WORLD RESOURCES INSTITUTE

CHOOSING THE RIGHT PATH:

Low-Cost Policy Options for Enhancing Mexico's Climate Goals While Achieving Long-Term Social Benefits

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FOREWORD

Time is running short if we aim to achieve the goals set out in the Paris Climate Agreement and avoid unabated global warming. In Mexico, we are already witnessing the growing impacts of climate change to our livelihoods and ecosystems. We have seen that extreme weather events, particularly hurricanes and droughts, have increased in their intensity and frequency. We also have longer and hotter summers, with impacts on agriculture, ecosystems, and human health.

These impacts could become worse if Mexico and all nations do not act quickly to stabilize global warming below 1.5° C (2.7° F), warn the world's top climate scientists in a recent Intergovernmental Panel on Climate Change report. Transformational change is needed in all areas-- from the way we power our homes and businesses, to how we build new infrastructure and transportation networks to what sustainable agricultural and livestock practices we adopt to put food on the table.

WRI Mexico's new research shows that the country is not on track to achieving its long-term climate goal of reducing greenhouse gas emissions by 50 percent from the years 2000 to 2050. Nor is the country doing what is required to achieve the temperature goals of the Paris Agremeent to avoid runaway global warming.

The good news in our findings: pursuing ambitious climate and clean energy policies will benefit Mexico's economy, resulting in savings of US $5 billion in government expenditures over the next decade. It will also save more than 25,000 lives, by improving air quality for current and future generations.

The analysis builds on our 2016 publication "Achieving Mexico's Climate Goals: An Eight Point Action Plan," that used modeling tools and scenario analysis to demonstrate that Mexico can achieve its greenhouse gas emission reduction targets and significant cost-savings by taking steps like implementing a carbon tax, boosting industrial energy efficiency, and capturing methane from natural gas extraction sites.

Furthermore, WRI Mexico's research adds to the growing body of evidence that shows that climate action around the world is a smart economic move – a $US 26 trillion economic opportunity according to the New Climate Economy. Technological advances and the falling costs of renewable energy are making low-carbon, sustainable investments more cost-competitive with traditional fossil fuel-based technologies. For instance, UN Environment found that a record 157 gigawatts of renewable power was commissioned last year, far out-stripping the net 70 gigawatts of fossil-fuel generating capacity added in the same time period.

Also attractive are the potential side benefits of climate action: less polluted and more livable cities, resilient power and water systems, housing that can withstand increasingly frequent and severe climate extremes, and ecosystems that are more productive, robust, and resilient. This is a powerful argument in a country like Mexico, which is a relatively high greenhouse gas emitter, but still an emerging economy with legitimate aspirations to foster economic growth, create employment, and abate poverty.

We look forward to sharing this valuable research with you and to continuing the dialogue on how we can accelerate climate action and sustainable development during these urgent times.

Adriana de Almeida Lobo
Executive Director
WRI México

EXECUTIVE SUMMARY

This report aims to help policymakers identify what options could be included in a low-cost policy package (a combination of policies, measures, and technologies) to achieve Mexico´s GHG abatement targets and a more ambitious emissions trajectory, along with the benefits associated with both. The report addresses both current targets, included in Mexico's unconditional and conditional NDC to the Paris Agreement of 22 and 36 percent GHG mitigation relative to baseline, respectively, by 2030, as well as a more ambitious long-term target defined by Mexico in the General Climate Change Law in line with a 2°C global warming goal. Mexico has not set a target that is aligned with a 1.5°C goal.

HIGHLIGHTS

- This report identifies a mix of 21 policy levers with which it would be possible to achieve Mexico's conditional nationally determined contribution (NDC) at a low cost (at an average cost of US$12/ton).
- With the implementation of the proposed policy levers, greenhouse gas (GHG) emissions decrease from 902 million tons of carbon dioxide equivalent ($MtCO_2e$) in the reference case to 623 $MtCO_2e$ by 2030, a 31 percent abatement. The reference case is a business-as-usual (BAU) trend defined using 2016 prospective studies. If compared to Mexico's NDC reported GHG baseline (972 $MtCO_2e$), achieved abatement in 2030 reaches 36 percent below the baseline and is consistent with the unconditional NDC target.
- Overall, three sectors (electricity, transportation, and industry) contribute almost two-thirds of the abatement. The sectors with the greatest relative decrease in emissions are land use, land use change, and forestry (63 percent); waste management (52 percent); and electricity (50 percent).
- The implementation of the proposed conditional NDC policy package will require a significant capital investment. Nevertheless, its net effect is positive for the economy considering cost savings and cobenefits. It would also bring several cobenefits, including an estimate of over 25,000 accumulated avoided deaths by 2030 and over 38,000 by 2050.
- Implementation barriers include limited financial resources, lack of inter-institutional coordination, and lack of capacity. Overall feasibility varies by policy.
- Presently even if its NDC commitments were achieved, Mexico would not be on track to achieve its long-term strategy emissions abatement goal. To achieve Mexico´s GHG abatement goals, efforts should be made for implementing sectoral policies, securing financing, addressing implementation barriers, building capacity, and innovating.

To achieve this report's objective, we use the Energy Policy Simulator (EPS) model, which allows the user to estimate the effects of the application of different policies that affect energy use and emissions in various sectors of the economy. These policies come from a pool of policies with high abatement potential included in the EPS. Among them, there is a broad spectrum of levers such as a carbon tax, fuel economy standards for vehicles, reducing methane leakage from productive processes, and accelerated research and development (R&D) advancement of various technologies, among several others.

With the results from the model runs, we are able to estimate the level of effectiveness of different policy actions and mitigation packages (in terms of emissions, fuel type use, energy efficiency objectives) as well as the costs (or savings) involved. Furthermore, the EPS provides rough estimates of the main cobenefits linked to health impacts. Additional considerations, such as policy implementation barriers and what enabling conditions might be needed, are also included in the report.

We expect the outcomes of this analysis and scenario modeling exercise to be useful for policymaking in the years to come, especially to the newly appointed federal administration, when a path forward to achieve the NDC targets and a more ambi-

tious mitigation goal in line with the Paris Agreement may be established. It is thus very relevant to ask the question of what options are available for achieving Mexico's climate targets. Besides, not only Mexico but all countries should make additional efforts to substantially reduce their GHG emissions both in the short and long term since current NDCs will not be enough to achieve the mitigation of emissions needed to reach the goal of staying below 2°C warming, let alone 1.5°C.

The results presented in this report indicate that through the implementation of a technically feasible policy package, Mexico can attain GHG emissions reductions in line with its conditional NDC mitigation objectives. The selected policy package is composed of 21 policy levers across all sectors of the economy. These levers were identified through model testing and expert feedback.

Our analysis shows that Mexico can achieve its unconditional and conditional GHG reduction targets while saving money, through efficient operations and with cobenefits in public health. Policy implementation would require substantive total capital investment, close to $100 billion by 2030, and would be economically rational, with an estimated profit of $105 billion, considering cost-savings and cobenefits, in the same period.

The conditional NDC scenario simulates a carbon tax that grows linearly to reach $50/tCO$_2$e in 2030. The tax applies to the oil and gas, power generation, transportation, industry, agriculture, and waste management sectors. The tax is modeled as revenue neutral, and could contribute 19 MtCO$_2$e abatement and net savings of an estimated $35 per abated ton in 2030, due to the improved energy efficiency and shifts in consumption patterns. At this level, the tax falls within the range that is considered necessary to stay consistent with achieving a 2°C warming goal.

Presently, even if its NDC commitments were achieved, Mexico would not be on track to achieve its long-term strategy emissions abatement goal. This goal was set in absolute terms as 50 percent of the total emissions of year 2000 by 2050 and is roughly equivalent to per capita emissions of 2 tCO$_2$. It implies nearly a third of current per capita emissions. To achieve it, there is a need to move faster toward implementation, and to substantially increase ambition.

INTRODUCTION

Mexico has made great progress in terms of policy design and institutional arrangements to address the challenges posed by climate change. It has set ambitious GHG mitigation targets and is globally recognized as a climate leader, given its progressive positions in international fora. Still, the move toward effective cross-sectoral implementation of actions is slow. The identification and analysis of options to achieve Mexico´s targets and set more ambitious ones in a cost-effective way is expected to support Mexico in identifying and addressing areas of opportunity.

Mexico is recognized as a leader in international climate fora. It played a key role in getting the multilateral process back on track after the failure of Copenhagen's 15th Conference of the Parties (COP) meeting in 2009, up to COP 16 in Cancún one year later. It was the first country in the Global South to publish six national communications to the United Nations Framework Convention on Climate Change (UNFCCC), and to submit its intended Nationally Determined Contribution (iNDC) to the Paris Agreement.

It is also one of a handful of countries, and the only one in Latin America, to have presented its Mid-Century Climate Strategy. Often, because of its position as a developing country within the Organisation for Economic Co-operation and Development (OECD), Mexico has played a bridging role in negotiations, trying to provide middle ground for developing and developed countries to achieve a compromise.

To attain widespread recognition and to maintain a constructive position on climate negotiations, it has helped that Mexico's legal and institutional framework is relatively well developed. Thanks particularly to the General Climate Change Law (LGCC) approved by Congress in 2012 and updated in April 2018 to incorporate Mexico's NDC (DOF 2018), a comprehensive climate change system was put in place consisting of institutions across government levels and sectors, planning documents, and climate targets. Its capacity to tackle climate issues and to design policies has substantially improved over time, and a more participatory process now exists all throughout the climate policy cycle.

Moving from all this to actual policy implementation, however, is still a challenge. A recent evaluation of the Special Climate Change Program 2014–2018 (PECC), published by the National Climate Policy Evaluation Committee (INECC 2017), which was the first one done by this independent body whose creation was mandated by the Climate Change Law, states that, by the end of 2016, there was a delay in the implementation of PECC. Out of a total of 199 lines of action within the program (SEMARNAT 2014), 43 percent were progressing according to schedule, 28 percent had experienced delays, and the remaining 29 percent were no longer reported or were eliminated by the public agencies in charge of their implementation. Subsequent work by the Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) with the corresponding ministries updated PECC progress to almost 85 percent by the first quarter of 2018. Nevertheless, PECC's potential contribution to mitigation goals is relatively small since it only includes actions by the federal government, proposed by agencies themselves. Adding to that the fact that not all actions committed are implemented, its relevance is diminished.

A look at the latest official GHG emissions inventory (INECC 2018a) with reference year 2015 shows that total gross emissions during the last five years analyzed (2010–15) grew at a rate of 0.86 percent annually, going from 672 to 702 million tons of carbon dioxide equivalent ($MtCO_2e$). The annual growth rate of GHG emissions decreased from the average of the previous 10 years, 2000 to 2010, when it was in the order of 2 percent annually. Still, to achieve the unconditional NDC target, emissions from 2015 to 2030 should be limited to 0.55 percent annual growth. In the case of the conditional target, emissions should decrease 0.79 percent annually. There is clearly a gap.

Throughout the recent electoral process, some civil society organizations demanded that the next federal administration should move faster to achieve the goals set in law and to increase ambition in general (ICM et al. 2018). ICM et al. (2018) stated that the current policies are not enough to comply with Mexico's climate commitments. Some research groups have also questioned whether Mexico will be able to achieve its GHG mitigation targets, which are also deemed as insufficient to meet the goals of the Paris Agreement (CAT 2018). The need for greater speed of implementation and increased climate ambition seem to be the clear messages.

About This Report

The main objective of this report is to determine a low-cost policy package (combination of policies, measures, and technologies) to achieve Mexico's unconditional and conditional NDC mitigation targets (22 and 36 percent reduction of GHG emissions below the business-as-usual[BAU] baseline, respectively) by 2030. This analysis builds on the working paper, "Achieving Mexico's Climate Goals: An Eight Point Action Plan" (Altamirano et al. 2016), which used a previous version of the EPS-model. All inputs were reviewed, and significant updates were made with current official planning documents.

For the purposes of this report, a low-cost policy package is understood as the way to reach abatement targets through policies that have a net economic benefit or the lowest cost among available options. The EPS model is capable of combining different solutions and identifying those with the best result at a lower cost, relying on the Mexico version of the model, which was improved, to include additional levers to those considered in previous runs, refine sectors and update databases, and extend the modeling horizon up until 2050.

A further motivation driving the analysis relates to whether the policy alternatives assessed are implementable. In this respect it was important to conduct consultations with key stakeholders to get their input about financial, legal-political, and social feasibility.

A remaining question for further study has to do with socioeconomic impacts, which are relevant if we think of costs in a broader sense, to include not only financial costs and GHG abatement but also some implications for instance in gross domestic product (GDP), employment, or distributional impacts. This assessment may be done externally to the model, with an approach yet to be defined.

The report is organized as follows: After the introductory sections, where we set the questions and rationale driving the analysis, we move on to discuss the context and previous studies, in view of which this report is relevant. Then, we explain our research approach and results. Finally, we address feasibility factors and present main conclusions and findings.

Relevance

Since it was first published, the question of how much it would cost to achieve Mexico's NDC to the Paris Agreement had remained largely unanswered. Only until very recently did the National Institute of Ecology and Climate Change (INECC) estimate a cost of $136 billion, aggregated between 2014 and 2030 (INECC 2018b). The institute's assessment was based on a set of 30 measures across eight sectors that were originally considered as part of Mexico's unconditional target. Most of the specific measures, however, have not yet become concrete government commitments, leaving room to consider alternative combinations of measures. As a matter of fact, some stakeholders we consulted have expressed interest in considering alternatives. Additional elements that make this a valid concern are the rapid progress on the learning curve of key clean technologies, as well as the need to increase ambition globally in order to achieve Paris's targets, or a global warming of maximum 1.5°C, which would require a greater mitigation effort from all countries.

Besides, Mexico's NDC does not commit a specific set of actions to achieve the overarching goal of a 22 percent reduction of its GHG emissions by 2030, in regard to BAU, and a peak in emissions by 2026, except for a very small number of measures included in either the Climate Change Law, the

energy reform, or in Mexico's NDC (for instance, a clean energy penetration target of 35 percent by 2024 or net-zero deforestation by 2030). There are no other binding commitments, even less so for reaching the conditional target of 36 percent mitigation below BAU or the long-term (2050) strategy. With such flexibility, Mexico is open to exploring different pathways to achieve its goals.

It is therefore very relevant and opportune to ask what options are available for achieving Mexico's climate targets. The answer to this question will be fundamental for policymaking in the years to come, especially after the change of administration that took place in late 2018, when a path forward to achieve the NDC targets will have to be established.

The outcomes of this analysis should be particularly useful for the incoming federal administration, which has recognized climate change as the greatest environmental challenge facing the planet and one to which Mexico is highly vulnerable. Newly appointed officials have indicated that they will "adjust public policies in order to comply with the Paris Agreement" (NaturAMLO 2018).

It is important to stress that meeting the objective of the Paris Agreement requires not only compliance with mitigation targets set domestically but also increasing ambition globally in the context of sustainable development and poverty eradication (UNFCCC 2015). The Paris Agreement relies on all countries making additional efforts to reduce substantially their emissions both in the short and long term, as we will discuss in the next section of this report. Presently, the sum of all NDCs submitted to the Paris Agreement would not be enough to mitigate the emissions needed to be on a pathway toward the goal of staying below 2°C global warming (UNEP 2017). Achieving the ambitions of the current NDCs would not limit global warming to 2°C, even if supplemented by very challenging abatement efforts after 2030 (IPCC 2018). Significantly strengthened mitigation efforts are needed well before 2030 to reduce global emissions. Even assuming that the totality of the emission reductions pledged is achieved, we would be on a path toward a median warming of 2.7–3.7°C by the end of the century (CAT 2015).

