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A Comprehensive Climate Mitigation Strategy for Mexico

by Simon Black, Koralai Kirabaeva, Ian Parry, Mehdi Raissi, and Karlygash Zhunussova

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Abstract

This paper discusses a comprehensive strategy for implementing Mexico's climate mitigation commitments. Progressively increasing carbon prices from current levels of US$3 per ton to US$75 per ton by 2030 would achieve Mexico's mitigation pledges, while raising annual revenues of 1.8 percent of GDP and cumulatively averting 11,600 deaths from local air pollution. The carbon price would raise fossil fuel and electricity prices, imposing burdens of 2.7 percent of consumption on the average Mexican household. However, recycling carbon pricing revenues would offset most of this burden, and targeted transfers could make the reform pro-poor and pro-equity. Additionally, the economic efficiency costs of carbon pricing (0.3 percent of GDP in 2030) are more than offset by local air pollution and other domestic environmental benefits (before even counting climate benefits). Mexico would need a more ambitious 2030 target if it were to follow many other countries in adopting a midcentury 'net-zero' emissions target. To enhance the effectiveness of the mitigation strategy, carbon pricing can be reinforced with sectoral instruments, such as feebates in the transport, power, industry, building, forestry, extractive, and agricultural sectors. Complementary policies are also needed to support public investment in the clean energy transition.

JEL Classification Numbers: Q48, Q54, Q58, H23

Keywords: Climate change, Mexico climate mitigation, carbon pricing, carbon tax, emissions trading system, feebate, natural gas, industry, buildings, transportation, agriculture, forestry.

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I. INTRODUCTION[1]

1. **Ambitious climate policy is in Mexico's national interest.** A comprehensive mitigation strategy with carbon pricing as its centerpiece can mobilize valuable government revenues, save lives by reducing local air pollution exposure, reduce poverty, increase employment in clean energy sectors, and present Mexico as a leader in combating the global climate challenge.

2. **Mexico has pledged to reduce greenhouse gas emissions (GHGs) by 22 percent below country-estimated baseline levels in 2030 or by 36 percent conditional on external support**. To support its climate goals, Mexico introduced a carbon tax in 2014, though with low rates and exemptions for natural gas. More recently, it has implemented a pilot emissions trading system (ETS) for power generation and industry.

3. **Achieving Mexico's existing emissions commitments will require stronger carbon pricing**. The form of carbon pricing (a tax, ETS, or hybrid of the two) is less important than getting the basic design details right—comprehensively covering emissions with a common price that rises steadily and predictably while being aligned with mitigation targets. Additionally, Mexico may need to strengthen its 2030 target if it follows other countries in pledging 'net-zero' emissions by mid-century at COP26 in November 2021.

4. **Mexico will need a comprehensive mitigation strategy with carbon pricing, complemented by other measures to enhance effectiveness and acceptability.** Additional instruments are likely needed for the power, industry, transportation, and building sectors which are less efficient than carbon pricing but might be scaled up more rapidly as they impose smaller burdens on households and firms. Additional pricing, or proxy pricing instruments can reduce broader emissions sources, notably from the extractives, forestry, and agricultural sectors. Recycling the potential revenues from carbon pricing could boost the economy in an equitable way while assisting vulnerable households, workers, and regions. Even with robust carbon pricing, additional measures are needed to liberalize power generation and support investment in low-carbon technologies, thereby facilitating Mexico's clean energy transition.

5. **This paper outlines a comprehensive mitigation strategy for Mexico and is organized as follows**.[2] The next section provides background on emissions trends, targets, carbon pricing, and energy prices in Mexico. Section III quantifies the impacts of reforms to strengthen carbon pricing. Section IV discusses additional complementary instruments for the transport, power, industry, buildings, extractives, forestry, and agricultural sectors. Section V discusses the burden of carbon pricing on households and firms, and the use of revenues and measures to assist vulnerable households, and workers from both the energy transition and climate impacts. Section VI estimates investment needs for clean energy transition and supportive policies. Section VII summarizes the main recommendations.

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[1] The authors are grateful to the Mexican authorities, Saad Quayyum, and Gregor Schwerhoff for helpful comments and suggestions.

[2] 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, Batini and others 2020, Black and others 2021, Parry 2021).

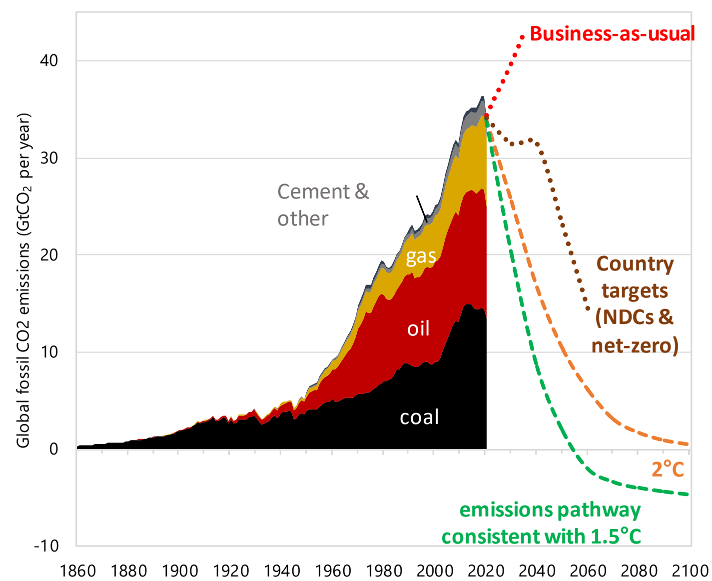
6. **The paper uses extensive quantitative analysis.** Most of this analysis is based on a flexible and transparent spreadsheet model—the Carbon Pricing Assessment Tool (CPAT)—developed by Fund and Bank staff. This model projects fuel use and CO_2 emissions by major energy sectors, includes a model of investment and dispatch in the power sector, and assumptions about the price responsiveness of electricity demand and fuel use in other sectors that are representative of the broader climate modelling literature. CPAT also quantifies the emissions, fiscal, local environmental (e.g., air pollution mortality), economic welfare, and distributional impacts of carbon pricing. The model is described in Annex A.

II. Emissions and Policy Background

A. The Global Picture

7. **The window of opportunity for containing global warming to below 2°C—the central goal of the 2015 Paris Agreement—is closing rapidly**. To contain projected warming to 1.5° or 2°C above pre-industrial levels, global carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions must be cut by 50 or 25 percent respectively below 2019 levels by 2030, followed by a rapid transition to zero net emissions, or negative net emissions in the case of 1.5°C (see Figure 1).[3] At the global level, containing temperature rises to below 2°C requires phasing in measures (on top of existing measures) equivalent to a global carbon tax of around $75 per ton or more by 2030 and rising further beyond 2030.[4] Without rapid reductions in global GHGs over the next decade, the likelihood of meeting temperature stabilization goals will decline rapidly, as the remaining carbon budget consistent with warming targets is exhausted more quickly.

Figure 1. Global Fossil CO_2 Emissions Pathways



Sources: Global Carbon Budget (2021); IPCC (2021); IMF staff calculations.
Note: Baseline and NDC projections from CPAT (170 countries, >95percent of global emissions). Assumes linear path for countries with net-zero emission targets.

8. **A recent landmark report[5] from the UN's climate science body confirms that observed global warming to date of 1.2°C is caused by human (as opposed to natural)**

[3] Net zero emissions allows for positive emissions in some sectors so long as they are offset by negative emissions elsewhere, for example, through technologies that directly remove CO_2 from the atmosphere or expansion of forestry and other biological carbon sinks.

[4] For example, Stern and Stiglitz (2017), IMF (2019a).

[5] IPCC (2021).

factors and warming is happening faster than previously projected. Warming is already causing a wide range of climate impacts including heatwaves, droughts, floods, hurricanes, higher sea levels, and swings between climate extremes, and the frequency and severity of these impacts will rise alarmingly as the planet continues to warm (see Box 1). Moreover, the risks of tipping points in the global climate system (e.g., runaway warming from release of underground methane, collapse of major ice sheets causing dramatic sea level rises, shutting down of ocean circulatory systems, destruction of the natural world) rise exponentially with warming above 1.5ºC.[6]

Box 1. Impacts of Existing and Projected Climate Change

Heat waves. Extreme heat waves, such as the deadly one that occurred in many parts of North America in summer 2021, are already about five times more likely to occur with existing warming of 1.2ºC. At 2ºC warming, this frequency increases to 14 times as likely to occur. Heat waves are getting hotter, and with 2ºC of warming, the hottest temperatures would reach nearly 3ºC higher than previous heat waves.

Droughts. Climate change is increasing the frequency and severity of droughts—such as the summer 2021 drought affecting Mexico and the Western United States. Severe droughts that used to occur at an average of once per decade are now occurring about 70 percent more frequently. If warming continues to 2ºC, these droughts will occur between two and three times as often, with concomitant destruction of agriculture and livelihoods and impacts on food prices.

Flooding. Climate change is intensifying the water cycle on both sides. While more intense evaporation will lead to more droughts, warmer air can hold more water vapor to produce extreme rainfall (as played out dramatically in Western Europe and China in summer 2021). On average, the frequency of heavy downpours has already increased by about 30 percent and they contain about 7 percent more water.

Hurricanes. Hurricanes are growing stronger and producing more rain as global temperatures increase. It has already been observed that, globally, a higher percentage of storms are reaching the highest categories (categories 3, 4 and 5) in recent decades. This is expected to continue as temperatures climb.

Sea level rise. Sea level is rising around the world, and the rate is increasing—even if warming is kept below 2ºC, sea levels are projected to rise 2-3 meters by 2300 and by 5-7 meters with greater warming. Higher sea levels are worsening high-tide flooding and storm surge. By 2100, once-in-a-century coastal flood events will occur at least once per year at more than half of coastlines across the world.

Weather whiplash. Climate change is not just increasing the severity of extreme weather, it is interrupting the natural patterns, leading to 'weather whiplash'—wild swings between dry and wet extremes. This has been experienced recently in California, with 'atmospheric rivers' causing destructive floods one year and extreme drought causing water shortages the next.

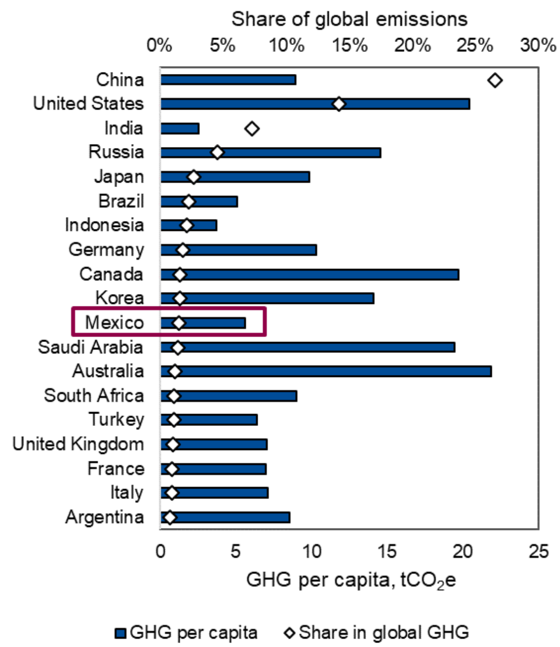
Source. IPCC (2021).

[6] IPCC (2018).

B. Emissions Trends in Mexico

9. In per capita terms, Mexico's emissions are around the global average, but Mexico remains a large global emitter in absolute terms (Figure 2). Mexico's GHG emissions amounted to 5.6 tons of carbon dioxide equivalent (CO_{2e}) in 2018, compared with a global average of 6.3 tons per capita. At the same time, Mexico was the twelfth largest global emitter in absolute terms in 2018 producing GHG emissions of 700 million tons or 1.2 percent of the global total. Actions to mitigate emissions in Mexico are therefore significant at the global level and could help to catalyze mitigation action among other countries, especially in the Latin American and Caribbean region.

Figure 2. Per Capita Emissions and Global Shares, 2018



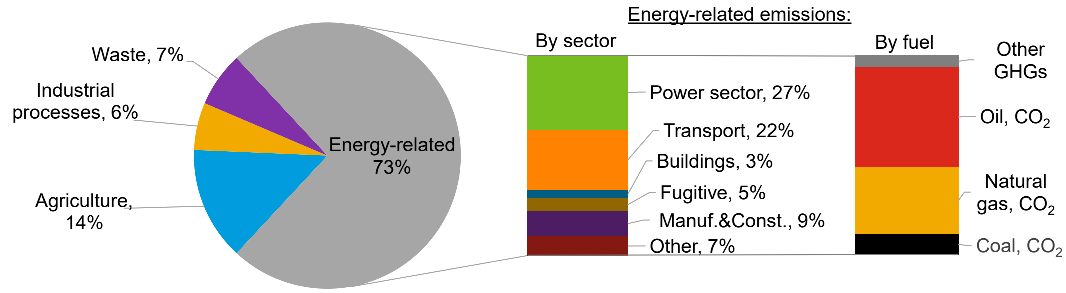
Sources: UNFCCC (2021); WRI (2021)
Note: GHGs exclude land use, land use change & forestry (LULUCF) emissions.

10. Energy-related CO_2 emissions accounted for 73 percent of Mexico's GHG emissions in 2018, excluding land-use, land-use change and forestry (LULUCF) emissions. By sector, power generation accounted for 27 percent of Mexico's GHGs, transportation 22 percent, industry (manufacturing and construction) 9 percent, and (direct fuel combustion in) buildings 3 percent. Fugitive emissions, primarily methane leaks from extracting and processing oil and gas, accounted for a further 5 percent of emissions and industrial process emissions (e.g., CO_2 released during cement production, fluorinated gases from air conditioners, aerosols, and refrigerants[7]) 9 percent. Agriculture and waste accounted for 14 and 7 percent of GHG emissions respectively. Combustion of coal, oil, and natural gas accounted for 11, 53, and 36 percent of energy-related CO_2 emissions. See Figure 3. LULUCF emissions were estimated at 15 million tons in 2018[8], though measurement of these emissions is less accurate and more contentious than for energy-related CO_2 emissions.

[7] Under its obligations for the Kigali Amendment to the 1987 Montreal Protocol, Mexico will progressively reduce fluorinated gases by 30 percent in 2035 and 80 percent in 2045—the phaseout is being implemented through a progressively tightening quota system.

[8] WRI (2021).

