GREENHOUSE GAS EMISSIONS IN TAMAULIPAS AND REFERENCE CASE PROJECTIONS 1990-2025

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Acronyms and Key Terms

bbls – Barrels

BOD – Biochemical Oxygen Demand

Btu – British Thermal Unit

C – Carbon

$CaCO_3$ – Calcium Carbonate

CCS – Center for Climate Strategies

CCT – Carbon Calculation Tool

CFCs – Chlorofluorocarbons

CH_4 – Methane

CHP – Combined Heat and Power

CO_2 – Carbon Dioxide

CO_2e – Carbon Dioxide equivalent

CONAFOR – Comisión Nacional Forestal

EAF – Electric Arc Furnace

EIIP – Emission Inventory Improvement Program

Gg – Gigagram

GHG – Greenhouse Gas

GWh – Gigawatt-hour

GWP – Global Warming Potential

H_2CO_3 – Carbonic Acid

HCFCs – Hydrochlorofluorocarbons

HFCs – Hydrofluorocarbons

HNO_3 – Nitric Acid

HWP – Harvested Wood Products

INEGI – Instituto Nacional de Estadísticas, Geografía, e Informática

IPCC – Intergovernmental Panel on Climate Change

kg – Kilogram

kWh – Kilowatt-hour

lb – Pound

LF – Landfill

LFGTE – Landfill Gas Collection System and Landfill-Gas-to-Energy

LPG – Liquefied Petroleum Gas

Mg – Megagrams

MMBtu – Million British thermal units

MMt – Million Metric tons

MMtCO_2e – Million Metric tons Carbon Dioxide equivalent

MSW – Municipal Solid Waste

N_2O – Nitrous Oxide

NEMS – National Energy Modeling System

NH_3 – Ammonia

ODS – Ozone-Depleting Substance

OEIDRUS - Oficina Estatal de Información para el Desarrollo Rural Sustentable

PFCs – Perfluorocarbons

ppb – Parts per billion

ppm – Parts per million

ppmv – Parts per million by volume

ppt – Parts per trillion

RCI – Residential, Commercial, and Industrial

SEMARNAT – Secretaría de Medio Ambiente y Recursos Naturales

SENER – Secretaría de Energía

SF_6 – Sulfur Hexafluoride

SIACON -- Sistema de Información Agropecuaria de Consulta

SIT – State Greenhouse Gas Inventory Tool

T&D – Transmission and Distribution

t – Metric ton (equivalent to 1.102 short tons)

US – United States

US EPA – United States Environmental Protection Agency

WW – Wastewater

yr – Year

Executive Summary

The Center for Climate Strategies (CCS) prepared with the Agencia Ambiental para el Desarrollo Sustentable (AADS) a preliminary assessment of the State's greenhouse gas (GHG) emissions from 1990 to 2005 and a forecast of emissions through 2025. AADA contributed with leadership and coordination to the development of the inventory and forecast. The inventory and forecast estimates serve as a starting point to assist the State with an initial comprehensive understanding of Tamaulipas's current and possible future GHG emissions.

Tamaulipas's anthropogenic GHG emissions and anthropogenic sinks (carbon storage) were estimated for the period from 1990 to 2025. Historical GHG emission estimates (1990 through 2005)[1] were developed using a set of generally accepted principles and guidelines for State GHG emission inventories, relying to the extent possible on Tamaulipas-specific data and inputs. The initial reference case projections (2006-2025) are based on a compilation of projections of electricity generation, fuel use, and other GHG-emitting activities for Tamaulipas, which are based on official government projections and alternatively on an extrapolation of historical trends. The data sources, methods, and detailed sector-level results are provided in the appendices of this report.

The inventory and projections cover the six types of gases included in Mexico's national GHG enissions inventory[2] and commonly reported in international reporting under the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric, CO_2 equivalents (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential- (GWP-) weighted basis.[3]

As shown in Table ES-1, activities in Tamaulipas accounted for approximately 24.8 million metric tons (MMt) of *gross production-based*[4] CO_2e emissions in 2005, an amount equal to about 3.8% of Mexico's gross GHG emissions in 2005 excluding carbon sinks, such as accumulation of carbon stocks in forested land. Tamaulipas's gross production-based GHG emissions increased by 43% from 1990 to 2005, while national emissions rose by 31% from 1990 to 2005. [5] The growth in Tamaulipas's emissions from 1990 to 2005 is primarily associated with electricity consumption and transportation activities.

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[1] The last year of available historical data varies by sector; ranging from 2000 to 2005.
[2] Inventario Nacional de Emisiones de Gases de Efecto Invernadero (INEGEI)
[3] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC, 1996). Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth), http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm. Estimates of CO_2e emissions are based on the GWP values listed in the IPCC Second Assessment Report (SAR).
[4] "Gross" emissions exclude GHG emissions removed (sequestered) due to forestry and other land uses and "consumption-based" emissions exclude GHG emissions associated with exported electricity.
[5] Comparison with national results were drawn from *Mexico Tercera Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático*. Mexico: INE-SEMARNAT, 2006. Available at www.ine.gob.mx. Available annual emissions values were on the order of 498,748 and 618,072 gigagrams in 1990 and 2002 respectively. 2005 emissions were derived from these values at 655,477 gigagrams.

Initial estimates of carbon sinks within Tamaulipas's forests and landfill carbon storage have also been included in this report. However additional work is needed to gain an understanding of CO_2 emissions/sinks for urban forests, land use change, and cultivation practices leading to changes in agricultural soils. In addition, there is considerable need for additional work for the initial forestry sink estimates provided in this report (e.g. to account for losses/gains in forested area; see Appendix H). Additional work to improve the forest and agricultural carbon sink estimates could lead to substantial changes in the initial estimates provided in this report. The current estimates indicate that about 2.4 $MMtCO_2e$ were sequestered in Tamaulipas forest biomass and landfills in 2005; however, this excludes any losses associated with forest land conversion due to a lack of data. Inclusion of emission sinks leads to *net production based* emissions of 22.5 $MMtCO_2e$ in Tamaulipas for 2005.

Figure ES-1 compares the State's and Mexico's gross production based emissions per capita and per unit of economic output.[6] On a per capita basis, Tamaulipas emitted about 5.6 metric tons (t) of gross CO_2e in 1995, slightly less than the 1995 national average of 6.0 tCO_2e. Tamaulipas's per capita emissions increased to 8.2 tCO_2e in 2005, while national per capita emissions for Mexico grew to 6.4 tCO_2e in 2005. Tamaulipas's economic growth exceeded emissions growth for the 1995-2000 period leading to declining estimates of GHG emissions per unit of state product.

As illustrated in Figure ES-2 and shown numerically in Table ES-1, under the reference case projection, Tamaulipas's gross consumption based GHG emissions continue to grow and are projected to reach 28.7 $MMtCO_2e$ by 2025. This would be an increase of 77% over 1990 levels. In 1995 and 2005, emissions drop because of reduced energy consumption in the Residential/Commercial/Industrial sector. As shown in Figure ES-3, the transportation sector is projected to be the largest contributor to future emissions growth in Tamaulipas, followed by emissions in the electricity sector.

Some data gaps exist in this analysis, particularly for the reference case projections. Key tasks in resolving the data gaps include review and revision of key emissions drivers that will be major determinants of Tamaulipas's future GHG emissions (such as the growth rate assumptions for electricity generation and consumption, transportation fuel use, industrial processes, and RCI fuel use). Appendices A through H provide detailed methods, data sources, and assumptions made for each GHG sector. Also included are descriptions of significant uncertainties in emission estimates and/or methods and suggested next steps for refinement of the inventory and reference case projection.

[6] Historic population available from Instituto Nacional de Estadísticas Geografía e Informática (INEGI). Population projection were available from Comisión Nacional de Población (CONAPO).

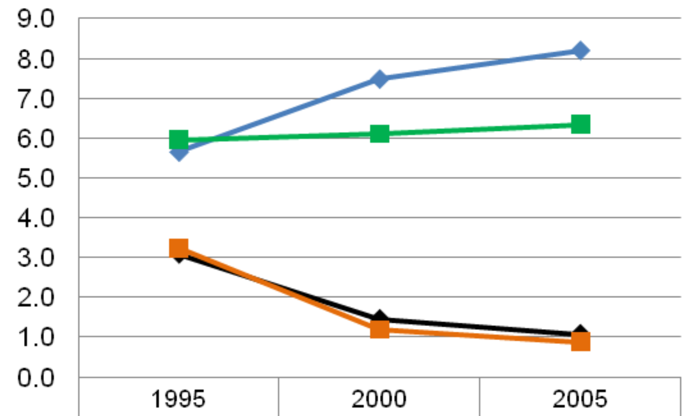
Table ES-1. Tamaulipas Historical and Reference Case GHG Emissions by Sector