Context

With the Paris Agreement reached at COP 21 in late 2015 (UNFCCC 2015), a major achievement for international climate negotiations was reached. For the first time in the negotiations' history, practically all Parties to the UNFCCC, regardless of whether they are developed or developing countries, proposed to contribute to reach a common objective of limiting global warming to a maximum 2°C above pre-industrial levels, with additional efforts to be made to not go beyond 1.5°C. Applying an innovative approach in multilateral processes, the agreement was built on the basis of NDCs that were meant to represent the countries' best efforts for adapting to climate change and mitigating GHG emissions. NDC implementation, particularly in the case of low-income countries, will be supported with appropriate mobilization of finance, capacity building, and technology transfer.

The initial set of national NDCs is insufficient to reach the collective long-term warming goal, even in the hypothetical case that they were fully implemented (CAT 2015). This was expected even at the time of the negotiations, so the Paris Agreement calls for periodic revisions of NDCs in order to reach a sufficient collective level of ambition (UNFCCC 2015). The Agreement also sets a transparency framework for tracking action and support. A stock-take exercise to assess progress will be done every five years. It was also agreed that several measures would be put in place to enhance action prior to 2020, including efforts to communicate new or updated NDCs. Countries are also invited to submit their long-term strategies (LTS) by 2020 (UNFCCC 2015).

In early 2015, Mexico became the first developing country to submit its iNDC in the lead-up to COP 21 in Paris (Gobierno de la República 2015). This document later became its NDC, once the Paris Agreement was ratified by Mexico on September 21, 2016. The document includes GHG and black carbon mitigation and adaptation goals, highlighting this country's high vulnerability to climate change.

The mitigation targets set by Mexico in its NDC are economy-wide and imply a relative deviation from a BAU trajectory (the baseline). The baseline

was projected from the National GHG Emissions Inventory 2013, using sociodemographic and economic growth assumptions, with official energy and industry prospective studies to define its trajectory. Projected emissions by 2030 are 972 $MtCO_2e$, and a peak would be reached in 2026. An unconditional GHG mitigation target of 22 percent and a more ambitious conditional one of 36 percent below the baseline, both by 2030, were defined. The NDC also sets black carbon targets and adds them to its GHG goals in CO_2e, using a conversion factor that lacks general consensus. The conditional target is subject to reaching "a global agreement addressing important topics including international carbon price, carbon border adjustments, technical cooperation, access to low-cost financial resources and technology transfer, all at a scale commensurate to the challenge of global climate change" (Gobierno de la República 2015).

Mexico has set longer-term targets since 2012 when the General Climate Change Law included what it called an "aspirational goal" of 50 percent reduction in annual emissions by 2050 with regard to absolute emissions in 2000 (DOF 2018). This target was later reflected in Mexico's Mid-Century Strategy (INECC 2016a), submitted to the UNFCCC at the end of 2016 as part of a joint effort of the countries in the North American region that had also previously signed the North American Climate, Clean Energy, and Environmental Partnership. By late 2018, Mexico was the only country in Latin America and one out of ten countries worldwide to have prepared and submitted its LTS.

The LTS was built from the 2013 National Climate Change Strategy and added additional modeling. It considers direct action in five important areas: clean energy transition, energy efficiency and sustainable consumption, sustainable cities, reduction of short-lived climate pollutants, and sustainable agriculture and protection of natural carbon sinks. The LTS also identifies critical crosscutting issues for long-term climate policy, including the need for market-based instruments to price carbon, increased innovation, more research and development of new technologies, and the need to build a climate culture with mechanisms for social and private-sector participation (INECC 2016a).

Although there are challenges for achieving implementation of climate action across all relevant sectors, whether with climate motivations or not, progress has been observed in recent years. One example of this relates to the energy reform that opened the oil and gas and electricity markets to increased competition, supplemented by clean energy penetration targets and economic incentives established in the Energy Transition Law passed by Congress on the eve of reaching the Paris Agreement. Another example widely referred to domestically and internationally is the carbon tax imposed on fossil fuels, which will be complemented with an emissions trading system, whose rules are currently in the process of publication. Recently, strict methane emissions regulations have been proposed and are going through the official revision process.

Building upon Previous Analysis

In 2016, WRI along with Centro Mario Molina (CMM) and Energy Innovation (EI), produced a working paper that identified and evaluated key climate and energy policies available to Mexico in support of the implementation of its iNDC (Altamirano et al. 2016). By applying a stepwise policy screening process (evaluating planned and potential policies in Mexico for GHG abatement potential, imple-

mentation cost, political feasibility, health benefits, and energy security), the study found that Mexico could meet its announced iNDC reduction targets while saving at least 200 billion pesos (around $11 billion at the time) and 15,000 lives cumulatively through 2030. Moreover, the study found that, by significantly enhancing existing policies and implementing additional ones, Mexico could reach its conditional mitigation target while still achieving cost savings.

The analysis was done using the first adaptation of the EPS model for Mexico (version 1.1.4) and provided a road map for meeting Mexico's iNDC objectives through the following eight-point policy action plan:

- Improve fuel efficiency in vehicles and industry and promote the switch to clean fuels in industrial activities.
- Strengthen actions to reduce emissions of non-CO_2 gases.
- Reduce distortions in the economy through introducing carbon pricing and phasing out fossil fuel subsidies.
- Increase capacity and efficiency in the electricity sector (transmission and distribution).
- Promote synergies with adaptation objectives (deforestation and reforestation) and other sectoral actions (agriculture).
- Prompt the transition to clean and well-designed transportation options.
- Increase energy efficiency in commercial and residential buildings.
- Develop a comprehensive, long-term strategy for achieving net-zero GHG emissions in line with the long-term goals in the Paris Agreement.

The working paper of 2016 provided tools to assess alternative pathways for Mexico to reach its NDC objectives. It did not aim to propose a parallel process to develop official road maps for Mexico but to provide inputs for internal discussion as well as comparative analyses of policies and models. The work was done in full consultation with the government and was not designed to replace domestic efforts on the NDC implementation plans.

After the release of the working paper, a round of discussions with government officials took place. They recognized the added value of this analysis for advancing toward NDC implementation. In particular they found helpful that it included a validation of modeling parameters, policies (trade-offs), and scenarios through stakeholder discussions (bilateral and in workshops); that key data gaps for effective policymaking were identified; and in general that it allowed them to have an alternative tool to contrast with standard macroeconomic models. This led to an explicit request from SEMARNAT for updating and refining the analysis, which led to the preparation of this report.

In summary, this report builds on the analysis of Altamirano et al. (2016) broadening the scope by including additional levers to those considered in the previous study, refining the way sectors are modeled, updating databases, and extending the modeling horizon to reach 2050. By having a longer time horizon, it was possible to better illustrate the effect of policies that show significant abatement potential post-2030; for example, efficiency standards for vehicles or buildings.

RESEARCH APPROACH

This report relies largely on a scenario analysis, whose basis is the Energy Policy Simulator (EPS) for Mexico. A previous version of the EPS was updated to reflect better the Mexican economy, as well as to extend the modeling horizon up to 2050, in line with the long-term climate strategy recently prepared and submitted by Mexico. The EPS is a national scale, economy-wide, system dynamics type of model, which has now been replicated in other countries.

Our research approach consists of a multi-tiered analysis, which begins by identifying the potential levers and policies to avoid or reduce GHG emissions and, subsequently, by identifying their cost of implementation. This is particularly important in long-term analysis because other approaches may produce solutions that may make a lot of technical and economic sense in the short and medium term but fall short in the long term and may block the implementation of measures that allow greater abatement (lock-in) at later stages. To support the elaboration of this comprehensive, economy-wide analysis, we chose the use of the EPS model, explained below.

BOX 1 | System Dynamics Modeling

A variety of approaches exist for representing the economy and the energy system in a computer simulation. The EPS is based on a theoretical framework called system dynamics. As the name suggests, this approach views the processes of energy use and the economy as an open, ever-changing, non-equilibrium system. This may be contrasted with approaches such as computable general equilibrium models, which regard the economy as an equilibrium system subject to exogenous shocks, or disaggregated technology-based models, which focus on the potential efficiency gains or emissions reductions that could be achieved by upgrading specific types of equipment.

The use of a system dynamics model allows for stock carry-over between periods, making it possible to register changes in capacities, populations/fleets, and accumulated benefits in comparison to a reference scenario; it also allows for a gradual change in parameters that does not require recalculating a general parameter for a specific sector. This is useful in the industry sector to allow for progressive improvements in efficiency.

Source: EI 2015.

The Energy Policy Simulator (EPS) Model

The criteria for choosing a model to answer our research questions was that it should be able to represent the entire economy and energy system with an appropriate level of disaggregation, be easy to adapt to Mexico, be capable of simulating a wide array of relevant policy options, and offer results that include a variety of policy-relevant outputs. We selected the EPS, which is a powerful system dynamics computer model (see Box 1) that estimates the effects of various policies on emissions, financial metrics, electricity system structure, and other outputs.

The EPS has a wide array of policy options available to advance the goal of mitigating GHG emissions and is useful for analyzing the effects of climate mitigation policies quantitatively, while accounting for interactions across policies and within sectors (e.g., it will not double-count policies with similar effects but will estimate synergic effects). This is useful, since policies enacted together often produce different results (such as more or less emissions abatement) than the sum of the effects of those policies enacted individually. Policies may also be specific to one sector or type of technology (for instance, light-duty vehicle fuel economy standards) or economy-wide (such as a carbon tax). Because the model assesses both, it may illustrate cases when, for instance, a market-driven approach, a direct regulatory approach, or a combination of the two can be used to advance the same goal.

The EPS was developed by Energy Innovation LLC as part of its Energy Policy Solutions project (EI 2015), as an effort to inform policymakers and regulators about which climate and energy policies will reduce GHG emissions most effectively and at the lowest cost. The EPS model has been continuously developed and improved since October 2015 (v.1.0.0). The current version (v.1.4.2), released in July 2018, is the one used in this study. The model is open source and widely documented. The model and the files for running and editing it, as well as extensive documentation can be obtained directly online (see Appendix A).

Structure and Functionality of the EPS

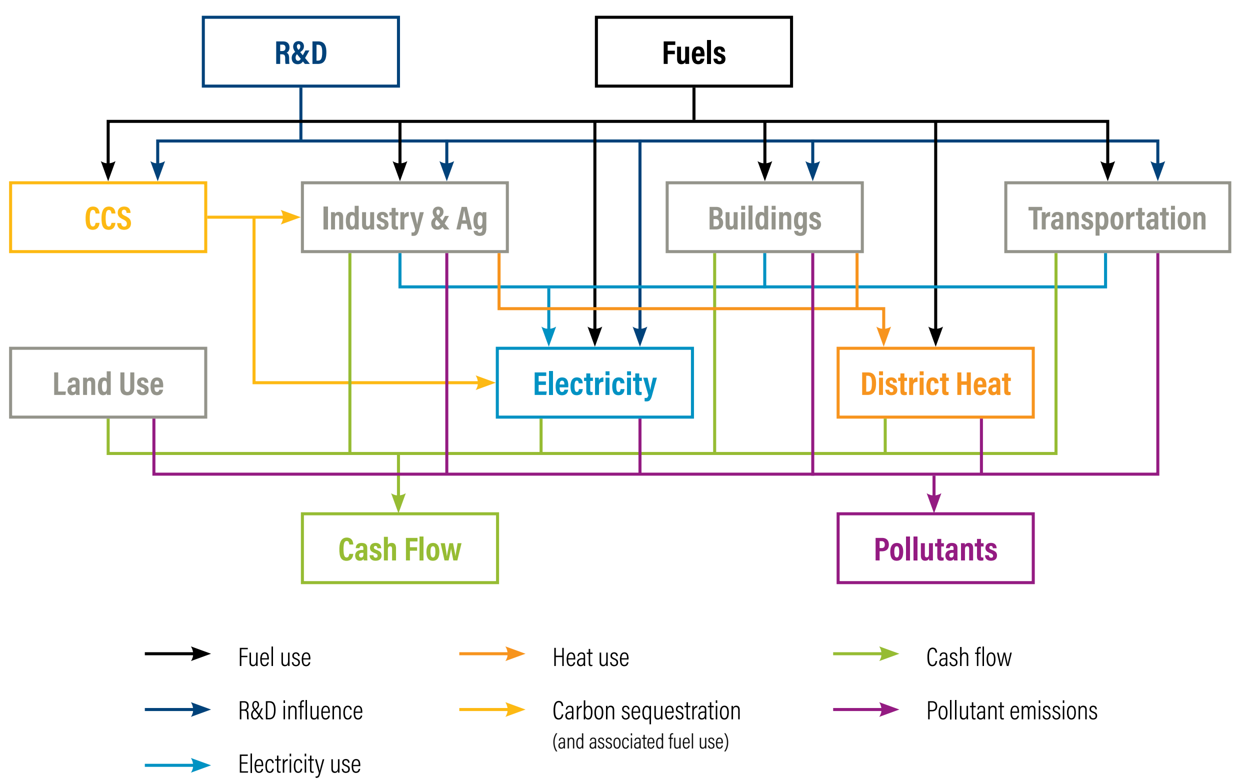
The EPS model runs in Vensim, a system dynamics modeling software by Ventana Systems Inc. In it, input data are read from flat files, which are, in turn, generated in well-documented Excel files for future reference.

The EPS model development included a web application with a high-level technical architecture that facilitates and simplifies model use and review. The web interface displays the most significant results of the model in easy-to-read and downloadable graphs that include emissions, policy abatement wedge diagrams, marginal abatement cost curves for selected policies, financials, social benefits, and specific results for each of the included sectors for each of the developed scenarios. The web application also includes a brief description for each policy, extensive documentation on model calculations and architecture, and clarification on how to design each policy well. The web application can be accessed at https://mexico.energypolicy.solutions.

The EPS uses a reference scenario that is affected in response to policy settings applied by the user. The reference scenario for Mexico was built into the model from official reports such as the National GHG Emissions Inventory (INECC 2018a), the National Forestry and Soil Inventory (CONAFOR 2009), energy use data from the Secretariat of Energy (SENER) prospective studies (SENER 2018), and from recognized technical studies, such as the Prospective Outlook on Long-Term Energy Systems (POLES) baseline model (Danish Energy Agency 2015) or the EPA Moves Mexico fleet projection (INECC 2016b). By following this approach, we were able to take advantage of existing work and official data, while providing novel capabilities to analyze policy options.

The model is designed to operate at a national scale and focuses on five sectors: transportation, electricity supply, buildings, industry (which includes oil and gas, agriculture, and waste management), and land use (see Figure 1). The model reports outputs at annual intervals from 2017 to 2050.

Figure 1 | Simplified EPS Structure Diagram



Note: Energy demand is determined in each sector (industry, buildings, and transportation) and fulfilled from fuel stocks or electricity generation, which in turn determines pollutant emissions and cash flows.
Source: EI 2015.

BOX 2 | Main Sources of Data by Component

ELECTRICITY

- System—SENER
- National Electric System Development Program 2018–2032 (PRODESEN)—SENER
- National Energy Balance 2016—SENER
- Energy Prospective 2017–2031
  - Renewable Energy Prospective
  - Natural Gas Prospective
  - Petroleum Industry Prospective
  - Electricity Sector Prospective

INDUSTRY

- National Greenhouse Gases and Compounds Emissions Inventory 2015 (INEGyCEI)—INECC
- Climate Change Mitigation and Adaptation Commitments 2020–2030—INECC
- National Climate Change Strategy Vision 10-20-40—SEMARNAT/INECC
- Energy Information System—SENER
- National Energy Balance 2016—SENER
- Energy Prospective Studies 2017–2031

TRANSPORTATION

- EPA MOVES Mexico onroad transportation fleet database—INECC
- Vehicle prices and fleet composition—INEGI
- Annual railway statistics—SCT
- Commercial aviation in numbers—SCT (1991–2016)
- Annual marine transportation statistics—SCT

BUILDINGS

- National household survey—INEGI
- Mexican Chamber of Construction Industry Annual Statistics—CMIC
- Energy Information System—SENER
- National Energy Balance 2016—SENER
- Distributed generation studies—CRE
- Land use, land-use change, and forestry (LULUCF)
- Reforestation, restoration, and maintenance costs report—CONAFOR
- National Greenhouse Gases and Compounds Emissions Inventory 2015 (INEGyCEI)—INECC

CROSS-SECTOR

- Energy Technology Perspectives (CCS)—International Energy Agency
- Air Quality Program for the Central Mexico Megalopolis 2017–2030—CAMe
- Air pollution impacts—INECC

Source: EPS Mexico 2018.

