CBAMs should also be adjusted

47. where emissions in the trading partner are subject to pricing.[25] Current uncertainties over the legalities of CBAMs should be resolved in part as the EU and other countries move ahead with them, and their experience should provide lessons for others subsequently adopting CBAMs.

Figure 19. Burdens on Trading Partners from $75 per tonne CBAM in Türkiye, 2020



Source: IMF staff calculations.

48. **A $75 CBAM for EITE industries in Türkiye would have most impact on the US, China, and EU. See Figure 19.** In the US case, revenues forgone on rebates to Turkish exporters would more than offset revenues from carbon charges on US imports to Türkiye. With domestic industry benchmarks more revenue would be collected from US and EU exporters (compared with country-specific benchmarks) and vice versa for China (embodied carbon in EITE industries in Türkiye is higher than for EU and US industries and lower than for Chinese industries). For example, basic metals in Türkiye, the United States and China have emissions intensities of 571, 256 and around 1000 tonnes of CO_2 per $1 million of output, respectively (OECD, 2020). The effective incidence of the import charge on trading partners is likely to be much lower than the formal amount of revenues collected from them however because much of the import charge would likely be passed forward to domestic consumers in Türkiye in the form of higher product prices.

[25] See Cosbey and others (2019) and Keen and others (2021).

Table 3. Comparing Instruments to Address Competitiveness

Metric	CBAMs	Exemptions for EITE Industry Emissions From Pricing	Tradable Emission Rate Sandard/Output-based Rebate for EITE Industries	Free Allowances Under ETS
Protecting Competitiveness of EITE Industries	Yes (compensates for abatement costs)	Full exemption is less effective (if it does not apply to indirect emissions)	Partial (does not compensate for abatement costs)	Partial (does not compensate for abatement costs)
Limiting Leakage	Yes	Full exemption is less effective (if it does not apply to indirect emissions)	Partially	Partially
Mitigation Incentives for Domestic EITE Industries	Promotes all incentives	Removes mitigation incentives for direct emissions	Reduces emissions per unit of production but not production levels	Promotes all incentives
Revenue Implications	Preserves carbon pricing revenue	Forgoes revenue	Forgoes revenue	Forgoes revenue
Administrative Burden	Significant if coverage beyond EITE products	Modest	Modest	Modest
Risk of Legal Challenge Under WTO	Depends on design features	N/A	N/A	Could be challenged as subsidy but has not been

Source: IMF staff.

49. **Other measures for addressing competitiveness are simpler administratively and are less vulnerable to legal challenge though, to varying degrees, are less a less robust instrument, reduce mitigation incentives for domestic EITE industries, and lose revenue.** Other measures include exemptions from pricing for EITE industries, using a tradable emission rate standard (or feebate) for industry instead of pricing—or equivalently, rebating revenues from carbon pricing in output-based subsidies—and free allowance allocations under an ETS. These instruments have been commonly used in pricing strategies to date (e.g., Canada, EU, South Africa). These approaches, however, do not compensate firms for abatement costs and become less robust at addressing competitiveness for deeper levels of decarbonization. In some cases, they also limit mitigation incentives for EITE industries—this is especially the case for exemptions, but tradable emission rate standards (or equivalent measures) also forgo opportunities for reducing emissions through lower production levels. All three approaches forgo the potential revenue from charges on EITE emissions. See Table 3.[26]

[26] From the perspective of addressing competitiveness while scaling up global mitigation action, however, the most effective approach would be a (pragmatically and equitably designed) international price coordination mechanism (see e.g., Parry and others 2021).

6. Reinforcing Sectoral Policies

50. **Carbon pricing needs to be reinforced by other, less efficient but likely more acceptable, measures at the sectoral level. Reinforcing measures are less efficient as they do not promote the full range of behavioral responses that are promoted by pricing instruments.**[27] For example, higher fuel taxes encourage a shift to more fuel efficient (or cleaner vehicles) and less driving, while fuel economy or emission per mile regulations only promote the former response. A motivation for sectoral measures however is that they may avoid political difficulties associated with significant increases in energy prices and the resulting burdens on households and firms which can be a key obstacle holding up carbon pricing.[28]

51. **The discussion here focusses on (revenue-neutral) feebates, which are the fiscal analogue of tradable emission rate regulations but have less familiarity with policymakers.** Feebates provide a sliding scale of fees on products or activities with above average emission rates and a sliding scale of rebates for products or activities with below average emission rates. Feebates, which could be applied by the finance ministry, can be more flexible and cost effective than emission rate regulations—the latter generally require extensive and fluid credit trading provisions across firms and time to be cost effective whereas feebates, by design, automatically promote efficiency without the need for trading. Feebates can be implemented quickly with minimal administrative cost, at least in sectors (e.g., transportation) where they would build off existing tax collection capacity. The discussion below considers in turn instruments for power, industry, transportation, buildings, extractives, agriculture, forestry, and waste—fuel tax reform is also briefly mentioned.

A. Power Generation

52. **There are strong economic reasons for expanding renewable generation capacity to meet rising demand for electricity in Türkiye. Electricity demand is expected to grow at about 3-4 percent annually.**[29] In 2019, coal and gas accounted for 33 and 17 percent of generation respectively, and hydro, wind, solar, and geothermal 26, 6, 3, and 3 respectively. Decentralized renewables accounted for 12 percent of electricity generation. An accelerated expansion of renewables should, however, be considered:

- The levelized costs of renewables have fallen substantially; [30] and

[27] For additional comparison of carbon pricing vs. non-pricing instruments across alternative set of indicators please see Borenstein and Kellogg (2022): while pricing emissions gives strong incentives to first eliminate generation with the highest social cost, a clean energy standard incentivizes earliest phaseout of the generation with the highest private cost.

[28] For example, France's planned increase in its carbon tax was suspended in 2018 at €45 per tonne due to a public backlash against pricing.

