Developing Mexico National Emissions Inventory Projections for the Future Years of 2008, 2012, and 2030

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ABSTRACT

The 1999 Mexico National Emissions Inventory (NEI) was the first comprehensive municipality-level emissions inventory of criteria air pollutants developed for the country of Mexico. However, more current and future year emissions inventory projections are essential to evaluate the future benefits of air quality control measures and to support various modeling analyses in Mexico. Therefore, the Western Governors' Association (WGA) has supported Mexico's National Institute of Ecology (INE – Instituto Nacional de Ecología) by sponsoring a project to develop future year emissions inventory projections. Also, support for the project was extended by the National Renewable Energy Laboratory (NREL) to evaluate the benefits of air quality control measures in Mexico at the national level.

This paper discusses the development of municipality-level emissions inventory projections for the years of 2008, 2012, and 2030 based upon the 1999 Mexico NEI. Adjustments made to the 1999 base year inventory due to municipality divisions are presented. The development of sector-specific point source growth factors for electricity generating units, refineries and other petroleum-related sources, primary metal facilities, manufacturing facilities, miscellaneous industrial facilities, and service facilities is described. The development of area source and nonroad mobile source growth factors based upon surrogate projections (e.g., population, fuel use, gross domestic product [GDP], etc.) is also presented. The results of a detailed analysis of the projected effects of Mexico's future low-sulfur fuel standards and new vehicle emission standards on on-road motor vehicle emissions are also incorporated are also described. This paper also discusses the interactions between the emissions projections and other projects related to greenhouse gases that are currently being conducted in Mexico.

INTRODUCTION

Background

Future year emission inventory projections are essential to evaluating the potential benefits of air quality control measures and supporting various modeling analyses. The Mexico NEI projections were developed for Mexico's National Institute of Ecology (INE – Instituto Nacional de Ecología) in support of the fourth phase of the Integrated Environmental Strategies (IES) Program sponsored by the U.S. Environmental Protection Agency (U.S. EPA) and the National Renewable Energy Laboratory (NREL) to evaluate the benefits of air quality control measures in Mexico at the national level. Point, area, on-road motor vehicle, and nonroad mobile source emissions from the 1999 Mexico National Emissions Inventory (NEI) were projected to the years of 2008, 2012, and 2030 at the municipality-level.[1] In addition, emission impacts in Mexico due to three control scenarios were developed in consultation with INE.

Projections Scope

Since the emission inventory projections were based upon the 1999 Mexico NEI, the scope of the projections was similar to the Mexico NEI, and included the following characteristics:

- Source types – Point sources, area sources (excluding paved and unpaved road dust), on-road motor vehicles, and nonroad mobile sources. Natural sources (i.e., biogenic and volcanic sources), although part of the 1999 Mexico NEI, were not included in the scope of the projections.
- Pollutants – Nitrogen oxides (NO_x), sulfur dioxide (SO_2), volatile organic compounds (VOC), carbon monoxide (CO), particulate matter with an aerodynamic diameter of 10 micrometers (µm) or less (PM_{10}), particulate matter with an aerodynamic diameter of 2.5 µm or less ($PM_{2.5}$), and ammonia (NH_3).
- Spatial aggregation – Municipality-level for all municipalities in Mexico.
- Reported units – Megagrams (Mg) per year (i.e., 1,000 kilograms [kg] or 1 metric ton).
- Results – Projected emission results were provided in spreadsheet, U.S. EPA Emissions Inventory Format (NIF) 3.0, and SMOKE/IDA modeling file formats.

Adjustments for New Municipalities

Prior to projecting the 1999 Mexico NEI to 2008, 2012, and 2030, it was necessary to adjust the baseline municipality-level emissions to account for municipality realignments since 1999. The 1999 Mexico NEI contained a total of 2,443 municipalities for the entire country.[1] However, the national municipality-level population projections that were provided by the National Council on Population (CONAPO – Consejo Nacional de Población) indicated that there were a total of 2,454 municipalities as of 2005.[2] The 11 new municipalities were formed in the states of Guerrero, México, Veracruz, and Zacatecas. Seven new municipalities were formed by the division of an existing municipality; four new municipalities were formed by the reorganization of multiple existing municipalities. Table 1 lists the new municipalities and their associated municipality codes.

Emissions from the existing municipalities included in the 1999 Mexico NEI (listed in Table 1) were allocated to the new municipalities. If this allocation had not been performed, then these 11 new municipalities would have zero emissions in the 1999 baseline inventory, as well as in the projected inventories. The emissions allocation for area sources, on-road motor vehicles, and nonroad mobile sources was based upon the ratio of 2005 population estimates. For example, Iliatenco (Guerrero) was formed from the municipalities of Malinaltepec and San Luis Acatlán. The 2005 populations of these municipalities were as follows: Malinaltepec – 27,231; San Luis Acatlán – 41,917; Iliatenco – 9,762; and three municipality total – 78,910. The calculated ratios for area sources, on-road motor vehicles, and nonroad mobile sources were then: Malinaltepec – 0.3451 (i.e., 27,231/78,910); San Luis Acatlán – 0.5312; and Iliatenco – 0.1237. For point source emissions, a Geographic Information System (GIS) was used to plot the point source locations to determine if any were located within the municipalities that were split to form new municipalities. It was confirmed that no reallocation of point source emissions was needed because none of the point sources are located within the 11 new municipalities.

PROJECTIONS METHODOLOGY

For the purposes of this study, baseline growth projections for 2008, 2012, and 2030 were initially developed assuming no future controls. Ideally, the development of growth factors would be conducted at the facility- or process-level. However, information concerning future year conditions was typically limited by insufficient detailed data. As a result, facility- or process-level growth factors were not developed; instead, national- and regional-level growth factors were developed. After the baseline growth projections were developed, three control scenarios were developed in conjunction with INE staff. Then, the three control scenarios were applied to the baseline growth projections.

Point Sources

The 1999 Mexico NEI point source emissions were projected to 2008, 2012, and 2030 using sector-specific growth surrogates. The first step was to classify all of the 1999 Mexico NEI point sources into one of six groups based upon 3-digit North American Industry Classification System (NAICS) codes. The assignment of the 3-digit NAICS codes is presented in Table 2. The six groups were:

- Electricity generating units (EGUs)
- Refineries and other petroleum-related industries
- Primary metals manufacturing
- Manufacturing industries (all other)
- Miscellaneous industries (not elsewhere classified)
- Service industries (e.g., auto repair, dry cleaners, etc.)

The methodology used to develop growth factors for each of these point source groups is described below.

EGUs Growth Factors

The growth factors for EGUs were developed from historical fuel use statistics and fuel use projections. The actual fuel consumption by the EGU sector for 1999 was obtained from a fuel balance developed as part of the 1999 Mexico NEI.[3] Fuel projections used for electricity generation for 2008, 2012, and 2030 were obtained from modeling conducted for Mexico greenhouse gas studies.[4] The growth factors for each year were estimated by calculating the ratio of the projected year demand data relative to the actual 1999 fuel combustion. Fuel-specific growth factors were only developed for natural gas, combustóleo (i.e., residual fuel oil), and coal. The EGUs contained in the 1999 MNEI were assigned a fuel type based upon power plant information from the North American Commission for Environmental Cooperation (CEC).[5] Based upon the CEC power plant information, fuel types were assigned to 41 of 73 EGUs contained in the 1999 Mexico NEI. For the remaining 32 EGUs, either natural gas or combustóleo was assigned based upon comparative SO_2 emissions relative to NO_x emissions at the facility level (i.e., EGUs with low SO_2 emissions were assigned to natural gas, while EGUs with high SO_2 emissions were assigned to combustóleo).

Refineries and Other Petroleum-Related Industries Growth Factors

The growth factors for refineries and other petroleum-related sources were developed from historical crude oil production statistics and production projections. The 1999 crude oil production was obtained from an analysis of the Department of Energy (DOE)/Energy Information Administration's (EIA) *International Energy Outlook*[6]; this study indicated a daily total crude production of 2.87 million barrels for Mexico in 1999. Crude production forecast data were obtained from the Organization of the Petroleum Exporting Countries' (OPEC) *World Oil Outlook*.[7] These data indicate a decrease in crude production for Mexico in future years (e.g., the crude production in 2030 is almost equal to that in 1999).

Primary Metals Manufacturing Growth Factors

The growth factors for primary metal manufacturing facilities were based upon historic copper, lead, and zinc production data in Mexico. Historic Mexican copper, lead, and zinc production data from 1990 to 2006 were obtained from the United States Geological Survey (USGS) Mineral Resources Program.[8] Aggregated copper, lead, and zinc statistics for primary refined metal were used to develop a linear regression equation to predict annual primary metal production for the years 2008, 2012, and 2030. Growth factors were then developed by dividing the projected primary metal production by the actual 1999 primary metal production.

Manufacturing Industries and Miscellaneous Industries Growth Factors

The growth factors for manufacturing industries, as well as miscellaneous industries were based upon Mexican gross domestic product (GDP). An annual GDP rate of 3.5 percent has been recently used for various environmental and economic studies; this annual growth rate was used for projecting emissions from the manufacturing industries and miscellaneous industries.[9]

Service Industries Growth Factors

The growth factors for service sector point sources were based upon municipality-level population estimates for the time period from 2005 to 2030.[2] As shown in Table 2, services industries include printing facilities, repair and maintenance shops, dry cleaners, and wastewater treatment plants. The growth of these types of point sources can largely be attributed to growth in population. Therefore, municipality-level population was used as a surrogate to project emissions from these sources.