(Million Metric Tons CO2e)	1990	1995	2000	2005	2010	2015	2020	2025
Energy Consumption Based	**13.1**	**11.2**	**17.1**	**16.0**	**17.3**	**19.8**	**22.1**	**24.8**
Electricity Consumption Based	**2.46**	**4.11**	**5.93**	**5.68**	**5.54**	**6.71**	**7.91**	**9.50**
Electricity Production Based	3.54	4.19	6.53	11.52	13.41	15.51	14.98	14.98
Gas/Diesel Oil	0.00	0.00	0.05	0.01	0.00	0.00	0.00	0.00
Natural Gas	0.65	0.74	1.85	7.75	12.80	15.40	14.87	14.87
Residual Fuel Oil	2.89	3.45	4.63	3.76	0.61	0.11	0.11	0.11
Net Imported Electricity	-1.08	-0.08	-0.60	-5.84	-7.87	-8.80	-7.07	-5.48
Res/Comm/Ind (RCI)	**7.10**	**2.73**	**5.16**	**3.23**	**3.16**	**3.10**	**3.14**	**3.25**
Gas/Diesel Oil	0.00	0.03	0.07	0.11	0.12	0.14	0.17	0.21
Liquefied Petroleum Gases	1.01	0.77	0.75	0.66	0.65	0.67	0.70	0.73
Natural Gas	0.57	0.71	1.85	1.77	2.03	2.09	2.15	2.23
Residual Fuel Oil	5.50	1.20	2.46	0.66	0.32	0.16	0.08	0.04
Solid Biofuels: Wood/Wood Waste	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Transportation	**3.49**	**4.30**	**5.94**	**6.92**	**8.21**	**9.55**	**10.61**	**11.69**
Road Transportation - Gasoline	1.93	2.49	2.92	3.83	4.58	5.27	5.79	6.31
Road Transportation - Diesel	1.38	1.62	2.30	2.67	3.32	3.92	4.43	4.94
Road Transportation - LPG	0.01	0.03	0.14	0.14	0.06	0.05	0.05	0.05
Road Transportation - Nat. Gas	0.00	0.00	0.00	0.00	0.02	0.04	0.06	0.08
Aviation	0.08	0.06	0.43	0.04	0.02	0.02	0.03	0.03
Marine Vessels	0.01	0.04	0.08	0.17	0.12	0.14	0.15	0.16
Rail	0.08	0.07	0.07	0.07	0.09	0.10	0.11	0.12
Fossil Fuel Industry	**0.03**	**0.03**	**0.07**	**0.16**	**0.41**	**0.45**	**0.39**	**0.35**
Natural Gas	0.02	0.02	0.06	0.15	0.40	0.44	0.38	0.34
NG Production	ND	ND	ND	ND	ND	ND	ND	ND
NG Processing	0.02	0.02	0.05	0.12	0.34	0.34	0.28	0.24
NG Transmission	0.00	0.00	0.01	0.01	0.03	0.07	0.07	0.07
NG Distribution	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03
Oil	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Oil Production	ND	ND	ND	ND	ND	ND	ND	ND
Oil Refining	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Oil Transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	**0.09**	**0.10**	**0.16**	**0.19**	**0.21**	**0.23**	**0.25**	**0.27**
Limestone and Dolomite Use	0.02	0.02	0.04	0.03	0.02	0.02	0.02	0.02
ODS Substitutes	0.07	0.08	0.12	0.16	0.19	0.21	0.23	0.25
Waste Management	**0.68**	**0.77**	**0.85**	**0.96**	**1.06**	**1.13**	**1.19**	**1.25**
Domestic Wastewater	0.27	0.30	0.33	0.36	0.38	0.40	0.42	0.44
Industrial Wastewater	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Solid Waste Disposal Sites	0.34	0.38	0.43	0.49	0.57	0.62	0.67	0.71
Open Burning	0.07	0.08	0.09	0.11	0.11	0.10	0.10	0.10
Landfill Carbon Storage	-0.06	-0.06	-0.07	-0.09	-0.10	-0.10	-0.11	-0.11
Agriculture	**2.36**	**2.10**	**1.86**	**1.80**	**1.89**	**2.01**	**2.17**	**2.36**
Enteric Fermentation	1.16	1.07	0.83	0.89	0.97	1.06	1.18	1.31
Manure Management	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06
Managed Soils	1.17	1.00	0.99	0.87	0.89	0.91	0.95	0.99
Forestry and Land Use	**-2.47**	**-2.20**	**-2.29**	**-2.23**	**-2.28**	**-2.28**	**-2.28**	**-2.28**
Forest (carbon flux)	-2.51	-2.25	-2.33	-2.27	-2.33	-2.33	-2.33	-2.33
Forest Fires (non-CO2 emissions)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Woody Crops	-0.082	0.006	0.009	-0.016	-0.011	-0.011	-0.011	-0.011
Gross Emissions Consumption Based	**16.25**	**14.18**	**20.01**	**18.98**	**20.52**	**23.21**	**25.71**	**28.70**
increase relative to 1990	*0%*	*-13%*	*23%*	*17%*	*26%*	*43%*	*58%*	*77%*
Emission Sinks	**-2.57**	**-2.31**	**-2.40**	**-2.36**	**-2.42**	**-2.43**	**-2.43**	**-2.44**
Net Emissions (incl. forestry*)	**13.68**	**11.87**	**17.60**	**16.62**	**18.10**	**20.79**	**23.28**	**26.27**
increase relative to 1990	*0%*	*-13%*	*29%*	*21%*	*32%*	*52%*	*70%*	*92%*

(Million Metric Tons CO2e)	1990	1995	2000	2005	2010	2015	2020	2025
Gross Emissions Production Base	**17.33**	**14.26**	**20.61**	**24.82**	**28.39**	**32.01**	**32.78**	**34.18**
increase relative to 1990	*0%*	*-18%*	*19%*	*43%*	*64%*	*85%*	*89%*	*97%*
Net Emissions (incl. forestry*)	**14.76**	**11.95**	**18.20**	**22.46**	**25.97**	**29.59**	**30.35**	**31.75**
increase relative to 1990	*0%*	*-19%*	*23%*	*52%*	*76%*	*100%*	*106%*	*115%*

Notes: ND = no data. Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Figure ES-1. Historical Tamaulipas and National Gross Production Base GHG Emissions per Capita and per Unit of Economic Output[7]



	1995	2000	2005
Tamaulipas GHG/Capita (tCO2e/capita)	5.64	7.48	8.21
MX GHG/Capita (tCO2e/capita)	5.96	6.10	6.35
Tamaulipas GHG/$ (kgCO2e/$)	3.09	1.45	1.08
MX GHG/$ (kgCO2e/$)	3.24	1.19	0.88

[7] Economic activity expressed in 2006 values. Information retrieved from INEGI, Banco de Información Económica.

Figure ES-2. Tamaulipas Gross Consumption-Based GHG Emissions by Sector, 1990-2025

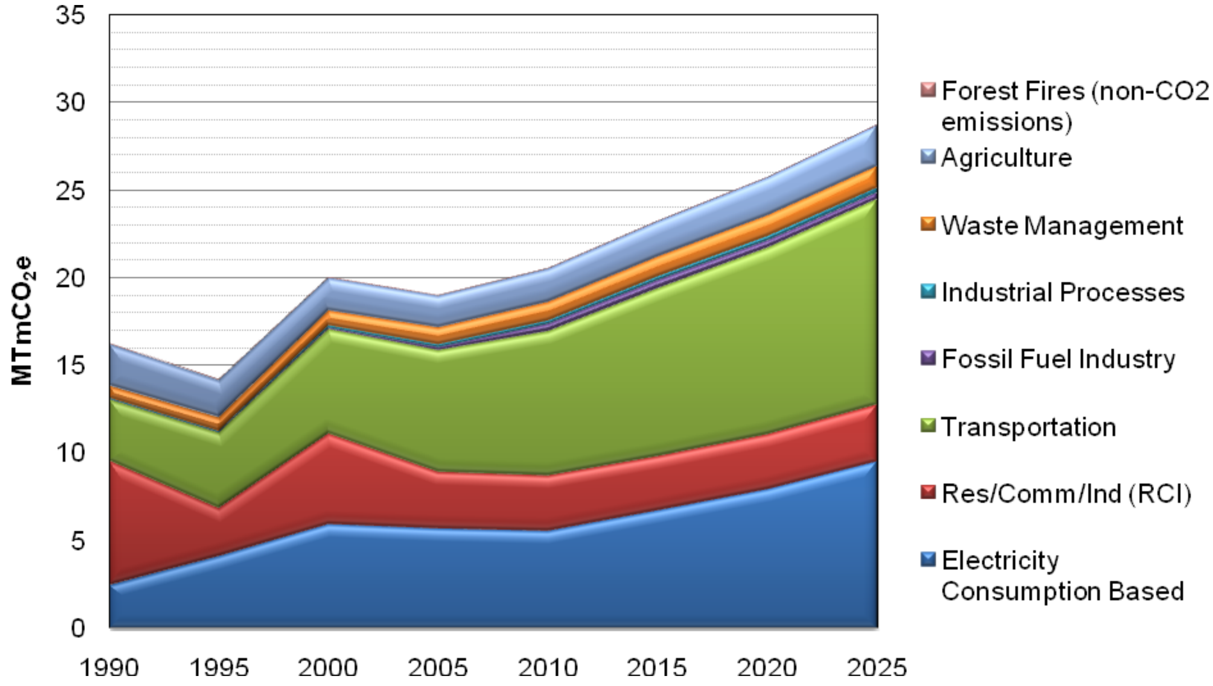
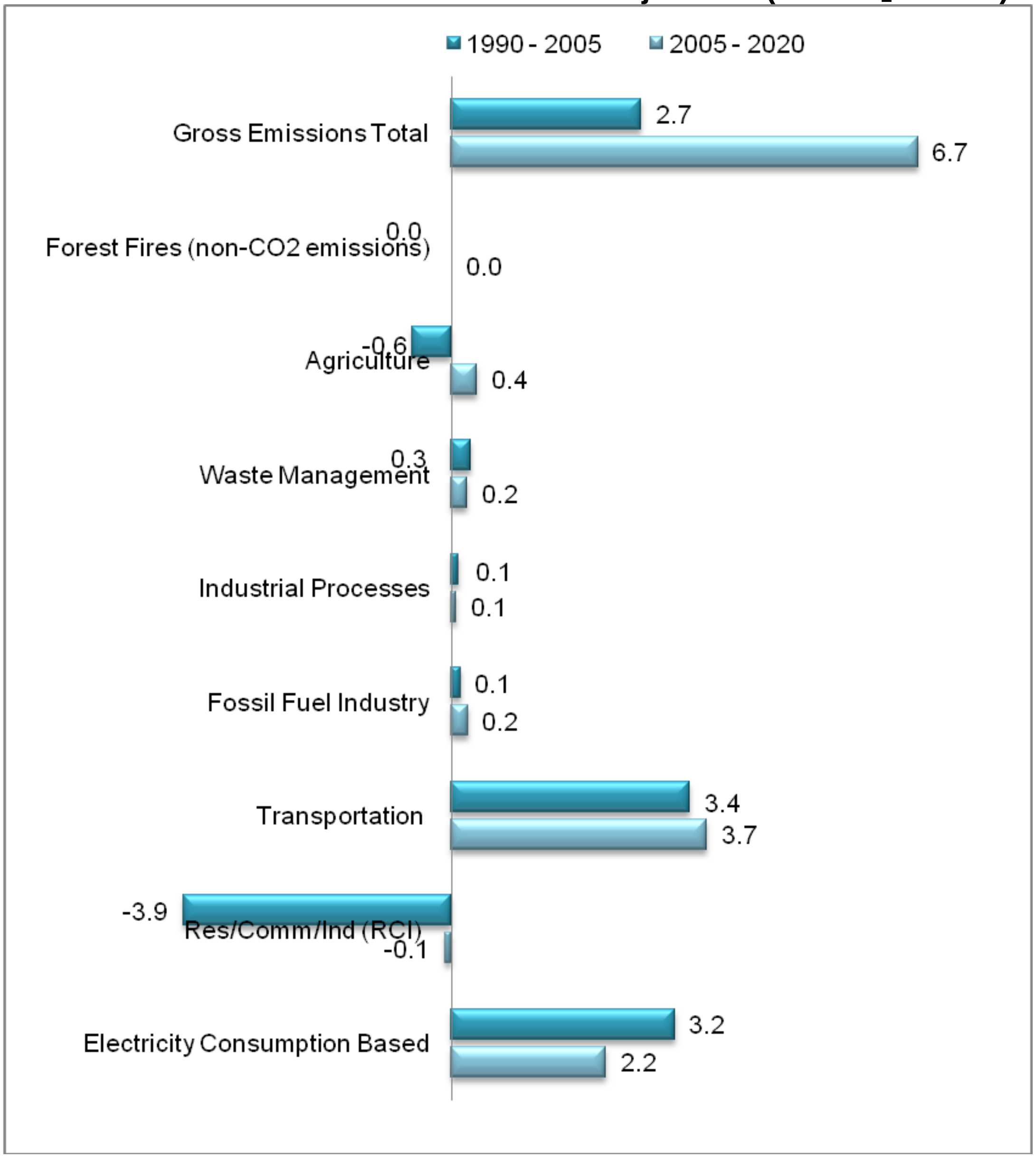