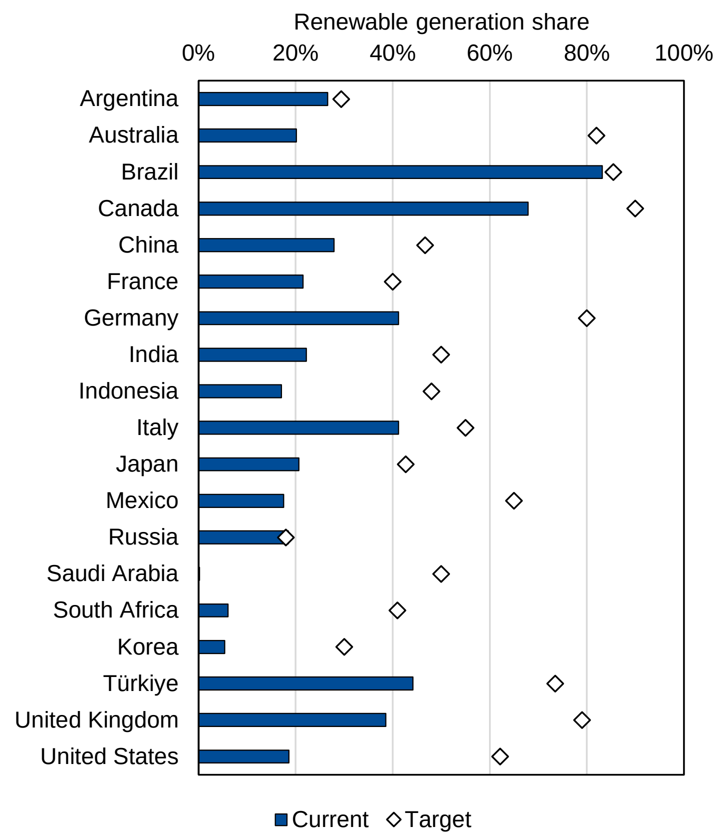
[29] See Erdin and Ozkaya (2019) and Turkish Electric Energy Demand Projection Report.

[30] Between 2010 and 2021 the global weighted average levelized costs of utility scale solar PV declined by 88 percent and onshore wind, concentrating solar, and offshore wind by 60-68 percent—see https://irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021.

- Reducing coal generation is critical for addressing CO_2, local air pollution emissions (see below), and water stress.[31]

53. **Türkiye has set a numeric target equivalent to a renewable generation share of 73 percent[32] in 2030.** The target is on the high side relative to renewable generation targets in most other G20 countries. As of 2021, actual renewable energy shares in generation in G20 countries varied between 2 percent (Saudi Arabia) and 83 percent (Brazil) and averaged 27 percent. See Figure 20.

Figure 20. Renewable Generation Shares and 2030 Targets, G20 countries



Note: IMF staff using CPAT.

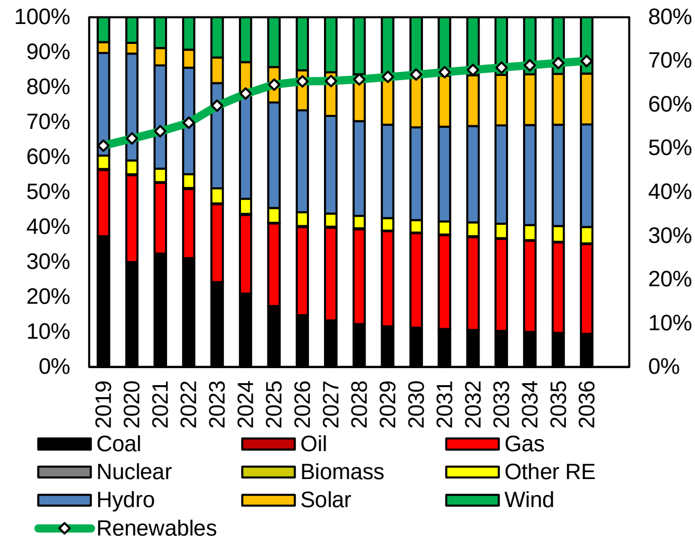
54. **Türkiye promotes renewables through a feed-in-tariff (FIT), net metering, and tendering.** The FIT was introduced in 2007 and extended in 2021. Net metering allows households to sell excess power they generate from solar panels to the grid. A tendering process to procure the production of renewable energy in suitable areas, allowing market participants to compete on a price basis (rather than the government setting the price) was introduced in 2016—prices of recent auctions show renewables are highly competitive relative to fossil fuels and nuclear.[33] Unlike carbon pricing, these policies provide the same reward for shifting from coal to renewables as for shifting from gas to renewables, even though the former results in a larger emissions reduction. In addition, these policies do not involve the pass through of charges on remaining emissions (such as from a carbon tax) into electricity prices, and therefore have a weaker impact on reducing electricity use in industry and buildings.

[31] Coal generation uses significant amounts of water for cooling and scrubbing air pollutants. Of particular concern is a planned 5 GW lignite power plant in Konya Karapinar (which would be one of the largest coal plants in the world) where sinking water levels in the region would damage agriculture and threaten household access to fresh water.

[32] Black and others (2022b)

[33] https://climateactiontracker.org/countries/Türkiye/policies-action.

Figure 21. Projected Electricity Generation Shares in Türkiye under Carbon Price Rising to $75 in 2030



Source: IMF staff calculations.

55. **Under a progressively rising carbon price to $75 per tonne, the projected renewable generation share rises to 67 in 2030.** This is in range of other literature estimates for 2030 – see Kilickaplan et al (2017). The coal and gas generation shares would fall to 10 and 23 respectively. See Figure 21. This can create a potential stranded assets issue.

56. **If carbon pricing is constrained because of opposition to higher electricity prices, the authorities might consider a feebate.** A feebate would promote all the behavioral responses for reducing the emissions intensity of power generation (e.g., shifting from coal to gas and from these fuels to renewables and nuclear, improving production efficiency) that are promoted under carbon pricing—and cost effectively, as the carbon price provides the same reward for reducing an extra tonne of CO_2 across each response. Feebates may have greater acceptability than carbon pricing in the power sector in the sense that they have a much weaker impact on electricity prices. Under carbon pricing, a generator pays a charge on all its emissions and these payments are passed forward in higher electricity prices—in contrast, under a feebate on average a generator is not charged for their emissions.