Area Sources

The 1999 Mexico NEI area source emissions were projected to 2008, 2012, and 2030 using various growth surrogates, as shown in Table 3. A majority of the area source categories were projected to 2008, 2012, and 2030 using population and fuel use surrogates. The development of each growth surrogate is described below.

Population Growth Surrogate

A population surrogate was used to project emissions growth for 14 area source categories as shown in Table 3. Municipality-level population estimates for Mexico for the time period 2005-2030 were obtained from CONAPO[2]; 1999 municipality-level population data were obtained from the 1999 Mexico NEI.[1] Municipality-level population growth factors were calculated by dividing 2008, 2012, and 2030 population by 1999 population.

Fuel Use Growth Surrogates

Fuel use surrogates were used to project emissions growth for fuel combustion of six different fuels (i.e., distillate, residual, natural gas, LPG, kerosene, and wood), as well as commercial marine vessels and the distribution of gasoline and LPG. Fuel use projections for 2008, 2012, and 2030 were obtained from modeling conducted for Mexico greenhouse gas studies.[4] The projection data consisted of actual energy demand data for the years 1999 through 2006 and forecasted energy demand data for the years 2007 through 2030. These data were available by sector (e.g., industrial, commercial, residential, agricultural, transportation, etc.) and by fuel type. Sector- and fuel-specific growth factors were calculated by dividing the energy demand projections (in petajoules [PJ]) by 1999 energy demand (in PJ).

LPG demand for all sectors was summed together to estimate the growth factors for the LPG distribution source category. Gasoline demand for the transportation sector was used to calculate growth factors for the gasoline distribution source category.

Gross Domestic Product (GDP) Growth Surrogates

Mexican GDP was used as a growth surrogate to project 1999 emissions to 2008, 2012, and 2030 for locomotives, industrial surface coatings, and degreasing. As discussed for point sources, a GDP rate of 3.5 percent has been recently used for various environmental and economic studies.[9] This annual growth rate was used for projecting these three source categories. A slight modification was used for locomotives. The same annual growth rate of 3.5 percent was used to develop the 2008 and 2012 growth factors; however, no growth was assumed to occur after 2012 (i.e., the 2030 growth factor was assumed to be the same as the 2012 growth factor) due to expected minimal growth after 2012.[10]

Planted Acreage Growth Surrogates

Historical planted acreage by state was used as a surrogate to develop growth factors for the pesticide application, agricultural tilling, fertilizer application, and agricultural burning. State-level historical planted acreage from 1980 to 2006 was obtained from the Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food Supply (SAGARPA – Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación).[11] Using these data, a long-term annual average planted acreage was calculated for each state. Long-term annual average planted acreage was used rather than linear regressions because the state-level year-to-year statistics appeared to have some reporting gaps and tend to be very erratic. It was then assumed that the planted acreage in 2008, 2012, and 2030 will be equal to the long-term annual average planted acreage. Growth factors were developed by dividing the long-term annual average planted acreage by the state-level 1999 planted acreage. In some cases, the growth factor was less than 1.0 (i.e., the long-term annual average planted acreage was less than the 1999 planted acreage). For agricultural burning, only historical averages of wheat and sugarcane planted acreages were used to derive growth factors. Burning of sugarcane prior to harvest is a common agricultural practice throughout the world in order to remove leafy trash. Post-harvest burning of wheat is commonly practiced to eliminate wheat stubble; recent inventory efforts in San Luis Río Colorado, Sonora and Mexicali, Baja California indicate that the practice is fairly common in Mexico.[12,13]

Livestock Population Growth Surrogates

Historical livestock population by state was used as a surrogate to develop growth factors for the livestock ammonia and beef cattle feedlots. State-level livestock populations from 1996 to 2005 were obtained from SAGARPA for the following seven livestock categories: beef cows, dairy cows, pigs, sheep, horses, chickens, and turkeys.[14] Using these data, historical average populations were calculated for each livestock category for each state. It was then assumed that the livestock populations in 2008, 2012, and 2030 would be equal to the historical average populations. Growth factors were developed by dividing the historical average populations by the state-level 1999 livestock populations. In some cases, the growth factor was less than 1.0 (i.e., the historical average populations were less than the 1999 livestock populations). The overall 1999 Mexico NEI emissions for livestock ammonia were split into emissions by livestock type, and growth factors were applied to each livestock type to project emissions to 2008, 2012, and 2030.

Burned Forest Acreage Growth Surrogates

Historical data on burned forest acreage by state were used as a surrogate to develop growth factors for wildfires. State-level burned forest acreage from 1970 to 2005 was obtained from the National Forest Commission (CONAFOR – Comisión Nacional Forestal).[15] Historical burned forest acreage was calculated at the state level and was assumed to be equal to the burned forest acreage in 2008, 2012, and 2030. Growth factors were developed by dividing the state-level historical burned forest acreage by the 1999 burned forest acreage.

Border Crossing Vehicle Traffic Growth Surrogates

Historical border crossing vehicle traffic data were used to develop growth factors for border crossings. Historical traffic data from 1995 to 2007 (including buses, trucks, and personal vehicles) were obtained from the U.S. Bureau of Transportation Statistics (BTS).[16] These data were used to develop a linear regression equation to predict the total vehicular traffic at border crossings in 2008, 2012, and 2030. After predicting the annual traffic counts for 2008, 2012, and 2030, growth factors were developed by dividing the projection year vehicular traffic by 1999 vehicular traffic. Traffic data were limited to border crossing traffic for vehicles crossing from Mexico into the U.S. Emission estimates for vehicles crossing from the U.S. into Mexico were not estimated as part of the 1999 Mexico NEI because of insignificant wait times. Also, the 1999 Mexico NEI did not include emissions for border crossings at Mexico's borders with Guatemala and Belize because of data unavailability.

Aircraft Passenger Volume

Annual air passenger traffic data were used to develop growth factors for aircraft emissions. Total passenger volume data (both domestic and international) from January 2001 through August 2008 for 13 airports in north and central Mexico.[17] Although there are more than 13 airports located in Mexico, it was assumed that these 13 airports reasonably approximated the national level of aircraft activity. For the year 2008, the eight months of data from January to August were extrapolated to obtain an annual estimate for 2008. After completing the extrapolation of the 2008 annual estimate, the data from 2001 to 2008 were used to develop a linear regression equation to predict annual total passenger volume for 2012 and 2020. Once the annual air passenger volumes for the years 2008, 2012, and 2030 was obtained, growth factors were developed by dividing the projection year air passenger volume by 1999 air passenger volume.

Public Wastewater Treatment Growth Surrogates

Historical public treated wastewater quantities were used to develop growth factors for wastewater treatment. Annual treated wastewater quantities from 1999 to 2006, as well as planned treatment rate increases until 2012, were obtained from the National Water Commission (CNA – Comisión Nacional del Agua).[18] Due to the unavailability of data, it was assumed that 2030 treatment quantities would be equal to 2012. The 2008 and 2012 planning values were divided by the 1999 actual treated quantities to obtain the growth factors.

On-Road Motor Vehicles

The 1999 on-road motor vehicle emissions were projected to 2008, 2012, and 2030 using two different growth factors. The first growth factor accounted for the increased demand of motor vehicle fuels projected between 1999 and 2030. As with many of the area source categories, gasoline use projections were obtained from modeling conducted for Mexico greenhouse gas studies.[4] The second growth factor addressed the changes in vehicle technologies and emissions due to the turnover of the Mexican fleet. Over time, newer vehicles with improved technologies (e.g., improved catalysts, etc.) and lower emissions will enter the vehicle fleet and gradually replace older vehicles with limited or no technology. The effects of vehicle turnover were estimated using the MOBILE6-Mexico on-road motor vehicle emission factor model.[19] The MOBILE6-Mexico model was run for all years (i.e., 1999 base and 2008, 2012, and 2030 projected years) and fleet average emission rates were generated. The ratio of fleet average emission rates for each future year relative to the 1999 base year was calculated; this ratio was the "turnover" factor. The overall growth factor for each of the projection years was estimated by multiplying the fuel growth factor by the fleet turnover factor. A more detailed explanation of the MOBILE6-Mexico modeling process is provided below.

Fuel Regulations

The MOBILE6-Mexico model was modified to reflect new gasoline and diesel fuel standards regulations that would be in effect in Mexico in the future. Mexican fuel standards are split into three regions (i.e., Metropolitan Zone [ZM], Frontier Zone [ZF], and the remainder of the country [RP]) with each region having an applicable gasoline and diesel sulfur standard. Table 4 lists the Mexican fuel sulfur standards by fuel type and region for the 1999 base year and the three projected years. These fuel sulfur standards were obtained from the fuel standard implementation schedule provided by PEMEX.[20] It should be noted that individual values in Table 4 represent maximum standards, while split values (e.g., 30/80) represent average/maximum standards, respectively. Also, for Magna gasoline, the Frontier Zone (ZF) is considered to be part of the remainder of the country (RP). Although both Magna and Premium gasoline are used in Mexico, only Magna gasoline (i.e., the predominant motor vehicle fuel) was used in the modeling runs in order to simplify the analysis.