The EPS includes a built-in set of 58 policies comprising the main identified abatement actions in each sector. The EPS allows the user to control each of these policies and see, in real time, how they affect energy use and emissions. Among the policies included are a carbon tax, fuel economy standards for vehicles, control of methane leakage from industry, and accelerated research and development (R&D) advancement of various technologies. To better represent possible actions, the model allows for customized implementation schedules for different policies.

The model produces the following outputs:

- Emissions of 12 different pollutants: carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur oxides (SO_x), fine particulate matter ($PM_{2.5}$), and eight others, aggregating GHGs according to their carbon dioxide equivalency (CO_2e).
- Direct cash flow impacts (costs or savings) for consumers, industry, and the government.
- Health benefits, due to avoided mortality from exposure to pollutants.
- Electricity generation capacity and output by technology and fuel.
- Energy consumption by technology and fuel.

Input Data

The model has significant input data requirements and demands the use of a variety of data sources (see Box 2). In some cases, data requirements are very specific; for instance, the number of kilometers that passengers travel via different vehicle types, or the quantity of fuel used by different industries. Data selected for the model were validated by comparing against alternative sources.

To choose among available data sources, we used the following prioritization criteria:

- Data from Mexican government sources are always the preferred option.
- Second best is the use of data specific to Mexico, published by reputable sources, such as the International Energy Agency and the U.S. Environmental Protection Agency.
- When no Mexico-specific data were available, regional or international data were used to represent Mexico by proxy, adjusted by population, GDP, or other factors where applicable.
- Finally, when data were not available from any of the aforementioned sources, we extrapolated present-day values using projections of Mexico's GDP, population, or other relevant scaling factors.

The EPS Mexico considers six main components, aggregating the eight sectors generally reported in Mexico (see Table 1).

It is important to highlight that the model structure aggregates, under the Industry component, three sectors that are normally reported separately in Mexico: agriculture, waste management, and the industrial sector. The industrial sector is subsequently split into six subsectors: oil and gas, cement and other carbonates, iron and steel, chemicals, coal mining, and other industries. For the purposes of this report, we have analyzed oil and gas separately from the rest of the industrial subsectors due to the weight this subsector carries in Mexico and the fact that it is a mix between the public and private sectors.

The buildings component is subdivided into the urban residential, rural residential, and commercial subsectors. The commercial sector includes public or government buildings.

Table 1 | EPS Mexico—Sector Aggregation

EPS COMPONENT	INCLUDES:	ENERGY FLOW OR AREA
Electricity	Electricity	Energy generation
Industry	Oil and gas	Energy generation/use
	Industrial	Energy use
	Agriculture	Energy use/land use
	Waste management	Energy use/cities
Buildings	Buildings	Energy use/cities
District Heat	Not used in Mexico model	Energy use/cities
Transportation	Transportation	Energy use/cities
Land Use, Land-Use Change, and Forestry (LULUCF)	LULUCF	Land use

Source: EPS Mexico 2018.

The transportation sector reflects fuel demand and emissions from both on-road and nonroad public and private transportation. On-road transportation includes light duty vehicles (LDV), heavy duty vehicles (HDV) for passenger and freight use, and motorcycles. Nonroad transportation includes rail, ship, and aviation.

Land use is modeled in a more general way than other sectors, as it does not involve any energy use. Reference case land-use emissions are input from the National GHG Inventory. The potential for emissions abatement involves three forest policies: afforestation and reforestation, forest set-asides, and improved forest management. The level of implementation of any of these policies is a user-controlled setting. It is relevant to note that, consistent with Mexico's NDC baseline methodology, land-use emissions from land remaining (absorptions)[1] are not considered. In this report, only emissions from converted land are accounted for.

The electricity component determines emissions and changes in cash flow that derive from meeting electricity demand from the industry, buildings, and transportation sectors in the least costly way, within the technical and regulatory limitations represented in the model. This includes load factors, peak or nonpeak power generation, import-export capacity, flexibility points, power grid transmission capacity, and regulations such as renewable energy standards or bans on specific plant types.

The carbon capture and sequestration (CCS) component, includes both its contribution as a carbon sink at power plants and industrial facilities, as well as the energy demand required by the CCS process itself. Policies to promote the use of CCS technologies typically consist of sector- or economy-wide carbon pricing policies or emissions limits for facilities.

The district heat component is not used in the Mexico model as there is no widespread need or use of this technology. The component links to the industrial sector within the model, allowing for synergies with combined heat and power technologies (from heat demand in the commercial and residential sectors).

Model Limitations

The use of the EPS for the kind of analysis presented in this report may have the following limitations:

- The Energy Policy Simulator relies on various scientific studies and modeling results to establish the effects of policies on physical quantities and costs. The studies typically investigated these relationships under a particular set of real-world conditions. These conditions cannot reflect all possible policy settings that a user might select. Generally, the model's baseline case is likely to be closest to the conditions under which the various policies were studied by the creators of the input data. Therefore, the uncertainty of policy effects is likely smallest when policy levers do not represent significant changes to BAU; uncertainty increases as the policy package includes a greater number of policies, and the settings of those policies become more extreme.
- It is difficult to characterize uncertainty numerically for this model due to the fact that input data lack numerical uncertainty information. Even if such bounds had been available, it would have been difficult to carry them through the model to establish uncertainty bounds on the final result.
- Due to limits on available data that represent Mexico and the necessary use of scaled U.S. values for certain variables, certain policy responses may be larger or smaller in magnitude in the model than in reality. For example, average household income is lower in Mexico than in the United States, many price elasticities might be lower in the United States than in Mexico (since wealthier consumers are less price-sensitive), causing the estimated effects of these policies for Mexico to be conservative.
- Criteria for pollutant emissions abatement and its associated health benefits are determined as a rough estimation and are not region-specific. They serve only as an indication on the potential cobenefits of mitigation actions.

Stakeholder Engagement

As part of our research approach, the development of the model and its preliminary outputs were presented and extensively discussed in two workshops open to government institutions, independent organizations, international agencies, private-sector chambers, and recognized experts in the energy, transportation, industry, and land-use sectors. The initial (model development) workshop took place in March 2018. There, we presented information sources for the model and discussed better alternatives in terms of completeness or updated information, explored modeled abatement policies, and identified relevant actors for further discussion on specific subjects. The second (preliminary results) workshop took place in June 2018. In it, progress and initial outputs were presented, and additional proposals to strengthen the modeling exercise were discussed. During this workshop, participants had a chance to understand the use of the model's web tool to review current results in detail, propose different scenarios in general, or study methodologies for each of the model's policies at their leisure. With both workshops, we achieved the goal of introducing the modeling tool to potential users and increasing the robustness of the information sources and subsequent analysis.

Consultations took place as well during the process of writing up the working paper (Altamirano et al. 2016) that serves as a stepping stone for this report. These consultations were helpful for adapting the model to better represent Mexico.

Model Calibration

Once the EPS had all required input data and the model development stakeholder workshop had been held, the model was reviewed and calibrated. The calibration was carried out in a detailed process that involved a data consistency check and a sensibility analysis. The model was also tested against previous relevant mitigation analyses for Mexico. The most relevant and useful in this process, due to their level of detail, were INECC's 2013 NDC baseline, INECC's 2012 MAC curve, the 2050 calculator, and the Energy and Emissions balance done with the POLES model. Other studies were also used for spot checks of individual sectors or specific measures.

REFERENCE CASE SCENARIO

The reference case is an emissions trajectory against which to compare alternative abatement scenarios up to 2050. It can be thought of as a business-as-usual scenario, which does not consider any policy levers. It was defined taking into consideration a series of assumptions, and although it follows a similar trajectory, it should not be confused with the official emissions baseline referred to in Mexico's NDC, which extends up to 2030 only.

Reference Case Scenario

The model works with a reference case, which is built from the BAU input data and represents Mexico's current emissions trajectory across the modeled sectors, with no interference from additional policies and abatement actions.

This reference case can be summarized as follows:

- **PLANNING HORIZON:** base year 2016, modeling horizon 2017 through 2050: Determined from prospective studies on energy demand (fuels and electricity), emission factors for all pollutants and emissions from LULUCF. Detailed information from Mexico's prospective studies usually reaches 2030–31, so trends were extended from the final available data values to reach 2050.
- **SCOPE:** The model focuses on GHG emissions and associated criteria pollutants and the financial costs and benefits of implementation (considers capital expenditures and operating costs).
- **SCALE:** Mexico was modeled countrywide with no regional or political divisions, and national data were obtained from studies reporting a national total. The model includes every major sector of the economy.
- **UNITS:** GHG emissions are expressed in tCO_2e (or $MtCO_2e$ where indicated). Criteria pollutant emissions are expressed in thousand tonnes (metric tons). Costs are expressed in 2012 U.S. dollars.[3]
- **ASSUMPTIONS:** Compatible data sources were used as much as possible from prospective studies covering the same planning horizon and using the same base assumptions of population, gross domestic product, fuel prices, cost of capital, and set of policies and standards. The energy prospective considers Mexico's recent energy reform and energy transition legislation, the current carbon tax, and no carbon market.
- **ABATEMENT COST ASSUMPTIONS:** Any available abatement costs for Mexico from other studies were used as much as possible. When not available, regional or general data were used from respected sources.

It is important to note that Mexico's official GHG emissions baseline[4] and the EPS Mexico reference case do not represent the same thing. The baseline projects future GHG emissions without any climate-change mitigation actions, while the reference case projects a trend from our current standing (base year 2016). The reference case uses an updated GHG inventory and new projections on energy demand and fuel consumption (energy prospective studies).

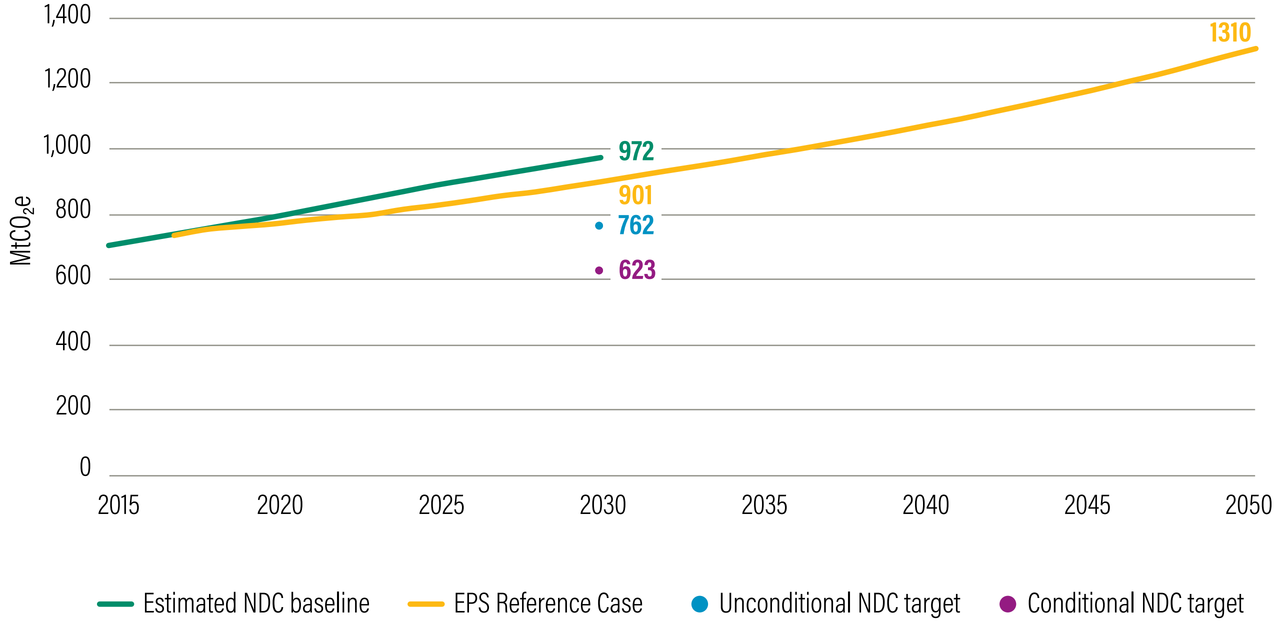
Any differences between them do not imply an increase or abatement in emissions, since most deviations correspond to differences in data. Even if the updated data may come from changes in the prospective case due to new policies or actions that affect current and future emissions, there are also differences in emission factors, activity levels, and methodologies, resulting in calculated emissions that do not correspond to the official determinations and are thus not fully comparable. In other words, the EPS model is not a substitute and does not strive to calculate emissions in the same way as the officially determined baseline does. As previously indicated, data were input into the model as defined by the EPS methodology and followed the logic of using the most updated and official values available.

Reference Case Scenario Trajectory

The reference case provides an emissions trajectory from which abatement is determined. It begins with 738 $MtCO_2e$ in 2017, growing to 902 $MtCO2_e$ by 2030, and reaching 1,311 $MtCO_2e$ in 2050 (see Figure 2). This corresponds to a 1.8 percent annual growth rate from 2017 to 2050. GHG emissions in 2017 are dominated by the electricity sector (22 percent), which grows at a slower rate than the total (0.8 percent) and reaches 16 percent of emissions by 2050 due to efficiency improvements. The sector with the highest emissions by 2050 is the transportation sector, which goes from 21 percent in 2017 to 24 percent by 2050, mainly due to vehicle fleet growth. Similarly, the industrial sector growth results in emissions reaching 20 percent by 2050, an increase from 16 percent in 2017. The oil and gas sector shows the steepest growth, at 3.4 percent annually, going from 9 percent of total emissions in 2017 to 16 percent in 2050. The agriculture and waste management sectors show growth similar to the total growth rate and retain a consistent share of emissions (13 and 6 percent, respectively, in 2050). The buildings and land-use sectors are the only ones that show a decrease in emissions in the reference case. This derives from expected efficiencies in the buildings sector and a trend in improved forestry actions (see Figure 3).