Figure ES-3. Sector Contributions to Gross Emissions Growth in Tamaulipas, 1990-2020: Reference Case Projections ($MMtCO_2e$ Basis)



Res/Comm – direct fuel use in residential and commercial sectors. ODS – ozone depleting substance. Emissions associated with other industrial processes include all of the industries identified in Appendix D except emissions associated with ODS substitutes which are shown separately in this graph. Data for US states indicates a high expected growth in emissions for ODS substitutes. Forest-fires – emissions include methane and nitrous oxide emissions only. Waste management – emissions exclude landfill carbon storage.

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Summary of Preliminary Findings

Introduction

The Center for Climate Strategies (CCS) prepared prepared this report with the Agencia Ambiental para el Desarrollo Sustentable (AADS). This report presents a preliminary assessment of the State's greenhouse gas (GHG) emissions and anthropogenic sinks (carbon storage) from 1990 to 2025. The inventory and forecast estimates serve as a starting point to assist the State with an initial comprehensive understanding of Tamaulipas's current and possible future GHG emissions, and thereby can serve to inform the future identification and analysis of policy options for mitigating GHG emissions. In this report, the terms "forecast" and "reference case projection" are used interchangeably.

Historical GHG emission estimates (1990 through 2005) were developed using a set of generally accepted principles and guidelines for State GHG emissions inventories, as described in the "Approach" section below. These estimates rely to the extent possible on Tamaulipas-specific data and inputs. The initial reference case projections (2006-2025) are based on a compilation of projections of electricity generation, fuel use, and other GHG-emitting activities for Tamaulipas, along with a set of simple, transparent assumptions described in the appendices of this report. While 2005 is commonly the year for the most recent historical data, there are some sources for which a different year applies. Still, the historical inventory will commonly be referred to here as the 1990 to 2005 time-frame. The sector-level appendices provide the details on data sources and applicable years of availability.

This report covers the six gases included in Mexico's national GHG emissions inventory and international GHG reporting under the Kyoto Protocol: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric, CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential- (GWP-) weighted basis.[1]

It is important to note that the preliminary emissions estimates reflect the *GHG emissions associated with the electricity sources used to meet Tamaulipas's demands,* corresponding to a consumption-based approach to emissions accounting (see "Approach" section below). Another way to look at electricity emissions is to consider the *GHG emissions produced by electricity generation facilities in the State.* This report covers both methods of accounting for emissions, but for consistency and clarity, all total results shown in summary tables and graphs are reported as *consumption-based.*

[1] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC, 1996). Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth), http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm. The CO_2e estimates presented in this report are based on the GWP values provided in the IPCC's Second Assessment Report (SAR).

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Tamaulipas Greenhouse Gas Emissions: Sources and Trends

Table 1 provides a summary of GHG emissions estimated for Tamaulipas by sector for the years 1990, 2000, 2005, 2010, 2020, and 2025. Table 1 presents results according to four types of GHG accounting: 1) consumption based emissions; 2) production based emissions; 3) nete emissions; 4) gross emissions. The specific type of accounting is specified in each of the figures and tables of the report. Moreover, it is important to note that comparisons with the Inventario Nacional de Emisiones de Gases de Efecto Invernadero (INEGEI) were made on the basis of *gross, production-base emissions* in order to be consistent with the type of GHG accounting employed by the authors of the INEGEI.

Details on the methods and data sources used to construct the emission estimates are provided in the appendices to this report**.** In the sections below, a brief discussion is provided on the GHG emission sources (positive, or *gross*, emissions) and sinks (negative emissions) separately in order to identify trends and uncertainties clearly for each. A net emission estimate includes both sources and sinks of GHGs.

This next section of the report provides a summary of the historical emissions (1990 through 2005) followed by a summary of the reference-case projection emissions (2006 through 2025) and key uncertainties. An overview of the general methodology, principles, and guidelines followed for preparing the inventories is then provided. Appendices A through H provide the detailed methods, data sources, and assumptions for each GHG sector.

Historical Emissions

Overview

Preliminary analyses suggest that in 2005, activities in Tamaulipas accounted for approximately 24.8 million metric tons (MMt) of CO_2e gross production based emissions, an amount equal to about 3.8% of Mexico GHG emissions (based on 2005 national emissions).[2] Tamaulipas's gross GHG emissions are rising at a higher rate than those of the nation as a whole (gross emissions exclude carbon sinks, such as forests). Tamaulipas's gross GHG emissions increased 43% from 1990 to 2005, while national emissions rose by 31% from 1990 to 2005.

Figure 1 compares the State's and Mexico's emissions per capita and per unit of economic output.[3] On a per capita basis, Tamaulipas emitted about 5.6 metric tons (t) of gross CO_2e in 1995, slightly less than the 1995 national average of 6.0 tCO_2e. Tamaulipas's per capita emissions increased to 8.2 tCO_2e in 2005, while national per capita emissions for Mexico grew to 6.4 tCO_2e in 2005. Tamaulipas's economic growth exceeded emissions growth for the 1995-2000 period leading to declining estimates of GHG emissions per unit of state product.

[2] Comparison with national results were drawn from: *Mexico Tercera Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático*. Mexico: INE-SEMARNAT, 2006. Available at www.ine.gob.mx. Available annual emission values were on the order of 498,748 and 618,072 gigagrams in 1990 and 2002 respectivively. 2005 emissions were derived from these values at 655,477 gigagrams.
[3] Historic population available from Instituto Nacional de Estadísticas Geografía e Informática (INEGI). Population projection were available from Comisión Nacional de Población (CONAPO).

Figure 2 compares gross production based GHG emissions for Tamaulipas to emissions for Mexico in 2005 according to GHG sectors used by Instituto Nacional de Ecología (INE). The principal source of Tamaulipas's GHG emissions is energy use. Energy use includes activities such as power generation, transportation, fossil fuel production and exploration as well as residential, commercial, and industrial consumption of primary fuels (e.g. gasoline, diesel, coal, natural gas, liquefied petroleum gas). In 2005, the energy sector accounted for 88% of total GHG emissions in the state of Tamaulipas. At the national level, the energy sector accounted for 63% of gross GHG emissions in 2005.

