Mexico Chapter

pathways to deep decarbonization

2014 report

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SUSTAINABLE DEVELOPMENT SOLUTIONS NETWORK
A GLOBAL INITIATIVE FOR THE UNITED NATIONS

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Preface

The Deep Decarbonization Pathways Project (DDPP) is a collaborative initiative, convened under the auspices of the Sustainable Development Solutions Network (SDSN) and the Institute for Sustainable Development and International Relations (IDDRI), to understand and show how individual countries can transition to a low-carbon economy and how the world can meet the internationally agreed target of limiting the increase in global mean surface temperature to less than 2 degrees Celsius (°C). Achieving the 2°C limit will require that global net emissions of greenhouse gases (GHG) approach zero by the second half of the century. This will require a profound transformation of energy systems by mid-century through steep declines in carbon intensity in all sectors of the economy, a transition we call "deep decarbonization."

Currently, the DDPP comprises 15 Country Research Partners composed of leading researchers and research institutions from countries representing 70% of global GHG emissions and different stages of development. Each Country Research Partner has developed pathway analysis for deep decarbonization, taking into account national socio-economic conditions, development aspirations, infrastructure stocks, resource endowments, and other relevant factors. The pathways developed by Country Research Partners formed the basis of the DDPP 2014 report: Pathways to Deep Decarbonization, which was developed for the UN Secretary-General Ban Ki-moon in support of the Climate Leaders' Summit at the United Nations on September 23, 2014. The report can be viewed at deepdecarbonization.org along with all of the country-specific chapters.

This chapter provides a detailed look at a single Country Research Partner's pathway analysis. The focus of this analysis has been to identify technically feasible pathways that are consistent with the objective of limiting the rise in global temperatures below 2°C. In a second—later—stage the Country Research Partner will refine the analysis of the technical potential, and also take a broader perspective by quantifying costs and benefits, estimating national and international finance requirements, mapping out domestic and global policy frameworks, and considering in more detail how the twin objectives of development and deep decarbonization can be met. This comprehensive analysis will form the basis of a report that will be completed in the first half of 2015 and submitted to the French Government, host of the 21st Conference of the Parties (COP-21) of the United Nations Framework Convention on Climate Change (UNFCCC).

We hope that the analysis outlined in this report chapter, and the ongoing analytical work conducted by the Country Research Team, will support national discussions on how to achieve deep decarbonization. Above all, we hope that the findings will be helpful to the Parties of the UNFCCC as they craft a strong agreement on climate change mitigation at the COP-21 in Paris in December 2015.

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1 Country profile

1.1 The national context for deep decarbonization and sustainable development

GHG emissions in Mexico are rising due to an increasing use of fossil fuels. As the population slowly stabilizes (projected to be 151 million by 2050)[1] and continued economic growth is expected, it is crucial to design a deep decarbonization strategy before new infrastructure is built. Many actions to mitigate climate change have valuable co-benefits (local health improvement, economic savings, and greater productivity, among others), and some are also linked to poverty reduction and social inclusion (for example food and energy security).

Proven reserves of oil in Mexico are estimated to be around 1,340 million tons of oil equivalent (toe), while gas reserves represent an additional 430 million toe.[2] The national energy reform approved recently is expected to boost investments in oil and gas production. Electricity generation is mainly produced from natural gas (50%), oil (11%), hydro (15%), and coal (13%); energy-intensive industry accounts for 13% of GDP.

Urban population reached 72% in 2010, and it is expected to be close to 83% by 2030. Around 98% of households have access to electricity to date, and there are 210 vehicles per 1,000 people. In some rural areas, wood is still used as the main fuel for heating and cooking.

1 Comisión Nacional de Población (CONAPO), at: http://www.conapo.gob.mx

2 Data reported for January 2014. SENER, 2014, at: http://egob2.energia.gob.mx/SNIH/Reportes/Portal.swf?ProgGuid=FCAF8F9D-21D6-4661-98B5-55D84B9C1D85

The majority of future economic growth is expected to be driven by tertiary activities (services), which could account for nearly 70% of national GDP by 2050; in 2010 they represented around 62% of the total GDP. As this sector is less intensive both in energy and in CO_2 than other economic activities in Mexico, this shift is expected to decrease GHG emissions.