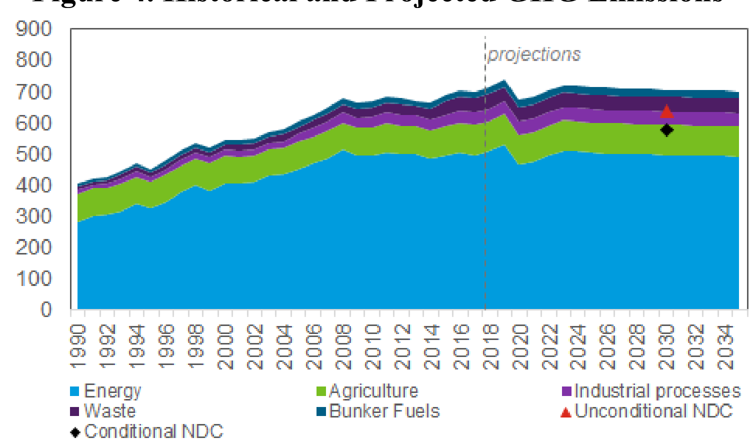
Figure 3. GHG Emissions by Sector and Fuel Type.



Sources: WRI (2021); IMF staff calculations.

11. Fossil fuels accounted for 79 percent of power generation in 2018. Generation shares for coal, gas, and oil were 9, 60, and 10 percent respectively. Hydro power accounted for another 10 percent of electricity output, and solar and wind power another 1 and 4 percent respectively. Nuclear accounted for 4 percent of generation.[9]

Figure 4. Historical and Projected GHG Emissions



Sources: WRI (2021); IMF staff calculations.
Note: GHGs exclude land use emissions.

12. GHG emissions rose rapidly in Mexico from 1990 but future baseline projections are relatively flat. GHG emissions in Mexico were about 70 percent higher in 2018 than in 1990 (though the emissions intensity of GDP fell by about a fifth during this period). In a business as usual (BAU) scenario, IMF staff project emissions will rise 7 percent from 2020 to reach about 721m tons in 2030. See Figure 4. The emissions growth in industry and waste (4 and 6 percent per year) and in the power and transport sectors between 1990 and 2018 (2.5 percent a year) was faster than for other sectors. The IMF BAU projections assume no new mitigation policies (beyond those implicit in recently observed fuel use) or tightening of existing mitigation policies. Although GDP in Mexico is projected to grow by approximately 25 percent in real terms between 2020 and 2030, the CO_2 emissions intensity of GDP declines 13 percent over this period, reflecting gradual improvements in energy efficiency (as older, less efficient capital is retired) and standard assumptions that the demand for fuels and electricity increase by less than in proportion to GDP.[10]

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[9] IEA (2021a).

[10] Emissions fell an estimated 6 percent in 2020 due to the economic crisis precipitated by COVID-19, though projected emissions expand rapidly from 2021 onwards. See CAC (2021) for further discussion of emissions projections for Mexico.

13. 2030 BAU emissions projections by the Mexican authorities are higher than in IMF projections. Mexico's second-round Nationally Determined Contribution (NDC) projects BAU GHG emissions of 991 million tons in 2030 (833 million tons including LULUCF absorption) compared with 721 million tons (including LULUCF) in the IMF BAU projections. The difference largely reflects, in the IMF projections: the inclusion of autonomous improvements in energy efficiency and productivity of renewables; energy demand responses to gradually rising international energy prices; and downward level adjustments to future GDP due to the pandemic. Relating future emissions targets to historical (observed) emissions, rather than future BAU emissions, is generally preferable given the latter projections are sensitive to modelling assumptions and change over time.

Box 2. Climate Mitigation Legislation in Mexico: A Brief History

Major legislative initiatives include:

- Mexico became the first large oil-producing emerging market to introduce climate change legislation in 2012. The General Law of Climate Change established an institutional framework for meeting emissions targets,[1] while also codifying the targets—the 2020 target was to cut GHGs 22 percent relative to BAU, and the target for the clean generation share was 35 percent by 2024.[2]
- In March 2015, Mexico became the first developing country to submit an (Intended) NDC for the 2015 Paris Agreement, reaffirming its 2050 emissions commitment and introducing a commitment to unconditionally reduce GHGs 22 percent below BAU levels in 2030 and by 36 percent conditional on external support. In total, 195 parties signed the Paris Agreement with almost all of them submitting first-round NDCs, though in many cases pledges for 2030 were not as ambitious as those for Mexico.[3]
- In December 2020, the government submitted its second-round NDC[4] which reaffirmed the 2030 and 2050 commitments and updated its BAU GHG projections to 804, 902, and 991 million tons CO_{2e} in 2020, 2025, and 2030, respectively—actual 2018 emissions were 13.5 percent below the 2020 BAU.

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[1] This framework included the National Institute of Ecology and Climate Change, responsible for emissions data collection and policy development; the Inter-Ministerial Commission on Climate Change, responsible for formulating and implementing climate policies; and a new National System on Climate Change to coordinate efforts across federal, state, and local governments. The law also created the basis for a voluntary emissions trading system (the first in Latin America).

[2] The law also pledged to reduce emissions of black carbon (soot) from fuel combustion which could amplify global warming if they are transported to polar regions and reduce the reflexivity of ice sheets. These emissions are not considered below however as black carbon is not considered a well-mixed global greenhouse gas covered under UNFCCC ('Kyoto gas').

[3] See for example IMF (2019a), Figure 1.2.

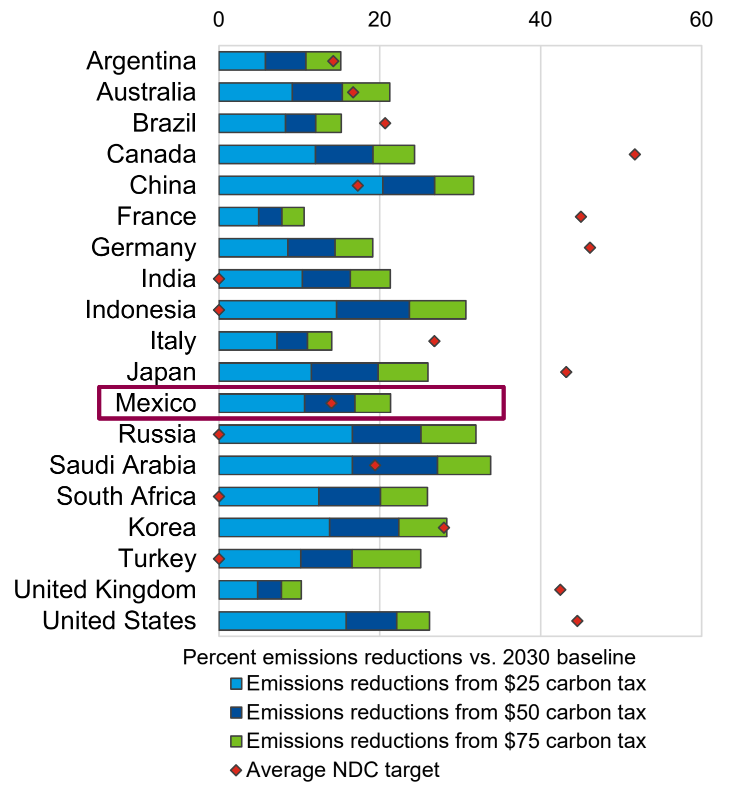
[4] See https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Mexico%20First/NDC-Eng-Dec30.pdf.

C. Emissions Targets and Progress on Meeting Them

14. Mexico was in the vanguard on climate change legislation[11] **and has pledged unconditionally to reduce GHGs by 22 percent relative to 833 $MtCO_2e$ BAU levels in 2030**. It has also pledged—conditional on external (financial and technical) support—to reduce GHGs 36 percent by 2030 relative to BAU levels, and by 50 percent by 2050 relative to 2020 levels. Box 2 briefly summarizes the history of climate mitigation legislation in Mexico.

15. The ambition of Mexico's mitigation pledge for 2030 is currently lower than the most of G20 countries, and Mexico has not yet strengthened its 2030 mitigation target ahead of the November 2021 Glasgow COP26. Averaging over conditional and unconditional pledges, meeting Mexico's second-round NDC would imply cutting GHGs 14 percent below IMF-projected BAU levels in 2030.[12] Thirteen G20 countries have more ambitious 2030 pledges and five have less ambitious (or even non-binding) pledges (see Figure 5). In terms of long-term commitments, over 130 countries, representing about 70 percent of global GHGs, have recently made net zero pledges,[13] including among G20 economies Germany (for 2045), Canada, EU, Japan, Korea, UK, U.S. (all 2050), China and Indonesia (2060). Many economies (notably the EU and U.S.) strengthened 2030 commitments in their second-round NDCs. Mexico has not specified

Figure 5. GHG Emissions Reductions for 2030 Pledges



Note: 2030 baseline emissions are IMF-estimated. NDCs targets are from first-round or (if applicable) second-round Paris pledge. Where country has a conditional NDC the target is defined as the average between the conditional and unconditional target. NDCs as of 23 July 2021.

[11] Mexico was the first large oil-producing emerging market to introduce climate change legislation (Averchenkova and Guzman Luna 2018).

[12] Or 25.5 percent below NDC-projected BAU levels (including LULUCF absorption) in 2030.

[13] See Energy and Climate Intelligence Unit (2021). For some countries, net zero refers to CO_2 only while in other cases it refers to total GHGs.

a net zero pledge and has not significantly increased its ambitions in its second round NDC.[14] There are many ways to estimate 'Paris-aligned' targets for countries—that is, targets aligned with limiting warming well below 2ºC. One potential approach[15] would imply lowering Mexico's 2030 emissions target from 704 million tons to, at most, 550 million tons in 2030. In turn, this would imply reducing Mexico's GHG emissions at least 22 percent below (IMF-projected) BAU levels in 2030, which would entail an 8 percent increase in its unconditional NDC.

16. According to IMF staff's estimates (Figure 4), on current policies, Mexico is likely to fall short of its current 2030 emission target and a Paris-aligned target. IMF staff estimate BAU GHG emissions (under current policies) will exceed current and Paris-aligned emissions targets by 10 and 18 percent, respectively.

17. In sum, Mexico's emissions commitments can be strengthened by:

- *Making a net zero emission pledge for 2050*; and
- *Aligning the 2030 target with any long-term net zero target (e.g., based on a linear emission reduction pathway over time from recent emissions to net zero).*

D. Current Mitigation Policies[16]

18. Mexico has put in place the architecture for carbon pricing, through both a carbon tax and a pilot emissions trading system (ETS). Carbon pricing is potentially the cornerstone of Mexico's future mitigation strategy, though it will need strengthening in terms of coverage and robust pricing (see Section III).

19. Mexico's carbon tax was implemented in 2014 though it lacks full coverage, and the current price is modest. The tax takes the form of an excise imposed midstream on suppliers of fossil fuels and is imposed on a fuel's CO_2 emissions in excess of the emission rate of natural gas—in other words, natural gas is exempt from the tax and a portion of the emissions from other fuels is also exempt. The carbon tax prices about a quarter of total GHGs in Mexico. The tax rate is US$3 per excess ton of CO_2, or less if (as for coal) the tax exceeds 3 percent of a fuel's price.[17]

[14] Recent policy actions in Mexico have also favored fossil fuels over renewable energy. For example, Mexico started refurbishment of its six existing oil refineries, construction of the Dos Bocas oil refinery, and extraction of non-conventional sources of hydrocarbons while cancelling the fourth round of electricity auctions which is the main instrument for promoting renewable power generation. The government has allocated a budget for upgrading coal and other fossil-fueled power plants, some of which had previously been set for retirement. See IMF (2020) and http://dof.gob.mx/nota_detalle.php?codigo=5593425&fecha=15/05/2020.

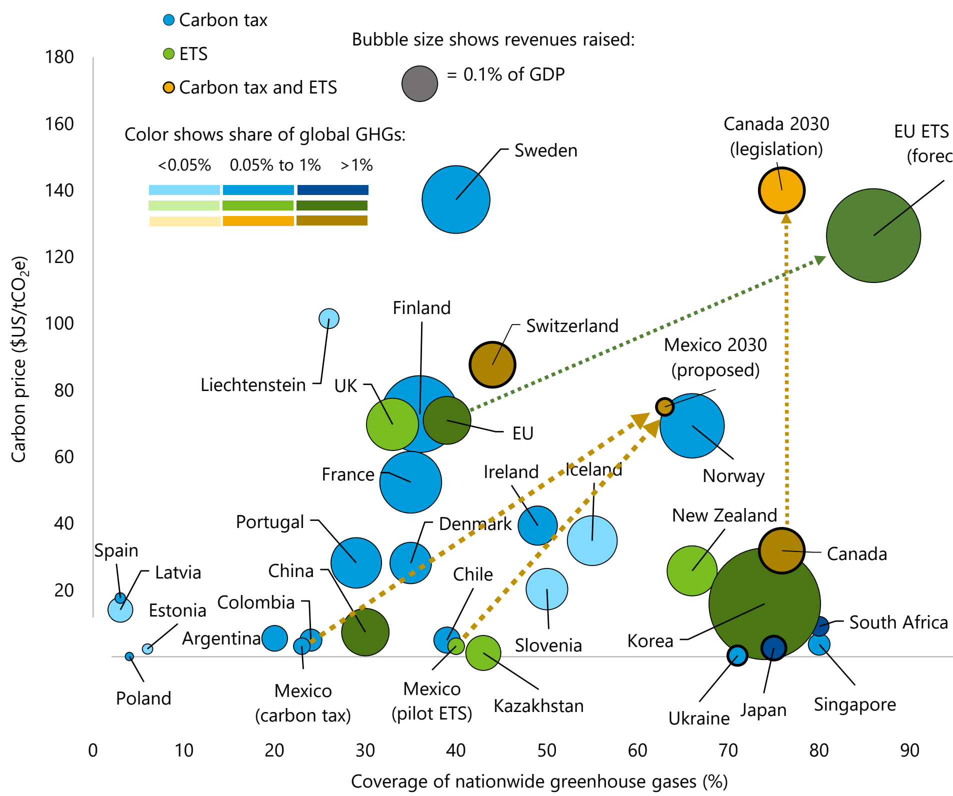
[15] Calculation assumes global GHGs are reduced by 25 percent by 2030 relative to 2019 levels (as consistent with a 2ºC target) and Mexico's GHGs relative to 2019 levels are reduced in proportion to global GHGs.