Other MOBILE6-Mexico Model Parameters

The average temperature range for Mexico was assumed to be a minimum of 55.6 °F and a maximum of 82.9 °F for all the model runs. The fuel Reid Vapor Pressure (RVP) was assumed to be 7.5 psi and the average vehicle speed was assumed to be 18.5 kilometers per hour for all the model runs.

Emission Standards

Mexico has motor vehicle emission limits standards that are equivalent to a combination of U.S. Tier 1 and Tier 2 standards and European EURO 3 and EURO 4 standards.[10] The equivalency of Mexican motor vehicle emission standards to EURO standards and U.S. standards is shown in Table 5. Because the MOBILE6-model is based an 80,000 km (i.e., 50,000 miles) certification rather than a 100,000 km certification, the U.S. Tier 1 and Tier 2 standards were used for the modeling runs and the EURO 3 and EURO 4 standards were not investigated further. The 1999 base year model runs in Mexico were assumed to be equivalent to U.S EPA's Tier 0 standards. For the future years of 2008, 2012, and 2030, the Mexican A, B, and C standards were incorporated into the MOBILE6-Mexico model runs. Mexican Standard A is similar to the U.S EPA's Tier 1 standard for VOC, CO, and NO_x. Standards B and C are a combination of U.S. EPA's Tier 1 and Tier 2 standards for VOC, CO, and NO_x. For particulate emissions, Mexican Standards A, B, and C were all the same as U.S EPA's Tier 1 standard. In addition, there are no emissions standards in Mexico for heavy-duty gasoline trucks and vehicles (HDGV and HDGT). Mexican Standards A, B, and C are presented in Table 6.[21] The vehicle types used in the Mexican standards are defined below:

- PV – Passenger vehicle (light-duty) with a maximum gross vehicle weight rating (GVWR) of 8,500 lbs or less
- LDT1 – Light-duty truck with a maximum loaded vehicle weight (LVW) of 3,750 lbs and GVWR not to exceed 6,000 lbs
- LDT2 – Light-duty truck with a minimum LVW of 3,750 lbs and GVWR not to exceed 6,000 lbs
- LDT3 – Light-duty truck with a maximum adjusted loaded vehicle weight (ALVW) of 5,750 lbs and GVWR greater than 6,000 lbs
- LDT4 – Light-duty truck with a minimum ALVW of 5,750 lbs and GVWR not to exceed 6,000 lbs.

The phase-in schedule of Mexican Standards A, B, and C as a percentage of vehicles within each model year are presented in Table 7. As shown in Table 7, the 2008 phase-in schedule indicates a 50 percent allocation for Standard A and 50 percent allocation for Standard B. The schedule for 2012 consists of a 75 percent allocation for Standard B and a 25 percent allocation for Standard C. By 2015, Standard C will be entirely phased in. Lacking information regarding additional future standards beyond Standard C, it was assumed that the Standard C would still be in effect in 2030.

Implementation Schedule Input File

The MOBILE6-Mexico external input file that contains information relevant to the emission standard implementation schedule is called the Mex_P94_Imp.dat. This file contains the implementation schedule from model year 1994 thru model year 2025 (inclusive). The file contains the fraction of implementation for different standards for each of the above mentioned years by vehicle type (e.g., Tier 0, Tier 1 [interim], Tier 1, Tier 2, Tier LEV [interim], Tier LEV, etc.). For purposes of this projection analysis, only Tier 1 and Tier 2 standards are analyzed for future year scenarios. The implementation schedule input file (i.e., Mex_P94_Imp.dat) was modified to represent the implementation schedule for Mexican Standards A, B, and C.

Certification Standards Input File

The MOBILE6-Mexico external input file that contains information regarding vehicle manufacturer certification standards is called Mex_T2CERT.dat. The Mex_T2CERT.dat file contains the 50,000 mile certification standards by certification bin by pollutant (HC, CO, and NO_x). The same modified Mex_T2CERT file was used for all MOBILE6-Mexico runs (i.e., 1999, 2008, 2012, and 2030).

Exhaust Emission Standards Input File

The MOBILE6-Mexico external input file that contains information regarding the phase-in schedule for the Tier 2 exhaust emission standards is called Mex_T2EXH.dat. Since this file only contains the phase-in schedule until 2015, it was assumed that 2030 standards will be the same as those in 2015. This external file is applicable only for HC, CO, and NO_x emissions and is same for all runs (i.e., 1999, 2008, 1012, and 2030).

Emission Factors

After making modifications to the three external input files (i.e., Mex_P94_Imp.dat, Mex_T2CERT.dat, and Mex_T2EXH.dat), the MOBILE6-Mexico model was then run to generate fleet average emission factors for the base year 1999, as well as for the future projection years of 2008, 2012, and 2030. These model runs accounted for both Mexican fuel standards and emission standards. After the fleet average emission factors were generated, turnover factors were calculated by dividing the future year emission factors by the base year 1999 emission factors. These future year turnover factors were then multiplied by the future year gasoline growth factors[4] to develop a set of composite projection factors that were used to project 1999 base year on-road emissions to 2008, 2012, and 2030. The composite projection factors by pollutant and region are presented in Table 8.

As can be seen in Table 8, there are projected to be significant reductions in NO_x, SO_2, VOC, and CO emission factors by 2030, in spite of increased motor vehicle fuel use. The reductions in NO_x, VOC, and CO are due to fleet turnover, which gradually incorporates cleaner vehicles into the overall fleet over time. The reductions in SO_2 are attributable to the lower sulfur contents in the future Mexican fuel standards. Increased PM_{10} and $PM_{2.5}$ emissions are the result of increased fuel use without any future PM standards, while increased NH_3 emissions are likely due to fleet turnover (i.e., new vehicle technologies, such as advanced catalytic converters tend to reduce NO_x, but increase NH_3).

Nonroad Mobile Sources

The 1999 nonroad mobile source categories were limited to diesel-powered agricultural equipment and diesel-powered construction equipment, only, due to the lack of Mexico-specific activity data for other types of nonroad equipment (e.g., recreational vehicles, lawn and garden equipment, etc.). These were projected to 2008, 2012, and 2030 using energy demand projections. Projected fuel use was obtained from modeling conducted for Mexico greenhouse gas studies[4]; these projections included disaggregated demand data for the transportation, industrial, commercial, and agricultural sectors.

Diesel energy demand in the agricultural sector was used as a surrogate to project nonroad emissions from the agricultural equipment source category. The data indicated an increase of approximately 75 percent in diesel usage for agricultural equipment in 2030 compared to 1999 usage. Diesel energy demand in the commercial sector was used as a surrogate to project 1999 nonroad emissions for construction equipment. The data indicated an increase of approximately 57 percent in diesel usage for construction equipment in 2030 compared to 1999 usage.

BASELINE RESULTS

The baseline growth projections for 2008, 2012, and 2030 were developed through the implementation of the methodologies described above. These projection results for point sources, area source, on-road motor vehicles, and nonroad mobile sources are presented below.

Point Sources

The overall projected baseline point source emission totals are presented in Table 9; the baseline point source emission totals are also disaggregated by group in Table 10.

Table 9 indicates an approximately threefold increase in baseline NO_x emissions from 1999 to 2030. Most of this increase can be attributed to the EGU sources, where the baseline NO_x emissions in 2030 increased by 279 percent from the 1999 levels. Similarly, the manufacturing sector is expected to have a threefold increase in 2030 NO_x emissions compared to the 1999 levels. However, the 2030 NO_x emissions in the refineries sector was nearly unchanged relative to the 1999 NO_x emissions.

According to Table 9, baseline SO_2 emissions in the year 2030 are expected to increase slightly more than 25 percent from 1999. Of the total SO_2 emissions from the EGU sector in 1999, power plants fired with combustóleo (residual fuel oil) contribute approximately 75 percent of the emissions. As Mexico is moving away from use of residual fuel oil in power plants, SO_2 emissions in 2030 from residual fuel-fired power plants are expected to drop by almost 87 percent. On the other hand, SO_2 emissions from natural gas-fired power plants should increase 30 percent and those from coal-fired power plants should increase by approximately 279 percent. Also, SO_2 emissions in the year 2030 from the manufacturing sector increased almost three-fold from the 1999 levels.

Over 50 percent of the VOC emissions from point sources in 1999 were from refineries. The 2030 emissions are expected to remain relatively unchanged compared to the 1999 emissions. The increase in VOC emissions from 1999 levels to 2030 levels can be attributed to manufacturing industries with 2030 VOC emissions increasing by almost 200 percent from their 1999 levels.

Approximately 72 percent of the total point source CO emissions in 1999 originate from refineries and manufacturing. While the emissions from refineries are expected to remain constant, emissions from manufacturing are projected to increase by approximately 200 percent in the year 2030. Manufacturing contributes slightly less than half of the total CO increase from 1999 to the year 2030. EGUs are responsible for a similar increase in CO emissions.