As GDP per capita increases, medium-sized cities are expected to grow. Historic trends show that urban centers expand in patterns that increase energy consumption and land use change. Smart urban development has been identified as a key way to transition towards more efficient and sustainable green growth schemes in Mexico.

1.2 GHG emissions: current levels, drivers, and past trends

Total GHG emissions in Mexico reached 748 $MtCO_2e$ in 2010.[3] The largest source of emissions is the combustion of fossil fuels (56%), and the greatest contributors to this category are the transport sector and electricity generation (Figure 1).

Historically, GHG emissions in Mexico have been driven by increases in both population and in GDP per capita (Figure 2a).[4] Energy use per capita has increased as well, at an average rate of about 1% per year between 1995 and 2010.

Total energy consumption reached around 176 million toe in 2010, including all consumption by final users (transport, industry, buildings), energy industries, and transmission losses.[5] The distribution of final energy use was spread over the following fuels: gasoline (32%), electricity (16%), diesel (16%), natural gas (11%), LPG (10%), and wood (5%). Approximately 30% of all energy use is dedicated to transportation, and close to 70% of that energy is consumed by passenger transport alone. This trend reflects the increase in vehicle ownership, which doubled from 2000 to 2010 to approximately 207 vehicles per thousand people. This increased ownership and use has caused GHG emissions from the transport sector to increase at an annual rate of 3.2% between 1990 and 2010.

2 National deep decarbonization pathways

2.1 Illustrative deep decarbonization pathway

2.1.1 High-level characterization

The illustrative deep decarbonization scenario described in this report has been devised to achieve reductions of CO_2 emissions as a result of changes in energy use and production towards less emission-intensive alternatives. As shown in Table 1, this analysis assumes a GDP growth rate of 3% every year,[6] from around 950 billion USD (at 2008 prices) in 2010 to some 3,100 billion USD in 2050.GDP per capita would reach $20,425 USD/person by 2050. Much of projected reduction in CO_2 emissions across sectors relies on reducing the carbon intensity of electricity generation coupled with a

3 Inventario Nacional de Emisiones de Gases de Efecto Invernadero 1990-2010, INECC-SEMARNAT, 2013.
4 GDP increased 28% from 1995 to 2000 causing final energy per dollar of GDP to decrease noticeably in the same period. The significant increase in GDP reflects a recovery from the economic crisis of 1995, so only a limited amount of information can be gained from an examination of the 1995 to 2000 time period.
5 Balance Nacional de Energía, Sistema de Información Energética, SENER, 2014.
6 In this study we assume 3% annual growth as illustrative of long-term sustained growth. Official estimates for annual GDP growth in 2014 have been recently adjusted from 3.1% to 2.8% (Banco de México, communiqué: http://www.banxico.org.mx/informacion-para-la-prensa/comunicados/resultados-de-encuestas/expectativas-de-los-especialistas/%7BB22F53FD-4129-ECE1-85E3-BCA42D652B16%7D.pdf).

switch from the combustion of fossil fuels to use of electricity in those final uses of energy where it is possible to do so. Although some assumptions were made regarding the future energy consumption of some appliances, the deep decarbonization scenario modeled does not include the effects of

Table 1. Development Indicators and Energy Service Demand Drivers

	2010	2020	2030	2040	2050
Population [Millions]	113	127	137	145	151
GDP per capita [$/capita]	8,339	9,987	12,407	15,764	20,425