[16] For more background on climate mitigation measures in Mexico, see COC (2021).

[17] For further discussion of the carbon tax see SEMARNAT (2014) and www.diputados.gob.mx/LeyesBiblio/pdf/78_241220.pdf

20. The ETS sets a cap on aggregate emissions by covered entities and allows participants to trade emission permits. A pilot ETS was introduced in 2020 as part of a two-phase process to establish a fully operational ETS in 2023. The pilot ETS is applied downstream at the point of fuel combustion and covers about 300 larger entities in the power and industrial sectors, with annual emissions exceeding 100,000 tons of CO_2 a year, that combined produce about 40 percent of Mexico's GHG emissions. The pilot phase, which established the capacity for implementing the program and monitoring emissions, will last three years followed by a transition to a fully-fledged ETS in 2023 with several hundred companies expected to participate. The 2021 emissions cap is set at 273 million tons of CO_{2e}. At present, emission allowances are freely allocated, though a transition to allowance auctions is under consideration. Entities can bank allowances within the pilot phase (but not across phases) and meet up to 10 percent of their obligations through purchasing emission offsets (for mitigation projects in other sectors outside the ETS) rather than acquiring allowances. Future, legally binding, emissions caps have not yet been established however.[18]

Figure 6. Selected (National Level) Carbon Pricing Schemes, 2021



Sources: WBG (2021); EMBER (2012); Climate Watch (2021); IMF staff calculations.
Note: Carbon prices are from April 01, 2021 from WBG (2021). EU ETS price is from July 19,2021 from EMBER. GHGs are from 2018. EU includes Norway, Iceland, Liechtenstein. Values less than 0.005 percent of GDP are of equal size for illustrative purposes. Canada's bubble reflects only the federal backstop, but the majority of their pricing uses provincial systems. The value of the UK's ETS is an estimation for 2021 based on a £50/tCO_2e price. Finland's transport fuels are priced at $73/t$CO_2$e. Ireland's F-gases are priced at $20/t$CO_2$e. Norway has a reduced rate on natural gas for EU ETS installations of $4/t$CO_2$e. Norway and Mexico prices represent carbon price upper bounds. Lower bounds are $3.9/t$CO_2$e and $0.37/t$CO_2$e respectively. Switzerland's price is a weighted average between carbon price and ETS by emissions covered.

[18] For further discussion of the ETS see ICAP (2021), COC (2021).

21. Compared with other national schemes, carbon pricing in Mexico currently has reasonably good coverage but very low prices. Of the 24 national and regional pricing schemes illustrated in Figure 6, only seven have greater emissions coverage than the combined coverage of Mexico's carbon tax and ETS, but only four have lower carbon prices. Momentum for carbon pricing is gaining steam at the international level with major schemes implemented in China and Germany in 2021, prices in the EU ETS rising above US$70 per ton, and Canada has recently announced its minimum carbon price will rise to US$135 per ton by 2030. At present, the U.S. Administration intends to rely on an investment and regulatory approach (e.g., involving tighter vehicle fuel economy standards and cleaner power generation mixes) rather than carbon pricing.

22. Effective carbon pricing in Mexico is large for road fuels but not for fuels used in other sectors. See Table 1 which includes fuels by sector that account for at least 1 percent of fossil fuel CO_2. This suggests there is significant scope for raising effective carbon taxes in other sectors. The effective tax is negative in the case of natural gas use in power generation, which is subsidized.[19]

Table 1. Effective Carbon Tax Rates in Mexico, 2018

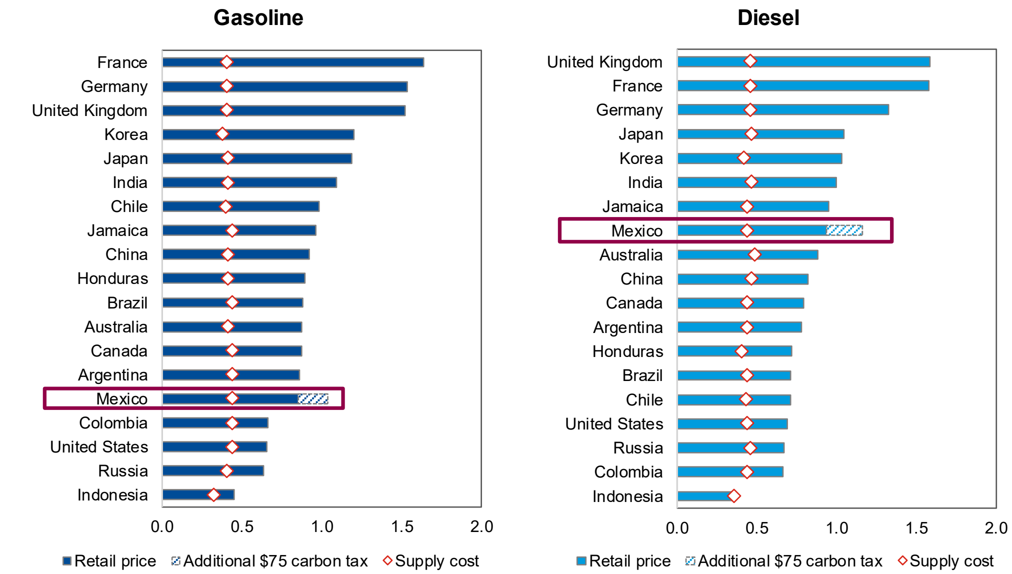
	Power		Industry			Transport			Residential
Sector/fuel type	coal	natural gas	coal	natural gas	other fossil fuels	gasoline	diesel	other products	other fossil fuels
Share in CO_2 emissions, %	7	22	4	14	8	25	10	1	4
Effective fuel tax, $/t$CO_2$	0.2	-64	0.6	-4	1.6	72.4	72.2	-0.4	-1.7

Source: IMF staff calculations
Note: Tax rates include fuel excises, fuel subsidies and the carbon tax. VAT is excluded as it applies to all consumer goods

23. Although road fuel taxes in Mexico are higher than in the U.S., Colombia, and Jamaica, they are lower than in most other G20 countries. And like in many other countries, diesel is tax-favored in Mexico relative to gasoline. Had Mexico unilaterally imposed a $75 per ton carbon tax in 2020, gasoline and diesel taxes would have been increased by 18 and 23 cents per liter respectively leaving fuel taxes in Mexico still broadly consistent with those in many other comparator countries. See Figure 7.

[19] IMF methodologies for computing fuel taxes and subsidies by country are outlined in Parry and others (2021a). For the fuels with non-negative taxes, the estimates in Table 1 are in line with those from OECD (2019). 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.

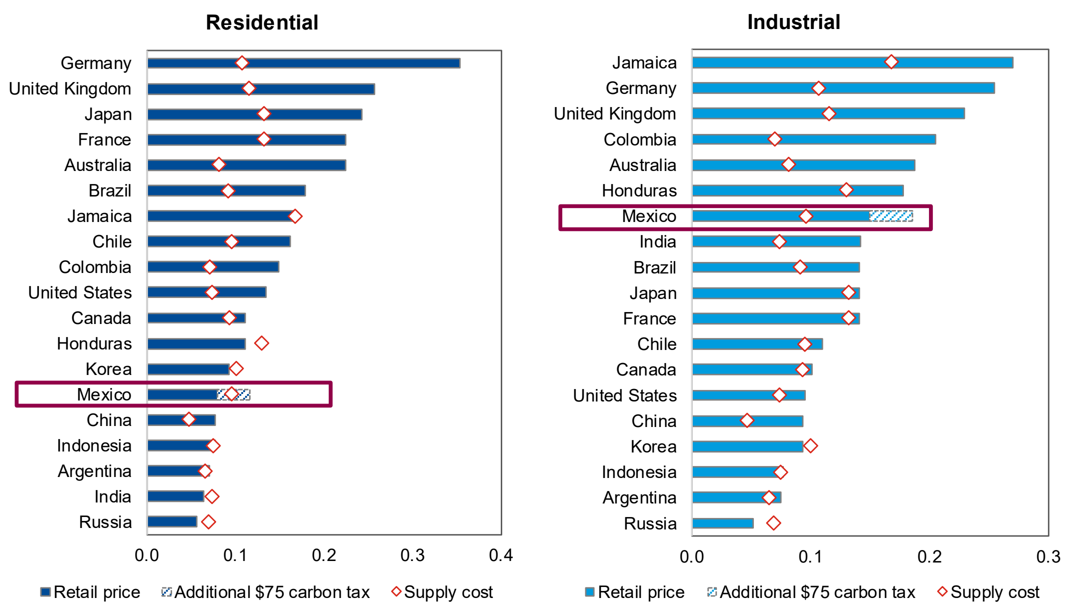
Figure 7. Gasoline and Diesel Prices and Supply Costs in 2030, $/lit



Source: IMF staff calculations based on OECD, IEA, Enerdata.

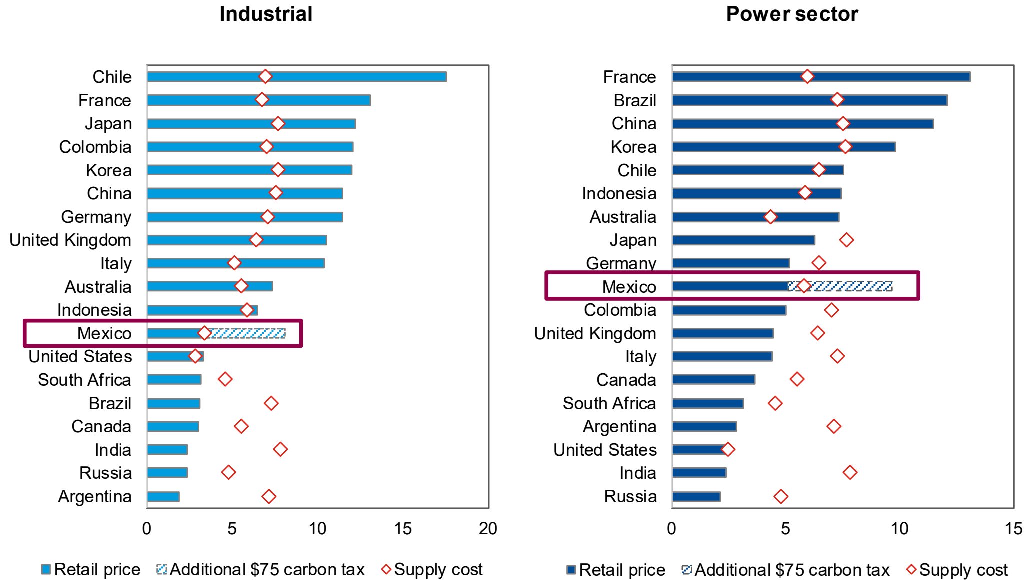
24. Supply costs for electricity in Mexico are broadly comparable with those in other countries but residential electricity prices in Mexico are on the low side, as electricity is not taxed. Indeed, residential electricity consumption is subsidized (at 20 percent) in Mexico. Had a $75 per ton carbon tax been in place in 2020, electricity prices would have increased by 4 cents per kWh, though electricity prices in Mexico would still have been broadly in line with those in other comparator countries. See Figure 8.

Figure 8. Residential and Industrial Electricity Prices and Supply Costs in 2030, $/kWh



Source: IMF staff calculations based on OECD, IEA, Enerdata.
Note: Carbon tax calculations use 2018 power mix.

Figure 9. Natural Gas Prices and Supply Costs in 2020, $/GJ



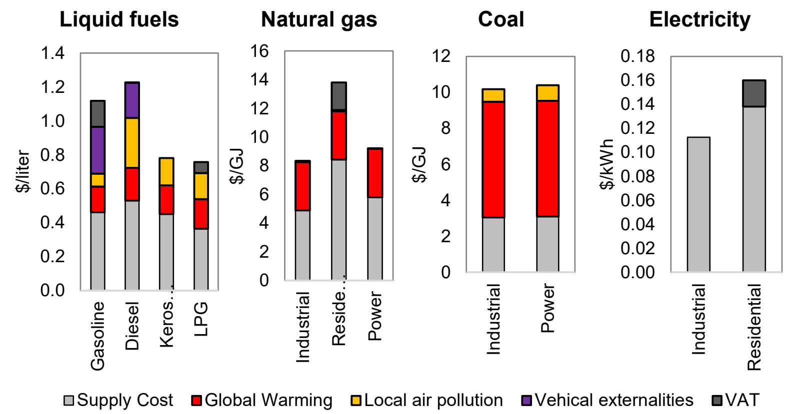
Source: IMF staff calculations based on OECD, IEA, Enerdata.

25. Supply costs, and especially prices, for natural gas use are lower in Mexico than in most other comparator countries. Although natural gas prices in Mexico for the power and industrial sectors would have increased by 88 and 127 percent with a $75 carbon price, they would still have been lower than in several comparator countries, especially for industry. See Figure 9.

26. Besides reflecting supply and climate costs, broader reforms could also reflect local environmental costs in fuel prices. These include local air pollution which elevates the risk of premature mortality from cancer, strokes, heart, and lung disease for exposed populations—coal and diesel contribute disproportionately to this pollution (natural gas is a relatively clean fuel in this regard and control technologies have gone a long way in reducing pollution from gasoline vehicles). Other local environmental costs include traffic congestion and accidents associated with the use of road fuels in vehicles. Some of these problems are best addressed though other instruments than fuel taxes—for example, road congestion can be efficiently managed by charging drivers for driving on busy roads with charges rising and falling over the rush hour—but until more fined tuned instruments are comprehensively implemented, it is efficient to reflect the full range of environmental costs in fuel taxes.

27. IMF staff have developed conceptual and quantitative tools for assessing the efficient set of fuel taxes on a country-by-country basis.[20] The results for Mexico suggest that the fossil fuels are substantially undercharged for externalities (climate damage, local pollution, and vehicle externalities). A charge on climate damage would be at least US$6.4 and US$3.4 per GJ for coal and gas, respectively. Local air pollution damage is relatively high for coal consumption in the power sector ($0.9 per GJ) and diesel ($0.3/liter).[21] Vehicles using gasoline and diesel also contribute to road accidents and road damages, and these externalities are a significant component of second-best efficient fuel taxes. See Figure 10.

Figure 10. Energy Externalities by Fuel in 2020



Source: IMF staff calculations.
Note: Potential VAT assumes general rate. Climate damages are valued at a target-consistent global value of $60 in 2020. All values are in 2021 constant prices.