57. **Under a feebate, a generator is subject to a fee depending on the average emissions associated with their generation given by:**

CO_2 price × [CO_2/kWh – pivot point CO_2/kWh] × electricity generation

The generator has incentives to exploit any behavioral response that lowers their emission rates—this reduces fees implied by plants with emission rates above the pivot point and increases rebates implied for plants with emission rates below the pivot point. Feebates can be (approximately) revenue neutral if the pivot point reflects recent industry average emission rates. Capacity requirements for a feebate include monitoring of CO_2 emission rates for power generators and applying the system of fees/rebates.

58. **For illustration, at current emission rates a feebate with price US$75 per tonne would apply fees equivalent to 2.8 cents per kWh for coal while providing subsidies of 6 and 2 cents per kWh for renewables and natural gas generation respectively (Figure 22).** Fees would increase, and subsidies for renewables decline, as the pivot point emission rate is updated over time (i.e., the red curve in Figure 20 shifts to the left).

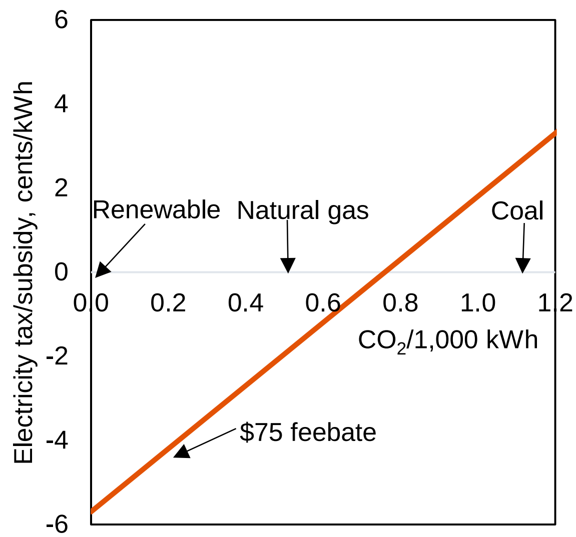
B. Industry

59. **EITE industries account for most industrial CO_2 emissions in Türkiye but (as in many other G20 countries) there is little in the way of concrete policies for the industrial sector.** Türkiye has a target of reducing the energy intensity of each industry at least 10 percent between 2011 and 2023.

60. **Feebates can reinforce incentives for cleaner production processes in EITE industries without a new tax burden on the average firm.** In this case, firms within an industry would be subject to a fee given by:

[CO_2 price] × [CO_2/output — industry-wide average CO_2/output] × [firm output]

Figure 22. Illustrative Feebate for Power Sector



Source: IMF staff calculations.

The feebate, which would apply to emissions from fuel combustion and process emissions, avoids a first-order tax burden on the average producer as they pay no charge on their remaining emissions. This helps to alleviate concerns about competitiveness compared with a pricing scheme that charge firms for their remaining emissions. If Türkiye moves ahead with an ETS, feebates could build off procedures for monitoring industrial firm emissions. Box 1 provides illustrative comparisons of the impacts of carbon pricing and feebates on production costs in the steel and cement industries.

Box 1. Illustrative Impacts of Carbon Pricing and Feebates on Production Costs for Steel and Cement

Steel. Traditionally steel is produced using an integrated process involving heating coal to form coke, feeding coke and iron ore into a blast furnace, and using an oxygen furnace to purify the molten metal—the process produces about two tonnes of CO_2 per tonne of steel.[1] Alternatives include an electrified process using scrap metal, and emerging technologies—for example, applying carbon capture, utilization, and storage (CCUS), or feeding an electric furnace with iron made by direct reduction (e.g., using natural gas). These alternatives produce CO_2 emissions of about 0.3–0.4 tonnes per tonne of steel.

A carbon price of $75 per tonne of CO_2 would increase the cost of integrated production by about $150 per tonne of steel through the first-order transfer payment, about 30 percent of recent steel prices.[2] And it would increase the cost under alternative technologies by about $30 per tonne of steel.[3] In contrast, under a feebate the cost for integrated production (given an assumed industry pivot point of 1 tonne of CO_2 per tonne of steel) would increase $75 per tonne of output, while alternative technologies would receive a subsidy of about $45 per tonne of output.

Cement. Most cement is produced using traditional kilns to decompose calcium carbonate into clinker and CO_2, and then using mills to mix clinker with other minerals, like limestone, and grinding it—the process produces about 1 tonne of CO_2 per one tonne of cement, with process emissions contributing about 70 percent of these emissions. Alternatives include state-of-the-art plants in terms of energy efficiency and CCUS—either post-combustion (where CO_2 is extracted from exhaust gases) or oxy-combustion (where fuel is burned with a mixture of pure oxygen and exhaust gases). State-of-the-art plants largely eliminate non-process emissions. Post- and oxy-combustion reduce emissions about 55 and 85 percent respectively, while increasing capital costs by about 25 and 100 percent respectively.

A carbon price of $75 per tonne of CO_2 would increase the cost of traditional production about $75 per tonne of cement, or about 60 percent, while increasing the price of more efficient and CCUS-fitted plants by $45, and $12–35 per tonne of output respectively through the first-order transfer payment. In contrast, a feebate with price $75 per tonne of CO_2 would only increase the cost of traditional production by $7 per tonne of cement, while providing a subsidy to more efficient and CCUS-fitted plants of $15 and $27–47 per tonne of output.

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[1] Unless otherwise noted, all data in this box is taken from van Ruijven and others (2016).