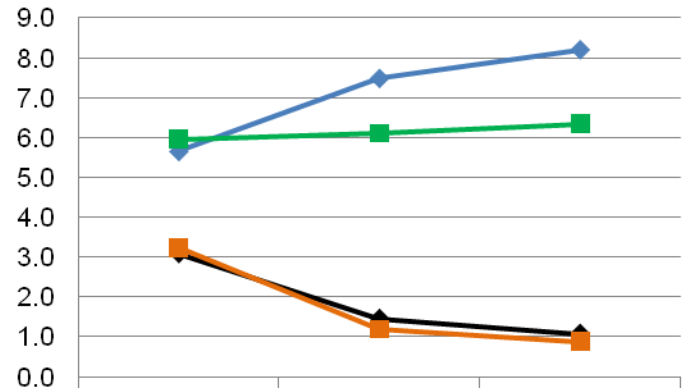
Table 1. Tamaulipas Historical and Reference Case GHG Emissions by Sector

(Million Metric Tons CO2e)	1990	1995	2000	2005	2010	2015	2020	2025
Energy Consumption Based	**13.1**	**11.2**	**17.1**	**16.0**	**17.3**	**19.8**	**22.1**	**24.8**
Electricity Consumption Based	**2.46**	**4.11**	**5.93**	**5.68**	**5.54**	**6.71**	**7.91**	**9.50**
Electricity Production Based	3.54	4.19	6.53	11.52	13.41	15.51	14.98	14.98
Gas/Diesel Oil	0.00	0.00	0.05	0.01	0.00	0.00	0.00	0.00
Natural Gas	0.65	0.74	1.85	7.75	12.80	15.40	14.87	14.87
Residual Fuel Oil	2.89	3.45	4.63	3.76	0.61	0.11	0.11	0.11
Net Imported Electricity	-1.08	-0.08	-0.60	-5.84	-7.87	-8.80	-7.07	-5.48
Res/Comm/Ind (RCI)	**7.10**	**2.73**	**5.16**	**3.23**	**3.16**	**3.10**	**3.14**	**3.25**
Gas/Diesel Oil	0.00	0.03	0.07	0.11	0.12	0.14	0.17	0.21
Liquefied Petroleum Gases	1.01	0.77	0.75	0.66	0.65	0.67	0.70	0.73
Natural Gas	0.57	0.71	1.85	1.77	2.03	2.09	2.15	2.23
Residual Fuel Oil	5.50	1.20	2.46	0.66	0.32	0.16	0.08	0.04
Solid Biofuels: Wood/Wood Waste	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Transportation	**3.49**	**4.30**	**5.94**	**6.92**	**8.21**	**9.55**	**10.61**	**11.69**
Road Transportation - Gasoline	1.93	2.49	2.92	3.83	4.58	5.27	5.79	6.31
Road Transportation - Diesel	1.38	1.62	2.30	2.67	3.32	3.92	4.43	4.94
Road Transportation - LPG	0.01	0.03	0.14	0.14	0.06	0.05	0.05	0.05
Road Transportation - Nat. Gas	0.00	0.00	0.00	0.00	0.02	0.04	0.06	0.08
Aviation	0.08	0.06	0.43	0.04	0.02	0.02	0.03	0.03
Marine Vessels	0.01	0.04	0.08	0.17	0.12	0.14	0.15	0.16
Rail	0.08	0.07	0.07	0.07	0.09	0.10	0.11	0.12
Fossil Fuel Industry	**0.03**	**0.03**	**0.07**	**0.16**	**0.41**	**0.45**	**0.39**	**0.35**
Natural Gas	0.02	0.02	0.06	0.15	0.40	0.44	0.38	0.34
NG Production	ND	ND	ND	ND	ND	ND	ND	ND
NG Processing	0.02	0.02	0.05	0.12	0.34	0.34	0.28	0.24
NG Transmission	0.00	0.00	0.01	0.01	0.03	0.07	0.07	0.07
NG Distribution	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03
Oil	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Oil Production	ND	ND	ND	ND	ND	ND	ND	ND
Oil Refining	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Oil Transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial Processes	**0.09**	**0.10**	**0.16**	**0.19**	**0.21**	**0.23**	**0.25**	**0.27**
Limestone and Dolomite Use	0.02	0.02	0.04	0.03	0.02	0.02	0.02	0.02
ODS Substitutes	0.07	0.08	0.12	0.16	0.19	0.21	0.23	0.25
Waste Management	**0.68**	**0.77**	**0.85**	**0.96**	**1.06**	**1.13**	**1.19**	**1.25**
Domestic Wastewater	0.27	0.30	0.33	0.36	0.38	0.40	0.42	0.44
Industrial Wastewater	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Solid Waste Disposal Sites	0.34	0.38	0.43	0.49	0.57	0.62	0.67	0.71
Open Burning	0.07	0.08	0.09	0.11	0.11	0.10	0.10	0.10
Landfill Carbon Storage	-0.06	-0.06	-0.07	-0.09	-0.10	-0.10	-0.11	-0.11
Agriculture	**2.36**	**2.10**	**1.86**	**1.80**	**1.89**	**2.01**	**2.17**	**2.36**
Enteric Fermentation	1.16	1.07	0.83	0.89	0.97	1.06	1.18	1.31
Manure Management	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06
Managed Soils	1.17	1.00	0.99	0.87	0.89	0.91	0.95	0.99
Forestry and Land Use	**-2.47**	**-2.20**	**-2.29**	**-2.23**	**-2.28**	**-2.28**	**-2.28**	**-2.28**
Forest (carbon flux)	-2.51	-2.25	-2.33	-2.27	-2.33	-2.33	-2.33	-2.33
Forest Fires (non-CO2 emissions)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Woody Crops	-0.082	0.006	0.009	-0.016	-0.011	-0.011	-0.011	-0.011
Gross Emissions Consumption Based	**16.25**	**14.18**	**20.01**	**18.98**	**20.52**	**23.21**	**25.71**	**28.70**
increase relative to 1990	*0%*	*-13%*	*23%*	*17%*	*26%*	*43%*	*58%*	*77%*
Emission Sinks	**-2.57**	**-2.31**	**-2.40**	**-2.36**	**-2.42**	**-2.43**	**-2.43**	**-2.44**
Net Emissions (incl. forestry*)	**13.68**	**11.87**	**17.60**	**16.62**	**18.10**	**20.79**	**23.28**	**26.27**
increase relative to 1990	*0%*	*-13%*	*29%*	*21%*	*32%*	*52%*	*70%*	*92%*

(Million Metric Tons CO2e)	1990	1995	2000	2005	2010	2015	2020	2025
Gross Emissions Production Base	**17.33**	**14.26**	**20.61**	**24.82**	**28.39**	**32.01**	**32.78**	**34.18**
increase relative to 1990	*0%*	*-18%*	*19%*	*43%*	*64%*	*85%*	*89%*	*97%*
Net Emissions (incl. forestry*)	**14.76**	**11.95**	**18.20**	**22.46**	**25.97**	**29.59**	**30.35**	**31.75**
increase relative to 1990	*0%*	*-19%*	*23%*	*52%*	*76%*	*100%*	*106%*	*115%*

Notes: ND = no data. Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Figure 1. Historical Tamaulipas and Mexico Gross GHG Emissions per Capita and per Unit Gross Product in Dollars[4]

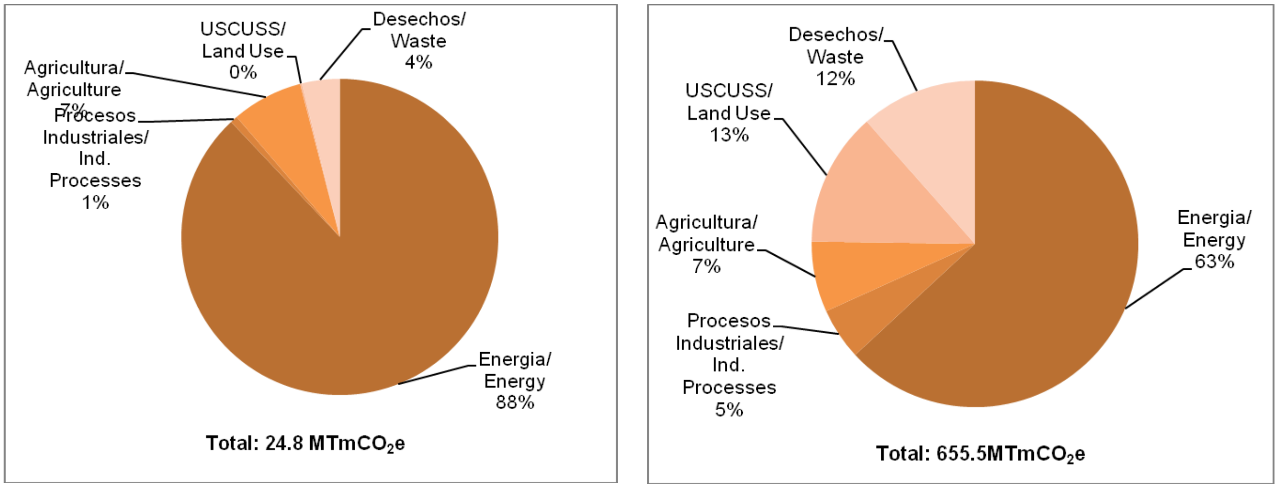


	1995	2000	2005
Tamaulipas GHG/Capita (tCO2e/capita)	5.64	7.48	8.21
MX GHG/Capita (tCO2e/capita)	5.96	6.10	6.35
Tamaulipas GHG/$ (kgCO2e/$)	3.09	1.45	1.08
MX GHG/$ (kgCO2e/$)	3.24	1.19	0.88

[4] Economic activity expressed in 2006 values. Information retrieved from INEGI, Banco de Información Económica.