A significant portion majority of PM_{10} emissions (i.e., 44 percent) and $PM_{2.5}$ emissions (i.e., 41 percent) in 1999 are from manufacturing. By 2030, particulate emissions from these sources are projected to increase by approximately 190 percent compared to 1999 levels. Out of the total increase in particulate emissions, manufacturing sources are expected to contribute approximately 73 percent of the PM_{10} increase and 70 percent of the $PM_{2.5}$ emissions increase. In addition, EGUs contribute approximately 11 percent of the PM_{10} increase and 26 percent of the $PM_{2.5}$ increase. Particulate emissions in the year 2030 from refineries should remain the same as 1999 levels.

Area Sources

The projected baseline area source emission totals are summarized in Table 11, along with the initial 1999 area source emission totals. Baseline area source emissions for 1999 and 2030 by Source Classification Code (SCC) are presented in Tables 12 and 13. (Due to length considerations, baseline area source emissions for 2008 and 2012 are not shown.)

As can be seen from the tables, SO_2 emissions in 2030 are projected to decrease by almost 88 percent compared to the 1999 base year emissions. This decrease in SO_2 emissions can primarily be attributed to changes in the industrial and commercial residual combustion category. SO_2 emissions from residual fuel combustion in 1999 were approximately 56,000 Mg/year. The energy demand projections from LEAP[4] indicated that there will be no residual fuel combustion in the commercial sector after 2002; therefore, SO_2 emissions from commercial residual fuel combustion in 2008, 2012, and 2030 were set to zero. Similarly, the energy demand data also indicate that emissions from industrial residual fuel combustion are projected to drop to 10 percent of 1999 levels.

The 2030 NO_x emissions, on the other hand, are projected to increase to nearly 200 percent of 1999 levels. Most of this increase can be attributed to the commercial marine vessel and LPG combustion source categories. The NO_x emissions from commercial marine vessels are projected to increase from approximately 76,000 Mg/yr in 1999 to almost 282,000 Mg/yr in 2030. The energy demand projections from LEAP[4] indicate a threefold increase in commercial marine diesel use in 2030 compared to 1999 levels. Also, NO_x emissions for all the LPG combustion categories (i.e., industrial, commercial, residential, transportation, and agriculture) are projected to grow from 72,750 Mg/yr in 1999 to 384,230 Mg/yr in 2030.

VOC emissions show a steady increase from 1999 to 2030. In 1999, approximately half the VOC emissions are from the solvent evaporation categories (e.g., industrial surface coatings, architectural surface coatings, degreasing, consumer solvent usage, etc.). The growth factors for these categories were based upon either population or GDP and the VOC growth tends to mirror these two growth factors.

Like VOC, the CO emission estimates also indicate a steady increase from the 1999 levels. However, it should be noted that almost all of the CO increase can be attributed to growth in transportation LPG combustion. The 1999 CO emissions from transportation LPG combustion are approximately 279,000 Mg/yr, corresponding to 11 percent of the total area source CO emissions. In 2030, the CO emissions for the same category projected to be 2,167,194 Mg/yr (i.e., an emissions increase of a factor of 8). This is due to an expected major increase in LPG usage by transportation sources, from 35.3 PJ in 1999 to 274.7 PJ in 2030.[4] Other significant area source contributors of CO emissions in 1999 (e.g., wildfires, agricultural burning, and residential wood combustion) are projected to decrease by 2030.

Residential wood combustion accounts for 51 percent of PM_{10} emissions and 68 percent of $PM_{2.5}$ emissions in the 1999 Mexico NEI. However, energy demand data indicate in a drop in residual wood combustion of almost 30 percent by 2030.[4] This decrease in residential wood combustion demand creates a drop in PM_{10} and $PM_{2.5}$ emissions in 2030 relative to 1999 levels. As a result of this decrease, the agricultural tilling category increases in relative importance.

The 2030 NH_3 emissions are projected to decrease by approximately 35 percent compared to the 1999 inventory. Most of this decrease can be attributed to reductions in livestock ammonia as a result of projecting historical average livestock statistics.

On-Road Motor Vehicles

The projected baseline on-road motor vehicle emission totals are summarized in Table 14, along with the initial 1999 on-road motor vehicle emission totals. Baseline on-road motor vehicle emissions by vehicle classification are presented in Table 15. As shown in these two tables, NO_x, SO_2, VOC, and CO emissions are expected to significantly decrease by 2030, in spite of increased motor vehicle fuel use. The reductions in NO_x, VOC, and CO are due to fleet turnover, while the SO_2 reductions are attributable to the lower sulfur contents in the future Mexican fuel standards. Increased PM_{10} and $PM_{2.5}$ emissions are the result of increased fuel use without any future PM standards, while increased NH_3 emissions are likely due to fleet turnover (i.e., new vehicle technologies, such as advanced catalytic converters tend to reduce NO_x, but increase NH_3).

Nonroad Mobile Sources

The projected baseline nonroad mobile source emission totals are summarized in Table 16, along with the initial 1999 nonroad mobile source emission totals. Emission totals for all pollutants are expected to rise due to the expected increase in diesel usage for agricultural equipment and construction equipment (i.e., 75 percent and 57 percent, respectively).

Overall Baseline Inventory

The entire projected baseline Mexico NEI emissions (i.e., 2008, 2012, and 2030) are summarized in Table 17 by emission type, along with the initial 1999 inventory. The overall inventory is projected to increase in the future.

In general, emissions from point sources, area sources, and nonroad mobile sources are projected to increase in future years relative to the 1999 base year. The projection factors for these source types are primarily driven by population growth, GDP growth, and fuel growth. There are also a few source categories with decreasing emissions (i.e., area source SO_2, PM_{10}, and $PM_{2.5}$); these are due to projected decreases in certain fuel types (i.e., commercial combustion of residual fuel oil and residential wood combustion). The relative decrease of area source and on-road motor vehicle SO_2 is shown in Figures 1 and 2.

Although point source, area source, and nonroad mobile source emissions are projected to increase, projected increases to the overall inventory are dampened by projected decreases in some on-road motor vehicle emissions. This trend is shown in Figure 3. As described above, on-road motor vehicle NO_x, SO_2, VOC, and CO emissions are projected to decrease in future years relative to the 1999 base year, while PM_{10}, $PM_{2.5}$, and NH_3 emissions increase. Although the demand for motor vehicle fuel will increase significantly in the future, the decreases in NO_x, SO_2, VOC, and CO emissions will also be significant due to the effects of new control technologies that will gradually be incorporated into the overall vehicle fleet due to turnover, as well as low sulfur fuels. Because new motor vehicle standards are not being implemented for PM_{10}, $PM_{2.5}$, and NH_3, emissions are projected to increase in the future for these pollutants.

CONTROL SCENARIO RESULTS

Following the development of base year emission projections for 2008, 2012, and 2030, additional analysis was conducted involving three control scenarios and their effect on future emissions. All three control scenarios focused only on on-road motor vehicles and do not affect point, area, or nonroad mobile sources. Details of the control scenarios and the associated control levels were developed by INE staff and are described in the following subsections.[22]

Control Scenario 1 – Increased Fuel Economy

The first control scenario considers an increase in fuel economy for new light-duty gasoline vehicles and trucks; the fuel economy for all other vehicle types is assumed to be unchanged. The baseline fuel economy for new vehicles is assumed to be 10.82 kilometers per liter (km/l), and will begin increasing by 1 km/l annual in 2011 until reaching a value of 15.82 km/l in 2015 and all subsequent years. The pollutant specific reductions are presented in Table 18. No emission reductions were projected for 2008; reductions will only occur in 2012 and 2030. In addition, no emission reductions were quantified for SO_2 or NH_3 for any of the years, because none of the control scenarios were applicable to these pollutants.

Control Scenario 2 – Use of Ethanol in Oxygenated Fuel

Oxygenated fuels have been used in the major metropolitan zones of Mexico since 1990 in order to reduce ozone levels. The oxygenated gasoline supplied by PEMEX (Petróleos Mexicanos – Mexico's state-owned petroleum company) contains methyl tert-butyl ether (MTBE) and/or tertiary amyl methyl ether (TAME). PEMEX is currently contemplating switching from MTBE/TAME to ethanol. The second control scenario involves the switch from MTBE/TAME oxygenates to ethanol while maintaining an oxygenate level of 2 percent by weight. The switch is assumed to begin in Guadalajara in 2010, follow in Monterrey in 2011, and finish in Mexico City in 2012. All other fuel characteristics (e.g., Reid vapor pressure [RVP], etc.) are assumed to remain unchanged. The switch to oxygenated fuel with ethanol was assumed to only affect gasoline-fueled vehicles (i.e., light-duty gasoline vehicles, light-duty gasoline trucks, heavy-duty gasoline vehicles, and motorcycles). The reductions for Guadalajara, Monterrey, and Mexico City are presented in Table 19. No emission reductions were projected for 2008; reductions will only occur in 2012 and 2030. The emission reductions were applied for all inventoried pollutants.

Control Scenario 3 – Combined Increased Fuel Economy and Use of Ethanol in Oxygenated Fuel

The third control scenario is the combined implementation of Control Scenario 1 and Control Scenario 2 and does not include any new control strategies. The effects of Control Scenarios 1 and 2 are applied by calculating the reduced emissions due to Control Scenario 1 and then applying the controls from Control Scenario 2. The effect of Control Scenario 3 is dependent on the vehicle classification, pollutant, or geographically location to which it is applied. For example, Control Scenario 3 for light-duty gasoline vehicle NO_x emissions in Guadalajara would include the control effects from both Control Scenario 1 and Control Scenario 2, while Control Scenario 3 for heavy-duty diesel vehicle emissions in the state of Sonora would have no control effects from Control Scenario 1 or Control Scenario 2.