28. A comprehensive mitigation strategy could have carbon pricing as its centerpiece and a variety of other complementary measures to enhance effectiveness and acceptability. These additional measures (see Box 3) include: (i) reinforcing feebates or regulations at the sectoral level; (ii) public investment in clean energy infrastructure networks and market reforms (e.g., in power generation) to enhance competition and investment; (iii) productive and equitable use of carbon pricing revenues; (iv) just transition measures to assist vulnerable households, workers and regions; (v) measures to address industrial competitiveness; and (vi) pricing of other emissions sources beyond energy-related emissions. The following sections take up all the key elements of a comprehensive strategy.

III. Enhancing Carbon Pricing

A. Conceptual Issues

29. Ideally carbon pricing would be the centerpiece of a country's mitigation strategy. Carbon pricing has several key attractions as it:

- Promotes the full range of opportunities for reducing energy use and shifting to cleaner energy sources across all covered sectors (by reflecting the cost of carbon emissions in the prices of fuels, electricity, and goods);

[20] See Parry and others (2014).

[21] Annual average air pollution concentrations in Mexico are double the levels recommended by the World Health Organization (Parry and others 2021a, Table 1).

- Automatically minimizes the costs of these responses (by equalizing the cost of the last ton reduced across fuels and sectors);
- Levels the playing field for clean technology investments (by establishing a clear price signal);
- Mobilizes a valuable source of revenue (which can be used to help meet climate, social, or broader fiscal objectives);
- Generates domestic environmental co-benefits (such as reductions in local air pollution deaths); and
- Is straightforward to scale-up from an administrative perspective (in Mexico's case building off already established capacity for the carbon tax and/or the ETS).

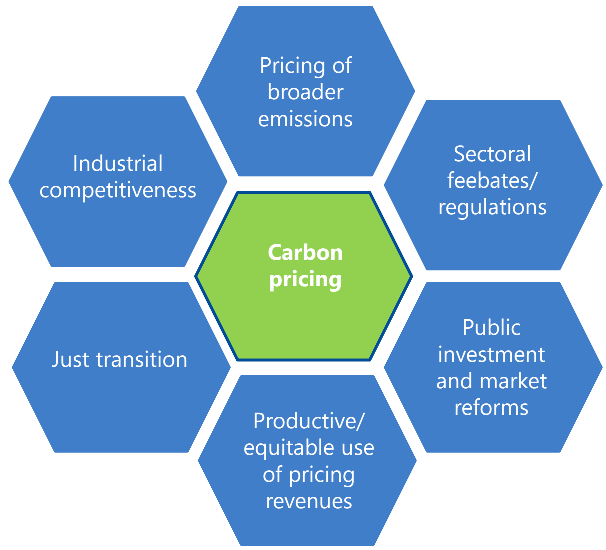
30. To make headway on Mexico's 2030 mitigation pledge, carbon pricing will need to: (i) comprehensively cover emissions; (ii) establish a rising and predictable price to induce the bulk of emissions reductions; and (iii) avoid unnecessary inefficiencies due to emissions exemptions or overlapping policies. These principles could be met through a carbon tax, an ETS, or a hybrid approach with taxes and ETSs covering different emissions sources. The choice between these three approaches, which are briefly discussed below, will depend in part on which ministry is primarily responsible for mitigation policy (carbon taxes are naturally under the purview of the finance ministry and the ETS under the environment ministry).

31. The most economically and environmentally effective form of a carbon tax would price all CO_2 emissions at the same rate, with the tax rate ramping up predictably each year. This would require removing the existing exemption for natural gas so all fossil fuels in all sectors are taxed in proportion to their full carbon content. Ideally, the carbon tax rate would ramp up as rapidly as possible, subject to acceptability constraints. For example, if the maximum acceptable tax rate in 2030 is deemed to be US$75 per ton (see below), the tax could start from US$25 per ton in 2022 and ramp up by US$6 per year. Acceptable tax rates will however depend on progress on carbon pricing in other major trading partners so some future discretion may be needed to adjust planned tax increases. Revenues from the carbon tax accrue automatically to the finance ministry and could be used for general or climate purposes.[22]

[22] Raising revenues for general budget purposes from a carbon tax may require amending the General Law of Ecological Balance and Environmental Protection and the General Law of Climate Change.

Box 3. Key Elements of a Comprehensive Mitigation Strategy

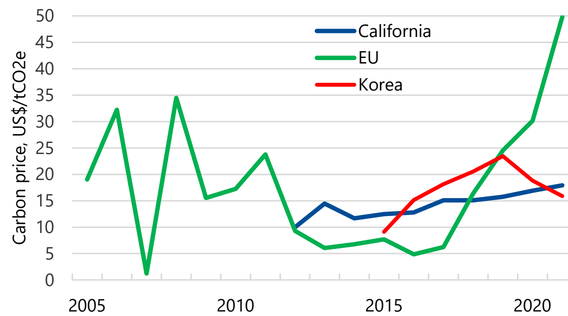
Supporting measures for a mitigation strategy centered on carbon pricing include:



- A balance between pricing and reinforcing measures—especially feebates or regulations—at the sectoral level that are less efficient than pricing but likely have greater acceptability;
- Public investment in the clean infrastructure networks that would not be adequately provided by the private sector (e.g., electric vehicle charging stations, high-voltage transmission lines to accommodate renewables sites) and market reforms (e.g., in petroleum supply which is currently dominated by the Pemex, a state-owned enterprise) to enhance competition and foreign direct investment in critical sectors like energy and transportation;
- Recycling of carbon pricing revenues in ways that boost the economy (e.g., through lowering taxes on work effort and investment or funding socially productive investments), making sure that benefits are equitably distributed across households;
- Just transition measures to assist vulnerable groups, such as stronger social safety nets or tax reliefs for low-income households, assistance programs for displaced workers and at-risk regions—impacts of both the energy transition and climate change need to be addressed;
- Measures to limit impacts of carbon pricing on industrial competitiveness; and
- Measures aimed at broader sources of GHGs beyond energy-related CO_2 emissions including emissions from extractive industries, agriculture, and forestry.

32. Alternatively, the authorities can rely on the existing ETS as the principal tool for carbon pricing in Mexico. The ETS already covers the sectors (power and industry) where emissions are generally more responsive to pricing (see below). Extending the coverage of the ETS to emissions from transportation and buildings would require applying it midstream to the suppliers of fuels for those sectors based on the carbon content of those fuels. In principle, a trajectory of progressively tighter emissions caps could be specified in line with the 2030 emissions pledge, though this might lead to prices that exceed acceptable levels (see below). Price increases might be contained through combining the ETS with a ceiling price where extra allowances are put into the system at this price to prevent further price increases. The more likely scenario perhaps is that emissions caps may not be sufficiently stringent to meet mitigation targets, implying prices that are too low. Prices may also be volatile as they vary with shifts in the demand and supply of fuels and this price uncertainty can deter clean technology investments with high upfront costs and long-range emissions reductions—indeed, existing ETSs have a history of price volatility (see Figure 11). Price stability can be promoted through combining the ETS with an exogenous price floor—implemented, for example, through a minimum price on allowance auctions—where the floor price ramps up predictably over time.[23]

Figure 11. History of Prices in ETSs



Source: WBG Carbon Pricing Dashboard (2021)
Notes: Prices are in nominal terms from April 1 of each year.

33. At present, the Mexican ETS does not exploit the fiscal opportunities from carbon pricing, which in turn can imply higher overall costs for the economy. If allowances were fully auctioned (with revenues transferred to the finance ministry), ETSs would raise the same revenue as an equivalently scaled carbon tax—these revenues could be used to boost growth and employment, for example, by lowering taxes on work effort and funding socially productive investments (e.g., for Sustainable Development Goals). In contrast, freely allocating allowances to firms in a lump sum fashion provides windfall profits to them without improving economic efficiency and forgone fiscal revenues to the government become larger as ETS prices rise over time. A key motivation for free allowance allocations is that they help to address concerns about industrial competitiveness, but a border carbon adjustment is a potentially more effective instrument for this (see Section V).

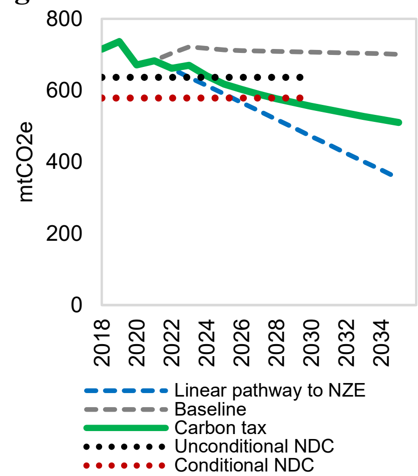
34. Under a hybrid approach, the ETS could address emissions from the power and industry sector and the carbon tax emissions from the transportation and building sectors. These hybrid approaches have been used elsewhere—for example, in the EU power and industry emissions are covered by the EU-wide ETS 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 rates.

[23] See Flachsland and others (2018) for discussion of price floor mechanisms. Another way to limit price volatility would be to link the Mexican ETS with other trading systems (e.g., in California and Canada), but then prices would be largely determined outside of Mexico—it may be preferable to retain discretion over domestic carbon prices (which can be adjusted according to national circumstances and progress on pricing in other countries).

B. Quantitative Assessment

35. IMF staff projections suggest a carbon price of around US$75 per ton by 2030 is in line with Mexico's conditional mitigation target for 2030, in the absence of other mitigation measures. Progressively increasing the carbon price to US$75 per ton in 2030 reduces CO_2 emissions 23 percent below (IMF-projected) BAU levels in 2030 (and GHGs excluding LULUCF by 21 percent). See Figure 12. A price above $75 per ton would be needed to stay on a net-zero emissions pathway by 2050. Carbon prices implicit in mitigation pledges are also well above $75 per ton in half of the G20 countries (see Figure 5).

Figure 12. GHG Emissions vs NDC



Source: IMF staff calculations.
Notes: 2015 NDC target for Mexico is a 22 percent reduction and a 29 percent conditional reduction in emissions in 2030 against country-estimated business-as-usual, corresponding to 636 and 579 $MtCO_2e$, respectively. Conditional NDC is conditional on climate finance.

36. A US$75 carbon price has a large impact on coal and natural gas prices and intermediate impacts on prices for electricity, LPG, and road fuels. Coal and natural gas prices increase by 300 and 87 percent above BAU levels in 2030, electricity prices increase 29 percent and the price of other petroleum products by 19–25 percent. Aside from gasoline and LPG however, these energy products are largely intermediate inputs used by firms rather than directly consumed by households.

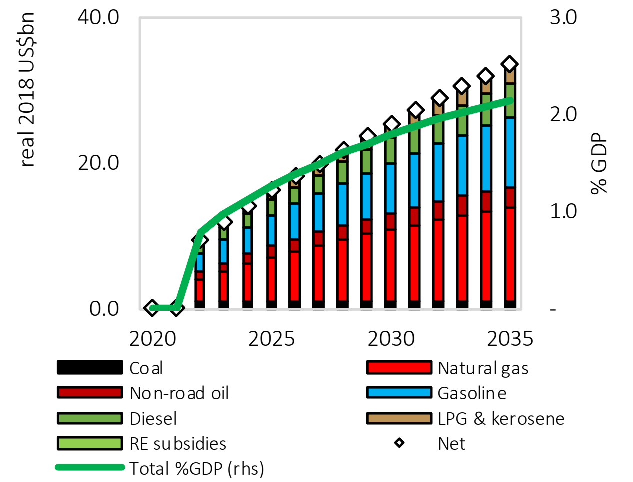
Table 2. Energy price changes and shares in consumption by fuel, 2030

Fuel	Unit	Baseline price in 2030, $/unit	Price with $75 carbon tax in 2030, $/unit	% change	Share in energy-related CO2 emissions,	Share of household consumption, 2018
Gasoline	liter	1.13	1.34	19%	25%	90.8%
Diesel	liter	1.18	1.45	22%	13%	0.1%
LPG	liter	0.68	0.84	25%	7%	73%
Kerosene	liter	0.71	0.92	29%	0%	0%
Oil	barrel	59.80	97.81	64%	9%	0%
Coal	GJ	2.57	10.29	300%	11%	0%
Natural gas	GJ	5.25	9.81	87%	36%	3%
Electricity	kWh	0.08	0.10	29%	-	21%

Source: IEA (2021), IMF staff
Notes: household consumption is calculated as a share in total industrial, transport, and residential consumption. We assume that households consume 91% of gasoline in transport consumption and all LPG

37. Under the $75 carbon price, 57, 28, 14, and 2 percent of the reduction in fossil fuel CO_2 emissions come from the power, industry, transportation, and building sectors respectively. The contribution to emissions reductions from each sector depends on: (i) the sector's share in BAU emissions (much larger for power and transport than industry and buildings); 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 and fuel price responsiveness (which is broadly similar across fuels in IMF modelling).[24]

Figure 13. Projected Fiscal Revenues

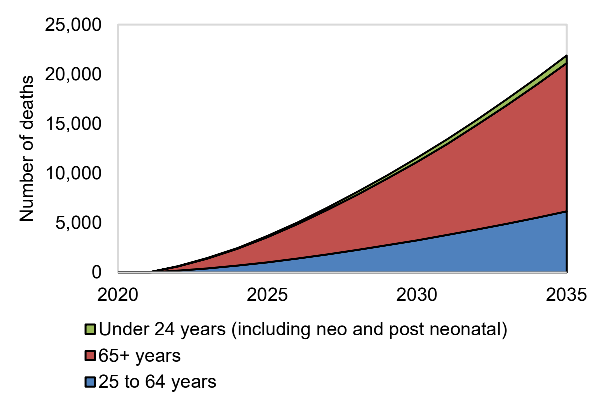


Source: IMF staff calculations.
Note: Shows total additional (vs. baseline) fiscal revenues from the policy net of renewable energy subsidies.

38. A US$75 carbon price could potentially raise revenues of 1.8 percent of GDP ($26 billion) in 2030. 36 percent of the revenue would come from charges on natural gas, 28 percent from gasoline, 30 percent from diesel and other oil products, and 5 percent from coal (see Figure 13).[25]

39. Cumulated over 2021–30, a carbon price rising progressively to US$75 per ton by 2030 would save 11,600 premature fatalities from local air pollution exposure. See Figure 14. 68 percent of the avoided deaths are people over the age of 65 years (who are more likely to have pre-existing conditions) and 82 percent are in urban areas. In addition, 14 and 73 percent of the avoided deaths are due to reduced use of coal and oil products respectively.