Figure 1. Decomposition of GHG and Energy CO_2 Emissions in 2010

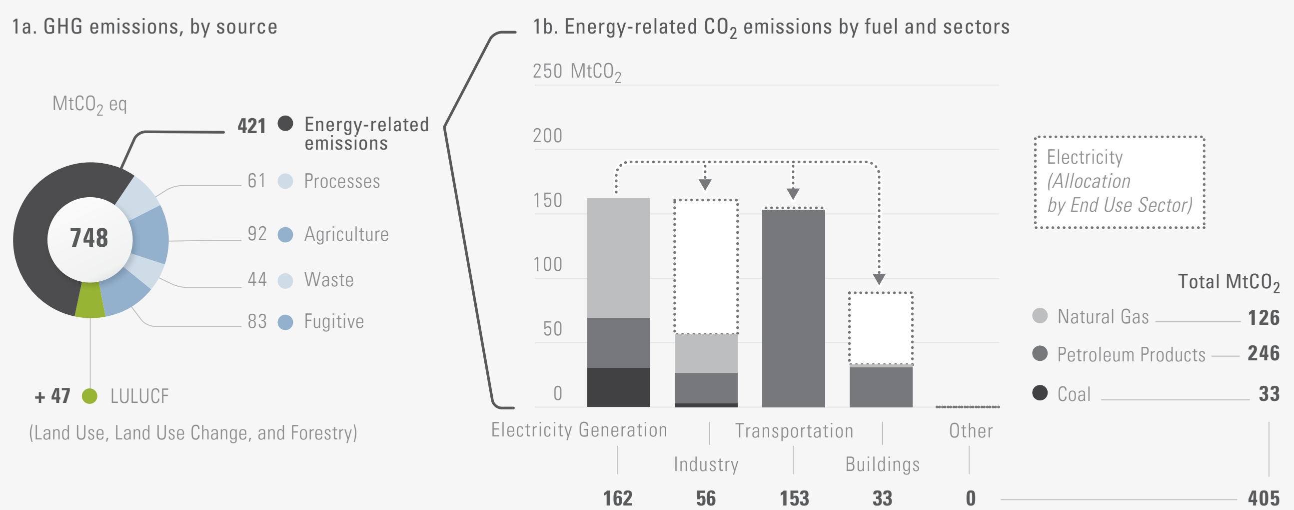
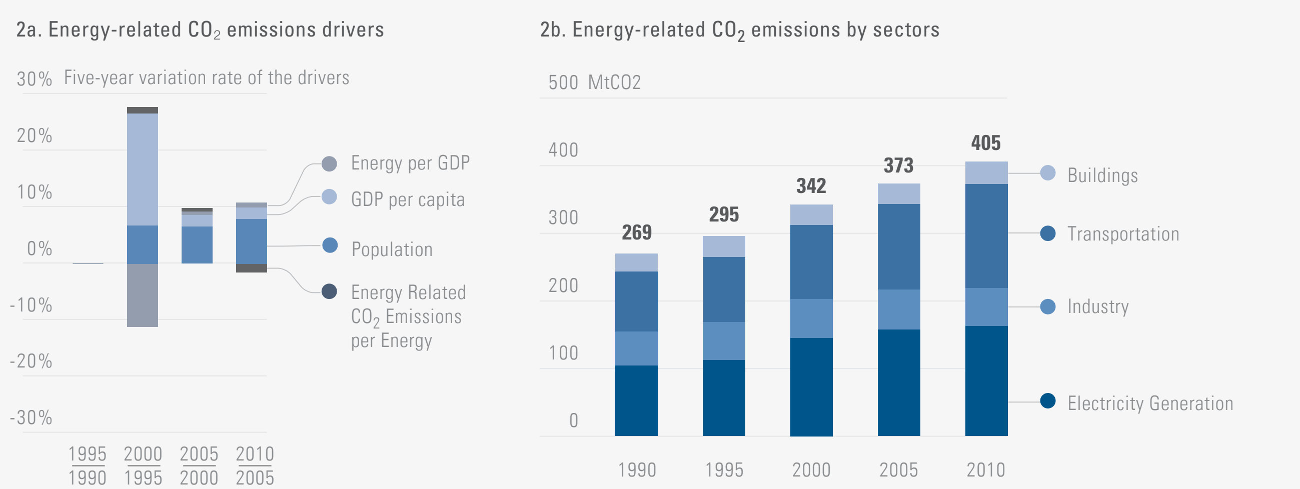


Figure 2. Decomposition of historical energy-related CO_2 Emissions, 1990 to 2010



dedicated schemes to accelerate improvement of energy efficiency faster than historical trends. Non-electric fuel switches include a shift to natural gas from petroleum coke, coking coal, diesel, and residual fuel oil used in industry, as well as partial use of ethanol, natural gas, and biodiesel in transport to reduce gasoline and diesel consumption.