Figure 2. Gross GHG Emissions by Sector, 2005, Tamaulipas and Mexico

Tamaulipas[5] Mexico



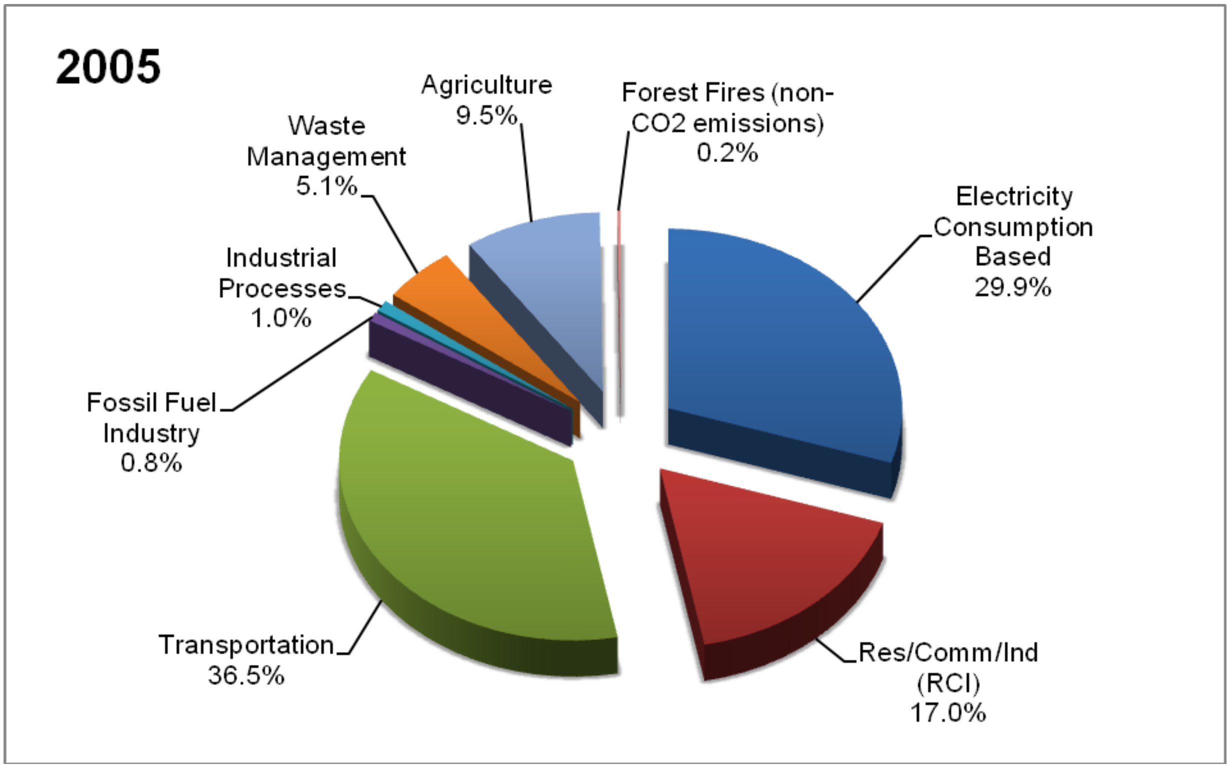
Summary results in this inventory and forecast for Tamaulipas are presented with additional disaggregation of emission sources in comparison with the summary results of the *Inventario Nacional de Emisiones de Gases de Efecto Invernadero* prepared by INE. Table 2 provides correspondence between the Tamaulipas and INE GHG sectors and Figure 3 shows the distribution of emissions according to Tamaulipas GHG activity sectors for the year 2005.

Table 2. Correspondence between INE and Tamaulipas GHG Sectors

INE	Tamaulipas
Energia / Energy	Electricity (Consumption Based)
Energia / Energy	Fossil Fuel Industry
Energia / Energy	RCI Fuel Use
Energia / Energy	Transportation Road/Gasoline
Energia / Energy	Transportation Road/Diesel
Energia / Energy	Aviation
Agricultura / Agriculture	Agriculture
Procesos Industriales / Ind. Processes	ODS Substitutes
Procesos Industriales / Ind. Processes	Other Ind. Process
Desechos / Waste	Waste Management
USCUSS / Land Use	Forestry and Land Use (net emissions)

[5] Additional work to improve carbon flux due to land use and changes to land use (USCUSS) could lead to substantial differences in the initial estimates provided in this report. Due to limited information, the current estimates focus on carbon flux within selected land uses, excluding carbon losses due to deforestation (e.g when forest land is converted cropland).

Figure 3. Tamaulipas Gross GHG Emissions by Sector, 2005



A Closer Look at the Two Major Sectors: Electricity Supply and Transportation

Electricity Supply Sector

Emission associated with the electric sector accounted for 30% of Tamaulipas's gross GHG emissions in 2005. Consumption of electricity in Tamaulipas in 2005 resulted in 5.7 MMtCO_2e of GHG emissions. In 2007, seven combined cycle plants (Rio Bravo CC, Rio Bravo II, Rio Bravo III, Rio Bravo IV, Altamira II, Altamira III & IV, and Altamira V) generated 96% of the state's electricity using natural gas; less than 4% of the state's electricity was generated at conventional thermal facilities from a mixture of residual fuel oil, and natural gas; and a small amount of electricity (3 GWh) is imported from the U.S.

Consumption-based electricity sector emissions are estimated to increase to 9.5 MM tCO_2e in 2025, a 67% increase over 2005 emissions. Natural gas is expected to remain the dominate source of fuel for the electricity sector in Tamaulipas, accounting for 99% of emissions in 2025.

Transportation Sector

The transportation sector in Tamaulipas includes road transportation, marine vessels, rail engines, and aviation. During inventory years (1990 through 2005), total transportation emissions increased by 98% reaching 6.9 MMtCO_2e in 2005. The largest transportation sources of GHG emissions were activities related to onroad gasoline and onroad diesel combustion, accounting for 94% of total transportation GHG emissions in 2005.

In 2025, total transportation emissions are expected to be almost 11.7 $MMtCO_2e$, representing a 235% increase from 1990. Road transportation emissions (gasoline and diesel) are expected to account for 97% of total transportation emissions in 2025. Marine diesel emissions are expected to increase to 2.5% of transportation emissions in 2025 from 0.3% in 1990. Aviation emissions estimated to account for less than 0.3% in 2025, down from 0.5% in 1990. Rail emissions are expected to account for 1% of total transportation emissions in 2025, the same as in 1990.

Reference Case Projections

Relying on a variety of sources for projections, as noted below and in the appendices, CCS developed a simple reference case projection of GHG emissions through 2025. As illustrated in Figure 4 below and shown numerically in Table 1 above, under the reference case projections, Tamaulipas gross GHG emissions continue to grow steadily, climbing to about 28.8 $MMtCO_2e$ by 2025, 72% above 1990 levels. This equates to an annual rate of growth of 1.6% per year for the period starting 1990 through 2025.

Inventory estimates and reference case projections are shown in Figure 4 for all sectors. Sector contributions to growth in gross GHG emissions are shown in Figure 5. Figure 5 provides estimates of contribution to growth in gross GHG emissions between inventory (1990-2005) and reference case projection (2005-2025) estimates. The largest increases in emissions from both 1990-2005 and 2005-2025 are seen in the industrial processes and electricity supply sectors. Table 3 summarizes the growth rates that drive the growth in the Tamaulipas reference case projections, as well as the sources of these data.

Figure 4. Tamaulipas Gross GHG Emissions by Sector, 1990-2025

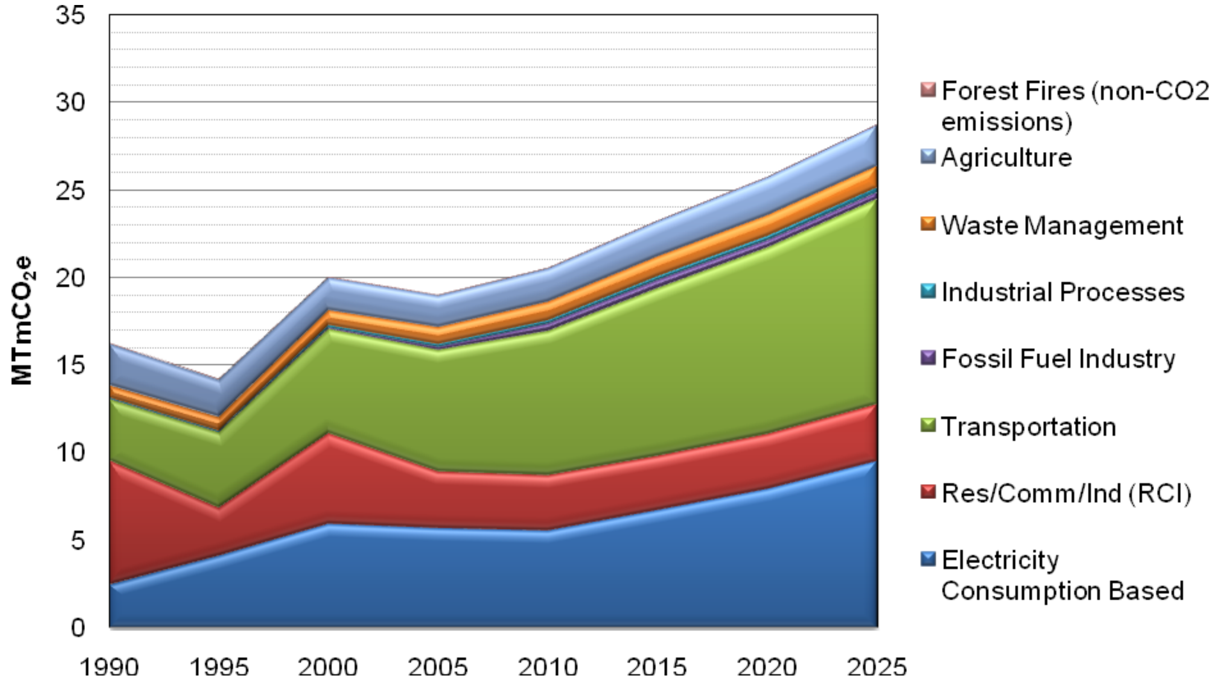
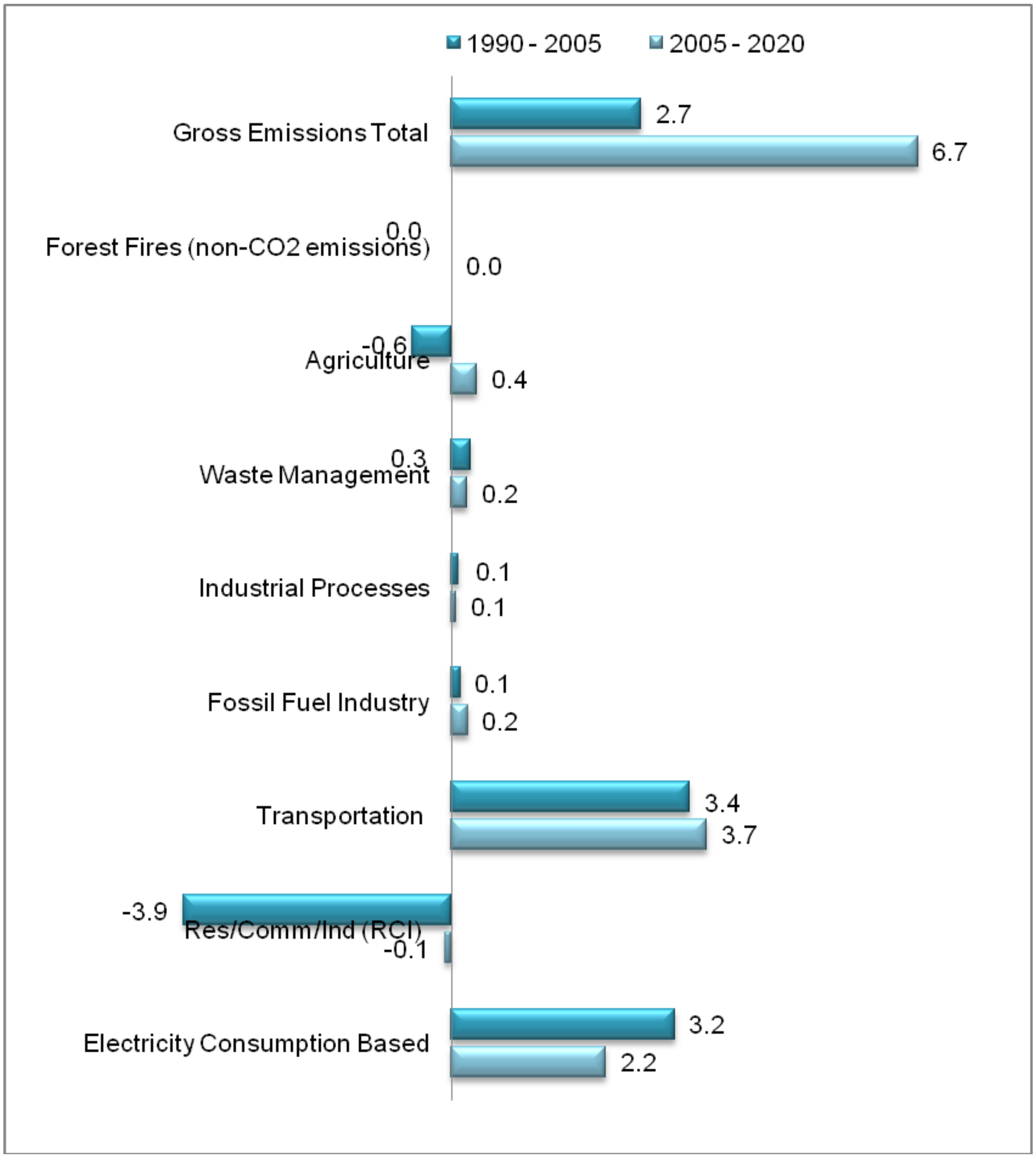