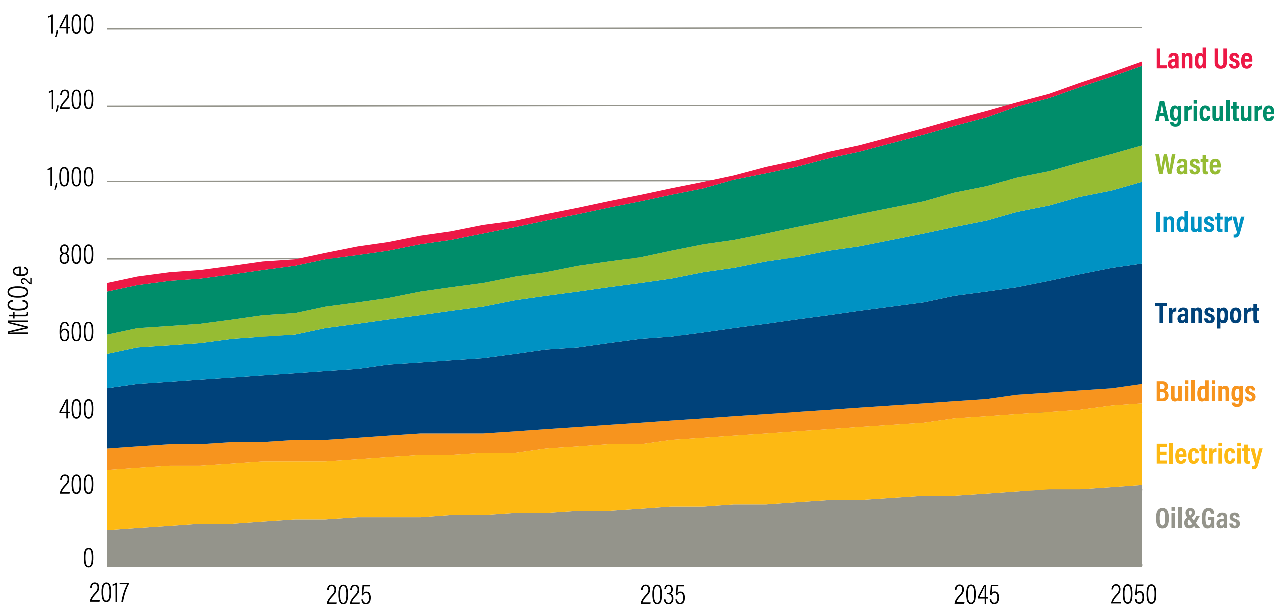
A comparison between the official NDC baseline (Gobierno de la República 2015) and the EPS reference case is useful for understanding their differences. Variations in the industry, waste treatment, agriculture, and land-use sectors result from differences in their source data. The NDC baseline was based on the National GHG Inventory 2013, while EPS relies on the updated 2015 version of

Figure 2 | Reference Case Scenario—Emissions Trajectory



Source: EPS Mexico 2018.

Figure 3 | Reference Case Scenario—Sector Split



Source: EPS Mexico 2018.

the inventory. On the other hand, variations in the buildings, oil and gas, transportation, and electricity sectors come from using different methodological approaches. Total emissions trajectories show a 3 $MtCO2_e$ (0%) difference in 2017, and a 70 $MtCO_2e$ (7%) difference in 2030 (see Table 2).

The following sections present the main results of the modeling exercise. We begin by describing the scenarios that were designed and analyzed and move from there to illustrate and discuss outputs in terms of relevant variables, such as emissions, costs and cobenefits of policy levers.

Table 2 | Comparison between EPS Reference Case Scenario and Estimated NDC Baseline by Sector

SECTOR	NDC BASELINE ESTIMATE 2017 ($MTCO_2E$)	EPS REFERENCE CASE 2017 ($MTCO_2E$)	DIFFERENCE	NDC BASELINE ESTIMATE 2030 ($MTCO_2E$)	EPS REFERENCE CASE 2030 ($MTCO_2E$)	DIFFERENCE
Buildings	27	55	28	28	53	25
Transportation	169	159	(10)	229	199	(30)
Electricity	136	160	24	202	164	(38)
Oil and gas	108	68	(40)	137	100	(37)
Industry	148	118	(30)	202	177	(25)
Waste	36	48	12	49	59	10
Agriculture	85	112	27	93	134	41
Land Use	32	18	(14)	32	16	(16)
TOTAL	**741**	**738**	**(3)**	**972**	**902**	**(70)**
			0%			**-7%**

Source: Gobierno de la República 2015; EPS Mexico 2018.

RESULTS

The comparison between alternative policy scenarios and the reference case illustrates potential gains in terms of GHG abatement during the modeling horizon, as well as costs and cobenefits associated. The main focus is on the conditional NDC scenario, which would get Mexico closer to an abatement of emissions aligned to the Paris Agreement global warming goals. Mitigation potential can be disaggregated by sector and lever. A mix of 21 policies was identified, on the basis of their mitigation potential, cost, and feasibility.

Two distinct policy scenarios were designed in this analysis:[5]

- The unconditional NDC scenario, with policy levers adequate to achieve Mexico's 2030 unconditional NDC target of 22 percent GHG abatement vs. baseline.
- The conditional NDC scenario, with policy levels adequate to achieve Mexico's 2030 conditional NDC target of 36 percent GHG abatement vs. baseline.

The emissions trajectory under each of these scenarios evolves as illustrated in Figure 4.

Conditional NDC Scenario Outcomes

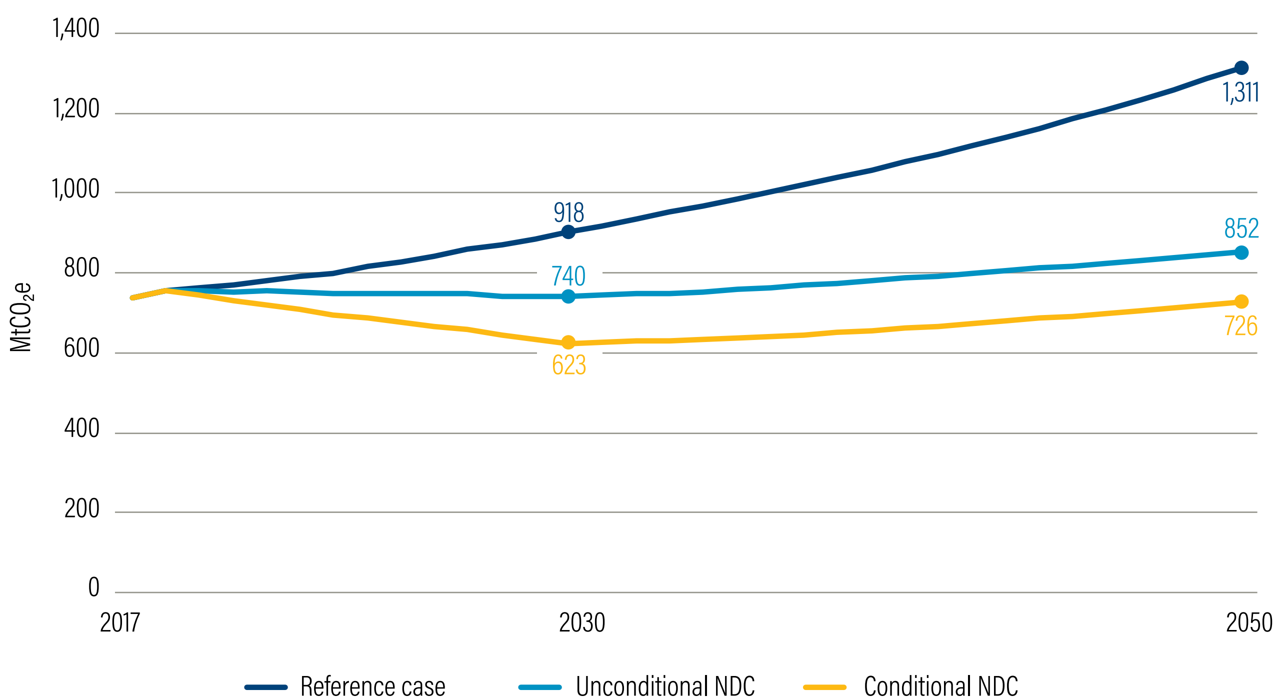
This report concentrates on the conditional NDC scenario, due to the fact that it is closer to the contribution required from Mexico to achieve Paris Agreement targets, but also because most of the conditions set to move along this more ambitious mitigation trajectory (Gobierno de la República 2015) have already been met. These conditions include reaching a global agreement addressing topics including international carbon price, technical cooperation, access to low-cost financial resources, and technology transfer.

The following section details the most relevant model outputs for the conditional NDC scenario. These are presented first in aggregate and then by sector. Outputs illustrate the effects of applied policy levers on GHG emissions and other relevant variables, such as electricity generation and consumption, vehicle fleet composition, or land use, depending on the nature of the policy.

Conditional NDC Scenario Policy Package 2017–2030

We identified a mix of 21 policy levers with which it would be possible to achieve the conditional NDC at a low cost. Policies were selected on the basis of feasibility, abatement potential, and marginal cost. Table 3 shows the description and level of implementation required for each one. The implementation level indicated for each policy lever in the third column indicates either a percentage of achieved technical abatement potential or a fixed input according to how it is modeled within EPS.

Figure 4 | EPS Mexico — Emissions Trajectories by Modeled Scenario



Source: EPS Mexico 2018.

Table 3 | Conditional NDC Scenario—Policy Package

POLICY	DESCRIPTION	POLICY IMPLEMENTATION LEVEL BY 2030, (% OF IDENTIFIED POTENTIAL)	POLICY EFFECT BY 2030	GHG ABATEMENT IN 2030 ($MTCO_2E$)
Fuel Efficiency				
Industry Energy Efficiency Standards	Increases efficiency of industrial equipment of all industrial subsectors by applying stronger standards, resulting in reduced fuel consumption.	20%	Increases rate of improvement in energy efficiency from 1.2% in the reference case to 1.44%, reducing energy consumption per year. Maximum identified potential is 2.4% per year.	20.6
Industry Cogeneration and Waste Heat Recovery	Reduces fuel consumption in the industry sector through cogeneration and improved heat conservation technologies.	100%	Reduces fuel consumption to maximum identified potential of 7.87%.	8.2
Cement Clinker Substitution	Substitutes a portion of clinker in cement composition with other inputs such as fly ash, resulting in reduced CO_2 emissions from clinker production.	100%	Reduces the proportion of clinker in cement to the maximum identified potential, from 84% in the reference case to 70%.	9.0
Non-CO_2 Emissions (Methane & F-Gases)				
Methane Capture	Reduces methane emissions into the atmosphere through capture and better containment and use in oil and gas production, mining, and waste management.	100%	Reduces emissions from uncontained and leaked methane to maximum identified potential: 39% reduction in the oil and gas sector, 5% in mining, and 24% in waste management.	44.8
Methane Destruction	Reduces methane emissions from the industry sector by increasing the burning of methane that is currently being released into the atmosphere due to industrial processes.	100%	Reduces emissions by destroying excess methane to maximum identified potential: 36% in mining and 1% in waste management.	8.4
F-Gases Reduction	Reduces emissions of F-gases (with high global warming potential) from the industry sector by improving production processes and by substituting less-harmful chemicals.	100%	Reduces F-gases to maximum identified potential: 81% in the chemical industry and 3% in the other industry sector.	13.3
Carbon Pricing				
Carbon Tax in the Electricity, Transportation, and Industry Sectors	This policy applies a tax on fuels used in the electricity, transportation, and industry sectors based on their greenhouse gas emissions.	50 USD/tCO_2e	The carbon tax increases fuel costs according to their carbon content and the base cost of capital equipment according to its embedded carbon content.	48.5

Table 3 | Conditional NDC Scenario—Policy Package (Cont'd.)

POLICY	DESCRIPTION	POLICY IMPLEMENTATION LEVEL BY 2030, (% OF IDENTIFIED POTENTIAL)	POLICY EFFECT BY 2030	GHG ABATEMENT IN 2030 ($MTCO_2E$)
Power Generation				
Renewable Portfolio Standard	Determines the fraction of electricity generation that must come from qualifying renewable sources (wind, solar, and biomass).	50%	Increases renewable energy penetration from 18% in the reference case to 48%.	16.9
Distributed Solar Carve-Out	Determines a minimum of the total retail electricity demand (in residential and commercial buildings) to be generated by distributed solar systems (typically rooftop PV).	15%	Increases distributed solar PV generation capacity from 1 GW to 20.9 GW in 2030.	9.4
Early Retirement of Power Plants: Hard Coal	This policy causes the specified quantity of otherwise nonretiring coal capacity to be retired.	750 MW	Reduces electricity generation from coal from 4.7 GW in the reference case to 0 GW by 2030, working in conjunction with other policies, such as carbon tax.	9.1
Land-Use (Agriculture and Forestry)				
Afforestation and Reforestation	Increases the sequestration of CO_2 by afforestation and reforestation actions. Planted forests are assumed to be managed (not used for timber harvesting).	100%	Additional afforestation and reforestation actions in 0.9 million hectares by 2030.	2.4
Forest Management	Increases CO_2 sequestration by forests through improved forest management practices, which include enhanced thinning techniques, longer rotation periods, and other changes to timber harvesting.	100%	Additional improved forest management actions in 4.5 million hectares by 2030.	4.5
Forest Set-Asides	This policy avoids the release of CO_2 from forests by reducing timber harvesting.	100%	1.3 million hectares of newly established Natural Protected Areas and Environmental Management Areas by 2030.	4.1
Cropland Management	This policy reduces GHG emissions from agriculture through cropland management practices, such as improved crop rotations, reduced soil tillage, and improvements in fertilizer composition and application.	50%	Implementation of actions to achieve 50% of identified technical abatement potential (9.5% cropland emissions abatement). Additional abatement would drastically increase cost.	2.0
Livestock Measures	This policy reduces GHG emissions from agriculture through livestock-related measures, such as feed supplements to prevent enteric fermentation and manure management.	50%	Implementation of actions to achieve 50% of identified technical abatement potential (5.7% livestock emissions abatement). Additional abatement drastically increases cost (up to 300% for full abatement potential).	18.8

Table 3 | Conditional NDC Scenario—Policy Package (Cont'd.)

POLICY	DESCRIPTION	POLICY IMPLEMENTATION LEVEL BY 2030, (% OF IDENTIFIED POTENTIAL)	POLICY EFFECT BY 2030	GHG ABATEMENT IN 2030 ($MTCO_2E$)
Clean Transportation and Mobility				
LDV Feebate	Sets a fee on the price of inefficient LDV to be rebated to buyers of efficient ones, increasing light-duty vehicle fuel economy. The feebate policy is revenue-neutral, all fees collected go into efficient vehicle rebates.	100%	Application of a best practice feebate rate of $727 (about $13,700 MXN) results in an increase of 48% in LDV average fuel economy for new vehicles by 2030 (11.7 to 6.1 km/L).	4.6
Fuel Economy Standards: Gasoline LDVs and Diesel HDVs	Set fuel economy standards for new light-duty vehicles (primarily cars and SUVs) with gasoline engines, resulting in an improvement in fuel economy (distance traveled on the same quantity of fuel with the same passenger loading).	100%	New LDV fuel economy increases from 11.7 to 20.2 km/L in 2030. Total LDV efficiency increases from combined policies result in a 40% emissions reduction per vehicle in 2030, partially offsetting increased emissions from fleet growth.	7.8
	Set fuel economy standards for new heavy-duty vehicles (trucks and buses) with diesel engines, resulting in an improvement in fuel economy (distance traveled on the same quantity of fuel with the same cargo loading).	66%	New HDV fuel economy increases from 2.6 to 3.2 Km/l in 2030. Total LDV efficiency increase from combined policies result in a 33% emission reductions per vehicle in 2030, partially offsetting increased emissions from fleet growth.	7.8
Low Carbon Fuel Standard	This policy specifies the percentage reduction in carbon emissions from the transportation sector that must be achieved via fuel switching.	10% of reduced carbon emissions.	Carbon emissions from transportation fuel use is further reduced by 10%.	13.9
Transportation Demand Management (TDM)	Implementation of TDM policies aimed at reducing demand for travel. Passenger TDM focuses on private automobiles and includes public transit systems, more walking and bike paths, zoning for higher density along transit corridors, zoning for mixed-use developments, roadway and congestion pricing, and increased parking fees. Freight TDM is aimed primarily at shifting freight from trucks to rail.	100%	Reduces travel demand to the maximum identified potential by the IEA-OECD BLUE Shifts scenario.*	15.8

Table 3 | Conditional NDC Scenario—Policy Package (Cont'd.)