This exploratory deep decarbonization scenario to 2050 assumes that primary energy systems in Mexico migrate from a heavy dependence on oil to pipeline gas and renewables and that end-use energy will be provided mainly by electricity and natural gas (Figure 3). However, it is important to emphasize that a number of factors make it impossible to anticipate what specific technology choices will be made in Mexico, including the fact that the country is undergoing a major reform of its energy sector, which will affect regulation, planning, and the presence of private sector providers. As a result, this scenario in no way represents an expected or recommended pathway, and is neither government policy nor an official

Figure 3. Energy Pathways, by source

3a. Primary Energy

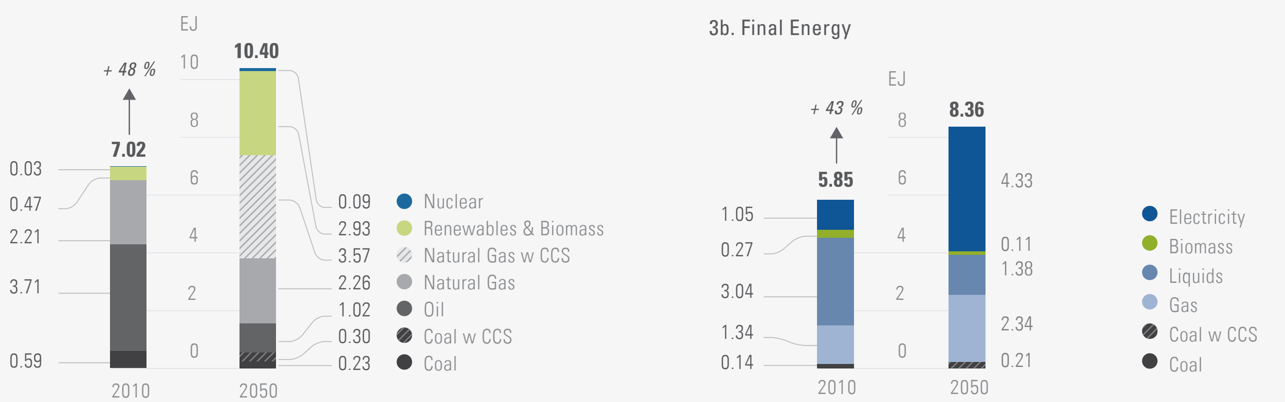
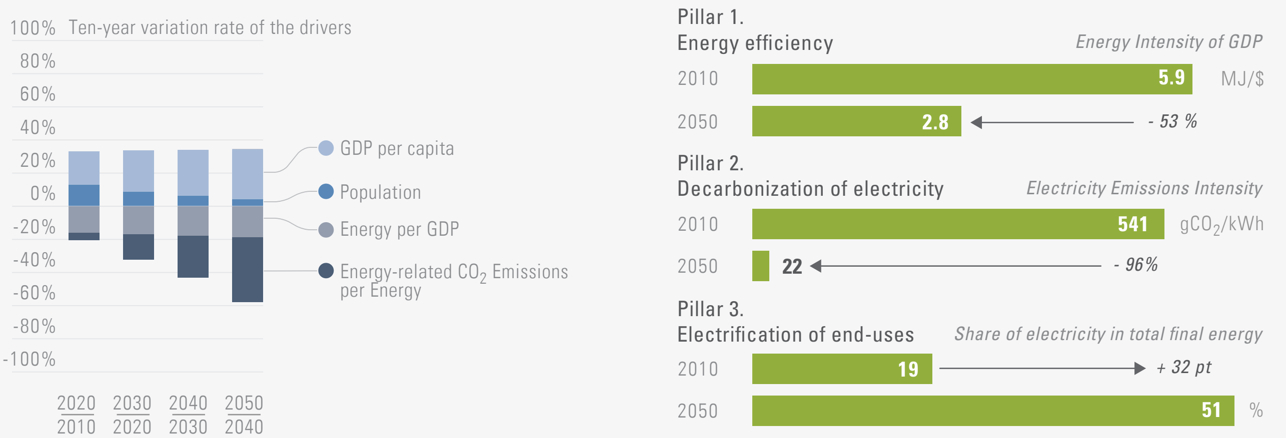