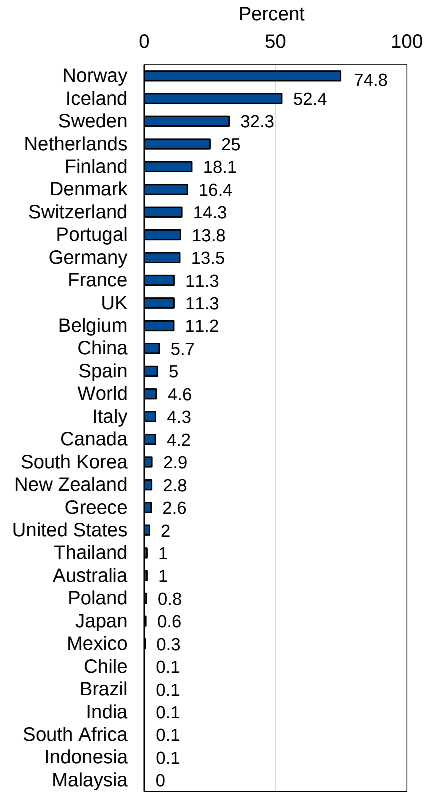
[2] See www.focus-economics.com/commodities/base-metals.

[3] Technology switching is more likely to take the reform of retrofitting existing plants, rather than scrapping plants and building new ones, given that existing steel factories can potentially produce for several decades. Incentives will vary across plants, for example with local fuel and electricity prices.

C. Transportation

61. **Unlike most other G20 countries, Türkiye does not have emissions rate targets for new vehicles, though it does have targets for EV penetration.** 13 G20 countries have future targets for either the grams of CO_2 per km or the fuel economy of their new, light-duty vehicle fleets and all but three G20 countries have plans to expand sales of EVs or scale back sales of internal combustion engine (ICE) vehicles.[34] Türkiye aims to have 1 million EVs on the road by 2030. EVs were less than 1 percent of new vehicle sales in 2020 however—this share was 10-25 percent in some European countries, and 52 and 75 percent in Iceland and Norway respectively, and about 5 percent globally.[35]

Figure 23. EV Sales Shares 2020, Selected Countries



Source: IEA (2021b)

62. **Türkiye provides tax incentives for EVs, and registration fees vary with engine size.** EVs are taxed at a more advantageous rate than conventional vehicles. Passenger cars with conventional engines are subject to SCT at rates ranging from 45 to 220 percent, according to the engine capacity and SCT base (tax-free value of the vehicle). SCT is collected from vehicles with only electric motors at rates ranging from 10 to 60 percent, according to electric motor power and tax brackets. Hybrid vehicles with an engine volume between 1,600 and 2,500 cm^3 are taxed at a more advantageous rate than conventional vehicles in the same category. However, beyond smaller engine size, there are many other ways to reduce the CO_2 emission rates of vehicles (e.g., through lighter materials, smaller cabin size), and the incentives may further favor diesel vehicles. Annual ownership taxes are lower for older cars providing incentives to delay their retirement.[36] Türkiye has no policies to promote low emission heavy-duty vehicles.

63. **Carbon pricing or higher fuel taxes have only a relatively modest impact on retail fuel prices, and they are unpopular with the public, therefore additional instruments are needed to decarbonize road transportation.** Integrating a feebate into the vehicle registration tax system would strengthen incentives for progressively and cost-effectively decarbonizing the vehicle fleet, while avoiding a fiscal cost to the

[34] See Black and others (2022b), Table A5.
[35] BNEF (2021).
[36] Vehicles that are 16 years or older account for a third of the on-road car fleet in Türkiye (WBG 2022b).

government. A feebate would provide a sliding scale of fees on vehicles with above average emission rates and a sliding scale of rebates for vehicles with below average emission rates. That is, each new vehicle would be subject to a fee given by:

CO_2 price × [CO_2/km ─ CO_2/km of the new vehicle fleet] × [average lifetime vehicle km]

The feebate:

- Promotes the full range of behavioral responses for reducing emission rates, as there is always a continuous reward (lower taxes or higher subsidies) from switching from any vehicle with a higher emission rate to one with a lower emission rate;
- Is cost effective, as the reward is always proportional to the reduction in the emission rate; and
- Maintains (approximate) revenue neutrality—by definition, fees offset rebates as the average emission rate in the formula is updated over time.

64. **For illustration, a feebate with a price of $600 per tonne of CO_2 would provide a subsidy of $7,000 for zero emission vehicles and apply a tax of $5,000 to a vehicle with 200 grams CO_2/km (see Figure 24).** Some European countries impose higher taxes on emissions-intensive vehicles. Subsidies for zero emission vehicles would decline over time as the average fleet emission rate declines, which is appropriate as the cost differential between these vehicles and their gasoline/diesel counterparts falls over time (e.g., with improvements in EV battery technology).

D. Buildings

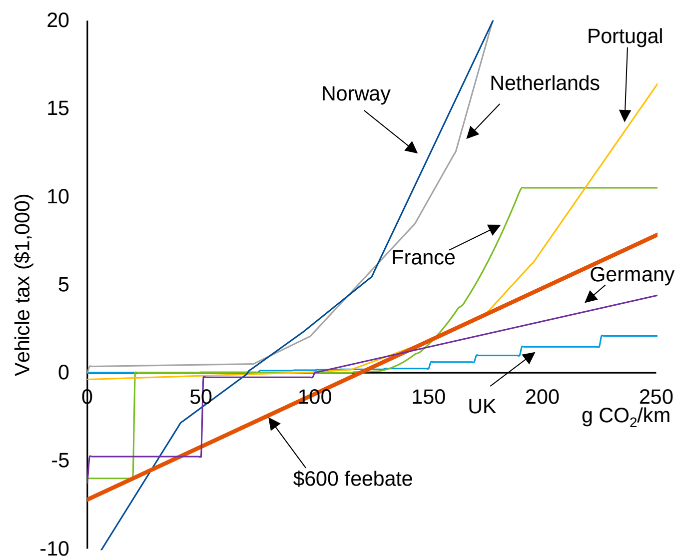
65. **Türkiye committed to the newly launched initiative on Zero Carbon Buildings for All, with a target to develop and implement policies to drive the decarbonization of all new buildings by 2030 and all existing buildings by 2050. Opportunities for reducing fuel and electricity use in buildings include:**

- R etrofitting of existing buildings (e.g., insulation upgrades);
- Installing solar panels;
- Switching to cleaner and more efficient heating equipment, including electric heating;
- Deploying energy-efficient lighting and appliances;
- Digitalization to “smart” homes (such as optimal automatic adjustment of heating temperatures).
- Although there are some short-term initiatives to improve building efficiency,[37] Türkiye does not have a long-term energy retrofitting strategy for existing buildings.