POLICY	DESCRIPTION	POLICY IMPLEMENTATION LEVEL BY 2030, (% OF IDENTIFIED POTENTIAL)	POLICY EFFECT BY 2030	GHG ABATEMENT IN 2030 ($MTCO_2E$)
Energy Efficiency in Buildings				
Building Efficiency Standards	Use of tightened energy efficiency standards for building components in buildings. The policy only applies to new equipment each year (including new buildings or replacement of old components of existing buildings and retrofitting).	10% in heating; 20% in cooling and envelope; 33% in lighting and appliances; 10% in other components.	Energy demand in buildings decreases by 9%, from 1,019 PJ in the reference case to 942 PJ in 2030, due to the combined effect of increased standards.	5.3
Building Component Electrification	This policy replaces the specified fraction of newly sold nonelectric components in urban, rural, and commercial buildings with electric-powered components.	50% in urban and commercial; 30% rural buildings	Share of electricity used by building components increases from 41% in the reference case to 51% in 2030, resulting in a 17% increase in electricity demand but a 3.3 $MtCO_2e$ reduction in GHG emissions. Total energy demand decreases from electrification.	3.3

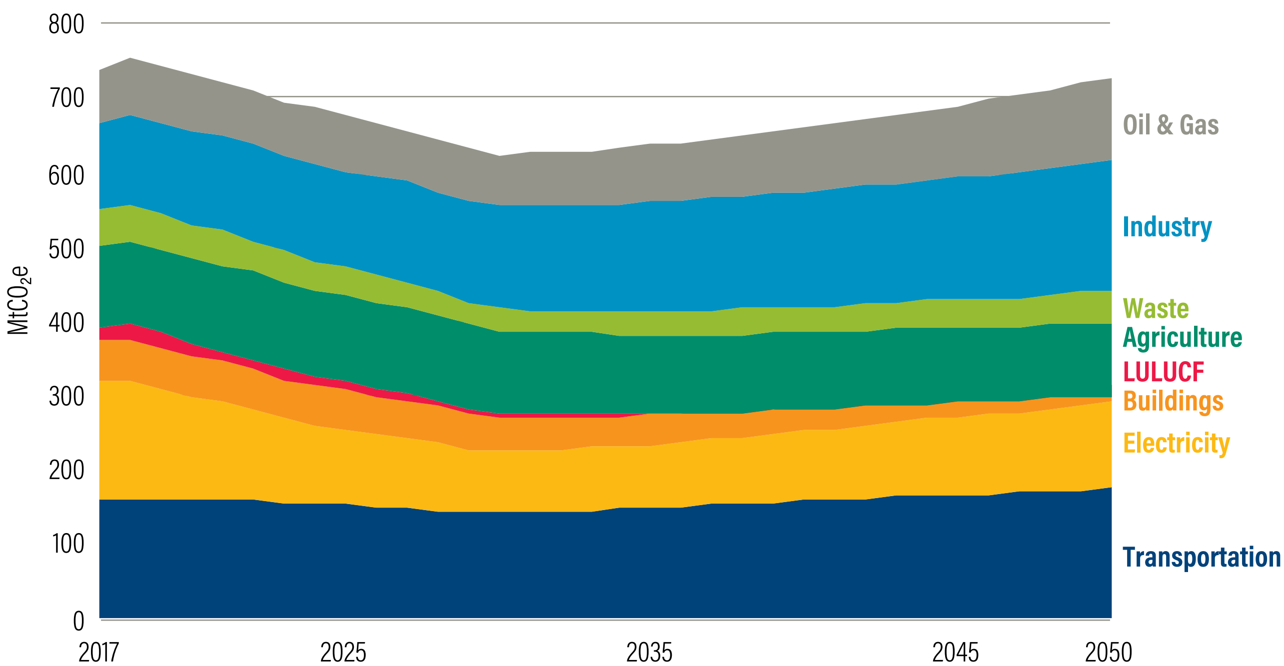
Note: *TDM policies come from the report "Transport, Energy, and CO_2: Moving toward Sustainability" (IEA and OECD 2009).
Source: EPS Mexico 2018.

GHG Emissions Abatement

With the implementation of the policy levers proposed in the conditional NDC scenario, GHG emissions decrease from 902 $MtCO_2e$ in the reference case to 623 $MtCO_2e$ by 2030, a 279 $MtCO_2e$ (-31 percent) abatement. Compared to Mexico's NDC reported baseline (972 $MtCO_2e$), achieved abatement reaches 349 $MtCO_2e$ (-36 percent). Overall, three sectors (electricity, transportation, and industry) contribute almost two-thirds (178 $MtCO_2e$) of this abatement (see Figure 5). The sectors that present the greatest relative decrease in emissions are LULUCF with 63 percent, waste management with 52 percent, and electricity with 50 percent (see Table 4).

In Table 4, we see an abrupt change in the GHG emissions trajectory in 2030. This is explained by the fact that implementation of policies, in accordance to the NDC time horizon, are modeled to reach maximum implementation in 2030 or earlier. From thereon, no additional policies are modeled, since abatement policy feasibility and technology evolution are unknown.

Figure 5 | Conditional NDC Scenario—GHG Emissions by Sector



Note: The total emissions line dips below the accumulated sector emissions due to the LULUCF sector becoming negative (a net carbon sink) by 2036.
Source: EPS Mexico 2018.

Table 4 | Conditional NDC Scenario—GHG Emissions Abatement by Sector in 2030

SECTOR	REFERENCE CASE 2030 EMISSIONS ($MTCO_2E$)	CONDITIONAL NDC SCENARIO 2030 EMISSIONS ($MTCO_2E$)	ACHIEVED 2030 ABATEMENT ($MTCO_2E$)	CHANGE
Transportation	199	143	-56	-28%
Electricity	164	81	-83	-51%
Buildings	53	47	-6	-11%
LULUCF*	16	6	-10	-63%
Agriculture	134	111	-23	-17%
Waste	59	29	-30	-51%
Industry	177	138	-39	-22%
Oil & gas	100	68	-32	-32%
TOTAL	**902**	**623**	**-279**	**-31%**

Note: *With relation to Mexico's NDC reports BAU baseline emissions (972 $MtCO_2e$ by 2030), the conditional NDC scenario projects a 349 $MtCO_2e$ abatement (36% vs. baseline) by 2030.
Source: EPS Mexico 2018.

By 2050, total abatement is equivalent to 42 percent of reference case emissions. We can observe in the long term a wider spread of the mitigation burden across sectors. Two sectors alone (transportation and electricity) contribute nearly 43 percent of total abatement. The LULUCF sector reaches negative net emissions by 2050, implying the net-zero deforestation targets have been met and the forestry sector becomes a net carbon sink absorbing 15 $MtCO2_e$ (see Table 5). We can observe

Table 5 | Conditional NDC Scenario—GHG Emissions Abatement by Sector in 2050

SECTOR	REFERENCE CASE 2050 EMISSIONS ($MTCO_2E$)	CONDITIONAL NDC SCENARIO 2050 EMISSIONS ($MTCO_2E$)	ACHIEVED 2050 ABATEMENT ($MTCO_2E$)	CHANGE
Transportation	317	175	-142	-45%
Electricity	212	115	-97	-46%
Buildings	48	25	-23	-48%
LULUCF	13	-15	-28	-215%
Agriculture	167	98	-69	-41%
Waste	84	42	-42	-50%
Industry	261	175	-86	-33%
Oil & gas	209	111	-98	-47%
TOTAL	**1311**	**726**	**-585**	**-45%**

Source: EPS Mexico 2018.

that, without further actions, Mexico is not on track to achieve its LTS goal of 50 percent abatement of emissions in absolute terms relative to year 2000.

Abatement Cost

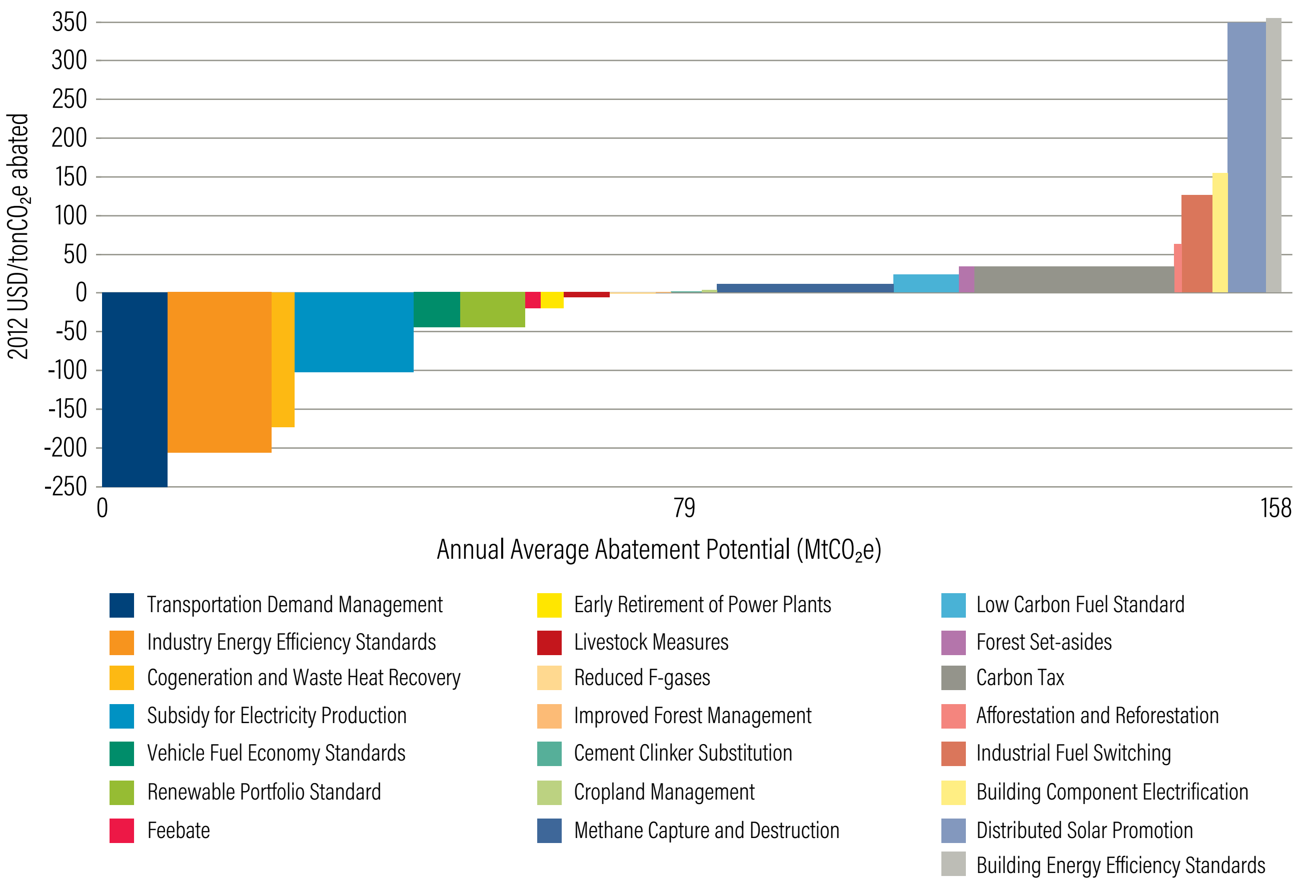
The marginal abatement cost curve (MAC curve) reflects Net Present Values (NPV) of individual policy levers (see Figures 6 and 7). MAC curves relate the NPV of the marginal abatement cost[6] per an extra ton of CO_2e emissions (shown in 2012 U.S. dollars, in the vertical axes), with each policy's abatement potential (shown in $MtCO_2e$, in the horizontal axes). The policies are ordered by increasing abatement cost. In other words, policies that represent a net savings (shown negative in the vertical axes) are the first ones from left to right. The magnitude of each policy's emissions abatement is illustrated by the width of its corresponding bar.

The MAC curves for the NDC conditional scenario by 2030 and 2050 are shown in Figures 6 and 7, respectively. Policies that have a strong abatement potential and represent a net revenue include transportation demand management, industry efficiency standards, and subsidy for electricity production. On the other hand, policies that represent a net cost (shown positive in the vertical axes) with a significant potential abatement are methane capture and destruction, carbon tax, and distributed solar promotion.

For the conditional NDC, our analysis shows that it is possible to achieve 62 percent of the 2030 target at negative net costs through policies that, although they require investments, often have relatively short payback periods, such as the ones relating to efficiency improvements. An additional 30 percent of the total conditional mitigation is possible at a cost under \$40/tCO_2e (see Figure 6). In all, 92 percent of the conditional NDC mitigation target could be achieved for under \$40/tCO_2e.

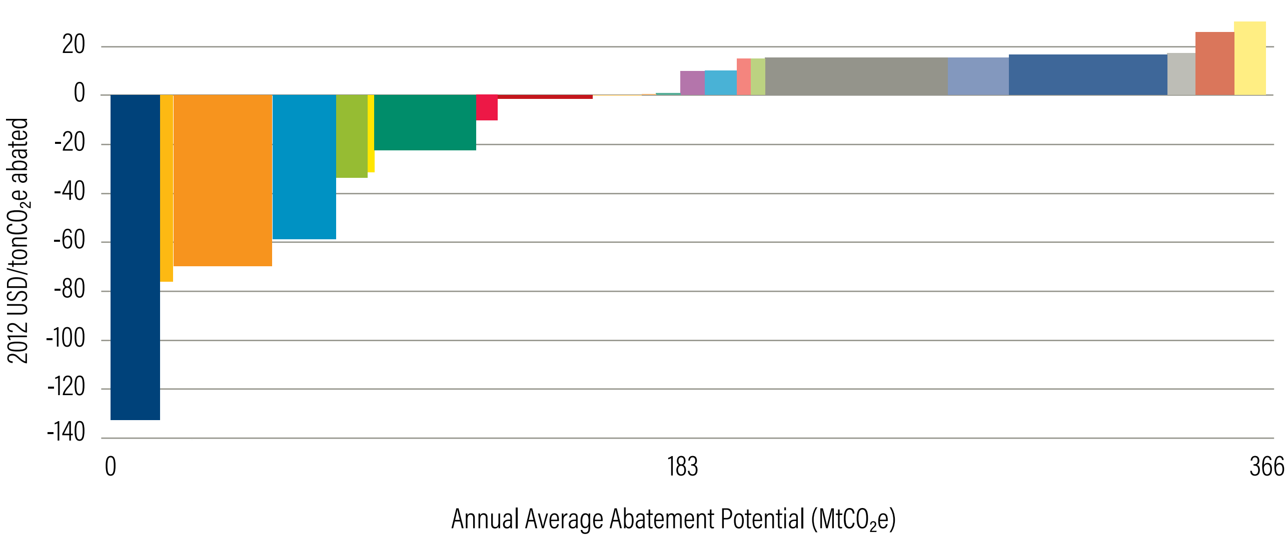
The implementation of the proposed conditional NDC policy package will require significant capital investment, up to 100 billion dollars (2016 U.S. dollars) between 2018 and 2030, which represents about 7 percent of Mexico's 2017 annual GDP (INEGI 2018), or roughly 0.8 percent annually if spread evenly across the modeled horizon. Nevertheless, the net effect will result in a positive impact to the economy, with an estimated \$105 billion in net present value by 2030. The model results show that climate mitigation, although it requires investments, would have a positive economic impact in the medium term.

Figure 6 | Conditional NDC Scenario—Marginal Abatement Cost Curve through 2030 (NPV)



Source: EPS Mexico 2018.