Figure 5. Sector Contributions to Gross Emissions Growth in Tamaulipas, 1990-2020



Res/Comm – direct fuel use in residential and commercial sectors. ODS – ozone depleting substance. Emissions associated with other industrial processes include all of the industries identified in Appendix D except emissions associated with ODS substitutes which are shown separately in this graph. Data for US states indicates a high expected growth in emissions for ODS substitutes. Forest-fires – emissions include methane and nitrous oxide emissions only. Waste management – emissions exclude landfill carbon storage.

Table 3. Key Annual Growth Rates for Tamaulipas, Historical and Projected

Activity Data	Rate Period	Mean Annual Rate (%)	Sources
Population	1990 - 2005 2005 - 2025	1.99 0.94	Historical population, INEGI Projected population, CONAPO
Electricity Demand	1990 - 2007 2008 - 2017	6.89 1.87	SENER: *Prospectiva del Sector Eléctrico 2008-2017*
Diesel	1990 - 2007	4.97	Sistema de Información Energética, PEMEX
Gasoline	1990 - 2007	4.67	Sistema de Información Energética, PEMEX
Jet Kerosene	1990 - 1997	-5.19	Sistema de Información Energética, PEMEX
Vehicle Registration	1990 - 2007	4.12	INEGI. Estadísticas de vehículos de motor registrados en circulación
Livestock Population	1990 - 2005	3.26	SIACON
Crop Production	1990 - 2005	2.28	SIACON

Key Uncertainties and Next Steps

Some data gaps exist in this inventory, and particularly in the reference case projections. Key tasks for future refinement of this inventory and forecast include review and revision of key drivers, such as demand for electricity from fuel oil, imported electricity, and electricity from hydroelectric plants. Additional information relating to the segregation of in-state diesel consumption by mode of transportation (marine vessel, railway, onroad) for inventory years can help reduce uncertainty in projected emissions. Historical activity data relating to cement production, lime production, and limestone use can also reduce uncertainty associated with forecast estimates.

Additional work is needed to: further refine the carbon sequestration estimates for the forested landscape; add sequestration estimates for urban forests; add soil carbon flux in cropland; and add net carbon flux associated with land use change (e.g. losses/gains in forest acreage). As described in Appendix H, the lack of data to adequately capture net carbon flux due to land use change is a key area for future work. The current estimates of a net carbon sink in the forestry sector could change dramatically once the land use change emissions are quantified due to historic and potential future losses of forest area.

Applied growth rates are driven by uncertain economic, demographic and land use trends (including growth patterns and transportation system impacts), all of which deserve closer review and discussion. These are listed in Table 3. More details on key uncertainties and suggested next steps for the refinement of the estimates presented in this report are provided in each of the sector appendices.

Approach

The principal goal of compiling the inventory and reference case projection presented in this document is to provide the State of Tamaulipas with a general understanding of Tamaulipas's historical, current, and projected (expected) GHG emissions. The following sections explain the general methodology and the general principles and guidelines followed during development of these GHG estimates for Tamaulipas.

General Methodology

The overall goal of this effort was to provide simple and straightforward estimates with an emphasis on robustness, consistency, and transparency. As a result, CCS relied on reference forecasts from best available State and regional sources where possible. In general state-level forecast data for Tamaulipas were lacking. Therefore, CCS used straight-forward spreadsheet analysis and constant growth-rate extrapolations of historical trends rather than complex modeling to estimate future year emissions.

CCS followed similar approaches to emissions accounting for historical inventories as recommended by INE in its national GHG emissions inventory[6] and its guidelines for States.[7] These inventory guidelines were developed based on the guidelines from the Intergovernmental Panel on Climate Change (IPCC), the international organization responsible for developing coordinated methods for national GHG inventories.[8]Any exception to this approach is identified in the applicable sector appendix with a rationale provided for the selection of alternative methods or data sources. The inventory methods provide flexibility to account for local conditions. A summary of the key sources of inventory data and overall methods used are shown in Table 4 along with a comparison to methods used to construct Mexico's national inventory (INEGEI). The reader should consult the associated sector appendix for a detailed discussion of methods and data sources used to construct the inventory and forecast for that sector.

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[6] INE. *Tercera Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático*.,2006 http://www.ine.gob.mx/cpcc-lineas/637-cpcc-comnal-3. http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

[7] PNUD, FMAM, INE. Manejo del Proceso de Elaboración del Inventario Nacional de Gases de Efecto Invernadero. http://www.ine.gob.mx/cpcc-estudios-cclimatico.

[8] http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm.

Table 4. Key Data Sources and Methods and Comparison to National Inventory Methods

Sector	Key Data Sources	Method	Comparison with INEGEI
Electricity Consumption and Supply	SENER and CFE: state-level sector-based electricity consumption data; INEGI: state-level electricity generation data	2006 IPCC, Tier 1 method, where fuel consumption is multiplied by default emission factors.	1996 IPCC, Tier 1 method; national electricity production data from SENER.
Residential, Commercial, and Industrial (RCI) Fuel Combustion	SENER: state-level fuel consumption for RCI sectors	2006 IPCC, Tier 1 method, where fuel consumption is multiplied by default emission factors	1996 IPCC, Tier 1 method; national-level fuel consumption from SENER.
Transportation Energy Use	SENER: State-level fuel consumption by fuel type SCT: State-level statistics used to allocate fuel sales to end use (e.g. rail infrastructure, national cargo movement by water)	2006 IPCC, Tier 1 method, where fuel consumption is multiplied by default emission factors.	1996 IPCC, Tier 1 method; SENER provided fuel consumption data for all sources except aircraft. 1996 IPCC, Tier 2 method for aviation based on landing & takeoff statistics.
Industrial Processes and Product Use	CANACEM : national cement production allocated to state-level as a function of population	2006 IPCC, Tier 1 method, where clinker production is multiplied by a default emission factor.	1996 IPCC, Tier 1 method; national cement production data from CANACEM.
	Servicio Geológico Mexicano: mineral production by state	2006 IPCC, Tier 1 consumption is multiplied by a default emission factor. Consumption is obtained through mass balance using state production.	1996 IPCC, Tier 1 method, where mineral production from Servicio Geológico Mexicano production is multiplied by a default emission factor. Consumption is obtained through mass balance using national production, and import/export data.
	INEGI: state-level vehicle registration data and IPCC emission factors for HFC emissions as originally developed by Centro Mario Molina, Inventario Estatal de Emisiones de GEI del Estado de Tamaulipas, 2005	IPCC: HFC emissions - the number mobile air conditioning (AC) units are multiplied by an IPCC default emission factor.	1996 IPCC, Tier 1 method, where fugitive HCF are calculated through mass balance using national production, import and export data.