Figure 14. Cumulative Averted Deaths from Reduced Air Pollution by Age Group



Source: IMF staff calculations.

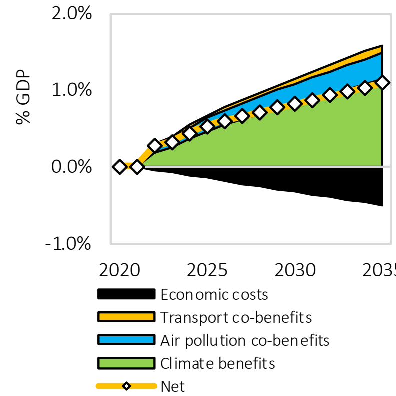
40. A US$75 carbon price imposes a relatively modest economic efficiency cost in Mexico equivalent to about 0.3

[24] Fuel price elasticities are typically around -0.5 in the medium to longer term based on other modelling and empirical literature.

[25] The revenue estimate accounts for the base erosion of pre-existing fuel taxes, or profits from the state-owned petroleum company Pemex.

percent of GDP in 2030 and these are offset by domestic environmental co-benefits. See Figure 15. That is, the carbon price does not impose a net cost on Mexico, before even counting the climate benefits. 75 percent of the domestic environmental co-benefits reflect fewer local air pollution deaths and 25 percent reductions in traffic congestion and accident externalities. Adding the global climate benefits increases environmental benefits from 0.3 to 0.9 percent of GDP, or three times the economic efficiency costs.[26] These efficiency costs are measured by the value of foregone consumption to fossil fuel consumers, less savings in supply costs, and are the standard way economists measure mitigation costs.[27]

Figure 15. Total Monetized Welfare Benefits for US$75 Carbon Tax p/tCO2e by 2030



Source: IMF staff calculations.
Notes: Shows monetized net welfare benefits. Economic costs are deadweight losses from the tax before revenue recycling.

IV. The Role of Complementary Sectoral Mitigation Instruments

41. **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. 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 key justification for sectoral measures is that they 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] It may therefore be more practical to rapidly scale up reinforcing instruments than carbon pricing (not least because the US has no plans at present to implement carbon pricing).

42. **The discussion here recommends use of revenue neutral feebates—which are the fiscal analogue of emission rate regulations—or similar pricing schemes**. Feebates provide a sliding scale of fees on products to activities with above average emission rates and a sliding scale of rebates for products or activities with below average emission rates. Feebates, which would be applied by the finance ministry, can be more flexible and cost effective than emission rate regulations—the latter generally require extensive credit trading

[26] Climate benefits are highly uncertain but are taken here to be $75 per ton of CO_2, the price consistent with Mexico's mitigation pledge.

[27] Equivalently, efficiency costs measures losses in consumer and producer surplus net of revenue gains to the government (accounting for the erosion of pre-existing fuel tax bases). Effectively, efficiency costs primarily reflect the annualized costs of adopting cleaner, but more expensive, technologies, net of any savings in lifetime energy costs.

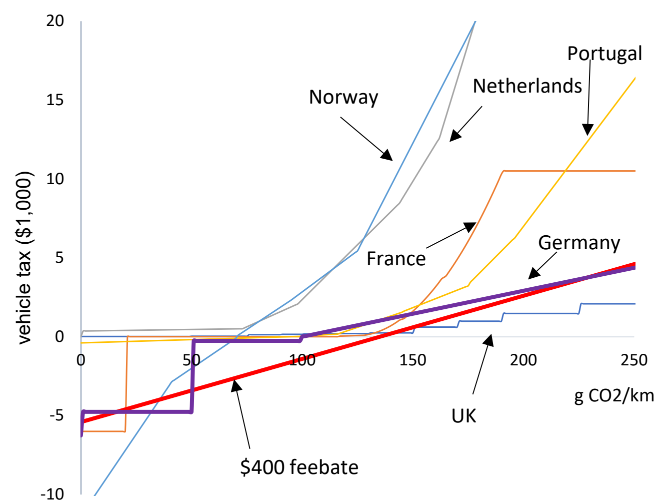
[28] For example, France's planned increase in its carbon tax was suspended in 2018 at €45 per tonne due to a public backlash against pricing.

provisions across firms and time whereas feebates, by design, automatically promote efficiency without the need for additional trading provisions. And feebates can be implemented quickly with minimal administrative cost, at least in sectors (e.g., transportation, power, industry) where they would build off existing capacity for vehicles taxes and the ETS. The discussion below considers in turn instruments for transportation, power, industry, buildings, forestry, extractives, and agriculture.[29]

A. Transportation

43. Road transportation is especially difficult to decarbonize through carbon pricing (or higher gasoline and diesel excises) alone due to the relatively modest impact it has on retail fuel prices and public resistance to higher road fuel prices. Besides applying fuel taxes, the Mexican government sets CO_2 emission rate standards for cars (averaged across manufacturers' sales fleets)—current standards are 136 grams CO_2/km[30] but these are relatively lax compared with those in many advanced countries.[31] Electric vehicles made up only 0.1 percent of new vehicle sales in 2018.[32]

Figure 16. CO_2- Based Components of Vehicle Taxes, Selected Countries



Sources: ACEA (2018); IMF staff calculations.
Notes: Feebate assumes a fleet average emission rate of 135 g CO_2/km. Circulation taxes for Germany are expressed on a lifetime basis assuming a 13-year life and 7 percent discount rate.

44. 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 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:

$$CO_2 \text{ price} \times [CO_2/\text{km} - CO_2/\text{km of the new vehicle fleet}] \times [\text{average lifetime vehicle km}]$$

Emission rate data by model type currently used to administer the CO_2/km standards provides the data needed to assess the fees and rebates for each vehicle. The feebate:

[29] See Altamirano and others (2016) for a discussion of broader measures (beyond pricing and feebates) to implement Mexico's climate mitigation strategy.

[30] ICCT (2017), pp. 29.

[31] In the EU current standards are 95 grams CO_2/km and these will be progressively tightened by a further 37.5 percent by 2030. See https://ec.europa.eu/clima/policies/transport/vehicles/regulation_en.

[32] CT (2019).

- 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;[33]

- 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.

45. For illustration, a feebate with a price of $400 per ton of CO_2 would provide a subsidy of $5,500 for zero emission vehicles and apply a tax of $2,600 to a vehicle with 200 grams CO_2/km (see Figure 16). Many European countries impose higher taxes on emissions-intensive vehicles, though the share of these vehicles in sales fleets is smaller than for Mexico. 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 electric vehicle battery technology).

46. Broader reforms using other fiscal instruments could address other transportation externalities while maintaining government revenue. One key reform would be to introduce charges on passenger vehicle use related to km driven that vary with the prevailing degree of road congestion (i.e., charges per km would be higher for driving in congested conditions than non-congested conditions)—this approach would more efficiently manage road congestion while enabling a transition to a robust funding source as the base of fuel taxes is progressively eroded.[34]

B. Power Generation

47. Ideally a complementary instrument for the power sector—that avoids a significant increase in electricity prices—would cost-effectively exploit all behavioral responses for reducing the emissions intensity of generation. These responses include: (i) shifting from coal to gas; (ii) shifting from coal and gas to renewables;[35] (iii) shifting from coal and gas to nuclear and fossil fuel plants with carbon capture and storage (these two responses however are excluded from IMF staff modelling); and (iv) efficiency improvements which lower the use of coal and gas required to generate a kWh of electricity (e.g., by reducing heat loss during fuel combustion).

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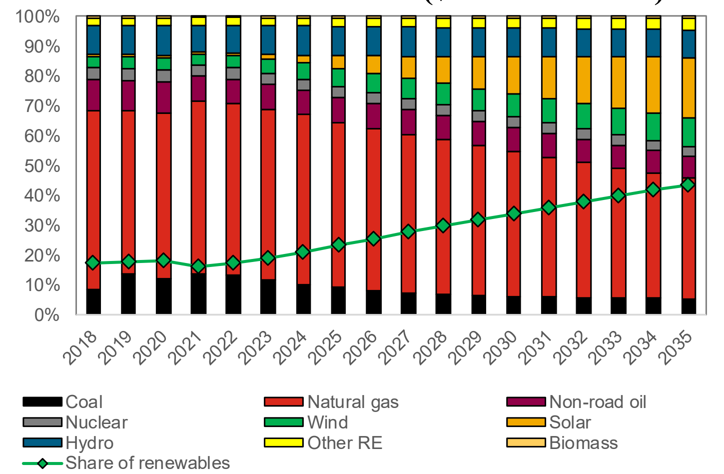
[33] Vehicle manufactures are therefore rewarded for going beyond prevailing CO_2/km standards (and penalized for not meeting them)—in this way, the feebate reinforces the existing standards.

[34] See Parry and Timilsina (2010) for a discussion of efficient road pricing for different vehicle types in Mexico City.

[35] In fact, Mexico has one of the most promising solar markets in Latin America—removing the import taxes on solar panels and reducing regulatory barriers would complement other measures in helping to promote solar energy.

48. All these behavioral responses are promoted under carbon pricing. Combined they account for about 65 percent of the CO_2 reductions in the power sector under a US$75 carbon tax in Mexico in 2030—the other 35 percent comes from reductions in electricity demand. Emissions reductions are cost effectively allocated across all these responses as the carbon price provides the same reward for reducing an extra ton of CO_2 across each response. Thus, the cost-effective generation mix in 2030 is 2 percent coal, 42 percent gas, 9 percent hydro, and 26 percent solar (see Figure 17). Regulations or fiscal incentives to promote renewable power generation promote a much narrower range of behavioral responses compared with carbon pricing—they only promote response (ii) above and they do not reduce electricity demand.

Figure 17. Projected Electricity Generation Sources and Share of Renewables ($75 Carbon Tax)



Source: IMF staff calculations.

49. Like carbon pricing, a feebate also cost-effectively reduces the emissions intensity of generation. Under a feebate a generator is subject to a fee depending on the average emissions associated with their generation given by:

$$CO_2 \text{ price} \times [CO_2/\text{kWh} - \text{pivot point } CO_2/\text{kWh}] \times \text{electricity generation}$$

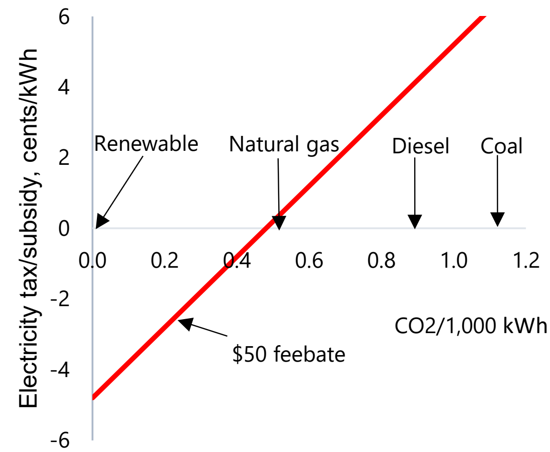
The generator has incentives to exploit any behavioral response that lowers their emission rates—this reduces fees implied by plants with emission rates above the pivot point rate and increases rebates implied for plants with emission rates below the pivot point. As with carbon pricing, the efficient allocation of responses is promoted, as a generator receives the same benefit for any response that cuts CO_2 by an extra ton. Feebates can be (approximately) revenue neutral if the pivot point reflects recent industry average emission rates. And an exogenous trajectory of future pivot point emission rates can be set based on expected declines in future emission rates, to preserve approximate revenue neutrality. 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. Capacity requirements for implementing a feebate are minimal given that generation emissions are already monitored under Mexico's pilot ETS.

50. For illustration, a feebate with price US$50 per tonne would apply fees equivalent to 6.6, 4.3, and 0.2 cents per kWh for coal, diesel, and natural gas generation, while providing a subsidy of 4.8 cents per kWh for renewables (Figure 18). Fees would increase, and subsidies for renewables decline, as the pivot point emission rate is updated over time.

C. Industry

51. Energy-intensive sectors such as steel, chemicals, metals, cement, glass, and paper generate most industrial GHGs in Mexico. About 60 percent of the emissions are from fuel combustion in furnaces while 40 percent are process emissions.[36] Section V discusses policies to address the competitiveness impacts of carbon pricing. Here the discussion is about feebates that can complement carbon pricing and reinforce incentives for cleaner production processes in these carbon-intensive 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:

Figure 18. Illustrative Feebate for Power Sector



Source: IMF staff calculations based on 2018 data.

$$[CO_2 \text{ price}] \times [CO_2/\text{output} - \text{industry-wide average } CO_2/\text{output}] \times [\text{firm output}]$$

52. The feebate, which would apply to emissions from fuel combustion and process emissions, avoids a first-order 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 charges for remaining emissions. Again, the scheme could build off existing procedures for monitoring industrial firm emissions under the existing ETS.

D. Buildings

53. Oil combustion in homes (for space heating) accounts for only 4 percent of energy-related CO_2 emissions in Mexico but residential use of electricity accounts, indirectly, for a further 7 percent of emissions—reducing energy use in buildings is therefore a potentially important component of Mexico's mitigation strategy. 61 percent of electricity consumption by Mexican households in 2018 was used for appliances, 22 percent for air conditioning, and 17 percent for refrigeration.[37] Improving the energy efficiency of buildings through better insulation, and cleaner and more efficient heating equipment, including electric heating, is one channel for reducing energy use. Other energy reduction channels include energy-efficient lighting and appliances, digitalization to "smart" homes (such as optimal automatic adjustment of heating temperatures), and renewable energy-based water heating systems.

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[36] About one-fifth of process emissions are from metal manufacturing (e.g., CO_2 released during the production of pig iron used in steel manufacturing) and two-thirds from mineral production (e.g., CO_2 released during the burning of clinker to produce cement). See IEA (2021c), UNFCCC (2021). Industrial emissions are lightly regulated from an environmental perspective—energy efficiency regulations affected only 16 percent of industrial energy use in 2017 (IEA 2021b).

[37] Oropeza-Perez and Petzold-Rodriguez (2018).

54. Building renovation rates may, however, 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. In 2017, the government presented a roadmap for reducing energy consumption by 35 percent in the building sector through energy efficiency measures, and for constructing only near-zero energy buildings by 2050 (the roadmap also envisages that by 2030 all states will enforce an energy building code)[39]—Mexico does not however have an energy retrofitting strategy for existing buildings.