Figure 4. Energy-related CO_2 Emissions Drivers, 2010 to 2050

4a. Energy-related CO_2 emissions drivers



document of planning or intent. It merely seeks to lay out what a potential scenario could look like, in order to explore possible interplays between technologies and their feasibility considerations. This deep decarbonization scenario shows a substantial (96%) reduction in the GHG emissions released per unit of electricity produced from 2010 and 2050 (Figure 4). Energy intensity of GDP also decreases, at a less aggressive rate of 2% each year to yield an overall reduction of 53% from 2010 to 2050. Finally, there is a substantial increase in the share of electricity in final energy use from 19% in 2010 to 51% by 2050.

The scenario assumes drastic reductions in the GHG emissions from electricity generation and transportation and lower reductions in buildings when comparing emission levels from 2050 to 2010 (Figure 5).

Figure 5. Energy-related CO_2 Emissions Pathway, by Sector, 2010 to 2050

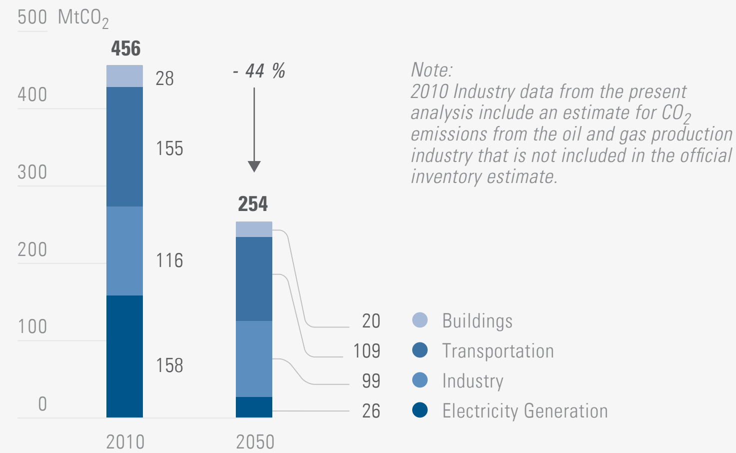
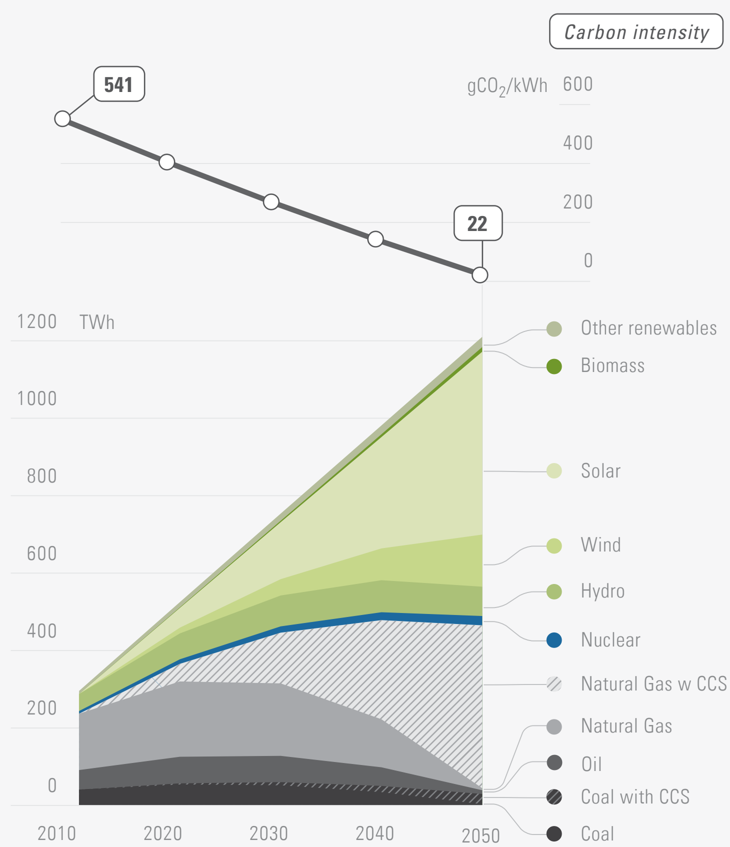


Figure 6. Energy Supply Pathway for Electricity Generation, by Source



2.1.2 Sectoral characterization

The prominent role of electrification as a decarbonization strategy prioritizes a reduction of GHG emissions intensity in the electricity generation sector.