Sector	Key Data Sources	Method	Comparison with INEGEI
Fossil Fuel Industry	SENER, PEMEX, CRE: data on production, transmission and distribution infrastructure (e.g. state-level transmission & distribution pipelines, gas compressors, storage facilities)	EPA, SIT method, where fossil fuel industry infrastructure is multiplied by US industry average emission factors.	1996 IPCC, Tier 1 method, where national production data from PEMEX is multiplied by default emission factors.
Agriculture	SAGARPA - SIACON: crop and livestock production data at the state-level, International Fertilizer Industry Association: fertilizer application data	2006 IPCC, Tier 1 method and emission factors.	1996 and 2003 IPCC guidelines and SAGARPA-SIACON national data. A number of emission factors were the updated based on field studies conducted in Mexico.
Waste Management	SEDESOL: state-level solid waste generation data CONAGUA: domestic wastewater treatment data at the state-level	2006 IPCC, Tier 1 method and emission factors.	1996 IPCC, Tier 1 method with SEDESOL national data for solid waste generation.
Forestry and Land Use	United Nations Food and Agriculture Organization (FAO): total forested area by state SEMARNAT- CONAFOR: state-level wood harvest, forest fire, and diseased acres SIACON: Acreage on woody perennial crops	2006 IPCC, Tier 1 method. CCS relied on forest coverage statistics from FAO and woody crop coverage from SIACON. CCS' assessment covers carbon flux in selected land use categories due to land use practices.	2003 IPCC methods. INE assessed carbon flux based on national digital maps (mapas de vegetación del INEGI, 1993, 2003). INE's assessment covers carbon flux in selected land use categories due to land use practices, and changes in land use.

General Principles and Guidelines

A key part of this effort involves the establishment and use of a set of generally accepted accounting principles for evaluation of historical and projected GHG emissions, as follows:

- **Transparency:** CCS reported data sources, methods, and key assumptions to allow open review and opportunities for additional revisions later based on input from subsequent reviewers. In addition, key uncertainties are reported, where they exist.
- **Consistency:** To the extent possible, the inventory and projection were designed to be externally consistent with current or likely future systems for State and national GHG emissions reporting. In nearly all sectors, CCS used IPCC methodologies and gave special attention to the way these were adapted in Mexico to fit national needs. These initial estimates were then augmented and/or revised as needed to conform with State-based inventory and reference-case projection needs (i.e. needs of GHG mitigation planning analyses). For consistency in making reference case projections, CCS defined reference case actions for the purposes of projections as those *currently in place or reasonably expected over the time period of analysis*.
- **Priority of Existing State and Local Data Sources:** In gathering data and in cases where data sources conflicted, CCS placed highest priority on local and State data and analyses, followed by regional sources, with national data or simplified assumptions such as constant linear extrapolation of trends used as defaults where necessary.
- **Priority of Significant Emissions Sources:** In general, sources with relatively small emissions levels received less attention than those with larger GHG contributions.
- **Comprehensive Coverage of Gases, Sectors, State Activities, and Time Periods:** This analysis aimed to comprehensively cover GHG emissions/sinks associated with activities in Tamaulipas. It covers all six GHGs covered by IPCC guidelines and reported in national inventories: CO_2, CH_4, N_2O, SF_6, HFCs, and PFCs. The inventory estimates are for the year 1990, with subsequent years included up to most recently available data (typically 2005 to 2007). The projection for each source begins in the year following the most recent inventory year and extends for each year out to 2025.
- **Use of Consumption-Based Emission Estimates:** For the electricity supply sector, CCS estimated emissions that are driven by electricity consumption in Tamaulipas. The rationale for this common method of reporting is that it more accurately reflects the impact of State-based policy strategies aimed at energy efficiency on overall GHG emissions. Although this is a common approach for state and local GHG inventory development, it can differ from how some inventories are compiled, if they are based on an in-state electricity production basis.

As mentioned above, CCS estimated the emissions related to electricity *consumed* in Tamaulipas. This entails accounting for the electricity sources used by Tamaulipas utilities to meet consumer demands. As this analysis is refined and potentially expanded in the future, one could also attempt to estimate other sectoral emissions on a consumption basis, such as accounting for emissions from transportation fuel used in Tamaulipas, but also accounting for extraction, refining, and distribution emissions (some of these occurring out of state). As in this example, this can require venturing into the relatively complex terrain of life-cycle analysis. In general, CCS recommends considering a consumption-based approach, where it will significantly improve the estimation of the emissions impact of potential mitigation strategies. For example, in the solid waste management sector, re-use, recycling, and source reduction can lead to emission reductions resulting from lower energy requirements for material production (such as paper, cardboard, and aluminum), even though production of those materials, and emissions associated with materials production, may not occur within the state.

While the primary data and methods for most sectors are consistent with the national inventory, for some sectors, state-level or region-level data were used. Table 4 summarizes these key data sources and methods. However, the reader should consult the applicable appendix listed below for details on the methods and data sources used to construct the inventories and forecasts for each source sector:

- Appendix A. Electricity Use and Supply
- Appendix B. Residential, Commercial, and Industrial (RCI) Fuel Combustion
- Appendix C. Transportation Energy Use
- Appendix D. Industrial Processes
- Appendix E. Fossil Fuel Industry
- Appendix F. Agriculture
- Appendix G. Waste Management
- Appendix H. Forestry and Land Use

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Appendix A. Electricity Supply and Use

Overview

This appendix describes the data sources, key assumptions, and the methodology used to develop an inventory of greenhouse gas (GHG) emissions associated with the generation of electricity supplied by the Tamaulipas' electric utility and distributed by the Comisión Federal de Electricidad (CFE) and Luz y Fuerza del Centro (LFC), and by independent producers. The appendix provides a description of the data sources, key assumptions, and methodology used to develop an inventory over the 1990-2007 period, as well as a forecast of GHG emissions for the period from 2008 through 2025. The historic inventory and reference case projections of GHG emissions from the electricity supply sector in Tamaulipas rely heavily on historical and projected electricity generation and fuel use provided by the Secretaría de Energía (SENER). From analytical, and ultimately a policy perspective, it is important to distinguish between GHG emissions that are associated with electricity produced within the state (some of which may be consumed outside the state) as compared with the GHG emissions associated with electricity consumed within the state (some of which may produced outside the state). Such a distinction requires an accounting for electricity imports and exports, and their associated emissions. Consequently, emissions information is provided in this appendix for both a production-based as well as a consumption-based approach. For the purposes of reviewing total state emissions summaries in the body of this report, consumption-based emission estimates are used.

The following topics are covered:

- *Scope of greenhouse gas inventory and reference case forecast:* this section provides a summary of GHGs included in the inventory, the level (upstream or downstream) at which these emissions are estimated, and a discussion of the production-based and consumption-based inventory and forecast assumptions.
- *Data sources:* this section provides an overview of the data sources that were used to develop the inventory and forecast.
- *Production-based greenhouse gas inventory and reference case forecast methodology:* this section provides an overview of the methodological approach used to develop the production-based Tamaulipas GHG inventory for the electric power sector.
- *Consumption-based greenhouse gas inventory and reference case forecast methodology:* this section provides an overview of the methodological approach used to develop the consumption-based Tamaulipas GHG reference case projections (forecast) for the electric power sector.
- *Greenhouse gas inventory and reference case forecast results:* for both the production-based and consumption-based methods, these sections provide an overview of key results of the Tamaulipas GHG inventory and forecast for the electric power sector.
- *Key uncertainties and future research needs:* this section covers the key uncertainties in this analysis related available data, emission factors, and other parameters and assumptions utilized to create this inventory and forecast.

Scope of Electricity Supply Inventory and Forecast

The GHGs included in this inventory and forecast of emissions from the electricity supply sector include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Emissions for this sector are estimated at the source of combustion – the electric power supply facility (i.e. downstream emissions). Emissions from the exploration, extraction, refinement, and transportation of fossil fuels (i.e. upstream emissions) are not included in this appendix. Upstream emissions from the electricity supply sector that occur within the borders of Tamaulipas are addressed in the Fossil Fuel Industry sector. Also, emissions of high global warming gases like sulfur hexafluoride and hydrofluorocarbons emitted by electricity generators are captured within the Industrial Processes sector.

Within the electricity supply sector, GHG emissions can be quantified on the basis of fuels combusted in the state during electricity generation (i.e. production-based estimate). Electricity supply sector emissions can also be characterized on the basis of electricity consumed within the state, which captures in-state generation, as well as electricity imports and exports (i.e. a consumption-based estimate). Both types of estimates are useful. Consumption-based estimates are particularly useful for GHG mitigation analysis when considering the implications of policies and actions that could impact demand from power plants both within and outside a state or region, such as electricity efficiency or renewable energy measures. For the purposes of presenting total state emissions summaries across all sectors in this report, consumption-based emission estimates are used.

The production-based inventory and forecast includes emissions resulting from electricity exported by Tamaulipas power producers, while the consumption-based inventory includes emissions from imported electricity and excludes emissions from exported electricity. Tamaulipas is a historic net importer of electricity, but a projected net exporter of electricity in future years. Therefore, the production-based inventory estimates are higher than the estimates for the consumption-based inventory for the latter portion of the historic inventory period and entire forecast period, while the consumption-based inventory emission estimates are higher for the early portion on the historic inventory period. The consumption-based inventory and forecast assume some loss through transmission & distribution (T&D) and theft. Emissions due to T&D loss and theft are inherently captured within the production-based estimates.