[37] For example, a 15 percent reduction in energy use form public buildings by 2023, transforming one quarter of the 2010 building stock to sustainable buildings by 2023. Political documents include Energy Efficiency Law (2007), By-law on Energy Performance in Buildings (2008) By-law on Green Certificate for Buildings and Settlements (2022), By-law on Environmentally Responsible Design of Energy-Related Products (2022), and Presidential Circular No. 2019/18 on Energy Savings in Public Buildings (2019)

66. **Building renovation rates may be hindered by possible market failures which would warrant some policy intervention, even when emissions are aggressively priced.**[38] For example, landlords may lack incentives to make energy-saving investments if the savings accrue to their tenants and they are unable to charge a rent premium for more energy efficient housing, while renters themselves may lack investment incentives, especially when their tenancy is short term and they reside in apartments. Some households may lack the upfront funds required for major energy-saving investments. And households may be uncertain about the savings in energy consumption from investments, which can be compounded by uncertainty over future energy prices and the quality of contractors for large renovations.

Figure 24. CO_2-Based Components of Vehicle Taxes, Selected Countries



Sources: ACEA (2018), IMF staff calculations.
Notes: Feebate assumes a fleet average emission rate of 120 grams CO_2/km. Circulation taxes for Germany are expressed on a lifetime basis assuming a 13-year life and 7 percent discount rate.

67. **Various feebate schemes could complement efforts to promote energy efficient appliances and buildings.** For example, sales of refrigerators, air conditioners, and other energy-consuming products could incur a fee given by:

$$CO_2 \text{ price} \times CO_2 \text{ per unit of energy}$$

$$\times \text{ [energy consumption per unit} - \text{industry-wide energy consumption per unit]}$$

$$\times \text{ number of units}$$

For refrigerators, for example, the energy consumption rate would be kWh per cubic foot cooled (and the number of units would be cubic feet). A similar scheme applying taxes to oil and gas-based heating systems (for existing buildings), and a subsidy for electric heat pumps, could accelerate the transition to zero-carbon heating systems for existing buildings. Feebate systems linked to the energy performance of buildings could also be integrated into property taxes to encourage energy saving renovations.[39]

[38] See for example Arregui and others (2020).

[39] Arregui and others (2020) discuss a variety of other complementary measures for the building sector.

E. Extractives

68. **Two-thirds of methane emissions from extractive industries in Türkiye are from coal mines and one third from gas/oil operations.**[40] These emissions are not presently monitored on a continuous basis, though technologies (e.g., satellites) are evolving. Possibilities for mitigating methane emissions include capturing methane at the mine mouth or wellhead and using it for on-site or regional power generation, compressing or liquifying the gas for sale, flaring methane (which releases CO_2 emissions which are a less potent GHG than methane), and improving maintenance of infrastructure for gas processing and distribution.

69. **Taxing methane emissions would promote the full range of behavioral responses for reducing the emissions intensity of extraction.** Emissions are released within Türkiye's borders, and therefore should be priced regardless of whether the fuel is sold on domestic or world markets. For illustration, an emissions tax of $70 per tonne CO_2 equivalent on fugitive emissions would apply charges equivalent (prior to mitigation) of approximately $1.5 per barrel of oil and $0.25 per thousand cubic feet of natural gas under default emission rates.[41] Pricing approaches are more flexible and cost-effective than regulatory approaches imposing the same standard on all firms, regardless of their mitigation opportunities.

70. **Methane taxes should be administratively feasible and could be based on production levels and emissions rates. Taxes could be integrated into existing fiscal regimes for extractives.** Taxes might take one of two forms. Firms might be required to develop their own capacity for metering emissions and remitting taxes based on their reported emissions—facilities would be subject to random or periodic government inspections with potential penalties for being out of compliance with reporting requirements. Norway's methane tax provides a good prototype for this approach. Alternatively, firms might be subject to proxy emissions taxes based on observable outputs (or inputs) and default emissions factors, with rebates for firms demonstrating, through their own metering, their emission rates are lower than the default. Default emissions factors might be based on zero mitigation scenarios or worst performing firms to ensure all firms are rewarded for cutting their emissions below the default rate. [42]

F. Agriculture

71. **Methane emissions from livestock operations accounted for about half percent of Türkiye's agricultural GHGs in 2020 and nitrous oxide emissions from soils (e.g., due to synthetic fertilizers) another 45 percent.**[43] At present, Türkiye does not current have concrete targets or policies for reducing agricultural GHG emissions.

72. **Agricultural GHGs could, however, be reduced through several channels.** Reducing livestock herds (particularly beef and dairy cattle), increasing livestock productivity (e.g., through breed switching), and shifting to alternative feed (e.g., with seaweed additive) can reduce methane releases from enteric fermentation and methane/nitrous oxide emissions from manure, while reducing crops for human and animal consumption, and reducing chemical fertilizers, reduces nitrous oxide emissions from soils.

[40] From UNFCCC (2022).
[41] Calculations using data from UNFCCC (2022) and IEA (2022).
[42] See Parry and others (2022b) for further discussion of methane fees for extractives.
[43] UNFCCC (2022).