Results with Controls

The projected on-road motor vehicle emission totals, including the effects of Control Scenarios 1, 2, and 3 are summarized in Table 20. Control Scenarios 1, 2, and 3 are identified with the abbreviations CS1, CS2, and CS3, respectively. For reference purposes, the baseline projected emission totals for 1999, 2008, 2012, and 2020 have also been included. Because Control Scenarios 1, 2, and 3 are based upon on-road motor vehicle control strategies, only on-road motor vehicle emissions are presented in Table 19. Point source, area source, and nonroad mobile source emissions are not impacted by Control Scenarios 1, 2, and 3.

The emission reductions due to Control Scenario 1 vary from 0.1 percent to 0.6 percent for 2012 and from 1.1 percent to 5.0 percent for 2030; Control Scenario 1 does not affect SO_2 and NH_3, so these are not included in these reduction values. The percentage reductions due to Control Scenario 1 relative to baseline emissions increase over time because new vehicles with improved fuel economy gradually penetrate the overall vehicle fleet over time, thereby raising the fleet average fuel economy and decreasing emissions from the fleet.

The percentage reductions due to Control Scenario 2 vary from 0.6 percent to 1.3 percent for 2012 and from 0.5 percent to 1.3 percent for 2030. The emission reductions due to Control Scenario 2 relative to baseline emissions are fairly constant from 2012 to 2030 because the switch from MTBE/TAME-based oxygenated fuels to ethanol-based oxygenated fuels is a one-time event that does not have increasing penetration over time.

As expected, emission reductions due to Control Scenario 3 are greater than those of Control Scenarios 1 or 2 applied individually, and range from 0.7 percent to 1.5 percent for 2012, and from 1.0 percent to 5.7 percent for 2030. The expected VOC emission reductions due to Control Scenarios 1, 2, and 3 are shown in Figure 4.

HARMONIZATION WITH GREENHOUSE GAS EMISSIONS INVENTORIES

Another objective accomplished as part of the development of emissions projections was to "harmonize" the criteria pollutant emission projections with current and future year greenhouse gas emissions inventories in Mexico. The term "harmonize" refers to standardizing or increasing comparability and/or convergence between inventories.

Because of methodological differences between criteria pollutant and greenhouse gas inventories, there are inherent differing aspects between the two types of inventories. For example, VOC emissions from consumer solvents are typically estimated with an annual per capita emission factor combined with population counts; however, consumer solvents do not generate greenhouse gas emissions. In contrast, fuel combustion is a source of both criteria pollutants (i.e., NO_x, SO_2, CO, and VOC) and greenhouse gases (i.e., carbon dioxide[CO_2], methane[CH_4], and nitrous oxide[N_2O]).

In order to ensure harmony between criteria pollutant and greenhouse gas emission inventories, INE provided important data and assumptions used in the development of Mexico's greenhouse gas emissions inventories. For example, future year fuel use projections from LEAP were developed to estimate greenhouse gas emissions in Mexico.[4] These future fuel use projections were then used in this project to generate criteria pollutant growth factors for a wide number of sources categories, including: point source electric generating units (EGUs), area source fuel combustion (i.e., industrial, commercial/institutional, residential, and agricultural), area source fuel distribution (i.e., gasoline and LPG), on-road motor vehicles (in conjunction with the MOBILE6-Mexico analysis), and nonroad mobile sources. In addition, underlying economic assumptions, such as annual Gross Domestic Product (GDP) growth rates[9], were used to develop projection factors for some point sources (i.e., manufacturing industries and miscellaneous industries) and some area source categories (i.e., locomotives, industrial surface coating, and degreasing) in this project.

A certain level of harmony was obtained by using this information from Mexico greenhouse gas inventories to develop projection factors for the future year criteria pollutant projections. In some cases, momentary pauses in the project schedule occurred to ensure that the most up-to-date greenhouse gas inventory information was obtained, rather than using outdated information or information unrelated to greenhouse gas inventories.

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Table 1. New municipalities in Mexico.

State	New Municipality	Already Existing Municipalities
Guerrero	Marquelia (077)	Azoyú (013); Cuajinicuilapa (023)
Guerrero	Cochoapa el Grande (078)	Metlatónoc (043)
Guerrero	José Joaquín de Herrera (079)	Atlixtac (010); Chilapa de Alvarez (028)
Guerrero	Juchitán (080)	Azoyú (013)
Guerrero	Iliatenco (081)	Malinaltepec (041); San Luis Acatlán (052)
México	Luvianos (123)	Tejupilco (082)
México	San José del Rincón (124)	San Felipe del Progreso (074)
México	Tonanitla (125)	Jaltenco (044)
Veracruz	San Rafael (211)	Martínez de la Torre (102)
Veracruz	Santiago Sochiapan (212)	Playa Vicente (130)
Zacatecas	Santa María de la Paz (058)	Apozol (001); Atolinga (003); Benito Juárez (004); Jalpa (019); Juchipila (023); Tepechitlán (045); Teul de González Ortega (047)

Note: Parenthetical numbers are municipality codes.

Table 2. Point source groups and applicable NAICS codes.

Point Source Group	3-Digit NAICS	NAICS Description
EGUs	221	Utilities
Refineries	211	Oil & Gas Extraction
	324	Petroleum & Coal Products Manufacturing
	325	Chemical Manufacturing
	424	Merchant Wholesalers, Nondurable Goods
Primary Metals	331	Primary Metal Manufacturing
Manufacturing Industries	311	Food Manufacturing
	312	Beverage & Tobacco Product Manufacturing
	313	Textile Mills
	314	Textile Product Mills
	315	Apparel Manufacturing
	316	Leather & Allied Product Manufacturing
	321	Wood Product Manufacturing
	322	Paper Manufacturing
	324	Petroleum & Coal Product Manufacturing
	325	Chemical Manufacturing
	326	Plastics & Rubber Products Manufacturing
	327	Nonmetallic Mineral Product Manufacturing
	332	Fabricated Metal Product Manufacturing
	333	Machinery Manufacturing
	334	Computer & Electronic product Manufacturing
	335	Electrical Equipment, Appliance, and Component Manufacturing
	336	Transportation Equipment Manufacturing
	337	Furniture and Related Product Manufacturing
	339	Miscellaneous Manufacturing
	999	Undisclosed
Miscellaneous Industries	212	Mining (except Oil and Gas)
	424	Merchant Wholesalers, Nondurable Goods
Services Industries	323	Printing and Related Support Activities
	562	Waste Management and Remediation Services
	811	Repair and Maintenance
	812	Personal and Laundry Services

Note: In the 1999 Mexico NEI, state jurisdiction point sources that belonged to a particular NAICS group and numbered fewer than three facilities in any given municipality were assigned NAICS 999 to maintain confidentiality.

Table 3. Area source growth surrogates.

Surrogate	Area Source Categories
Population	• Charbroiling/street vendors • Bakeries • Construction activities • Architectural surface coatings • Autobody refinishing • Traffic markings • Dry cleaning • Graphic arts • Consumer solvent usage • Asphalt application • Open burning • Structure fires • Brick kilns • Domestic ammonia
Fuel use	• Distillate fuel combustion (industrial and commercial) • Residual fuel combustion (industrial and commercial) • Natural gas fuel combustion (industrial, commercial, and residential) • LPG fuel combustion (industrial, commercial, residential, transportation, and agriculture) • Kerosene fuel combustion (industrial, residential, and agriculture) • Residential wood combustion • Commercial marine vessels • Gasoline distribution • LPG distribution
Gross Domestic Product (GDP)	• Locomotives • Industrial surface coating • Degreasing
Planted acreage by state	• Pesticide application • Agricultural tilling • Fertilizer application • Agricultural burning
Livestock population	• Livestock ammonia • Beef cattle feedlots
Forest acreage burnt by state	• Wildfires
Vehicular traffic at border crossings	• Border crossings
Airline passenger volume	• Aircraft
Residential wastewater treated quantities	• Wastewater treatment

Table 4. Mexican fuel sulfur standards by fuel type and region (in ppm).

Fuel Type	1999	2008	2012	2030
Premium	500	30/80 (avg/max)	30/80 (avg/max)	30/80 (avg/max)
Magna (ZM)	500	421/500 (avg/max)	30/80 (avg/max)	30/80 (avg/max)
Magna (RP)	500	421/500	30/80 (avg/max)	30/80 (avg/max)
Diesel (ZM)	500	300	300	15
Diesel (ZF)	500	15	15	15
Diesel (RP)	420/500 (avg/max)	420/500 (avg/max)	420/500 (avg/max)	15

Table 5. Equivalency of Mexican standards to EURO and U.S. standards.

Mexican Standard	Equivalent Standard
A	U.S. EPA's Tier 1
B	Combination of U.S. EPA's Tier 1 and Tier 2 for 80,000 km certification or EURO 3 for 100,000 km certification
C	Combination of U.S. EPA's Tier 1 and Tier 2 for 80,000 km certification or EURO 4 for 100,000 km certification

Table 6. Mexican motor vehicle emission standards (g/km).