55. 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-based heating systems (for existing buildings), and a subsidy for electric heat pumps, could accelerate the transition to zero-carbon heating systems for pre-existing buildings. Feebate systems linked to the energy performance of buildings could also be integrated into property taxes to encourage energy saving renovations.[40]

E. Fugitive Emissions from Extractives

56. Most fugitive emission leaks from oil are from extraction while a sizeable portion for natural gas are also from processing, transmission, storage, and distribution.[41] Possibilities for mitigating fugitive emissions include: (i) reinjecting gas (for enhanced oil recovery) or storage (though the feasibility of this varies with the sedimentary rock); (ii) using methane for on-site or regional power generation; (iii) compressing the gas, or liquifying it, for sale; and (iv) improved maintenance of infrastructure for gas processing and distribution.[42]

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

[39] CT (2019).

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

[41] See https://di.unfccc.int/detailed_data_by_party.

[42] US EPA (2019).

57. Pricing schemes for fugitive emissions would promote the full range of responses for reducing emission rates and could be applied using default emission rates with rebating for firms demonstrating lower emission rates. Emissions monitoring technologies[43] generally provide only discrete measurements at a limited number of sites, though technologies are improving. Fuel suppliers might be taxed based on a default leakage rate with rebates to firms demonstrating lower leakage rates than the default rate through mitigation and installing their own continuous emission monitoring systems. Fugitive emissions are released within Mexican borders, and therefore should be priced regardless of whether the fuel is sold on domestic or world markets. Pricing approaches are more flexible and cost-effective than regulatory approaches imposing the same standard on all firms, regardless of their mitigation opportunities. For illustration, an emissions tax of $60 per ton on fugitive emissions would apply charges equivalent (prior to mitigation) of approximately $1.2 per barrel of oil and $0.2 per thousand cubic feet of natural gas under default emission rates—these charges are equivalent to about 2 and 6 percent of current supply prices.[44]

F. Forestry

58. 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. In its NDC, Mexico committed to unconditionally reduce CO_2 emissions from the forestry sector by 144 percent in 2030 from a BAU baseline of 32 million tons of CO_2 to negative 14 million tons.

59. 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 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[45]—to be revenue-neutral in expected terms (again, unlike an afforestation subsidy). And a feebate could be administered by the

[43] Including satellites, aircraft, drones, and remote sensing from vehicles.

[44] Calculations using data from https://di.unfccc.int/detailed_data_by_party and www.eia.gov.

[45] See Parry (2020) for details.

Ministry of Finance based on the registry of landowners used for business tax collection. Landowners who anticipate receiving rebates may offer political support for the program. Feebates have not previously been used in the forestry sector but they bear partial resemblance to environmental services payments programs that were first introduced in Costa Rica.[46]

60. 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.[47] 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.

61. 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 (LIDAR), 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.[48]

G. Agriculture

62. Agricultural GHGs can be reduced through several channels. Reducing livestock herds (particularly beef and dairy cattle) curtail methane releases from enteric fermentation (50 percent of Mexican agricultural GHGs) and nitrous oxide emissions from manure (20 percent), while reducing crops for human and animal consumption (18 percent) reduces nitrous oxide emissions from soils, especially where there is intensive chemical fertilizer

[46] 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).

[47] Sedjo and Marland (2003).

[48] Measuring above ground carbon only (usually about three quarters of the total) could also keep costs down. Along with 46 other developing countries, capacity is being developed to measure forest carbon inventories in Mexico under the REDD^{+} program (see www.forestcarbonpartnership.org).

use.[49] At the consumer level, shifting from meat and dairy products to plant-based and poultry diets would reinforce mitigation incentives.

63. Pricing 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 estimated indirectly using farm-level data (on livestock herds, feed, crop production, fertilizer use, and acreage) and default emissions factors.[50] Proxy emissions taxes would likely face strong political opposition and could cause significant carbon leakage as the tax burden can reduce the international competitiveness of Mexican farmers. A feebate approach is worth studying based, for example, on GHG equivalent emission rates per hectare or nutritional value.[51] 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).[52]

V. TRANSITION POLICIES

A. Distributional Incidence of Carbon Pricing and Use of Revenues

64. 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. Assessing the household incidence from higher energy prices is therefore important and measures that might be taken to counteract these burdens. Most of the burden of carbon prices on households comes indirectly as higher energy costs for industry are passed forward into higher prices.

65. A standard two-step approach is used here to assess the burdens on households from these energy price increases. First, an input-output table is used to calculate the effects on different categories of consumer goods (the table is adjusted for 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.[53]

[49] See FAO (2021).

[50] IPCC (2019).

[51] 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.

[52] See Batini and Pointereau (2021).

[53] Input-output tables used are those from GTAP and the household survey is from 2018. See Chepeliev (2020).

Figure 19. Mean Consumption Effect on Consumption Deciles Before Revenue-Recycling (Top) and After, Through a Mix of Labor Tax Reductions and Targeted Transfers on Average Households (Middle) or Wholly Targeted Cash Transfers on Regions (Bottom), for a $75 Carbon Price ptCO$_2$e in Mexico in 2030

Source: IMF staff calculations. Note: Top panels shows absolute (left) and relative to consumption (right) impact of the tax on consumption deciles before revenue recycling through increases in prices of energy and non-energy goods. Middle panels show absolute (left) and relative (right) impact when assuming 25 percent of revenues would be used for a targeted transfer (assumed targeting bottom 4 deciles with a 75 percent coverage and 25 percent leakage rate) and 75 percent for reducing labor taxes by raising lower income thresholds. Bottom panel shows impact on urban (orange) and rural (green) households when assuming all revenues are used to fund the same targeted transfer.

66. Modelling results show a $75 carbon price applied to all fossil fuel CO_2 emissions in 2030 imposes a burden on the average household of 2.7 percent of their consumption, and burdens relative to consumption decline, but only slightly, for higher income deciles (Figure 19, top panel). The burdens are largely driven by indirect increases in the price of general consumption goods. These estimates greatly overstate the net burden of carbon pricing on households in two regards. First, they ignore partially offsetting domestic environmental benefits, especially local air pollution mortality. Second, they ignore the benefits from recycling carbon pricing revenues.

67. Using revenues for targeted transfers and labor tax reductions could make the policy both pro-poor and pro-equity (Figure 19, middle panels). In principle, fully compensating the bottom 10, 20, and 30 percent of the income distribution would use 7, 10, and 17 percent of the carbon pricing revenues (though actual revenue needs would be larger if social protections involve significant leakage to higher income groups) and using a larger proportion could help achieve poverty and equity objectives. For example, using 25 percent of the revenues for a targeted, unconditional cash transfer aimed at the bottom four consumption deciles[54] and using 75 percent of the revenues to reduce labor taxes through increasing lower income thresholds would make the reform both pro-poor and equity-enhancing. On net, the bottom four deciles are better off from the reform with net benefits amounting to about 3 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 1.1 percent of consumption.

68. Separately, depending on use of revenues, the policy could be designed to enhance regional equity (Figure 19, bottom panel). Using all revenues for a targeted transfer this policy would enhance regional inequity as the rural poor would benefit more, by about 7 to 27 percent of annual consumption. However, there are sharp tradeoffs for efficiency by using revenues for cash transfers, which do not reduce the labor tax wedge.

69. As illustrated by this example, carbon pricing reforms can support broad government objectives like reducing poverty and tackling overall and regional inequities. Alternatively, revenue recycling through a reduction in labor taxes can offset 85 percent of the burden of carbon pricing on the average household. Or revenues could be used for achieving other objectives, such as for investments to meet Sustainable Development Goals which boost the economy and have important welfare benefits for the poor.[55] However, other just transition measures such as retraining and other employment support to carbon-intensive regions and industries may be needed.

B. Worker and Regional Assistance

70. Mexico needs to develop a national system of unemployment insurance, improve targeting of social benefits, and strengthen active labor market policies to address the

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[54] Assumes coverage rate (proportion of targeted that receive the transfer) of 75% and leakage rate (proportion of non-targeted wealthier households that erroneously receive the transfer) of 25%.

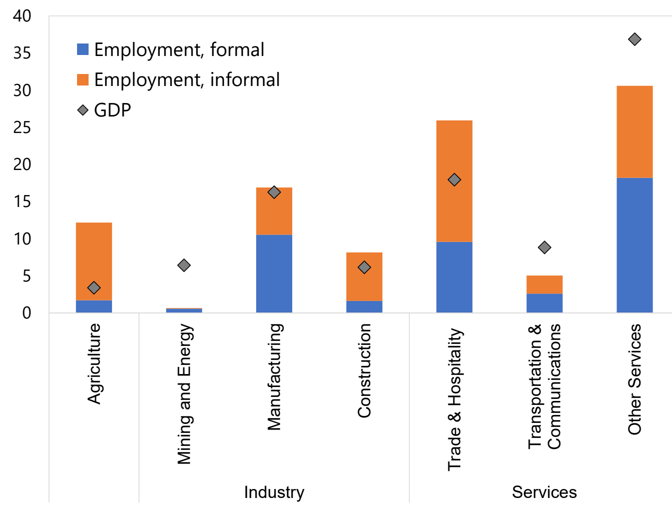
[55] See Gaspar and others (2019) and Jakob and others (2016).

employment impacts of the clean energy transition and climate change and to enhance the political viability of carbon mitigation. Measures could center around extended unemployment benefits, training and reemployment services, and financial assistance related to job search, relocation, and health care. Potentially useful features include outreach to increase awareness and take-up of the program, tailoring of job training to the needs of firms in energy-intensive sectors, and wage insurance or tax credits, especially for older workers. For the success of the program, beyond good design, the scale of support needs to be sufficiently generous. Attention should also be paid to the potential employment impacts of climate change on employment—see Box 4.

Box 4. Potential Employment Impacts of Climate Change and Mitigation

Mexico's labor market is characterized by a prevalence of informal employment, both as the large share of informal firms across firm-size categories and economic sectors, as well as the large share of employees who are employed in informal contractual relationships at formal firms. The main drivers of informality include an excessive regulatory burden including labor regulation, and an insufficient social protection system.[1] The most labor-intensive sectors are agriculture, domestic trade and hospitality services, and construction—those sectors are also dominated by informal employment. See Figure.

Employment and output shares, 2021Q1
(in percent of total)



Sources: Haver; ENOE

Climate risks. Climate change affect Mexico's labor market through impact on labor productivity and sectoral employment. Climate risks would have a larger impact on lower-income groups, informal workers, and poor - those who already experienced a heavier burden of the COVID-19 shock, thus increasing poverty.

Labor productivity. Higher temperatures have a potentially negative impact on worker productivity.[2] In the case of Mexico, some studies show that frequent heatwaves lead to a reduction in local employment, particularly for lower-wage work and non-farm labor. It also increases internal migration from rural to urban areas, and emigration to the U.S..[3]

Employment in tourism. The Yucatan Peninsula and the Caribbean coast, that support much of Mexico's tourism industry, are exposed to the economic effects of climate change as they have critical infrastructure such as hotels, roads, airports and ports that can be easily damaged by flooding events.[4]

Employment in agriculture and fisheries which will be affected by higher temperatures and more frequent droughts. Coffee production is projected to decline as droughts become more frequent.[5] There are also concerns about emigration due to declines in agricultural productivity.[6] And the Gulf of Mexico is home to eight major fishing ports and two industrial ports—greater prevalence of extreme weather events is expected to adversely affect these major economic hubs. Ocean acidification also presents a threat to fisheries in the area.

Box 4. Potential Employment Impacts of Climate Change and Mitigation (concluded)

Health and mortality. Other (indirect) impact on workers includes higher mortality as a result of outdoor air pollution, due to stroke, heart disease, lung cancer and chronic respiratory diseases. It tends to affect more the lowest income group and would add to pressure on Mexico's health system.[7]

Impact of mitigation policies:

Employment. Studies for various countries suggest the aggregate impact of decarbonization policies on employment is generally small. The higher energy prices may adversely affect employment in high-pollution industries (e.g. manufacturing of petrochemicals, iron, steel) and in less productive firms. On the other hand, environmental policies were found to have positive effects on employment and productivity of low-pollution industries and more productive firms.[9] The net impact would depend on the capacity of the labor market adjusts smoothly to policy-induced structural changes. According to ILO (2014), in Mexico economic activities with highest potential for green jobs are organic agriculture, green construction and manufacturing.

Informality. Similar to employment effects, higher carbon prices could reduce the share of informal firms through cleansing effect: informal firms, which tend to be less profitable and more financially distressed, could be forced to exit the market. The impact on share of informal employment within formal firms could be ambiguous. The carbon tax may increase share of informal workers within the formal firms to offset higher production costs resulted from the carbon tax. However, it may also incentivize firms to invest more into worker skills to raise labor productivity (similar to the efficiency wage theory), hence, promoting formal employment.

[1] See Alvarez and Ruane (2019), OECD (2021).

[2] For example, Burke and others (2015) and Kahn and others (2019).

[3] Jessoe and others (2018).

[4] See www.climatehotmap.org/global-warming-locations/cancun-mexico.html.

[5] Gay and others (2006).

[6] Feng and others (2010).[7] Cohen and Dechezlepretre (2019).

[7] IMF (2020), Chateau and others (2018), Yamazaki (2017).

[8] Dechezlepretre et al (2021). (The results are for a country sample of the OECD countries, including Mexico.)

71. **Support to affected regions needs to go beyond assistance to displaced workers because firm closures often take a toll on communities with limited alternative employment opportunities, and declining home values make it difficult for people to move**. Assistance for reclaiming abandoned drilling sites and temporary budget support for local governments could help to create jobs and to bridge the transition for adversely affected communities. Additional investments or other geographically targeted policies (such as subsidies or grants to individuals or firms in the affected regions) may also be warranted to help the regions engage in economically viable and sustainable opportunities.[56]

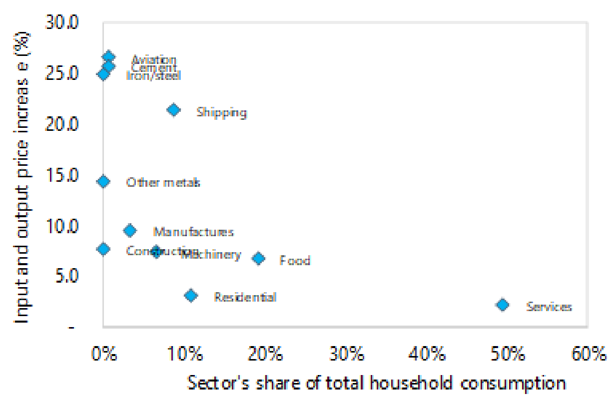
72. **Using carbon tax revenues to support complementary structural reforms aimed at reducing regulatory burden, strengthening social protection, and promoting**

[56] See WB (2018).

competition would enhance positive impact of mitigation policies on employment and could also reduce informality. The positive impact of green transition on employment was found to be stronger in countries with better quality of institutions.[57] The informal firms tend to be less compliant with existing regulation and invest less in environmental-friendlier production.[58] Since carbon pricing acts as a withholding tax for informal firms, it is more difficult to evade, hence, it could be more effective in reducing emissions relative to regulations in a country with a larger share of informal economy.