Electricity generation

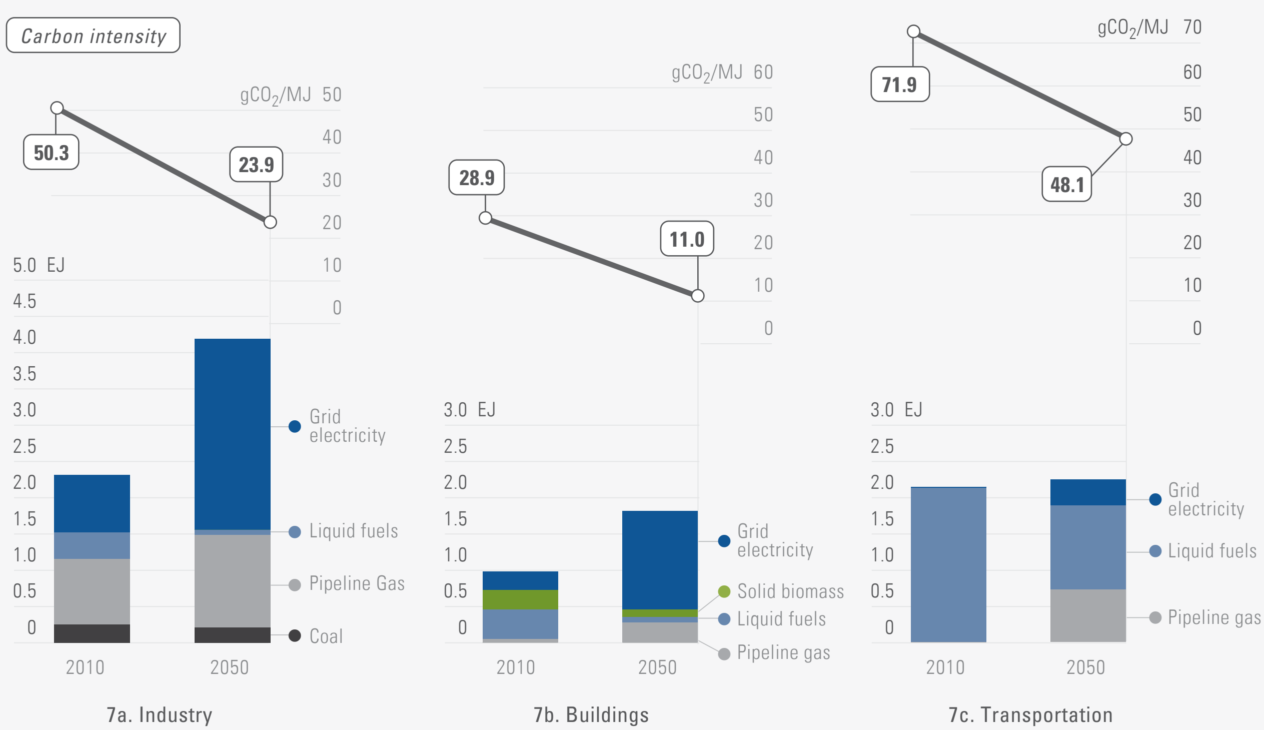
In 2010, electricity generation was associated with a CO_2 emissions intensity of 541 gCO_2 per kWh. Results of an initial analysis show that in order to be consistent with the deep decarbonization objective, carbon intensity would need to fall to around 20 gCO_2 per kWh by 2050. To accomplish this, the illustrative deep decarbonization scenario assumes electricity in Mexico will be generated from a larger share of renewables (especially solar), and natural gas with CCS.