Figure 7 | Conditional NDC Scenario—Marginal Abatement Cost Curve through 2050 (NPV)

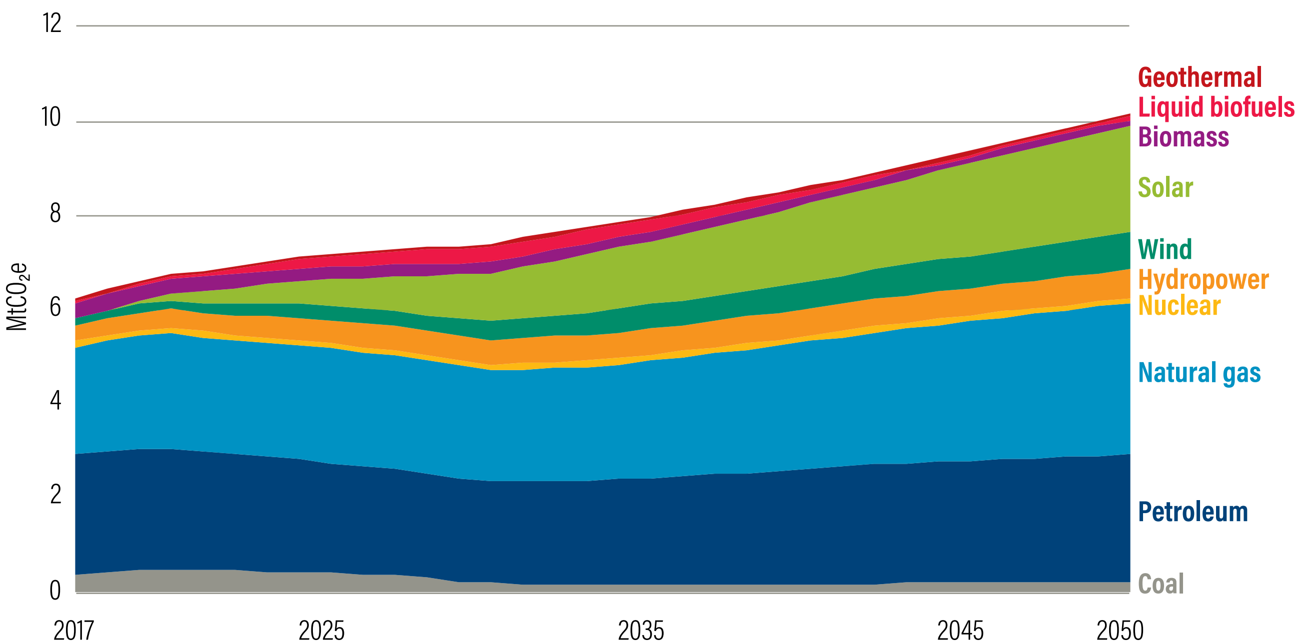


Source: EPS Mexico 2018.

Energy Use

In comparison to the reference case, the conditional NDC scenario implies a lower annual growth rate of primary energy consumption, going from 2.2 to 1.5 percent. Still, we can observe a continuous growth in primary energy consumption up to 2050, as well as a change in the relative contribution of each source (see Figure 8). The evolution of the energy consumption mix derives from the implementation of policies that facilitate an energy transition toward renewables. We can observe that solar and wind increase significantly from 2017 to 2030. Other clean sources (geothermal and nuclear) remain roughly constant through the modeled period. Regarding fossil fuel consumption, on the other hand, we can see only a slight increase in natural gas, while petroleum fuels remain constant and coal decreases.

Figure 8 | Conditional NDC Scenario—Primary Energy Consumption by Source



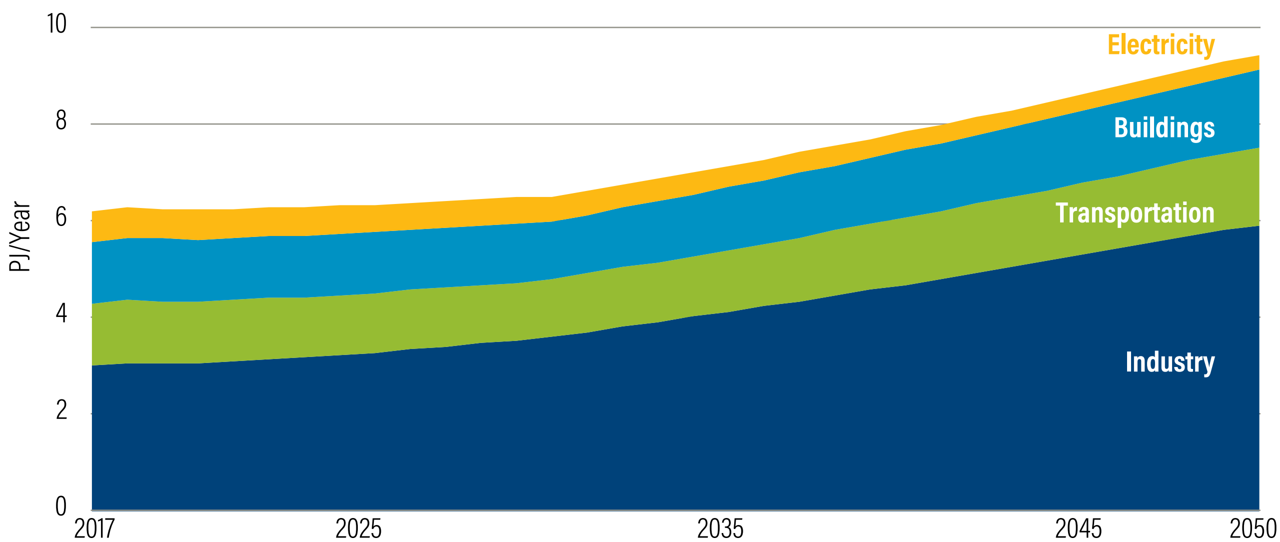
Source: EPS Mexico 2018.

Figure 9 shows the primary energy consumption by sector for the conditional NDC scenario. Throughout the modeling horizon up to 2030, the industry sector remains the largest consumer and the only one displaying growth (note that the industry sector includes oil and gas activities).

The conditional NDC scenario results in a significant reduction in electricity generation (see Figure 10). This is mainly explained by the combined effect of energy efficiency standards across sectors and process improvements in the industrial sector. By 2030, electricity generation decreases by 82 TWh/year (roughly 20 percent).

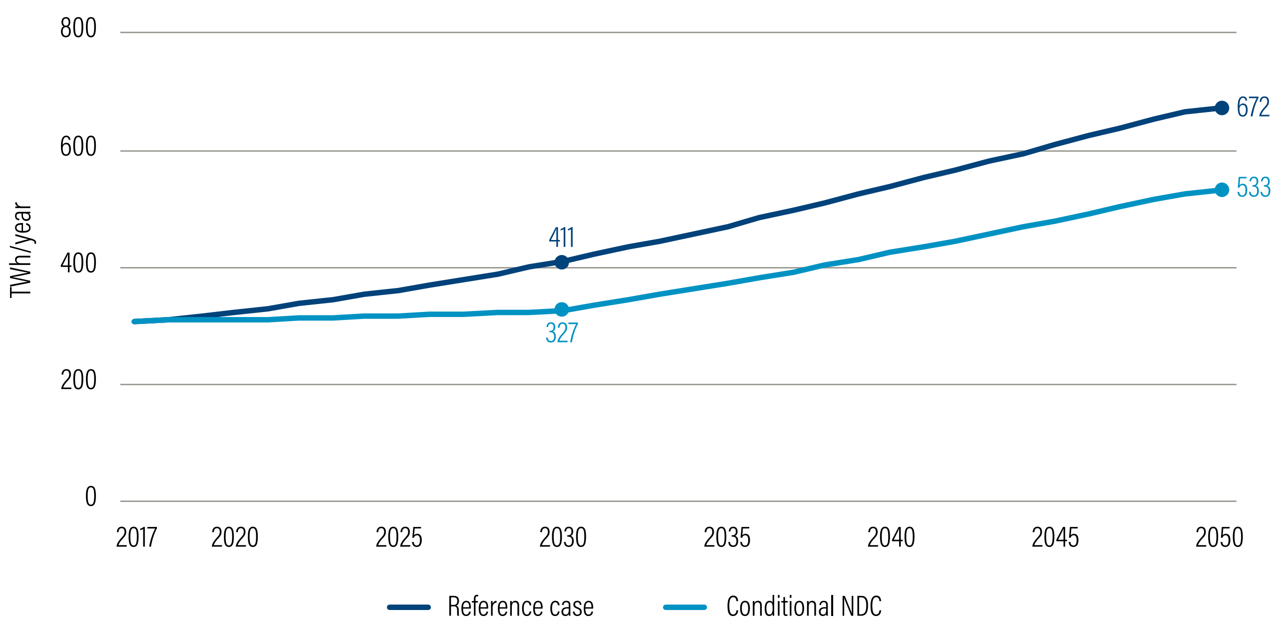
In terms of electricity generation, the policy levers included in the conditional NDC scenario effectively work toward increasing renewable penetration from

Figure 9 | Conditional NDC Scenario—Primary Energy Consumption by Sector



Source: EPS Mexico 2018.

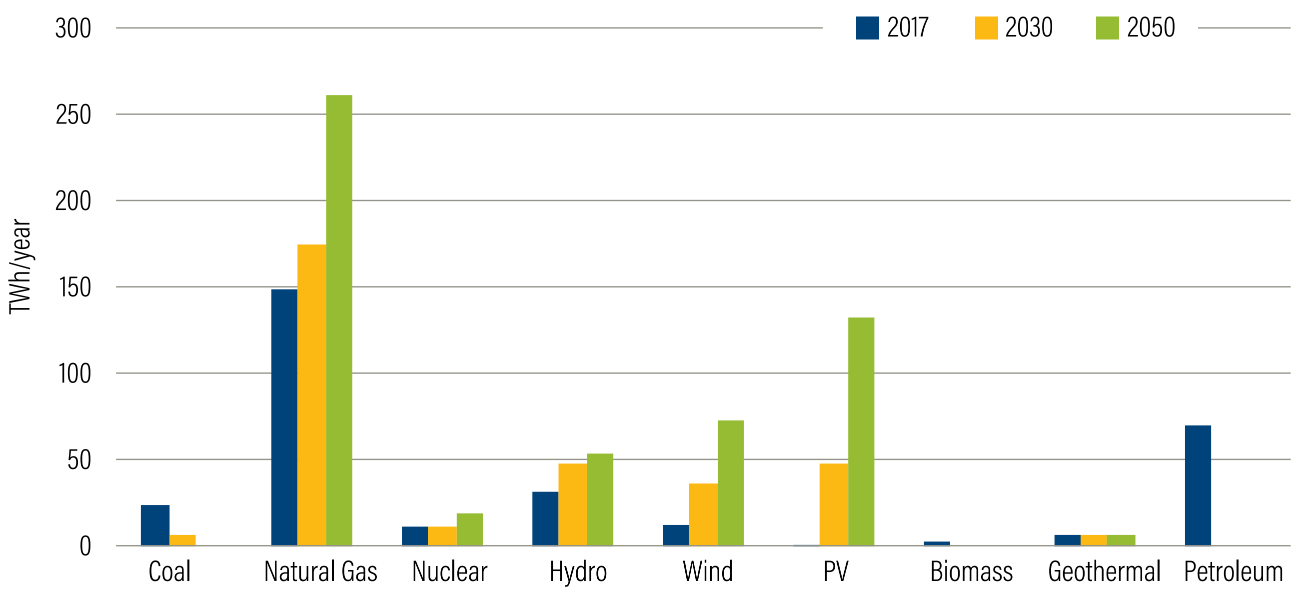
Figure 10 | Electricity Generation under Conditional NDC and Reference Case Scenarios



Source: EPS Mexico 2018.

18 percent in 2017 to achieving Mexico's renewable generation target of 35 percent in 2024 and reaching higher levels of 42 percent by 2030 and 50 percent by 2050. Thus, the electricity generation matrix shifts to natural gas, solar PV, and wind, with constant or slight increases in participation from geothermal, nuclear, and hydroelectric power; while coal, petroleum, and biomass technologies phase out by 2050 (see Figure 11). As for renewable generation capacity, wind and solar PV represent about 6 percent of total generation capacity by 2017, growing to 50 percent in 2030 and about 60 percent by 2050.

Figure 11 | Conditional NCD Scenario—Electricity Generation by Type

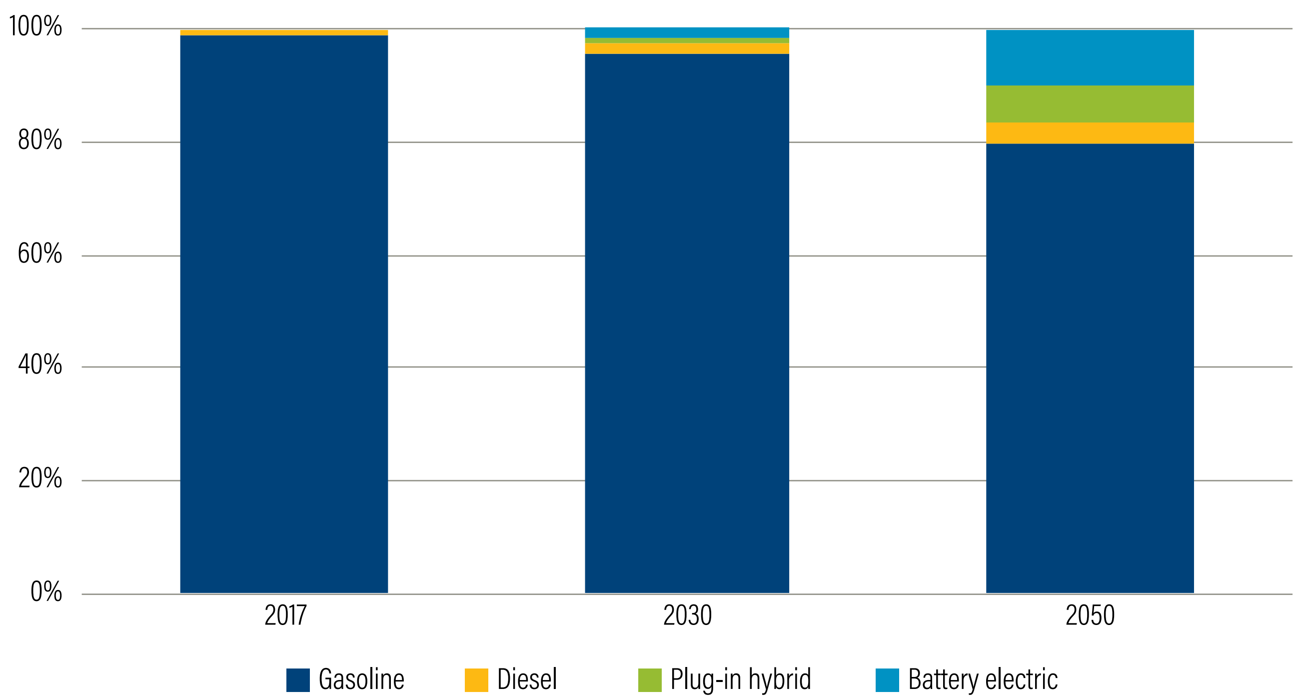


Note: Distributed solar generation is included in Solar PV.
Source: EPS Mexico 2018.

Vehicle Electrification

Transportation demand management-related policies and the carbon tax included in the conditional NDC scenario contribute to the reduction of about 3 million LDV passenger vehicles by 2030, and around 11 million by 2050. Figure 12 shows the composition of LDV passenger vehicle fleet by technology, including gasoline, diesel, plug-in hybrid, and battery EV. Penetration of EV reaches 10 percent of the LDV fleet by 2050, while plug-in hybrid technology penetration reaches 7 percent in the same year; conventional fossil fuel technologies reduce their share of fleet from 99 percent in 2017 to 83 percent in 2050.

Figure 12 | Conditional NDC Scenario—LDV Passenger Vehicle Fleet Composition by Technology



Source: EPS Mexico 2018.