C. Addressing the Industrial Competitiveness Impacts of Carbon Pricing

Figure 20. Sectoral price increases by sector (% for $75 carbon tax in 2030)



Source: IMF staff calculations

73. Carbon pricing increases industrial production costs which may raise competitiveness concerns, especially for energy-intensive, trade-exposed (EITE) industries like aluminum, steel, cement, iron, chemicals, plastics, wood products, and textiles. Production cost increases have three components. First, industrial firms will incur a direct tax payment, or allowance purchase requirement, for emissions they continue to emit directly. Second, firms will incur abatement costs to the extent they cut emissions, for example, by switching to cleaner (but costlier) technologies and fuels. Third, they incur an indirect payment for carbon charges on emissions embodied in their inputs, especially electricity. At more modest abatement levels, the direct tax payment would be expected to be much higher than the abatement costs, though this is less likely at deeper levels of decarbonization.[59] A $75 carbon price in 2030 would increase prices for iron/steel and cement about 14 percent (relative to BAU costs in 2030) and other metals (e.g., aluminum, copper, and titanium) about 8 percent. See Figure 20. This may raise competitiveness concerns, especially for Mexican firms exporting to world markets, and policymakers may wish to consider measures to address these concerns. Some studies suggest however that carbon pricing may not have significant impacts on competitiveness[60] and industrial firms may benefit in part from recycling of carbon tax revenues (e.g., if they reduce labor tax burdens).

74. Unit production cost increases would tend to be larger for Asian emerging market economies (EMEs) than for Mexico and other countries in the American region.

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[57] Aldieri, Barra, Ruggiero, and Vinci (2021).

[58] Blackman et al (2006).

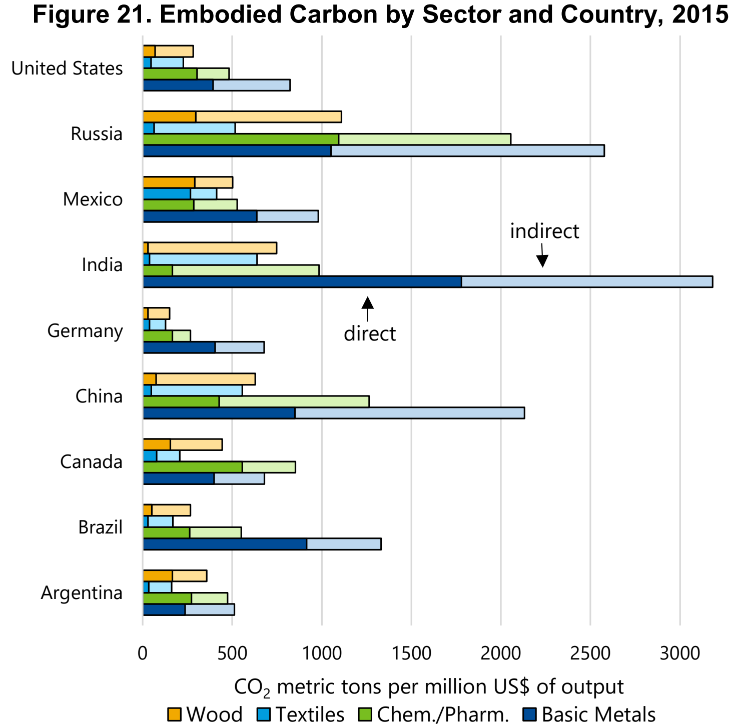
[59] See Keen and others (2021) for a graphical explanation.

[60] For example, Dechezleprêtre and Sato (2017).

For a given carbon price, unit cost increases would be larger for countries like China and India than Argentina, Brazil, Canada, Germany, Mexico, and the U.S., given the higher embodied carbon in industrial products in the former cases (Figure 21).

75. The currently envisioned mechanism of free allowance allocations for industrial firms to compensate Mexican firms for the cost increases under carbon pricing will ultimately become less effective with higher carbon prices and deeper decarbonization. This largely explains the growing interest in border carbon adjustments (BCAs) which have been proposed in the EU and are under consideration elsewhere (e.g., Canada, U.S.). Free allowances do not compensate firms for mitigation costs or charges on carbon embodied in their inputs allocations and they also forgo government revenue collection from firms receiving free allocations. A BCA imposes charges on the carbon content of imported products and may provide rebates for carbon embodied in exports—in this way it prevents a deterioration in competitiveness for a jurisdiction with carbon pricing. The net revenue impact of import charges and export rebates will vary by country, but the BCA allows the collection of revenue for carbon pricing on domestic firms.

Figure 21. Embodied Carbon by Sector and Country, 2015



Source: IMF staff calculations based on OECD Input-Output Tables.

76. For countries with ETSs (rather than carbon taxes) BCAs can take the form of an allowance purchase requirement for foreign exporters with rebates for allowance purchases from domestic exporters. A simple requirement to acquire allowances from a domestic ETS to cover embodied carbon for imported products (without changing the total allowances available in the ETS) may be undesirable as it would put upward pressure on, and increase uncertainty about, allowance prices. Another approach (proposed by the EU) would be to require importers to purchase allowances from a separate pool where the allowance price is aligned with the domestic ETS price—this scheme would be operationally equivalent to an import tax. The primary concern in Mexico however would be to compensate industrial exporters for domestic carbon pricing, and without undoing their mitigation incentives—this might be achieved through export rebates based on exogenous industry emissions benchmarks (rather than firm level emissions payments as the latter would undercut mitigation incentives).

77. There are several key features to consider in designing BCAs and these features have trade-offs in terms of addressing competitiveness, preserving domestic mitigation incentives, raising revenue, and limiting administrative and legal risks. Annex B provides a summary of the issues and legal uncertainties under the World Trade Organization (WTO) are discussed elsewhere.[61] Some noteworthy points include:

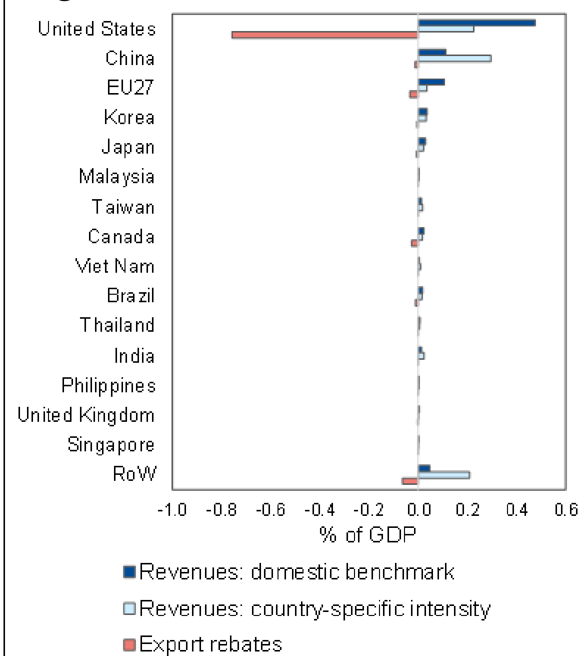
- Limiting the coverage of a BCA to EITE industries would simplify administration while focusing on the industries that are most vulnerable to carbon pricing and competition from foreign producers;

- Using domestic industry benchmarks to infer embodied carbon would preserve international competitiveness for Mexican exporters and simplify administration—it might however provoke legal challenges from trading partners with lower emissions intensity;

- In principle, BCAs could also be adjusted for carbon pricing in trading partners.

Current uncertainties over the legality of BCAs should be resolved in part as the EU and other countries move ahead with them, and their experience should provide lessons for others that subsequently adopt BCAs.

Figure 22. Potential Revenues and Losses



Sources: OECD TECO2; OECD BTDIxE; IMF staff calculations.
Notes: Embodied carbon data is from 2015.

78. A $75 BCA for EITE industries would raise revenues of about 0.9 percent of GDP in 2030 from import charges, however there would be approximately offsetting revenue losses from export rebates. The bulk of the revenue from import charges would, by far, come from U.S. exporters under a domestic industry benchmark, while under country-specific benchmarks slightly more revenue would come from China than the U.S. Nearly all the outlays for export rebates would be for exports to the U.S. See Figure 22. 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 because much of the import charge would likely be passed forward to domestic consumers in Mexico in the form of higher product prices.

79. A unilaterally implemented system of BCAs is not however an effective regime for scaling up global mitigation action. This is because BCAs only price emissions embodied in traded products which account for a minor fraction—usually less than 10 percent—of countries' total CO_2 emissions.[62] In contrast, an international carbon price

[61] For example, Keen and others (2021).

[62] Keen and others (2021), figure 9. BCAs do not price emissions from power generation, buildings, and transportation or from industrial firms selling to domestic consumers.

floor arrangement among large emitting countries would be far more effective, as it has much greater emissions coverage and coordinated international action on carbon pricing would be the most effective way to address competitiveness concerns. This approach would focus on a small group of large emitters (e.g., the G20 is 85 percent of global emissions) to facilitate negotiation. It could be designed equitably, with higher price floors for advanced countries and transparent compensation mechanisms for lower income EMEs, and flexibly, to accommodate participants for whom carbon pricing is difficult if they achieve equivalent emissions cuts through other policies.[63]

80. Meanwhile, Mexico could promote dialogue on a regional carbon price floor to facilitate more aggressive mitigation action and provide a prototype for price floors at the global level. Potential participants in a regional price floor might include countries with carbon pricing already in place, for example, Argentina, Chile, and Colombia in addition to Mexico. Participants would need to agree on a minimum trajectory of carbon prices that each would implement, emissions sources to be covered, and procedures for monitoring compliance (e.g., to deter chiseling on the agreement through lowering pre-existing fuel taxes).

VI. Investment Needs for Clean Energy Transition and Supporting Policies

A. Investment Needs for Clean Energy Transition

81. Model estimates suggest that reducing emissions to a level consistent with a 2°C temperature target would require increasing the projected global energy investment in 2030 (encompassing both public and private) from 2 percent of GDP to 2.3 percent of GDP (IMF 2019a; Figure 23.1).[64] The corresponding energy investment needs for Mexico are estimated at 1.7 percent of GDP (under the business-as-usual scenario) and 1.9 percent of GDP (consistent with a 2°C temperature target)—see Annex C. Thus, meeting temperature stabilization goals does not mean that overall energy investment must increase a lot.

82. The more important challenge for all countries, however, is to overhaul the composition of new investment, with the share of low carbon energy supply (renewables, nuclear, improved transmission and distribution networks, carbon capture and storage in power generation) rising from 40 percent in 2020 to 70 percent in 2035 and 80 percent in 2050 (Figure 23.2). According to REmap 2030, Mexico could generate up to 26 percent of its power generation by 2030 from renewable sources (wind and solar), hydropower, geothermal energy supplying, and biomass. While shifting the energy supply investment toward low carbon sources might require higher investment in renewables, total energy cost would nevertheless decline over time as renewables require less expenses for fuels.

[63] See Parry and others (2021c) for a discussion of international carbon price floors.

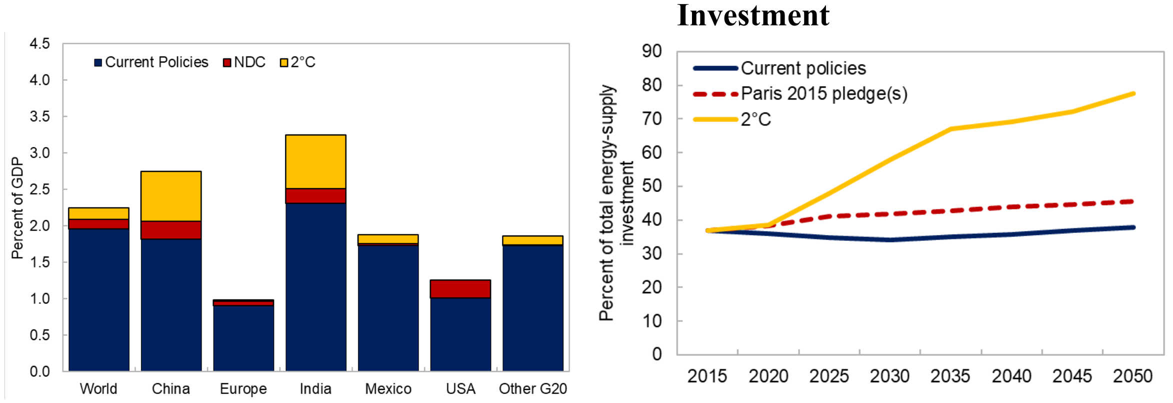
[64] Numbers for China, India, and the United States are obtained directly from the multi-model averages of McCollum and others (2018). Investment needs for Mexico and other G20 countries are those of the IMF staff based on estimates at the global level from existing studies (see Box 5 for details). Note that these numbers are subject to significant variation across models. Moreover, future technological breakthroughs and costs affect the size of investments. Adding investment needs for adaptation, the incremental investment needs would increase by a further 0.3 percent of GDP (April 2020 Fiscal Monitor, Chapter 2).

83. Energy infrastructure—for example, power plants and power grids—has an expected lifetime of 30–60 years. Choices made today will thus determine emissions for decades. Extra investment in energy efficiency is also needed for buildings (for example, design, heating, cooling, appliances), transportation (for example, electric cars), and industry. These demand-side investments can speed up the reduction in carbon emissions because of their shorter life cycles compared with energy infrastructure (IEA 2018).