73. **Pricing of agricultural GHGs could be based on proxy estimates of emissions, but a compensation scheme for the farm sector may be needed to enhance acceptability and limit carbon leakage.** Direct monitoring of farm level emissions is currently not practical, but emissions can be inferred indirectly using farm-level data (on livestock herds, feed, crop production, fertilizer use, and acreage) and default emissions factors.[44] Proxy emissions taxes would likely face strong political opposition and could cause significant emissions leakage as the tax burden can reduce the international competitiveness of Turkish farmers. A feebate approach is worth studying based, for example, on GHG equivalent emission rates per hectare or nutritional value.[45] Another approach would be to combine an emissions fee with the revenues recycled to the agricultural sector in the form of a rebate proportional to the value of farm output. This scheme would cost-effectively promote all behavioral responses for reducing the emissions intensity of farming and, from an administrative perspective, the fees and rebates could be integrated into collection procedures for business tax regimes for farmers. Demand responses at the household level might be promoted through taxes on meat and dairy products (from both domestic and overseas suppliers).[46]

G. Forestry

74. **The LULUCF sector has been a net sink for Türkiye since 2008.[47]** Policy documents such as National Forestry Programme (2004-2023) and National Strategy and Action Plan to Combat Desertification (2015-2023) also have led to extension and improvement of existing forest areas and contributed to the extension of the carbon sinks in Türkiye

75. **Türkiye aims to cover 30 percent of its land with forests by 2023 (current coverage is 29 percent).[48]** Ideally, forestry and land use policies would promote, nationwide, the main channels for increasing carbon storage. These include: (i) reducing deforestation; (ii) afforestation; and (iii) enhancing forest management (e.g., planting larger trees, fertilizing, tree thinning, increasing rotation lengths). To the extent forest coverage is expanded this can, moreover, generate other environmental co-benefits beyond carbon storage such as reduced risks of water loss, floods, soil erosion, and river siltation.

76. **A national feebate program could cost-effectively promote all responses for increasing carbon storage without a fiscal cost to the government.** The policy would apply to landowners—most importantly those at the agricultural/forestry boundary—a fee given by:

> **[CO_2 rental price] × [carbon storage on their land in a baseline period – stored carbon in the current period]**

This scheme would reward all three channels for enhancing carbon storage, either through reduced fees or increased subsidies (unlike an afforestation subsidy which just rewards one channel). Periods here could be

[44] IPCC (2019).

[45] Basing the feebate on emission rates per hectare could be problematic because livestock is land intensive and the emissions per hectare could be smaller than for crops. The feebate could be disaggregated with higher pivot points for beef producers and lower pivot points for crop producers—this might enhance acceptability (by lowering fees for the former) though it would lower incentives to switch from livestock to crop operations.

[46] See Batini and Pointereau (2021).

[47] GOT (2019).

[48] GOT (2019).

defined as averages over multiple years, given that carbon storage might be lumpy during years when harvesting occurs. Feebates can be designed—through appropriate scaling of the baseline over time[49]—to be revenue-neutral in expected terms. And a feebate could be administered by the Ministry of Finance based on the registry of landowners used for business tax collection. Feebates bear some resemblance to environmental services payments programs that were first introduced in Costa Rica.[50]

77. **Feebates could involve rental payments, rather than large upfront payments for tree planting, given that changes in carbon storage may not be permanent.** The problem with one-off, upfront payments is that afforestation may be reversed—for example, a new tree farm receiving an upfront rebate may be subsequently harvested or destroyed (by fires, pests, windstorms), requiring complex, ex-post re-payment procedures to provide adequate incentives for maintaining the land-use change. Rental payments should equal the product of the carbon price times the interest rate and the number of years in a period.[51] The carbon price would need to rise over time to provide ongoing (rather than one off) increases in carbon storage. Partial exemptions from fees may be warranted for timber harvested for wood products (e.g., furniture, houses) because the carbon emissions (released at the end of the product life) will be delayed, perhaps by several decades or more.

78. **Feebates have become more practical with advances in monitoring technologies.** Forest carbon inventories are estimated through a combination of satellite monitoring, aerial photography, and on-the-ground tree sampling. Satellite pictures can be used to measure forest coverage and over time reveal visible land use changes like clear-cutting of intact forest. Carbon storage per hectare of forested land is more difficult to verify however, as it varies with land productivity, tree species, and forest management practices (e.g., selective harvesting can reduce stored carbon without visible clear cuts). Low-level aerial photography along forest boundaries, using technologies like Light Detection and Ranging, can estimate wood volume (therefore implicitly account for selective harvesting and changes in forest management) much more cheaply than on the ground sampling. However, on-the-ground sampling (the most expensive technology) is still needed depending on forest density—administrative costs might be kept down by, for example, limiting sampling to once every several years.[52]

H. Waste

79. **Türkiye has launched Zero Waste Project in 2017 and has the National Waste Management and Action Plan for 2016-2023.** The Zero Waste project aims to avoid the wasting and promote using natural resources more efficiently through preventing the generation of waste, reducing the waste, and sorting the waste at the source and recycling it. National Waste Management and Action Plan for 2016-2023 prepared a framework of policies, strategies and legislations that aim to minimize the waste at the source, and promote

[49] See Parry (2020) for details.

[50] See, for example, www.fonafifo.go.cr/en. Costa Rica's scheme involves payments to develop and maintain forests but does not apply fees for reductions in forest coverage.

[51] Sedjo and Marland (2003).

[52] Measuring above ground carbon only (usually about three quarters of the total) could also keep costs down. Capacity is being developed to measure forest carbon inventories in numerous countries under the REDD+ program (see www.forestcarbonpartnership.org).

waste sorting, collecting, transporting, recovery, disposal, reusing, refining, converting waste into energy or sending it to the landfills.

80. **There is a limited range of behavioral responses for reduce methane releases from the waste sector.** At landfill sites these include collection and flaring of methane leaks and at the consumer/industrial level, they include reducing the demand for packaging and food, enhanced recycling, and composting of organic waste.

81. **The case for pricing methane from waste is less compelling than for pricing GHGs from other sectors.**[53] For one thing, it is more practical to mimic the effects of a tax with regulation given the very limited number of (readily observable) mitigation responses (indeed progress has already been made with landfill gas capture). In addition, downstream methane taxes would not promote reductions in the supply of waste—this would require fiscal or regulatory incentives at the household and industrial level.