The additional electrical power required to enable the electrification of energy demand is substantial at nearly 1,200 TWh by 2050. To meet this electricity generation need, the full potential for renewable energy resources identified to date has been taken into account[7], which includes 6,500 TWh/year of solar, 88 TWh/year of wind, 77 TWh/year of geothermal, 70 TWh/year of hydro,[8] and 11 TWh/year of biomass. Assuming that technological advances make it feasible to incorporate high levels of intermittency into the grid by 2050 (by developing energy storage capabilities, for example) a balanced mix was composed with the two main energy sources: solar (40%) and natural gas (35%). It is assumed that the rest of the supply is provided by wind (11%), hydro (6%), geothermal (2%), coal (2%), nuclear (2%) and oil (1%). Electricity generation from all fossil fuels (464 TWh) will require CCS in all generation plants (+60 GW) to comply with the stringent CO_2 emission intensity discussed above. Such a generation mix would have a share of intermittent renewable power of 50% and an average emission factor of only 19 g of CO_2 per kWh produced (Figure 6).

Energy consumption

Under the deep decarbonization scenario illustrated here, final energy consumption would amount to approximately 205 million toe by 2050 (from industry, transport, and buildings). In this exercise, the reduction in carbon intensity of the industrial activity is achieved by the massive substitution of oil products (residual fuel oil, coke and, diesel) by largely decarbonized electricity (to around 62% of energy demand projected by 2050) and natural gas (30%). The resulting carbon intensity after such measures would be about half of the current value (Figure 7a).

Figure 7. Energy Use Pathways for Each Sector, by Fuel, 2010 – 2050



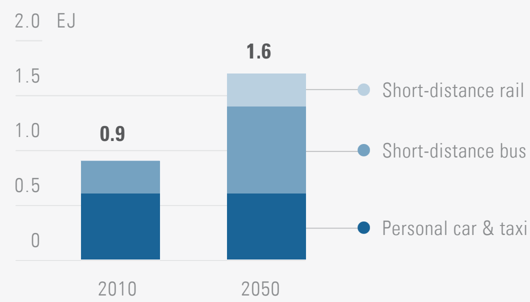
Note: Carbon intensity for each sector includes only direct end-use emissions and excludes indirect emissions related to electricity or hydrogen production.

Due to the low energy requirements in households and Mexico´s relatively mild weather, GHG emissions from buildings (residential and commercial sectors) have not historically been increasing at high rates. However, steps must be taken to ensure household energy consumption does not emulate North American trends. To reduce the building-related direct energy emissions, the scenario explores the substitution of gas (both LPG and natural gas) by electricity in final energy uses (Figure 7b).

In the transport sector, a massive fuel shift from gasoline and diesel to electricity and natural gas has been considered as an illustrative decarbonization approach (Figure 7c and Figure 8), using three exploratory assumptions:

1. A passenger modal shift to mass-public electric transportation systems to satisfy the increasing travel demand;
2. Freight shift to electric trains and gas powered trucks; and
3. 60% of light vehicles (private cars and taxis) would switch to electricity, and 90% of freight would switch to natural gas and biodiesel by 2050.

Figure 8. Land passenger travels, by mode



2.2 *Assumptions*

The preliminary deep decarbonization scenario outlined in this report relies heavily on the complementarity between the electrification of energy usage across sectors and the simultaneous abatement of GHG emissions in the power sector. In order to do this the implementation of large infrastructure and investments for clean energy are required. In this scenario, we have emphasized the role of solar energy, together with extensive use of CCS techniques at gas power plants.

Achieving this very ambitious solar target (≈270 TWh/year, assuming a capacity factor of 20%) requires an aggressive cost reduction strategy that allows massive roll-out of said technology, both as dedicated solar power plants feeding the grid, as well as distributed production for households and industries, and investment in transmission lines. Further advances in energy storage technology and smart grids will also be required to integrate so much intermittent resource into the grid, where these technologies would help limit demand on the grid and the need for even more generation and transmission infrastructure.

Given the large share of gas-fueled electricity projected in this scenario, Mexico would need the potential capacity to store approximately 200 million tons of CO_2 every year. A theoretical storage potential of 100 $GtCO_2$ has been identified in a preliminary study.[9]

Increasing the amount of electricity produced from renewable sources other than solar would require further exploration and technological development to exploit lower-yield potentials in wind, geothermal, and biomass resources.