84. Incremental investment needs would be greater if they also covered transportation and other infrastructure (water, sanitation, and telecommunication) that are essential to deliver the Sustainable Development Goals (SDGs), including SDG7 on clean energy access, and enhance the adaptive capacity to climate change (OECD 2017, IPCC 2018, and NCE 2018). **Taken together, incremental investment needs for climate change mitigation and adaptation in Mexico amounts to 0.5 percent of GDP (April 2020 Fiscal Monitor, Chapter 2).**

Figure 23. The Investment Challenge

1. Energy Investment Needs, 2030 | **2. Global Low-Carbon-Energy-Supply Investment**



Source: IMF staff calculations based on McCollum and others (2018).
Note: Paris 2015 pledges are those made by each country as part of the Paris Agreement in 2015. The Paris Agreement target is to be 'well below 2°C' while making effort towards 1.5°C but global pledges are currently not aligned with this.

B. Supporting Policies for Clean Technology Investment

85. Renewable energy resource base in Mexico is large and diverse. Given the right mix of policies (e.g., dealing with externalities and reducing risks for investors in renewable energy), the country has the potential to attract large-scale investment in renewables that can help diversify its energy supply and set Mexico on a pathway toward significantly reducing its GHG emissions. Policies that deal with environmental externalities (e.g., carbon taxation) are discussed in Section III.

86. Even with robust carbon pricing, investment in low-carbon technologies—essential for the transition to cleaner energy systems and thereby lower emissions—may be insufficient because of various technology-related market failures and impediments, including the following:

- Knowledge spillovers from R&D and technology diffusion that may prevent firms from capturing the full social benefits of developing and using new technologies;

- Scale economies that may deter firms from investing in a clean technology until they are confident about the size of the market;

- Network externalities where additional infrastructure needed for one investor (for example, to connect a remote renewables site to the power grid) could potentially benefit other firms;

- Market distortions that might impede low-carbon investment (for example, unfavorable business environment, regulated energy pricing, incomplete property rights); and

- Financial market imperfections reflecting limited financial instruments for low-carbon investments and the shorter-term horizons of investors.

87. There are several approaches for addressing these market impediments. These include public R&D support, targeted fiscal incentives (e.g., capital grants, tax credits, per-unit subsidies, feed-in tariffs), and regulations (e.g., on renewable generation shares) to deal with knowledge spillovers; public infrastructure investment (e.g., on charging stations for electric vehicles) to tackle network externalities; price liberalization and creating an enabling business environment to reduce market distortions; and financial sector policies.

88. Supporting policies should be part of a comprehensive strategy to promote supply-side investment in low-carbon technologies and demand-side energy-efficiency measures—including carbon pricing; fiscal incentives that are appropriately scaled, targeted, and designed; and direct public infrastructure investment. In this regard:

- Policy inconsistencies and redundancies should be avoided. For example, Mexico currently subsidizes renewables and fossil fuels at the same time. The preferential treatment of PEMEX and CFE insulates them from the improving competitiveness of renewables and might deter low-carbon investment from new entrants because they face disproportionately higher costs. Instead, the government should encourage competition in the power market to foster investments in clean energy and encourage retirement of the less efficient power plants.

- The government of Mexico could increase R&D support now and then gradually reduce support over time when technologies are widely deployed and used by firms and households. For example, public spending on energy R&D could focus on needed technologies currently furthest from the market that have strong social benefits (for example, smart grids, infrastructure for electric vehicles, and batteries to store intermittent renewable power). As the electricity generated from renewables is currently cheaper than fossil-fuel-generated power, subsidies to the former could be shifted from R&D to deployment (to achieve the necessary scale of production from renewables) and then progressively phased out.

- Production-based fiscal incentives, such as fixed subsidies per kilowatt hour of renewable energy, are more flexible than (i) investment-based incentives; (ii) regulations that force in the adoption of new technologies regardless of their future costs; and (iii) (commonly used) feed-in tariffs guaranteeing minimum prices per kilowatt hour that do not permit supply responses to changing market conditions (Löschel and Schlenker 2017). Regarding (iii), Mexico has moved away from pre-defined feed-in tariffs and have adopted tendering processes to reduce costs.

- Mexico should also increase public infrastructure investment to tackle network externalities (for example, funding of smart electricity grids to accommodate an intermittent supply of renewables). The new regulatory framework permitting the Mexican government to contract with private firms could alleviate the challenges of integrating wind into the power grid.

- Policies in the financial sector can help mobilize financing for climate change mitigation. Recent cross-country proposals have focused on fostering the financing of green projects and companies through (i) the establishment of standards, prototype green bond contracts, and benchmark indices of securities that meet environmental norms; (ii) amendment of prudential regulations and collateral eligibility criteria; and (iii) shifts in the portfolio choices of central banks and institutional investors (see IMF 2019a for details).

VII. Summary

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

- Define a net zero emissions target for 2050.

- Align the 2030 emissions target with the long-run targets.

- Build off the existing carbon tax and/or ETS to establish a carbon price that covers all fossil fuel emissions and rises predictably over time, insofar as possible aligned with the 2030 emissions target.

- Integrate a feebate into the vehicle registration tax system to promote adoption of clean vehicles.

- Consider feebates to reinforce mitigation incentives in the power and industry sectors without a significant tax burden on the average firm;

- 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;

- Use carbon pricing revenues for just transition measures and funding investments for Sustainable Development Goals;
- Consider more robust instruments for preserving international competitiveness with deeper carbon pricing, such as border carbon adjustments;
- Support low-carbon investments through enhanced competition; fiscal incentives that are appropriately scaled, targeted, and designed; and direct public infrastructure investment.

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ANNEX A. CARBON PRICING ASSESSMENT TOOL (CPAT)

The basic data on country level fuel consumption by sector, and fuel prices and taxes, along with projections of emissions and the impacts of mitigation policies is mostly taken from CPAT. CPAT provides, on a country-by-country basis for 191 countries, projections of fuel use and CO_2 emissions by major energy sector.[1] This tool starts with use of fossil fuels and other fuels by the power, industrial, transport, and residential sectors and then projects fuel use forward in a baseline case using:

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

In these projections, current fuel taxes/subsidies and carbon pricing are held constant in real terms.

The impacts of carbon pricing on fuel use and emissions depend on: (i) their proportionate impact on future fuel prices in different sectors; (ii) a simplified model of fuel switching and electricity dispatch within the power generation sector; and (iii) various own-price elasticities for electricity use and fuel use in other sectors.

The basic model is parameterized using data compiled from the International Energy Agency (IEA) on recent fuel use by country and sector.[2] GDP projections are from the latest (post-COVID) IMF forecasts in the World Economic Outlook.[3] Data on energy taxes, subsidies, and prices by energy product and country is compiled from publicly available and IMF sources, with inputs from proprietary and third-party sources (see below). International energy prices are projected forward using an average of IEA (which are rising) and IMF (which are flat) projections for coal, oil, and natural gas prices. Assumptions for fuel price responsiveness are chosen to be broadly consistent with empirical evidence and results from energy models (fuel price elasticities are typically between about -0.5 and -0.8).

Carbon emissions factors by fuel product are from IEA. Non-carbon externalities per unit of fuel use in different sectors are based on methodologies described in Parry and others (2014, 2021b).

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

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

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

One caveat is that the model abstracts from the possibility of mitigation actions (beyond those implicit in recently observed fuel use and price data) in the baseline, which provides a clean comparison of policy reforms to the baseline. Another caveat is that, while the assumed fuel price responses are plausible for modest fuel price changes, they may not be for dramatic price changes that might drive major technological advances, or non-linear adoption of technologies like carbon capture and storage. In addition, fuel price responsiveness is approximately similar across countries—in practice, price responsiveness may differ across countries with the structure of the energy system and regulations on energy prices or emission rates. The model also does not explicitly account for the possibility of upward sloping fuel supply curves, general equilibrium effects (e.g., changes in relative factor prices that might have feedback effects on the energy sector), and changes in international fuel prices that might result from simultaneous climate or energy price reform in large countries. Parameter values in the spreadsheet are, however, chosen such that the results from the model are broadly consistent with those from far more detailed energy models that, to varying degrees, account for these sorts of factors.

ANNEX B. DESIGN CHOICES FOR BCAS AND HOW THEY AFFECT MULTIPLE OBJECTIVES: A SUMMARY

Metric	Design Feature						
	Sectoral coverage: EITE industries vs. broader (all manufacturing, services, etc.)	Measuring embodied carbon		Rebates for domestic exporters	Revenue use	Lowering import charges for carbon pricing abroad	Exemptions for least developed countries
		Domestic vs. country-specific benchmarks	Recognize foreign firms with lower embodied carbon				
Protecting competitiveness of EITE industries	Either approach provides same protection	Country-specific preserves relative domestic/foregin prices despite carbon pricing	Little relevance	Preserves competitveness of exports	Little relevance	Appropriate for preserving level playing field	Little relevance
Limiting leakage	Broader coverage addresses leakage for more products but the benefits may be modest	Country-specific addresses leakage more efficiently	Little relevance	Reduces leakage	Little relevance	Can help reduce leakage	Little relevance
Promoting mitigation and carbon pricing in other countries	Broader coverage increases the base of charges on imports from trading partners	Country-specific provides stronger incentives on foreign producers and govts.	Gives incentive on foreign firm to reduce emissions	Little relevance	Little relevance	Promotes pricing but direct incentives may be modest	Little relevance
Mitigation incentives for domestic EITE industries	Either approach preserves incentives	Either approach preserves incentives	Little relevance	Preserves incentives if designed appropriately	Little relevance	Little relevance	Little relevance
Revenue implications	Broader coverage increases revenue from import charges (and revenue losses from export rebates)	Country-specific raises more revenue if trading partners have higher embodied carbon	Small reduction in revenue	Loses revenue	Not applicable	Reduces revenue	Forgoes some revenue
Administrative burden	Complex for broader coverage (more products, difficulties in measuring embodied carbon)	Administration for country-specific is more complex	Small if third parties provide verification	Additional burden but modest	Not applicable	Adds to burden, limited by EITE focus	Modest reduction
Risk of legal challenge under WTO	Leakage rationale more questionable for broader BCA	Domestic might help by reducing tariff and showing like treatment	Rebuttability provison should help with WTO compatibility	May be challenged as a subsidy	Using revenues for green transtion or intl. finance may reduce legal risks	May increase legal risks if not applied equally and equivalently across countries	Possible
Preliminary recommendation	***EITE*** *(at least initially)*	***Domestic initially to ease transition; later aim for country-specific***	***Yes***	***Yes***	***Consider environmental uses***	***Yes*** *(or mutual BCAs each with export rebates)*	***Yes***

Source: Keen and others (2021).

ANNEX C. METHODOLOGY FOR EXTRAPOLATING INVESTMENT NEEDS AT THE COUNTRY LEVEL

Using the contribution of each G20 country to total CO_2 emission reduction at the global level under Nationally Determined Contributions (NDCs) and 2°C scenarios (obtained from IMF 2019a and model-based projections from the literature), we calculate the slope of the marginal abatement cost (MAC) curve for G20 countries individually and collectively (the MAC shows the marginal cost of reducing emissions). We follow previous studies in postulating that the G20-wide total abatement cost (TAC) is a quadratic function of CO_2 emission reductions, or

$$\mathrm{TAC} = \theta(\Delta\mathrm{CO_2})^2 \,,$$

in which ΔCO_2 is the reduction in total CO_2 emissions at the G20 level from the reference scenario and θ is a scaling parameter. The MAC can then be derived as follows:

$$\mathrm{MAC} = 2\theta(\Delta\mathrm{CO_2}).$$

The slope of the G20-wide MAC curve can be estimated from model-based energy investment cost projections as

$$\beta = \frac{MAC}{\Delta\mathrm{CO_2}} = 2\theta.$$

Given that the G20-wide MAC curve is the horizontal sum of the individual-country MAC curves,[1] we can use β to calculate the slope of the MAC curve of country *i*:

$$\beta_i = \frac{MAC}{(\Delta\mathrm{CO_2})_i} = \frac{\beta*(\Delta\mathrm{CO_2})}{(\Delta\mathrm{CO_2})_i} = \frac{\beta}{\alpha_i} = \frac{2\theta}{\alpha_i},$$

in which α_i is the contribution of country *i* to total emission reductions, ensuring that emission abatement is achieved in the most cost-effective way.

The contribution of individual countries to total CO_2 emission reductions is known from the IMF spreadsheet tool (Annex 1.1 of IMF 2019a), so individual MAC curves can be estimated after solving for the scaling parameter θ. With a quadratic TAC function, the average abatement cost (AAC) is as follows:

$$\mathrm{AAC} = \theta(\Delta\mathrm{CO_2}),$$

implying that

$$\theta = \frac{AAC}{\Delta\mathrm{CO_2}}.$$

[1] The analogy is the following: the market supply curve is the horizontal sum of individual firm supply curves.

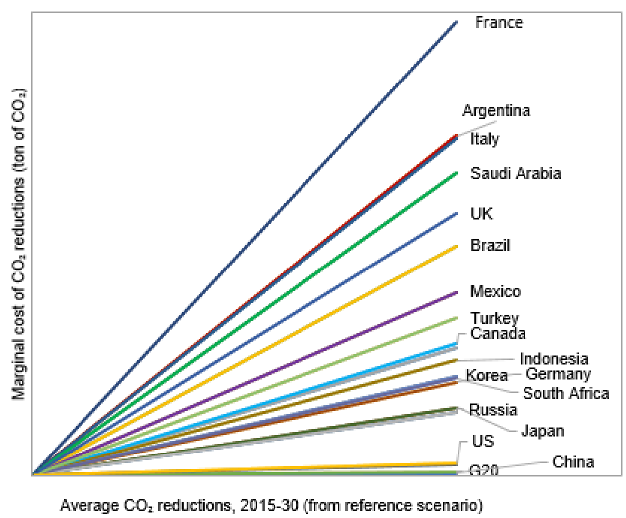
Hence, the individual MAC curve slope can be computed as

$$\beta_i = \frac{2\theta}{\alpha_i} = \frac{2}{\alpha_i} * \frac{AAC}{\Delta CO_2}.$$

Given that the total G20 investment needs under the Nationally Determined Contributions and 2°C scenarios are known from the literature, the average abatement cost per ton of emission reduction can be calculated and used to compute the slope of the individual G20 MAC curves (see Box 5 Figure 1 on MAC curves under the 2°C scenario). Once the slopes of the individual MAC curves are known, the total investment needs for an individual country *i* is computed as follows:

$$TAC_i = \frac{\alpha_i \beta_i}{2} (\Delta CO_2)_i{}^2.$$

Annex C Figure 1. Marginal Abatement Cost Curves for G20 Countries under 2°C Scenario



Source: IMF staff calculations based on McCollum and others (2018).