Land Use

The land-use policies selected in the conditional NDC scenario result in an impact of some sort in 6.67 million hectares by 2030, which is roughly equivalent to 10 percent of the total current forest coverage in Mexico (World Bank 2018). The EPS simulates the impact of three land-use policies: improved forest management practices; increased forest coverage through afforestation and reforestation efforts, and additional forest set-asides.[8]

The application of these policies contributes 11 $MtCO_2e$ abatement by 2030 (see Table 6), through:

- 1.3 million hectares of additional forest set-asides (2% of current forest surface).
- 0.9 million hectares of afforested/reforested surface (1% of current forest surface).
- 4.5 million hectares of forest with improved forest management (7% of forest current forest surface).

Table 6 | Conditional NDC Scenario—Land-Use Policy Abatement by 2030

LAND-USE POLICY	AREA AFFECTED (MILLION HECTARES)	ABATEMENT ($MTCO_2E$)	SHARE OF LAND-USE SECTOR ABATEMENT (%)
Forest set-asides	1.3	4.1	37%
Afforestation and reforestation	0.9	2.4	22%
Improved forest management	4.5	4.5	41%

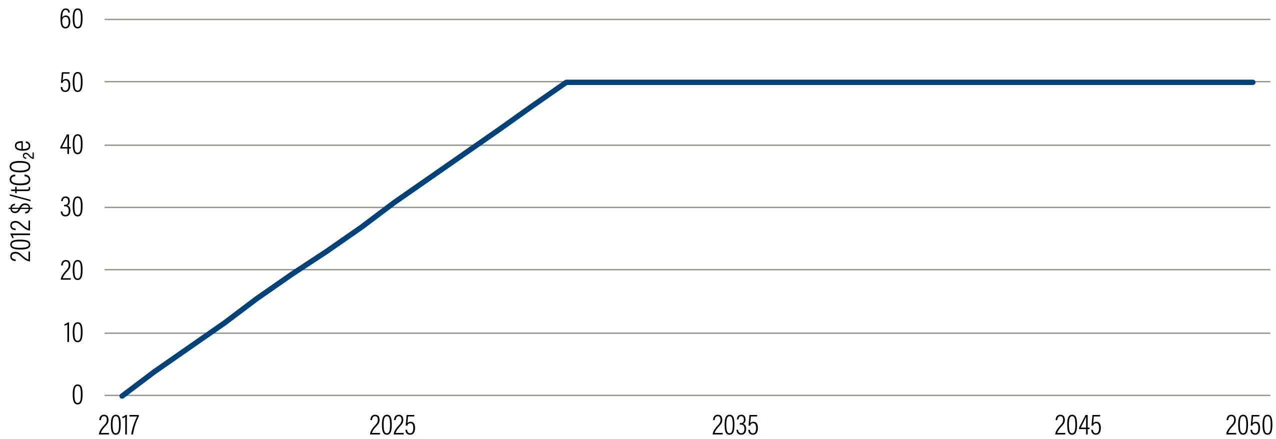
Source: EPS Mexico 2018.

Carbon Tax

The conditional NDC scenario simulates the gradual implementation of a carbon tax that applies to the oil and gas, power generation, transportation, industry, agriculture, and waste management sectors. The tax grows linearly to reach $50/$tCO_2e$ in 2030 and remains constant afterwards (see Figure 13). The tax would contribute 48.6 $MtCO_2e$ abatement and net savings of an estimated $35 per abated ton by 2030, due to improved energy efficiency and the behavioral changes it promotes. The conditional NDC scenario focuses on 2030 targets, so no further growth is assumed to analyze its effect on the 2050 targets. Nevertheless, it is important to mention that increasing the carbon tax value toward 2050 alone would not be enough to reach 2050 targets. Additional policies not currently covered in the model would be required. Both in the medium and long term, the implementation of this tax should be revenue neutral, meaning that all tax revenue should go into innovation and the implementation of low-carbon policies and technologies. The implementation of the carbon tax should be progressive, lessening the tax burden on lower-income segments, for instance, through rebates or financial schemes to support policy implementation among low-income households.

The High-Level Commission on Carbon Prices suggests that carbon taxes in a range of $40–80/$tCO_2e$ by 2020 and $50–100/$tCO_2$ by 2030, will be necessary to stay consistent with achieving the temperature goal of the Paris Agreement (World Bank 2017). The $50/$tCO_2e$ carbon tax analyzed in this report as part of the policies within Mexico's conditional NDC scenario is in line with those ranges. It is actually even conservative, since the $40/$tCO_2$ mark would be reached only by 2027.

Figure 13 | Conditional NDC Scenario—Carbon Tax Applied to Electricity, Transportation, and Industry Components



Source: EPS Mexico 2018.

Cobenefits

The implementation of policies to achieve the conditional NDC could bring several cobenefits, among them health improvement and related avoided deaths. This is the case because the implemented policies could potentially reduce criteria pollutant emissions, which affect human health and the environment at the local and regional level. Criteria pollutant emissions quantified by the EPS model include particulate matter ($PM_{2.5}$ and PM_{10}), organic carbon (OC), nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon monoxide (CO), and volatile organic compounds (VOC). Ground-level ozone (O_3), being a secondary pollutant, is not considered in the model.[9]

Criteria pollutant emissions have an impact on human health through increased mortality (registered deaths) and morbidity (incidence of nonfatal diseases). The effect on morbidity from individual criteria pollutant emissions is difficult to quantify and value. Therefore, our analysis only considers the effects on mortality, which are estimated by the EPS using dose-response functions. In Mexico, particulate air pollution ranks fifth as a health risk associated with premature deaths. In 2015, increased premature mortality associated with diseases caused by criteria pollutants in Mexico totaled nearly 29,000 deaths (INECC 2016c).

The implementation of some of the conditional NDC scenario policies has a direct impact on criteria pollutant emissions and their concentration levels in the atmosphere. Particulate matter, which is the pollutant most related to mortality, presents the strongest reduction potential through policy enactment in the conditional NDC scenario.

Comparing particulate matter emissions in the reference case and conditional NDC scenarios, PM_{10} emissions would be abated by 60 percent in 2030 and 50 percent by 2050; $PM_{2.5}$ emissions would be abated around 40 percent and 50 percent for the same years with the implementation of selected policies (see Table 7).

If the proposed policy package for the conditional NDC scenario were implemented, by 2030 the number of accumulated statistical lives saved due to reduced exposure to criteria pollutants would be nearly 26,000 and around 38,000 by 2050 (see Figure 14). Policies to reduce emissions from particulate matter and other criteria pollutants would have to be enhanced regardless of climate goals, anyway, so as to counter the 29,000 reported deaths associated with air quality in 2015 alone.

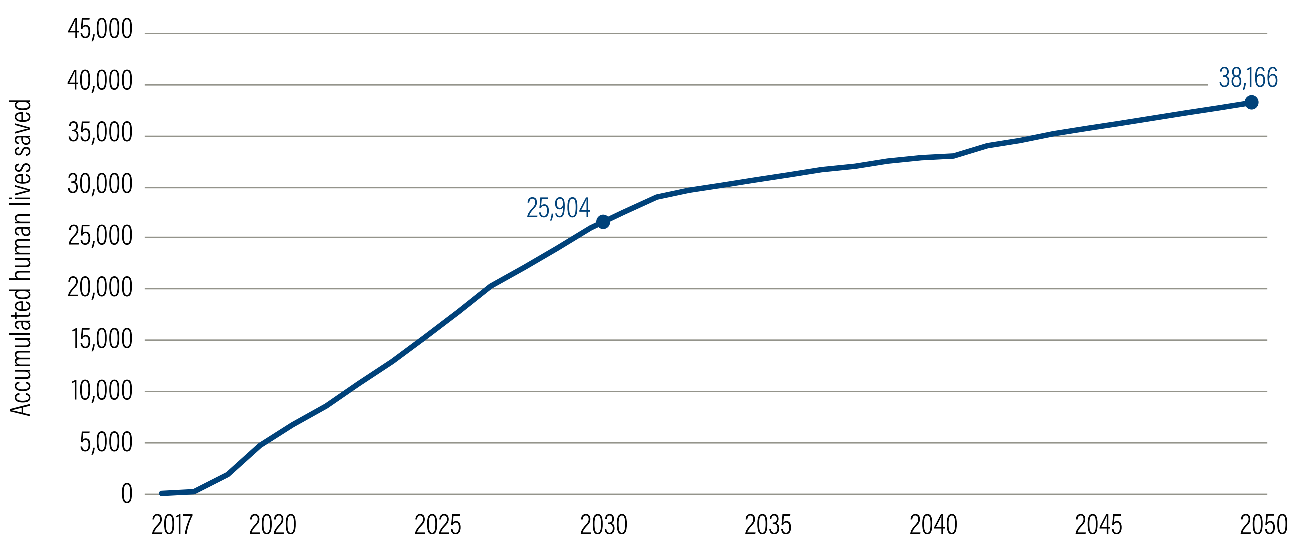
Data used to calculate the impact on mortality were taken from the Air Quality Improvement Program of the Megalopolis 2017–2030, developed by the Environmental Commission of the Megalopolis (CAMe 2017).

Table 7 | Conditional NDC Scenario—Criteria Pollutant Emissions Abatement in 2030 and 2050

CRITERIA POLLUTANT	2030	2050
$PM_{2.5}$ (particulate matter under 2.5 micrometers in diameter)	43%	50%
PM_{10} (particulate matter under 10 micrometers in diameter)	60%	60%
VOC (volatile organic compounds)	29%	39%
OC (organic carbon)	29%	47%
NO_x (nitrogen oxides)	21%	11%
SO_x (sulfur oxides)	48%	38%
CO (carbon monoxide)	26%	31%

Source: EPS Mexico 2018.

Figure 14 | Conditional NDC Scenario—Reduction in Mortality from Criteria Pollutant Abatement



Source: EPS Mexico 2018 (with data from CAMe 2017).

GENERAL FEASIBILITY FACTORS AND ENABLING CONDITIONS

We recognize that, in spite of their potential contribution, policy levers are often not easily implementable, due to a variety of factors. We discuss some that we perceive in general as the most relevant, even though they are case-specific. Issues like financing, legal and institutional constraints, and even technical aspects are addressed. A more comprehensive analysis would be required if we attempt to move toward levers' planning and implementation.

This report does not include a comprehensive feasibility analysis. It should be noted, however, that there are several factors that may hinder the implementation of climate policies analyzed, regardless of their cost-effectiveness. In Mexico, issues such as availability of financial resources, inter-institutional coordination, lack of capacity, economic factors, and legal-political barriers seem to be prominent (CICC2012; INECC2017; OECD 2013). For each specific policy and technology, overall feasibility varies and some of the barriers mentioned are more relevant than others. In the case of renewable energy penetration or increased energy efficiency, for instance, one of the main barriers relates to the existence of energy subsidies, followed by legal barriers and the lack of access to finance (OECD 2013). The introduction of fuel taxes or carbon pricing, as another example, would probably be more sensitive to political factors.

In general terms, there are a few enabling conditions that would make implementation of climate actions more likely to succeed, particularly at a pace and level of ambition required, as mentioned above. We discuss the main ones next.

Financing

In the abatement cost section, we identify that the capital costs involved in the implementation of the conditional NDC scenario and to fulfill Mexico's NDC target are close to $100 billion (in 2016 dollars) spread from 2018 to 2030. This highlights the relevance of having an assessment on the scale and pace of the investment needed to transform Mexico into a low-carbon economy. Fulfilling the NDC commitments may prove difficult given the large initial investments that are needed. In Mexico this is a major challenge because infrastructure investments in the country are not as large and dynamic as expected; for instance, at 1.6 percent of its GDP infrastructure investment is one of the lowest levels of this type of investment in Latin America, whereas in countries like Colombia and Peru investments reach levels of 4.5 percent and 4.7 percent respectively (Serebrisky et al. 2015; Holmes et al. 2017).

The estimate of the funding required to achieve Mexico's NDC differs from existing studies. The National Institute of Ecology and Climate Change (INECC) estimates $136 billion between 2016 and 2030 (INECC 2018b). The International Finance Corporation (IFC) estimates a total of $791 billion (Holmes et al. 2017). Other studies estimate $120 billion between 2014 and 2031 (Wences 2017) and $188 billion (Abramskiehn et al. 2017). These disparate estimates respond to the fact that studies consider different climate actions. The majority of studies focus mostly on renewable energy, infrastructure, and industrial energy efficiency while agriculture, forestry, and adaptation needs are seldom included. Hence, it becomes crucial to find sources of finance for the implementation of such actions. This will involve providing a detailed plan of where and how to access diverse sources of funding, from international public finance sources (e.g., Green Climate Fund [GCF]) to private-sector and domestic fiscal budgets. Among other requirements, for Mexico to have access to such sources of funding it will need to show a priority project pipeline, demonstrated specific institutional commitment, and an enabling environment for policy implementation and private-sector engagement addressing both technical and institutional barriers (CDKN 2016).

In the following section, we provide a summary of the major sources of funding available for financing Mexico's NDC actions.

Major NDC Implementation Funding Sources[10]

There are multiple sources to finance NDC actions. Often these are not clearly recognizable (for instance, because they are mixed with development aid) and come in different sizes from transformational finance for major climate actions (through the GCF) or small amounts of flexible and catalytic investments (e.g., through the Global Environment Facility's [GEF] Small Grants Program) (SIDA 2017). The specific financing activities should then be tailored to the specifics of each country. There are tools, such as the NDC Partnership's *NDC Funding and Initiatives Navigator*, that can help to identify the best available options for a country (NDC Partnership 2018).

At the international level, the major climate funds under the UNFCCC framework are the GEF, GCF, and the Adaptation Fund:

- The GEF provides support for adaptation and mitigation activities as well as capacity building and technology transfer. It contains the Least Developed Countries Fund (that funds adapta-

tion activities in least developed countries only and delivers them via an implementing agency [e.g., UNEP, UNDP]), the Special Climate Change Fund (open to all Non-Annex I countries and until now has supported mainly adaptation and technology transfer projects), and the GEF Small Grants Program (implemented by UNDP and that provides financial and technical support to communities and civil society organizations to attain global environmental benefits through community-based initiatives and actions). Mexico received approximately $8.5 for every dollar that it contributed to the GEF; thus under GEF-6 the allocation of funds totaled around $88 million. For GEF-7, a similar amount is expected, basically for NDC and biodiversity protection actions (SEMARNAT 2017).

- The GCF is a global fund that supports developing countries' actions to tackle and adapt to climate change. It promotes paradigm shifts to low-emission and climate-resilient development, taking into account the needs of nations that are particularly vulnerable to climate-change impacts. Under the GCF, Mexico is part of a regional program that provides $22 million for green bonds initiatives (SERMANT 2017).
- The Adaptation Fund finances projects and programs that help vulnerable communities in developing countries adapt to climate change. Funding for actions is based on country needs, views, and priorities; and access can be via the direct access modality or an implementing agency.

Additionally, there are the traditional UNFCCC mechanisms to mobilize climate funds, such as the Clean Development Mechanism (established under the Kyoto Protocol) and UN-REDD (collaborative program on Reducing Emissions from Deforestation and Forest Degradation in developing countries implemented by FAO, UNDP, and UNEP).

The Multilateral Development Banks (MDBs) are another option. MDBs are both providers of climate finance and implementing agencies for the climate funds. Climate finance is provided as grants and concessional and nonconcessional loans. The MDBs also provide support to help countries to develop tools and capacity to access climate finance:

- The World Bank Climate Investment Funds provide specialized funds for adaptation and resilience building, forestry, clean technology, and renewable energy; the NDC Platform aims to identify the needs, priorities, and resource gaps for countries' NDC implementation.
- The IFC provides direct investments in climate actions related to renewable energy and development of new de-risking and aggregation mechanisms.
- The Inter-American Development Bank Group (IDB) provides funding through NDC Invest, which is an integrated support platform designed to help countries access the resources needed to translate national climate commitments into investment plans and bankable projects. NDC Invest has four pillars: NDC programs, the NDC pipeline accelerator, the NDC market booster, and the NDC finance mobilizer.