I. Fuel Taxes

Table 4. Excise Taxes by Fuel and Sector in 2020, G20 Countries

(expressed in charges per tonne CO_2)[a]

	Power			Industry			Transportation[2]		Buildings[3]	
	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
Korea	0	39	12	24	78	92	296	175	-43	108
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
Türkiye	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
Simple average	**2**	**2**	**28**	**9**	**20**	**76**	**193**	**105**	**-20**	**69**

Source: Parry and others (2022a).

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

82. **Finally, even if carbon pricing is constrained, there is ample opportunity from an economic perspective for increasing individual fuel taxes.** While implicit carbon pricing from fuel excises in Türkiye is large for gasoline this is not the case for fuels used in other sectors. Indeed, diesel fuel is currently taxed at 1/3 of the rate for gasoline even though it's CO_2 emissions per liter are 16 percent higher than for gasoline and its

[53] See also WBG (2022c).

local emission rates are much higher—indeed, partly because of the tax differential, diesel vehicles are now about half of new car sales.[54] Another reform possibility would be to phase out the subsidy for use of natural gas in residences—this subsidy is currently equivalent to a negative CO_2 price of $133 per tonne.[55] According to IMF staff calculations, a tax on coal use in power generation and industry would have about 70 percent of the carbon mitigation effectiveness as an (equivalently scaled) carbon price on all fossil fuels. See Table 4.

6. Summary of Recommendations

83. **The main recommendations of the paper can be summarized as follows.**

- Define a GHG emissions target of around 290-300 million tonnes for 2030 in line with Türkiye's net zero target for 2053;
- Implement a comprehensive carbon price (though a carbon tax or ETS) rising progressively to $75 per tonne by 2030;
- Use revenues from the carbon price for reductions in labor income taxes and targeted support to low-income households (after recycling the average household is better off by 0.4 percent);
- Consider a border carbon adjustment to preserve the competitiveness of energy-intensive, trade-exposed industries in light of domestic carbon pricing;
- Consider feebates to reinforce mitigation incentives in the power and industry sectors without a significant tax burden on the average firm;
- Integrate a feebate into the vehicle registration tax system to promote adoption of clean vehicles;
- Consider feebates to promote adoption of energy efficient appliances and (through integration into property taxes) energy-saving building renovations;
- Consider proxy emissions pricing schemes for the extractive and agricultural sectors and a feebate for the forestry sector.

[54] See WBG (2022c) and for further details Türkiye's energy tax system. See Parry and others (2014) for detailed methodologies for measuring the environmental costs of vehicles.

[55] The subsidies for natural gas reflect differences between an international reference price (adjusted for processing, marketing and distribution costs and margins) and prices paid by power generators and industry

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

CPAT is a climate mitigation policy modelling platform developed jointly by the IMF and World Bank. Covering over 200 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.[1]

In the power sector,[2] 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) and the distribution of costs within generation sources (e.g., that coal and renewables plants have costs that vary around that generation

[1] 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 2021), 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.

[2] This sector also includes district heating.

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.[3] 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[4] 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.[5] 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)[6] and other sources (the latest data is for 2019). GDP projections are from the latest IMF forecasts.[7] 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.[8] 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 an average of IEA (which are rising) and IMF (which are flat) price projections as of mid-2021. 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 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

[3] 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).

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

[5] 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.

[6] See IEA (2021a).

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

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

calibrated to match those of EC-JRC (Crippa and others 2018), Global Carbon Budget (Friedlingstein and others 2021), and various sources.[9]

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.[10] 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.[11]

[9] For more details on model specification and parameters see Black and others (2022a).

[10] 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.

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

Annex B. Behavioral Responses Promoted by Alternative CO_2 Mitigation Policies

Comprehensive carbon pricing promotes the following responses:

- *Power generation*: shifting (both in terms of new investment and the daily dispatch mix) from coal to natural gas, from these fuels to renewables, and perhaps to nuclear and fossil generation with carbon capture and storage;
- *Industry*: reducing CO_2 and electricity intensity (e.g., through alternative heating sources than coal, enhanced recycling of scrap metal) and output levels;
- *Transportation*: shifting to more efficient internal combustion engine vehicles, from these vehicles to electric (or other zero emission) vehicles, and reducing vehicle miles travelled; and
- *Buildings*: reducing CO_2 intensity, electricity intensity, and energy demand (e.g., through energy efficient constructions, upgrading insulation of existing buildings, switching from fossil to electric heat pumps, improving the energy efficiency of appliances, turning down the heating).

Non-pricing mitigation instruments promote a narrower range of behavioral responses or lagged rather than immediate responses. Even within a sector, these instruments do not promote the full and immediate range of behavioral responses, for example:

- Renewable portfolio standards and feed-in tariffs for renewables only promote shifting from fossil to renewable generation;
- Emission rate regulations, or feebates, for new vehicles reduce emissions from the on-road fleet gradually over time as the fleet turns over (e.g., they do not accelerate retirement of old vehicles) and they do not reduce vehicle miles travelled—additionally, electric vehicle subsidies do not promote shifting to more efficient internal combustion engine vehicles; and
- Incentives for net zero new buildings reduce emissions from the building stock very gradually (given that typically less than 2 percent of the building stock is replaced each year).

A combination of non-pricing measures across sectors, and across new and existing capital, promotes a wider range of responses. But promoting cost effectiveness can be challenging—for example, under regulatory approaches it would require extensive and fluid credit trading markets across firms, programs, and sectors.

In practice, other mitigation instruments will be used to complement and reinforce carbon pricing. Although less efficient, non-pricing instruments may have greater acceptability as they avoid significant and politically sensitive increases in energy prices—unlike carbon pricing, they do not involve the pass through of carbon tax revenues or allowance rents in energy prices. Non-pricing instruments like feebates may have a key role in kick-starting de-carbonization of hard-to-abate sectors, particularly transportation and buildings. Policymakers need to strike a balance between carbon pricing (the most efficient but perhaps most politically challenging instrument) and other (less efficient but frequently more acceptable) reinforcing instruments.