<table>
<tr><th colspan="2"></th><th colspan="2">CO (g/km)</th><th colspan="2">NMHC (g/km)</th><th colspan="2">NO_x (g/km)</th><th colspan="2">PM (g/km)</th></tr>
<tr><th>Standard</th><th>Vehicle Class</th><th>Gas, LPG, NG</th><th>Diesel</th><th>Gas, LPG, NG</th><th>Diesel</th><th>Gas, LPG, NG</th><th>Diesel</th><th>Gas, LPG, NG</th><th>Diesel</th></tr>
<tr><td rowspan="5">A</td><td>PV</td><td colspan="2" rowspan="2">2.11</td><td colspan="2" rowspan="2">0.156</td><td rowspan="2">0.25</td><td rowspan="2">0.62</td><td rowspan="2">-</td><td rowspan="2">0.050</td></tr>
<tr><td>LDT1</td></tr>
<tr><td>LDT2</td><td colspan="2" rowspan="2">2.74</td><td colspan="2" rowspan="2">0.200</td><td rowspan="2">0.44</td><td rowspan="2">0.62</td><td rowspan="2">-</td><td rowspan="2">0.062</td></tr>
<tr><td>LDT3</td></tr>
<tr><td>LDT4</td><td colspan="2">3.11</td><td colspan="2">0.240</td><td>0.68</td><td>0.95</td><td>-</td><td>0.075</td></tr>
<tr><td rowspan="5">B</td><td>PV</td><td colspan="2" rowspan="3">2.11</td><td colspan="2" rowspan="3">0.099</td><td colspan="2" rowspan="5">0.249</td><td rowspan="2">-</td><td rowspan="2">0.050</td></tr>
<tr><td>LDT1</td></tr>
<tr><td>LDT2</td><td rowspan="2">-</td><td rowspan="2">0.062</td></tr>
<tr><td>LDT3</td><td colspan="2" rowspan="2">2.74</td><td colspan="2" rowspan="2">0.121</td></tr>
<tr><td>LDT4</td><td>-</td><td>0.075</td></tr>
<tr><td rowspan="5">C</td><td>PV</td><td colspan="2" rowspan="5">2.11</td><td colspan="2" rowspan="3">0.047</td><td colspan="2" rowspan="3">0.068</td><td rowspan="2">-</td><td rowspan="2">0.050</td></tr>
<tr><td>LDT1</td></tr>
<tr><td>LDT2</td><td rowspan="2">-</td><td rowspan="2">0.062</td></tr>
<tr><td>LDT3</td><td colspan="2" rowspan="2">0.087</td><td colspan="2" rowspan="2">0.124</td></tr>
<tr><td>LDT4</td><td>-</td><td>0.075</td></tr>
</table>

Table 7. Phase-in schedule for Mexican motor vehicle emission standards (% of model year vehicles).

Model Year	Standard A %	Standard B %	Standard C %
2004	100%	-	-
2005	100%	-	-
2006	100%	-	-
2007	75%	25%	-
2008	50%	50%	-
2009	30%	70%	-
2010	-	100%	-
2011	-	100%	-
2012	-	75%	25%
2013	-	50%	50%
2014	-	30%	70%
2015	-	-	100%
2030	-	-	100%

Table 8. Composite projection factors for on-road motor vehicles by region.

Region	Year	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
ZM	2008	0.9397	1.1012	0.6761	0.5905	1.6599	1.6790	1.6009
ZF	2008	0.9299	0.8057	0.7238	0.6383	1.6450	1.6624	1.6009
RP	2008	0.9299	1.3087	0.7238	0.6383	1.6700	1.6906	1.6009
ZM	2012	0.8599	0.4480	0.5836	0.4378	1.7768	1.7825	1.9523
ZF	2012	0.8492	0.0886	0.6117	0.4508	1.7593	1.7624	1.9523
RP	2012	0.8492	0.6996	0.6117	0.4508	1.7896	1.7965	1.9523
ZM	2030	0.3019	0.2258	0.5628	0.5486	3.7605	3.7276	4.9158
RP	2030	0.3011	0.2258	0.5579	0.6167	3.7605	3.7276	4.9158

Table 9. 1999, 2008, 2012, and 2030 baseline point source emissions (Mg/yr).

Year	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$
1999	448,826	2,633,799	247,878	167,648	297,264	198,917
2008	603,467	2,572,474	327,424	236,756	357,765	237,438
2012	692,807	2,623,275	349,642	265,297	394,071	261,330
2030	1,250,510	3,372,241	458,669	440,926	647,395	428,476

Table 10. Projected baseline point source emissions by group (Mg/yr).

Group	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$
1999						
EGUs	259,804	1,604,803	11,390	25,345	79,506	62,882
Refineries	74,025	755,267	129,135	58,348	43,246	29,871
Primary Metals	25,777	30,525	6,705	11,656	21,469	18,288
Manufacturing Industries	87,091	232,777	95,839	63,820	130,806	80,878
Miscellaneous Industries	2,048	10,223	276	8,466	22,187	6,956
Services	80	204	4,533	13	50	42
Total	**448,825**	**2,633,799**	**247,878**	**167,648**	**297,264**	**198,917**
2008						
EGUs	352,425	1,206,163	13,149	46,833	65,673	55,736
Refineries	97,750	997,330	170,523	77,049	57,107	39,444
Primary Metals	31,719	37,561	8,251	14,343	26,418	22,504
Manufacturing Industries	118,696	317,251	130,619	86,980	178,275	110,229
Miscellaneous Industries	2,791	13,933	376	11,538	30,238	9,480
Services	86	236	4,506	13	54	45
Total	**603,467**	**2,572,474**	**327,424**	**236,756**	**357,765**	**237,438**
2012						
EGUs	420,201	1,203,778	15,161	59,194	68,184	59,383
Refineries	97,750	997,330	170,523	77,049	57,107	39,444
Primary Metals	35,359	41,872	9,198	15,989	29,450	25,087
Manufacturing Industries	136,207	364,053	149,888	99,812	204,575	126,490
Miscellaneous Industries	3,203	15,989	431	13,240	34,699	10,879
Services	87	253	4,441	13	56	47
Total	**692,807**	**2,623,275**	**349,642**	**265,297**	**394,071**	**261,330**
2030						
EGUs	865,129	1,843,612	31,847	148,724	116,210	106,454
Refineries	74,599	761,120	130,136	58,800	43,582	30,102
Primary Metals	51,740	61,270	13,459	23,397	43,094	36,709
Manufacturing Industries	253,002	676,225	278,416	185,400	379,996	234,954
Miscellaneous Industries	5,949	29,699	801	24,593	64,453	20,207
Services	91	315	4,010	12	60	50
Total	**1,250,510**	**3,372,241**	**458,669**	**440,926**	**647,395**	**428,476**

Table 11. 1999, 2008, 2012, and 2030 baseline area source emissions (Mg/yr).

Year	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
1999	276,321	194,642	1,743,587	2,500,852	439,253	320,369	1,130,400
2008	363,963	119,763	2,106,842	3,068,145	483,735	355,488	724,092
2012	415,907	60,094	2,202,932	2,939,976	443,800	317,645	727,417
2030	854,999	23,223	3,170,187	4,167,536	412,043	286,518	738,330

Table 12. 1999 area source emissions by SCC (Mg/yr).

SCC	SCC Description	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
2102004000	Distillate fuel combustion – Industrial	2,562	637	21	534	107	26	
2102005000	Residual fuel combustion – Industrial	10,721	132,466	64	1,141	7,300	4,754	
2102006000	Natural gas fuel combustion – Industrial	28,404	61	558	8,521	771	771	
2102007000	LPG fuel combustion – Industrial	710	1	13	121	21	21	
2102011000	Kerosene fuel combustion – Industrial	28	6	0	6	1	0	
2103004000	Distillate fuel combustion – Commercial	235	62	4	59	13	10	
2103005000	Residual fuel combustion – Commercial	5,233	56,173	108	476	590	219	
2103006000	Natural gas fuel combustion – Commercial	305	2	17	256	23	23	
2103007000	LPG fuel combustion – Commercial	4,471	12	110	619	141	141	
2104006000	Natural gas fuel combustion – Residential	872	6	51	371	71	71	
2104007000	LPG fuel combustion – Residential	22,553	60	556	3,120	711	711	
2104008000	Wood fuel combustion – Residential	20,762	2,966	392,991	1,711,364	226,897	218,433	
2104011000	Kerosene fuel combustion – Residential	70	19	3	19	1	1	
2222222222	Border crossings	340		1,998	21,580			
2267000000	LPG fuel combustion – Transportation	44,927		27,680	278,881			
2267005000	LPG fuel combustion – Agricultural	91	0	2	13	3	3	
2275020000	Aircraft	4,373	343	2,048	7,424			
2280000000	Commercial marine vessels	76,096	902	669	7,497	1,867	1,822	
2285000000	Locomotives	43,489	387	1,640	4,296	1,080	970	
2302002000	Charbroiling/Street vendors	286		1,001	15,516	7,794	6,221	
2302050000	Bakeries			12,185				
2311000000	Construction activities					9,448	1,964	
2401001000	Architectural surface coatings			49,454				
2401005000	Autobody refinishing			23,492				
2401008000	Traffic markings			3,032				
2401990000	Industrial surface coatings			104,518				
2415000000	Degreasing			167,020				
2420000370	Dry cleaning			12,667				
2425000000	Graphic arts			35,835				
2460000000	Consumer solvent usage			346,608				
2461021000	Asphalt application			7,756				
2461800000	Pesticide application			23,563				
2501060000	Gasoline distribution			91,559				
2630010000	Wastewater treatment			41,263				
2801000003	Agricultural tilling					109,866	24,357	

Table 12. Continued.