The preliminary approach followed to deeply decarbonize the transport sector assumes the feasibility of implementation of extensive electric inter-modal mass transport systems. For this to be true at the required scale it would be necessary to change the present urban growth patterns. Today's medium-sized cities are expected to drive

7 Inventario Nacional de Energías Renovables, SENER, 2014, in http://iner.energia.gob.mx/publica/version2.0/

8 Includes estimates for large and small scale hydropower.

9 The North American Carbon Storage Atlas (NACSA), 1st Edition, 2012. www.nacsap.org

most of the future growth and would need to adopt and enforce best smart growth practices. This scenario also assumed that by 2050 electric vehicles will be widely available, and that it will be possible to divert freight from the road to electric trains without major technical issues.

2.3 Alternative pathways and pathway robustness

Given the dependence of this approach on the decarbonization of the electricity generation sector, it is important to explore alternative technological scenarios for this sector. In this analysis we assume the presence of competitive energy storage systems that enable grids to include a high share of intermittent sources (solar or wind power) and are valuable to manage overall demand. However, if such a solar plan is unfeasible, an alternative pathway must be devised, perhaps by increasing the share of nuclear power or natural gas with CCS.

2.4 Additional measures and deeper pathways

The projected GHG emissions resulting from measures considered in the illustrative deep decarbonization scenario could be further reduced by additional actions that have not been yet evaluated.

Other options that have not been explored at full capacity in the present study and that may have interesting potential are: additional renewables (wind, geothermal, and marine power), industrial processes redesigned to decrease energy intensity and byproduct GHG emissions, large-scale CCS in industrial facilities, massive adoption of hybrid vehicles, large-scale production of bio-fuels for transport, and partially substituting the natural gas in the pipeline network with lower-carbon alternatives. Municipal and agricultural waste can be a source of biogas, rather than GHG emissions. Utilizing biogas from landfills and water treatment operations might help lower future consumption of natural gas for electricity generation.

2.5 Challenges, opportunities and enabling conditions

Major challenges that may deter realization of this scenario include current energy subsidies (both for fossil fuels and electricity), economic potential, lack of resources to fund the transition, and the technological availability of cost-effective options for CCS, electric vehicles, solar power harvesting, and biofuels production.

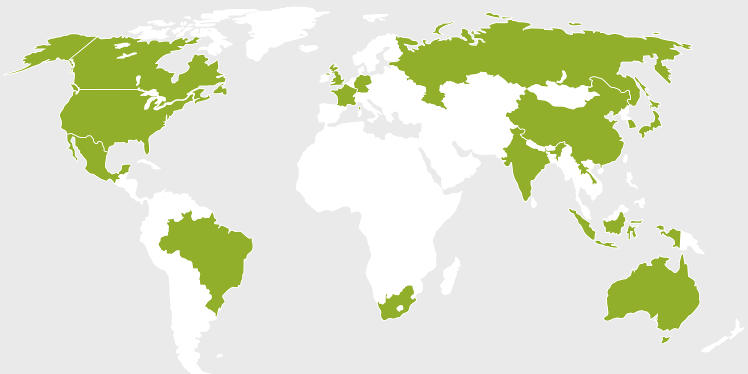
Amongst the enabling conditions that require international cooperation, we identify technology development for energy storage and energy management (smart demand and smart grids), carbon taxes to imports and exports of fossil fuels, and the development of zero carbon or carbon negative agriculture and forestry techniques to support production of sustainable bioenergy crops and reduce emissions from these sectors.

2.6 Near-term priorities

Although this is an initial exploration of deep decarbonization in Mexico, some conclusions can be drawn from the magnitude of the challenge at hand. Adoption of better practices in urbanization and territorial planning could prove crucial to lower future energy consumption per capita and simultaneously improve quality of life. Better-organized cities could induce the behavioral changes needed for mode shifts in transportation.

A robust low-carbon electricity generation policy is required to evaluate different future alternatives, increase certainty over governmental plans, and provide an economically feasible route for future development.

Energy efficiency programs coupled with appropriate energy price signals could help decrease the financial burden of the transformation needed by reducing energy demand and thus reducing the amount of funds needed to transition towards a deep decarbonization development pathway.



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