Annex C. Additional Details on Carbon Pricing Schemes

Annex Table C.1. Further Details on National, Subnational and Regional Level Carbon Pricing Schemes in Operation

Country/ Region	Year Introduced	Coverage of Energy Sectors: Power	Industry	Transport	Buildings	Coverage Rate, all GHGs (percent)	Price, $/tonne	Revenue/ Rent, % GDP	Point of Tax/ Regulation	Revenue Use
Carbon Taxes										
Argentina	2018	✓	✓	✓		20	5	0.070	Midstream	General budget
Colombia	2017	✓	✓	✓	✓	23	5	0.04	Midstream	Environmental spending
Chile	2017	✓	✓			29	5	0.05	Downstream	General budget
Indonesia	2022	✓				26	2	0.05	Midstream	General budget
Singapore	2019	✓	✓			80	4	0.04	Midstream	General budget
South Africa	2019	✓	✓	✓	✓	80	10	0.04	Midstream	General budget
Ukraine	2011	✓	✓		✓	71	1	0.05	Midstream	General budget
Uruguay	2022		✓	✓		11	127	1.15	Midstream	General budget, environmental spending
ETSs										
EU	2005	✓	✓			41	87	0.26	Downstream	General budget, environmental spending
Austria	2005	✓	✓			37	87	0.11	Downstream	General budget, environmental spending
Belgium	2005	✓	✓			38	87	0.19	Downstream	General budget, environmental spending
Bulgaria	2005	✓	✓			52	87	1.82	Downstream	General budget, environmental spending
Croatia	2005	✓	✓			32	87	0.33	Downstream	General budget, environmental spending
Cyprus	2005	✓	✓			51	87	0.43	Downstream	General budget, environmental spending
China	2013, 2014, 2016, 2021	✓				38	9	0.32	Downstream	Environmental spending proposal
Czech Republic	2005	✓	✓			51	87	0.78	Downstream	General budget, environmental spending
Germany	2005, 2021	✓	✓	✓	✓	85	62	0.44	Mid & Downstream	Environmental spending
Greece	2005	✓	✓			47	87	0.66	Downstream	General budget, environmental spending
Hungary	2005	✓	✓			30	87	0.39	Downstream	General budget, environmental spending
Italy	2005	✓	✓			34	87	0.18	Downstream	General budget, environmental spending
Kazakhstan	2013	✓	✓		✓	46	1	0.10	Downstream	General budget
Korea	2015	✓	✓	✓	✓	73	19	0.99	Downstream	Environmental spending
Lithuania	2005	✓	✓			30	87	0.44	Downstream	General budget, environmental spending
Malta	2005	✓	✓			34	87	0.28	Downstream	General budget, environmental spending
New Zealand	2008	✓	✓	✓		49	53	0.20	Downstream	General budget, environmental spending
Romania	2005	✓	✓			33	87	0.89	Downstream	General budget, environmental spending
Slovakia	2005	✓	✓			50	87	0.64	Downstream	General budget, environmental spending
US	2009, 2012, 2018, 2021	✓	✓	✓	✓	7	24	0.05	Up & Midstream	General budget, direct transfers, environmental spending
Hybrid										
Canada	2019	✓	✓	✓	✓	67	38	0.16	Downstream	Tax cuts, environmental spending
Denmark	1992, 2005	✓	✓	✓	✓	62	52	0.29	Mid & Downstream	General budget
Estonia	2000, 2005	✓	✓			63	79	1.26	Mid & Downstream	General budget
Finland	1990, 2005	✓	✓	✓	✓	67	77	0.76	Mid & Downstream	General budget, tax cuts
France	2005, 2014	✓	✓	✓	✓	56	64	0.41	Mid & Downstream	General budget, environmental spending
Iceland	2005, 2010	✓	✓	✓	✓	93	56	0.62	Mid & Downstream	General budget
Ireland	2005, 2010	✓	✓	✓	✓	59	62	0.23	Mid & Downstream	General budget,direct transfers, environmental spending
Mexico	2014, 2020	✓	✓	✓	✓	61	4	0.02	Midstream	General budget
Japan	2010, 2011, 2012	✓	✓	✓	✓	77	2	0.05	Midstream	Environmental spending
Latvia	2004, 2005	✓	✓			25.4	79	0.39	Midstream	General budget
Liechtenstein	2005, 2008	✓	✓	✓	✓	81	130	0.60	Mid & Downstream	General budget
Luxembourg	2005, 2021	✓	✓	✓	✓	79	38	0.048	Mid & Downstream	General budget
Netherlands	2005, 2021	✓	✓			46	87	0.270	Mid & Downstream	General budget
Norway	1991, 2005	✓	✓	✓	✓	55	87	0.94	Mid & Downstream	General budget
Poland	1990, 2005	✓	✓	✓	✓	51	81	1.45	Mid & Downstream	Environmental spending
Portugal	2015, 2005	✓	✓	✓	✓	70	56	0.52	Mid & Downstream	General budget, environmental spending
Slovenia	1996, 2005	✓	✓	✓	✓	89	47	0.48	Mid & Downstream	General budget
Spain	2005, 2014	✓	✓		✓	37	82	0.25	Mid & Downstream	General budget, environmental spending
Sweden	1991, 2005	✓	✓	✓	✓	77	109	0.52	Mid & Downstream	General budget
UK	2013, 2021	✓	✓			49	67	0.42	Downstream	General budget, tax cuts
Switzerland	2008	✓	✓		✓	44	114	0.16	Midstream	Tax cuts, direct transfers, environmental spending

Sources: World Bank Carbon Pricing Dashboard (2022); OECD (2019); World Bank (2019); Fraser Institute (2020); ICAP (2022); Government sources.
Notes: Revenue/rent excludes revenue loss from erosion of prior fuel tax bases. Mexico ETS is still in pilot phase.
Notes: [a]Argentina's revenues are distrubuted through the Federal Revenue Distribution System to designated entities including the National Housing Fund, the Transport Infrastructure Trust, and the social security system. Spain's carbon tax applies only to fluorinated GHG emissions (HFCs, PFCs, and SF6).

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