SCC	SCC Description	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
2801500000	Agricultural burning			14,672	148,569	13,975	13,327	
2801520004	Kerosene fuel combustion – Agricultural	3	1	0	1	0	0	
2801700000	Fertilizer application							154,968
2805000000	Livestock ammonia							876,807
2805001000	Beef cattle feedlots					8,391	958	
2810001000	Wildfires	5,942		35,654	207,981	24,270	21,578	
2810005000	Open burning – Waste	3,225	538	4,599	45,687	20,425	18,705	
2810030000	Structure fires	7		17	301	19	18	
3333333333	LPG distribution			332,099				
4444444444	Brick kilns	618		8,059	36,502	5,471	5,267	
5555555555	Domestic ammonia							98,625
	Total	**276,321**	**194,642**	**1,743,587**	**2,500,852**	**439,253**	**320,369**	**1,130,400**

Note: Blanks indicate the emissions were not estimated. A zero indicates emissions <0.5 Mg/yr.

Table 13. 2030 baseline projected area source emissions by SCC (Mg/yr).

SCC	SCC Description	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
2102004000	Distillate fuel combustion – Industrial	5,242	1,303	44	1,092	218	52	
2102005000	Residual fuel combustion – Industrial	1,041	12,862	6	111	709	462	
2102006000	Natural gas fuel combustion – Industrial	50,182	108	986	15,054	1,362	1,362	
2102007000	LPG fuel combustion – Industrial	824	2	15	140	25	25	
2102011000	Kerosene fuel combustion – Industrial	9	2	0	2	0	0	
2103004000	Distillate fuel combustion – Commercial	371	98	6	93	20	16	
2103005000	Residual fuel combustion – Commercial							
2103006000	Natural gas fuel combustion – Commercial	528	3	29	443	40	40	
2103007000	LPG fuel combustion – Commercial	8,109	22	200	1,122	256	256	
2104006000	Natural gas fuel combustion – Residential	6,631	42	388	2,822	536	536	
2104007000	LPG fuel combustion – Residential	26,017	69	642	3,600	820	820	
2104008000	Wood fuel combustion – Residential	14,570	2,082	275,792	1,200,998	159,231	153,292	
2104011000	Kerosene fuel combustion – Residential	13	4	1	4	0	0	
2222222222	Border crossings	542		3,185	34,393			
2267000000	LPG fuel combustion – Transportation	349,129		215,098	2,167,194			
2267005000	LPG fuel combustion – Agricultural	150	0	4	21	5	5	
2275020000	Aircraft	25,615	2,012	11,998	43,491			
2280000000	Commercial marine vessels	281,737	3,341	2,478	27,755	6,910	6,745	
2285000000	Locomotives	68,014	604	2,565	6,719	1,689	1,518	
2302002000	Charbroiling/Street vendors	355		1,242	19,251	9,670	7,718	
2302050000	Bakeries			15,118				
2311000000	Construction activities					12,433	2,584	
2401001000	Architectural surface coatings			61,357				
2401005000	Autobody refinishing			39,298				
2401008000	Traffic markings			3,286				
2401990000	Industrial surface coatings			303,629				
2415000000	Degreasing			485,197				
2420000370	Dry cleaning			17,669				
2425000000	Graphic arts			44,460				
2460000000	Consumer solvent usage			430,036				
2461021000	Asphalt application			8,406				
2461800000	Pesticide application			25,531				
2501060000	Gasoline distribution			404,975				
2630010000	Wastewater treatment			120,341				

Table 13. Continued.

SCC	SCC Description	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
2801000003	Agricultural tilling					119,206	26,428	
2801500000	Agricultural burning			14,909	150,223	14,059	13,407	
2801520004	Kerosene fuel combustion – Agricultural	4	1	0	1	0	0	
2801700000	Fertilizer application							168,017
2805000000	Livestock ammonia							448,224
2805001000	Beef cattle feedlots					6,964	795	
2810001000	Wildfires	11,082		66,493	387,876	45,262	40,242	
2810005000	Open burning – Waste	4,015	669	5,725	56,877	25,428	23,286	
2810030000	Structure fires	9		23	373	24	22	
3333333333	LPG distribution			598,484				
4444444444	Brick kilns	811		10,571	47,882	7,177	6,909	
5555555555	Domestic ammonia							122,089
	Total	**854,999**	**23,223**	**3,170,187**	**4,167,536**	**412,043**	**286,518**	**738,330**

Note: Blanks indicate the emissions were not estimated. A zero indicates emissions <0.5 Mg/yr.

Table 14. 1999, 2008, 2012, and 2030 baseline on-road motor vehicle emissions (Mg/yr).

Year	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
1999	435,665	24,453	573,042	4,671,842	20,567	18,845	7,609
2008	370,177	27,765	399,936	2,872,420	31,890	29,551	11,931
2012	336,519	12,490	340,519	2,065,988	34,019	31,258	14,533
2030	117,883	5,366	317,164	2,731,909	71,402	64,816	36,529

Table 15. Baseline on-road motor vehicle emissions by vehicle classification (Mg/yr).

Vehicle Classification	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
1999							
LDGV	90,438	9,885	321,776	2,485,068	5,655	5,159	3,670
LDGT	58,710	8,738	180,409	1,611,579	4,985	4,551	2,536
HDGV	12,221	1,451	26,992	305,053	219	186	208
MC	1,013	121	3,921	30,372	12	8	100
LDDV	672	31	769	1,466	134	123	30
LDDT	341	20	407	801	66	60	14
HDDV	272,270	4,206	38,768	237,504	9,497	8,756	1,052
Total	**435,665**	**24,453**	**573,042**	**4,671,842**	**20,567**	**18,845**	**7,609**
2008							
LDGV	84,432	11,511	226,961	1,540,345	9,403	8,680	5,875
LDGT	54,811	10,176	127,202	999,217	8,290	7,658	4,060
HDGV	11,404	1,690	18,994	187,792	365	313	334
MC	945	141	2,762	18,743	19	14	160
LDDV	538	31	464	776	190	177	41
LDDT	273	20	245	424	93	87	19
HDDV	217,774	4,196	23,307	125,123	13,529	12,622	1,442
Total	**370,177**	**27,765**	**399,936**	**2,872,420**	**31,890**	**29,551**	**11,931**
2012							
LDGV	77,166	5,186	193,315	1,107,835	10,070	9,218	7,165
LDGT	50,094	4,584	108,357	718,517	8,878	8,132	4,952
HDGV	10,422	761	16,190	135,641	391	332	407
MC	863	64	2,354	13,517	21	15	195
LDDV	487	14	392	554	202	187	49
LDDT	247	9	207	303	99	92	23
HDDV	197,240	1,873	19,704	89,620	14,358	13,283	1,743
Total	**336,519**	**12,490**	**340,519**	**2,065,988**	**34,019**	**31,258**	**14,533**
2030							
LDGV	27,257	2,232	180,128	1,466,991	21,265	19,230	18,041
LDGT	17,694	1,973	100,997	951,772	18,748	16,965	12,468
HDGV	3,683	328	15,115	178,241	825	693	1,025
MC	305	27	2,196	17,811	44	32	490
LDDV	170	6	361	721	421	384	122
LDDT	86	4	191	394	207	189	56
HDDV	68,689	795	18,178	115,978	29,894	27,322	4,327
Total	**117,883**	**5,366**	**317,164**	**2,731,909**	**71,402**	**64,816**	**36,529**

Table 16. 1999, 2008, 2012, and 2030 baseline nonroad mobile source emissions (Mg/year).

Year	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$
1999	263,768	3,486	35,169	153,604	37,240	36,123
2008	281,006	3,709	38,290	165,890	40,447	39,234
2012	296,402	3,911	40,463	175,197	42,734	41,452
2030	437,465	5,777	59,058	256,756	62,449	60,576

Table 17. Baseline Mexico emissions by source type (Mg/yr).