Additionally, Mexico receives funds for technical cooperation that are intended to contribute to its Climate Fund. Among them, €1.5 million from the French Development Agency, $1 million from the IDB, €22 million from the German Development Bank, and $1 million from the Latin American Development Bank.

National development banks (NDBs) and other domestic development finance institutions (DFIs) are a third option. Mexico has demonstrated leadership in developing instruments and finance schemes with its NDBs as well as through low carbon financial innovation. In Mexico, there are seven NDBs, and each of them is targeting specific market segments, from small and medium enterprises (National Financial Development Bank [NAFIN]), federal infrastructure (National Bank of Public Works and Services [BANOBRAS]), industry (National Bank of Foreign Trade [Bancomext]), agriculture and forestry (National Agricultural, Rural, Forestry and Fishing Development Fund [FND] and Trust Funds for Rural Development [FIRA]), and housing (Federal Mortgage Company [SHF]). For example, NAFIN was the first regional public bank to issue a green bond ($500 million in 2015 to finance nine wind projects) and BANOBRAS issued its first sustainable bond on September 2017 (Abramskiehn et al. 2017).

Domestic DFIs can provide support in different manners: direct investments (for instance, DFIs invest $641 million in Mexico), inclusion of climate in their mandates, considering NDC actions in their future planning or portfolios, mainstreaming climate actions into development and energy plans, and removing harmful subsidies (e.g., fossil fuels) and redirecting them to NDC implementation, among many others (Weischer et al. 2016).

Some countries have established their own climate funds to combine funding and to coordinate and align donor interests with national priorities. In Mexico, the Climate Change Fund (Fondo para el Cambio Climático) was established in 2012 (DOF 2018) to collect and channel financial resources (public, private, national, and international) that support climate change actions. The fund is led by SEMARNAT in coordination with the Secretariat of Agrarian, Land, and Urban Development (SEDATU); the Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food (SAGARPA); the Secretariat of Civil Service (SFP); the Secretariat of Communications and Transport (SCT); the Secretariat of Economy (SE); the Secretariat of Energy (SENER); the Secretariat of Finance and Public Credit (SHCP); the Secretariat of Governance (SEGOB); and the Secretariat of Social Development (SEDESOL) (UNEP 2013; CEPAL 2016).

Bilateral donors are mainstreaming climate change into their development programs; it is estimated that in 2013–2014, OECD's Development Assistance Committee members provided bilateral development (climate-related) assistance for a total of $25 billion per year, constituting more than half of the public climate finance. Among the many sources of bilateral funds that we can mention are the UK International Climate Fund, the German IKI Initiative (International Climate Initiative), the Government of Norway International Climate and Forest Initiative that supports REDD+ activities and the European Union's Global Climate Change Alliance.

Current funds available through public finance may not be enough to transition to a low-carbon economy, so public funds will be needed to leverage private capital investment in climate-change projects. There are enough opportunities for private investors (individuals; private equity, including venture capitalists; and larger institutional investors like pension funds, insurance companies, or sovereign wealth funds). For instance, it is estimated that by 2030 in Mexico there will be an investment potential of $75 billion in renewable energy and $3.4 billion investment potential in energy efficiency for industry, transportation, and buildings (IFC 2016b).

The potential of private finance could be fully exploited by a close public and private cooperation that incorporates the following principles (Homes et al. 2017):

- "Targeting public money efficiently to de-risk and leverage private capital. Signaling government involvement and commitment to the market to promote market growth.
- Creation and deployment of innovative financial instruments, such as pooling mechanisms.
- Providing early engagement on projects to provide a full range of tailored structured financing options. Complement lending activity by providing technical assistance services to facilitate smaller scale lending and reduce transactions costs."

Finally, philanthropy can also be a catalyst for climate finance by side-stepping obstacles faced by public and international actors, such as competing political priorities or slower-moving processes. For instance. The Rockefeller Foundation Zero Gap Fund catalyzes investments in adaptation and resilience, the foundation also funds the Global Innovation Lab for Climate Finance, a public-private sector initiative that identifies, develops, and launches innovative financial instruments to unlock private investment. In 2016 the lab raised more than $500 million for pilot instruments. There are other actors, such as the Children's Investment Fund Foundation, The Ford Foundation, the Oak Foundation, and The Climate Works Foundation.

Institutional and Legal Framework

As stated earlier in this report, the institutional and legal framework to support climate policymaking and implementation in Mexico is relatively well developed, particularly since the enactment of the LGCC in 2012. Capacity has increased, and coordination has improved throughout relevant sectors and the subnational levels, given the mandate put forward by law to establish a series of institutional arrangements and climate change coordination bodies and to develop a variety of sectoral and subnational planning instruments (DOF 2018). Nevertheless, capacities still vary across sectors and government levels. Notably, local level capacities are generally limited, which is of concern since part of the effort to comply with Mexican climate targets falls within the municipal jurisdictions.

Specific levers within the policy mixes assessed in our analysis would require particular changes to the legal or institutional framework in order to improve their chances of being implemented. When developing business plans or implementation road maps, these factors should be taken into account and resolved.

Technical Cooperation and Innovation Requirements

Mexico has several international cooperation agreements in place and a good history of collaboration with many countries. Such agreements have a proven track record in support of the climate agenda. The effective implementation of some of the proposed policies in the EPS conditional NDC scenario will greatly benefit from further technical cooperation, which can help create capacity, mobilize resources, and scale up and replicate efforts.

Some of the policy levers proposed in the EPS conditional NDC scenario will also require further research and technological advancement—among them, for instance, the implementation of electric power demand response systems, the reduction of power grid transmission losses, and an increase in electricity storage, all of which would allow a higher renewable energy penetration.


Mexico

CONCLUSIONS

It is possible for Mexico to achieve its mid-term climate targets with a combination of policy levers that are technically and economically feasible, even though they require substantial investment. Besides GHG mitigation, their implementation would bring economic and social benefits. Among all sectors of the economy, the greatest mitigation would be achieved through interventions in electricity, transportation, and industry. For the long term, increased ambition would be needed in order to achieve current targets.

The results of our analysis show that through the careful implementation of a technically feasible policy package at a low cost, Mexico can attain a GHG emissions reduction in line with its conditional NDC objectives. The selected policy package is composed of 21 policy levers across all sectors of the economy. These levers were identified through model testing and expert feedback. The economic impact of their implementation is positive in the medium term, due to cost reductions from fuel savings and process efficiency, but it requires a total capital investment close to $100 billion by 2030.

Our analysis shows that Mexico can achieve its unconditional and conditional GHG reduction targets while saving money through efficient operations and with cobenefits in public health. Nevertheless, there is a need for achieving effective and enhanced climate action in all sectors of the economy, financing significant up-front public and private investments using both domestic and international sources of capital, carrying out an effort to address barriers to implementation, and devoting substantial resources to capacity building and innovation.

As mentioned in the introduction and later confirmed by the analysis, the achievement of Mexico's NDC target will not put us on a direct path to the achievement of 2050's GHG abatement goal. There is a need for increased ambition for closing this gap, as well as a need for further studies to identify the key levers for long-term GHG abatement, decoupling economic growth from GHG emissions, required increases in carbon pricing, and the necessary areas of innovation and technological developments.

Main Findings

This report identifies a mix of 21 policy levers, with which it would be possible to achieve Mexico's conditional NDC at a low cost. With the implementation of the policy levers proposed for the conditional NDC scenario, GHG emissions decrease from 902 $MtCO_2e$ in the reference case to 623 $MtCO_2e$ by 2030, a 279 $MtCO_2e$ (-31%) abatement. Compared to Mexico's NDC reported baseline (972 $MtCO_2e$), achieved abatement reaches 349 $MtCO_2e$ (-36 percent).

Overall, three sectors (electricity, transportation, and industry) contribute almost two-thirds (178 $MtCO_2e$) of this abatement. The sectors that present the greatest relative decrease in emissions under the conditional NDC scenario by 2030 are LULUCF with 63 percent, waste management with 52 percent, and electricity with 50 percent.

The implementation of Mexico's conditional NDC policy package will require significant capital investment, up to $100 billion (2012 dollars) between 2018 and 2030, which represents less than 1 percent of the annual GDP if spread evenly across the modeled horizon. Nevertheless, the net effect will result in a positive impact to the economy, with an estimated $105 billion in net present value by 2030. It could also bring several cobenefits, among them health improvement and related avoided deaths. This is so because the implemented policies could potentially reduce criteria pollutant emissions, which affect human health and the environment at the local and regional level. If the proposed policy package for the conditional NDC scenario were implemented, by 2030 the number of accumulated statistical lives saved due to reduced exposure to criteria pollutants would be almost 26,000, and nearly 38,000 by 2050.

The conditional NDC scenario simulates a carbon tax that grows lineally to reach \$50/tCO_2e in 2030 and remains constant afterward. The tax applies to the oil and gas, power generation, transportation, industry, agriculture, and waste management sectors. It would contribute 19 MtCO_2e abatement and net savings of an estimated \$35 per abated ton by 2030 due to the improved energy efficiency and the behavioral changes it promotes. The implementation of this tax should be revenue neutral. The tax amount analyzed is within the ranges that are considered necessary to stay consistent with achieving the temperature goal of the Paris Agreement.

There are several factors that may hinder the implementation of climate policies analyzed, regardless of their cost-effectiveness. In Mexico, issues such as availability of financial resources, inter-institutional coordination, lack of capacity, economic factors, and legal-political barriers seem to be prominent. For each specific policy and technology, overall feasibility varies, and some of the barriers mentioned are more relevant than others.

Currently, Mexico is not on track to achieve its LTS goal of 50 percent abatement of emissions in absolute terms with regard to the year 2000. To achieve Mexico's GHG abatement goals, efforts should be made to design and implement effective and enhanced climate action in all sectors of the economy, financing significant up-front public and private investments using both domestic and international sources of capital, carrying out an effort to address barriers to implementation, and devoting substantial resources to capacity building and innovation.

Proposed Next Steps

The purpose of this report is to outline in broad strokes the type and magnitude of interventions that can help steer Mexico toward its GHG abatement goals. Further detailed analysis will no doubt be necessary to inform specific implementation approaches (including considerations related to competitiveness and distributional impacts), as well as barriers to implementation.

A new National GHG Emissions Inventory was released within Mexico's 6th National Communication to the UNFCCC, presented at COP 24 in Katowice. The EPS model considers the same data as the current GHG Emissions Inventory. Baseline data have not been revised since the NDC presentation at COP 21 in Paris. If an updated baseline is released, a new comparison should be developed to identify any significant changes in sector-specific emissions trajectories.

APPENDIX A. EPS WEB TOOL AND ONLINE DOCUMENTATION

The EPS model development included a web application with a high-level technical architecture that facilitates and simplifies model use and review. The web interface displays the most significant results of the model in easy-to-read and downloadable graphs that include emissions, policy abatement wedge diagrams, marginal abatement cost curves for selected policies, financials, social benefits, and specific results for each of the included sectors for each of the included scenarios. The interface also includes brief descriptions for each policy, extensive documentation on model calculations and architecture, and clarification on how to design each policy well.

The web application can be accessed at https://mexico.energypolicy.solutions.

By creating a user account, the model allows users to review preset scenarios and to construct personalized scenarios allowing the study of results from specific policies by modifying their implementation level and even allowing a customized implementation schedule.

Extensive on-line documentation on the web application use can be found at https://us.energypolicy.solutions/docs/online-model-tutorial.html.

ABBREVIATIONS

BANCOMEXT	National Bank of Foreign Trade
BANOBRAS	National Bank of Public Works and Services
BAU	Business as usual
CAMe	Environmental Commission of the Megalopolis
CAT	Climate Action Tracker
CCAC	Climate & Clean Air Coalition
CCS	Carbon capture and sequestration
CDKN	Climate and Development Knowledge Network
CENACE	National Center for Energy Control
CICC	Inter-Secretariat Commission on Climate Change
CMM	Mario Molina Center
CNH	National Hydrocarbons Commission
CONAFOR	National Forestry Commission
COP	Conference of the Parties
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CRE	Energy Regulatory Commission
DFI	Development finance institution
DR	Demand-response
EI	Energy Innovation LLC
EPA	Environmental Protection Agency (U.S.)
EPS	Energy Policy Simulator
EV	Electric vehicle
FAO	Food and Agriculture Organization of the United Nations
FND	National Agricultural, Rural, Forestry and Fishing Development Fund
GCF	Green Climate Fund
GDP	Gross domestic product
GEF	Global Environment Facility
GHG	Greenhouse gas
GMI	Global Methane Initiative
HDV	Heavy-duty vehicle
ICM	Mexico's Climate Initiative
IFC	International Finance Corporation
IMCO	Mexican Institute for Competitiveness
iNDC	Intended Nationally Determined Contribution
INECC	National Institute of Ecology and Climate Change
INEGI	National Institute of Statistics and Geography
INEGyCEI	National Greenhouse Gases and Compounds Emissions Inventory
LDV	Light-duty vehicle
LPG	Liquefied petroleum gas
LTS	Long-term strategy
LULUCF	Land Use, Land-Use Change, and Forestry
MACC	Marginal abatement cost curve
MDB	Multilateral Development Bank
NAFIN	National Financial Development Bank
NDC	Nationally Determined Contribution
NPV	Net present value
NO_x	Nitrogen oxides

OECD	Organisation for Economic Co-operation and Development
PECC	Special Climate Change Program
$PM_{2.5}$	Particulate matter of 2.5 micrometers and smaller
PM_{10}	Particulate matter of 10 micrometers and smaller
POLES	Prospective Outlook on Long-Term Energy Systems
PRODESEN	National Electric System Development Program
PV	Photovoltaic
REDD	Reducing Emissions from Deforestation and Forest Degradation
R&D	Research and development
SCT	Secretariat of Communications and Transport
SAGARPA	Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food
SEDATU	Secretariat of Agrarian, Land, and Urban Development
SEDESOL	Secretariat of Social Development
SE	Secretariat of Economy
SEMARNAT	Secretariat of Environment and Natural Resources
SEGOB	Secretariat of Governance
SENER	Secretariat of Energy
SFP	Secretariat of Civil Service
SHCP	Secretariat of Finance and Public Credit
SHF	Federal Mortgage Company
SO_x	Sulfur oxides
TDM	Transportation Demand Management
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

ENDNOTES

1. LULUCF remaining (absorptions) correspond to GHG inventory lines 3B1a, 3B2a, 3B3a, 3B4a, 3B5a, and 3B6a. They quantify the carbon sink from unconverted land.

2. Black carbon emissions are not converted to CO_2e and are only analyzed for their cobenefits. The model does not have the level of detail about their potential abatement to estimate black carbon's warming effects.

3. The total cost of implementation was reported in 2016 U.S. dollars, for easier comparison with other studies.

4. The latest version of which was presented with Mexico's NDCs and mid-century strategy (INECC 2016a).

5. Scenarios consider only GHG emissions abatement targets and exclude the black carbon abatement targets.

6. The marginal abatement cost represents the net present value of the net incremental cost (CAPEX+OPEX) of applying each policy as compared to the reference case; it considers the policy implementation costs and the benefits in operating costs from increased efficiency or value.

7. Improved forest management includes enhanced thinning techniques, longer rotation periods, and other changes to timber harvesting. These practices are promoted through the use of certification programs (for example, the Forest Stewardship Council).

8. Natural Protected Areas and other land conservation schemes such as Environmental Management Units.

9. Ground-level ozone is a product of photochemical reactions in the atmosphere; direct emissions are negligible.

10. Otherwise stated, this subsection is based on SIDA (2017), which provides an excellent overview of the different types of funding sources available as well as tools and resources available for identifying them.

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