	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
1999							
Point	448,826	2,633,799	247,878	167,648	297,264	198,917	
Area	276,321	194,642	1,743,587	2,500,852	439,253	320,369	1,130,400
On-Road	435,665	24,453	573,042	4,671,842	20,567	18,845	7,609
Nonroad	263,768	3,486	35,169	153,604	37,240	36,123	
Total	**1,424,580**	**2,856,380**	**2,599,676**	**7,493,946**	**794,324**	**574,254**	**1,138,009**
2008							
Point	606,053	2,575,537	328,096	237,926	359,919	239,274	
Area	363,963	119,763	2,106,842	3,068,145	483,735	355,488	724,092
On-Road	370,177	27,765	399,936	2,872,420	31,890	29,551	11,931
Nonroad	281,006	3,709	38,290	165,890	40,447	39,234	
Total	**1,621,199**	**2,726,774**	**2,873,164**	**6,344,381**	**915,991**	**663,547**	**736,023**
2012							
Point	686,509	2,615,816	348,004	262,449	388,825	256,861	
Area	415,907	60,094	2,202,932	2,939,976	443,800	317,645	727,417
On-Road	336,519	12,490	340,519	2,065,988	34,019	31,258	14,533
Nonroad	296,402	3,911	40,463	175,197	42,734	41,452	
Total	**1,735,337**	**2,692,311**	**2,931,918**	**5,443,610**	**909,378**	**647,216**	**741,950**
2030							
Point	1,239,873	3,359,643	455,901	436,116	638,533	420,929	
Area	854,999	23,223	3,170,187	4,167,536	412,043	286,518	738,330
On-Road	117,883	5,366	317,164	2,731,909	71,402	64,816	36,529
Nonroad	437,465	5,777	59,058	256,756	62,449	60,576	
Total	**2,650,220**	**3,394,009**	**4,002,310**	**7,592,317**	**1,184,427**	**832,839**	**774,859**

Table 18. Control Scenario 1 emission reductions (increased fuel economy for light-duty gasoline vehicles and trucks) (%).

Year	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
2008	0.000	NE	0.000	0.000	0.000	0.000	NE
2012	0.439	NE	0.204	0.140	1.028	0.986	NE
2030	3.837	NE	1.785	1.222	8.973	8.610	NE

NE = Not estimated

Table 19. Control Scenario 2 emission reductions (switching to ethanol) (%).

Year	Guadalajara	Monterrey	Mexico City
2008	0.000	0.000	0.000
2012	2.397	4.573	2.782
2030	2.182	3.934	2.709

Table 20. 1999, 2008, 2012, and 2030 on-road motor vehicle emissions with Control Scenarios 1, 2, and 3 (Mg/yr).

Year	NO_x	SO_2	VOC	CO	PM_{10}	$PM_{2.5}$	NH_3
1999	435,665	24,453	573,042	4,671,842	20,567	18,845	7,609
2008	370,177	27,765	399,936	2,872,420	31,890	29,551	11,931
2012	336,519	12,490	340,519	2,065,988	34,019	31,258	14,533
2030	117,883	5,366	317,164	2,731,909	71,402	64,816	36,529
2012 – CS1	335,960	12,490	339,902	2,063,431	33,824	31,087	14,533
2030 – CS1	116,159	5,366	312,147	2,702,347	67,812	61,699	36,529
2012 – CS2	334,644	12,362	336,077	2,038,494	33,766	31,027	14,372
2030 – CS2	117,269	5,310	313,197	2,699,202	70,904	64,365	36,150
2012 – CS3	334,092	12,362	335,469	2,035,972	33,574	30,859	14,372
2030 – CS3	115,566	5,310	308,247	2,670,003	67,357	61,287	36,150

CS1 = Control Scenario 1, CS2 = Control Scenario 2, CS3 = Control Scenario 3

Figure 1. 1999 Mexico SO_2 emissions by source type (Mg/yr).

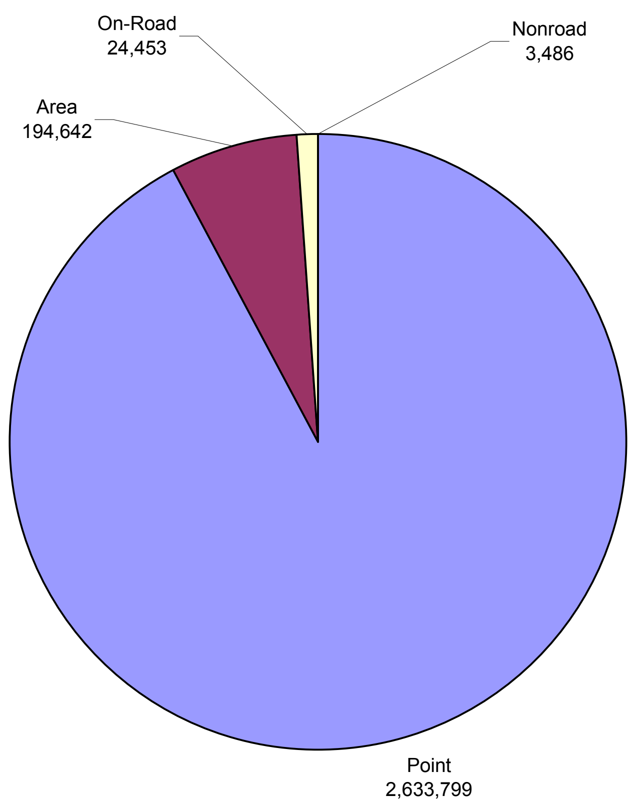

Figure 2. 2030 Mexico SO_2 emissions by source type (Mg/yr).

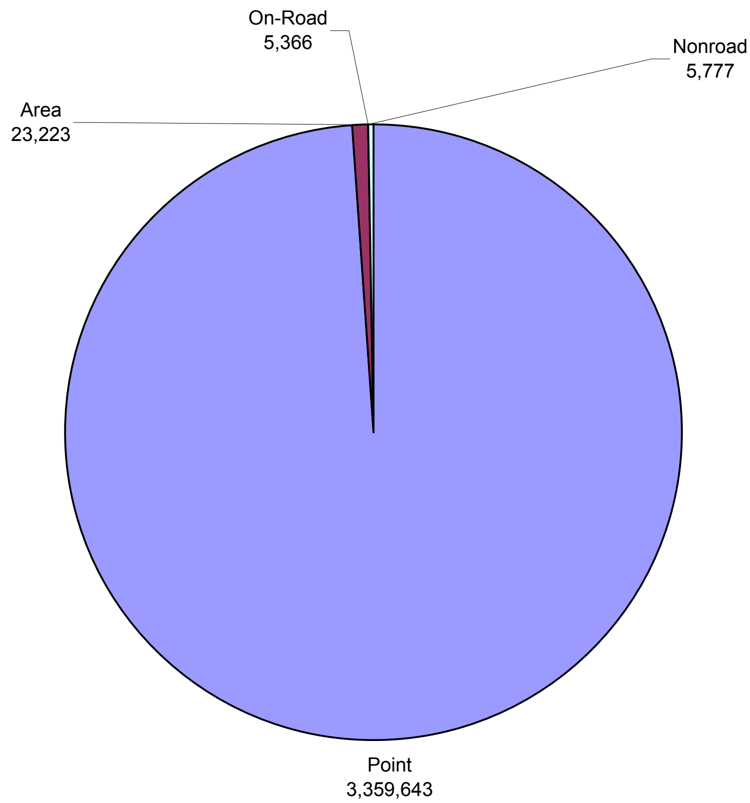

Figure 3. Mexico NO_x emissions by source type (Mg/yr).

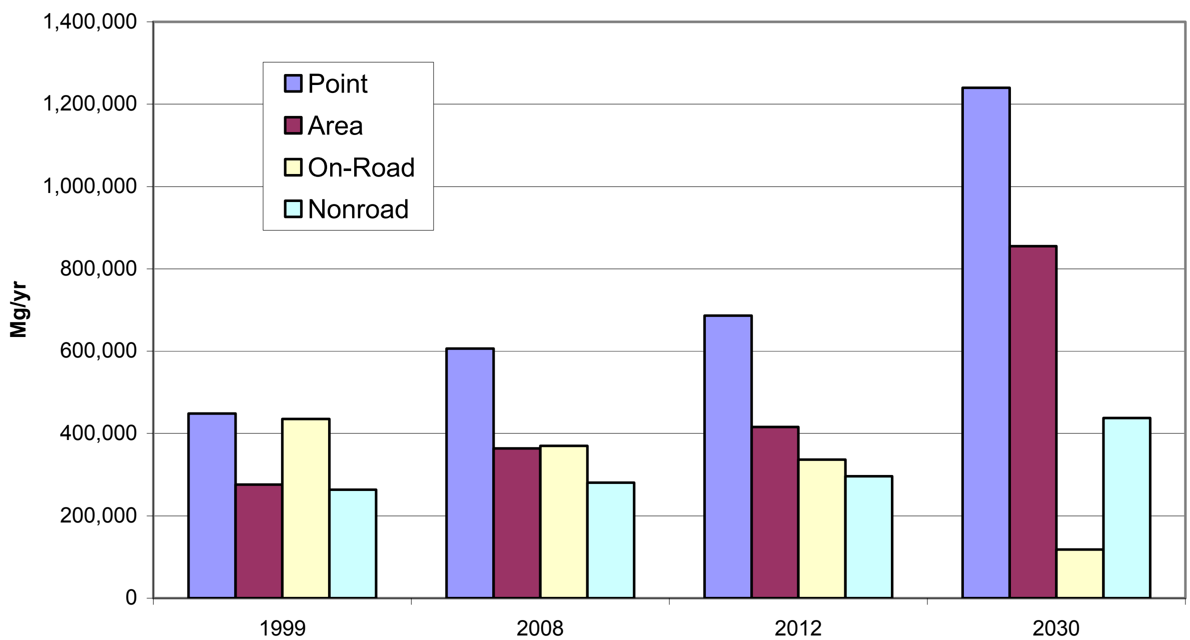

Figure 4. Mexico on-road motor vehicle VOC emissions by control scenario (Mg/yr).