Data Sources

CCS considered several sources of information in the development of the inventory and forecast for GHG emissions from the electricity supply sector in Tamaulipas. These are briefly summarized below:

- *Historic fossil fuel consumption*: an Excel workbook containing fuel consumption for residual fuel oil and diesel oil at electricity supply facilities in Tamaulipas and other Mexican border states was provided by SENER.[1] Additionally, CFE provided CCS with

[1] Historical fossil fuel consumption at power generation plants was obtained directly from Secretaría de Energía (SENER) in response to Nuevo Leon's Agencia de Protección al Medio Ambiente y Recursos Naturales letter of inquiry. March 2007.

plant-specific generation and fuel use data for some of the power plants in Tamaulipas for the years 1993-2005;[2]

- *Historic and projected demand of natural gas in the electricity supply sector:* this information was obtained from SENER publication *Natural Gas Market Outlook 2008-2017*.[3] This report provides historical data dating back to 1996, as well as projected natural gas consumption in the electricity supply sector through 2017;
- *Planned electrical power capacity additions:* this information was obtained from a SENER publication titled *Electricity Sector Outlook 2008-2017*. This source provided information on electricity generation units that are scheduled to open before 2017, including the rated capacity, technology, and fuel used to generate electricity. Projects in the developmental phase for which site and feasibility studies have not been completed are not considered in the forecast. The SENER report also provides technology specifications for the typical project, including capacity factor, efficiency, and own-use factor. According to this data source, there are no planned electric capacity additions in Tamaulipas through 2017;
- *State electricity generation data:* this information was obtained from a SENER publication titled *Electricity Sector Outlook 2008-2017*. This source provides historical data and projections for state electricity consumption, renewable and nonrenewable power plants installed capacity and average annual generation, and the electric power domestic and foreign trade needed to meet the increasing demand estimated for 2008-2017.[4] While this source provided records for historic electricity imports and exports with the U.S., there were no sources available that provided information on the quantity of electricity traded between Mexican states;
- *Electricity loss:* information on electricity lost through transmission, distribution, electricity generator internal use, and theft was provided by CFE. Loss data for CFE is available for the years 2000-2009;
- *Energy content of petroleum products:* this information was obtained from SENER publications titled *Balance Nacional de Energía 2007* and previous editions;[5]
- *CO_2, CH_4, and N_2O emission factors:* for all fuels, these emission factors were based on default values listed on Tables 2.2, 2.3, 2.4, 2.5, Chapter 2, Volume 2, of the 2006 Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories*;[6]

[2] CFE. “Informacion sobre tipos y cantidades de consume de combustibles fosiles.” Provided to CCS via e-mail to Juan Maldonado on July 13, 2009.
[3] SENER. 2009. “Prospectiva del Mercadode Gas Natural 2008-2017.” Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466
[4] SENER. 2009. “Prospectiva del Sector Eléctrico 2008-2017.” Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466
[5] SENER. 2008. “Balance Nacional de Energía 2007.” Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=48#prop2008
[6] IPCC. 2006. “2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories.” Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html

- *Global warming potentials:* the global warming potentials for CH_4 and N_2O are based on values proposed by the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report.[7]

General Greenhouse Gas Inventory and Reference Case Forecast Methodology

The 2006 IPCC Guidelines provide methods for estimating GHG emissions in terms of the source and gases, offering three approaches for estimating emissions from fossil fuels for stationary combustion. A Tier I approach was used to estimate GHG emissions from the electricity supply sector. According to the 2006 IPCC guidelines, a Tier I method is best suited when country-specific, technology-specific, or facility-specific emission factors are not available. Tier II methods are used when fuel combustion data from national energy statistics and country-specific emission factors are available. Tier III methods are appropriate when fuel combustion data and technology-specific emission factors are available. Tier III methods include emission measurements at power generation plants or emissions modeling that matches state fuel statistics. While Tier II methods (and to a lesser extent Tier III methods) might be more accurate and appropriate for Tamaulipas, available data and technology or facility-level emission factors are not sufficient to fully complete an inventory and forecast based on a Tier II or Tier III approach.

The IPCC Tier I method is fuel-based and emissions from all sources of combustion are estimated on the basis of the quantities of fuel combusted and fuel-specific emission factors. Tier I emission factors are available for each of the relevant greenhouse gases, and are presented in Table A-1. The quality of these emission factors differs between gases. For CO_2, emission factors mainly depend upon the carbon content of the fuel. Combustion conditions may vary by a small amount based on the age and condition of the combustion unit (combustion efficiency, carbon retained in slag and ash, etc.). However, given the lack of facility-specific emission factors, CO_2 emissions are estimated fairly accurately based on the total amount of fuels combusted and the average carbon content of the fuels.[8] Electricity imported by Tamaulipas from the U.S. originates in Texas. The emission factors for the ERCOT (Electric Reliability Council of Texas) US EPA eGRID subregion were used to calculate GHG emissions from imported electricity.[9]

[7] IPCC. 1995. "Intergovernmental Panel on Climate Change Second Assessment Report." Available at: http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm#1
[8] Emission factors for methane and nitrous oxide depend on the combustion technology and operating conditions and vary significantly, both between individual combustion installations and within the same unit over time. Due to this variability, use of average fuel-specific emission factors for these gases introduces relatively large uncertainties. This paragraph is quoted from Chapter 1, Volume 2 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories, page 1.6. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf
[9] The Climate Registry. 2008. "General Reporting Protocol v.1.1." Table 14.1. Available at http://www.theclimateregistry.org/downloads/GRP.pdf.

Table A-1. Emission Factors used for the Inventory and Forecast

Energy Source	EF CO_2	EF N_2O	EF CH_4
Natural Gas (kg/TJ)	56,100	0.1	1
Fuel oil (kg/TJ)	77,400	0.6	3
Diesel Oil (kg/TJ)	77,400	0.6	3
Imports (kg/MWh)	3,131	0.05	0.03

The approach used for inventorying GHG emissions gives priority to available historic records, namely electricity sector and natural gas reports by SENER, which provide both historic data and projections through 2017. The first set of historic records pertained to the volume of natural gas in millions of cubic feet per day used by the electricity supply sector in the state of Tamaulipas from 1996 to 2008.[10] The second set of historic records detailed diesel oil and residual fuel oil consumption within the electricity supply sector in Tamaulipas, expressed in Terajoules (TJ) for the period 1996 through 2008.[11] Finally, the third set of historic records provides international electricity imports and exports for 1993 to 2007, reported in SENER's *Electricity Sector Outlook* reports.[12] Imported flows of electricity to Tamaulipas are through interconnections existing between the U.S. and Mexico; these interconnections are managed by the Servicio Eléctrico Nacional (SEN) and ERCOT.

The forecasts of GHG emissions from the electricity supply sector are based on official forecast estimates of electricity sales and official forecast estimates of natural gas combustion within the electricity supply sector. Planned generation capacity additions and retirement of electricity generating units are considered in order to assure that the projected fuel combusted within the electricity supply sector does not exceed the amount of fuel that could be combusted at operational electricity generation facilities in each year. The following sections will show that there is insufficient capacity to maintain the 2008-2017 growth rate of natural gas consumption after 2017. Therefore, the amount of electricity produced will flatten out after 2017. However, as Tamaulipas is projected to be a net exporter of electricity in these years, it is expected that electricity consumption will continue to grow after 2017, with any remaining excess production continuing to sold for consumption outside of the state. As with the historical GHG inventory, GHG emissions are forecast for both the production-based and consumption-based scenarios.

Production-based Inventory Methodology

The production-based inventory utilized fuel consumption data, in addition to fuel-specific generation data at Tamaulipas electricity generation facilities to estimate the total electricity generated within the borders of Tamaulipas from 1990 to 2007. The following steps were taken

[10] SENER. 2009. "Prospectiva del Mercadode Gas Natural 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466
[11] Historical fossil fuel consumption at power generation plants was obtained directly from Secretaría de Energía (SENER) in response to Nuevo Leon's letter of inquiry. March 2007.
[12] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466

to apply available data and assumptions based on those data to generate the historic production-based inventory of GHGs from the electricity supply sector in Tamaulipas.

Electricity generation: the generation of electricity at Tamaulipas electricity generation facilities is reported in SENER's *Electricity Sector Outlook 2008-2017* and previous editions.[13] From these reports, electricity generation, by fuel, can be determined for the years 2003 through 2007. Total electricity generation values dating back to 1990 were supplied by SENER. In 2007, seven combined cycle plants (Rio Bravo CC, Rio Bravo II, Rio Bravo III, Rio Bravo IV, Altamira II, Altamira III & IV, and Altamira V) generated 96% of the state's electricity using natural gas; less than 4% of the state's electricity was generated at conventional thermal facilities from a mixture of residual fuel oil, and natural gas; and a small amount of electricity (3 GWh) is imported from the U.S.[14] Summaries of the 2007 data are displayed in Table A-2. Figure A-1 is a representation of the generation at these facilities from 2003 to 2007. Figure A-1 shows a great deal of variability in generation during this time period for some plants. This variability is driven by the fact that some plants were brought on-line during this time period and one (Rio Bravo CT) was phased out.

Natural gas: data concerning the quantity of natural gas used in the electricity supply sector are provided by the *Natural Gas Market Outlook 2008-2017*, and previous editions of that report. The energy content of the natural gas consumed was found by multiplying the volume of natural gas combusted each year (as reported by the *Natural Gas Market Outlook* reports) by the energy content, using the net energy content values per year published by SENER in *Balance Nacional de Energía 2007*.[15] The fuel consumption values for residual fuel oil were back-cast for the years 1990 to 1994 by assuming a constant share of total generation for each fossil fuel generation source. Electricity generation prior to 2003 was estimated by multiplying the energy content by the heat rate (TJ/GWh) for 2003, as calculated from the available fuel use and generation data.

Other fossil fuels: there is no known coal consumption by the electricity supply sector in Tamaulipas. The consumption data for residual fuel oil and diesel oil for the years 1996 through 2008 were provided directly to CCS by SENER.[16] The additional information provided by CFE includes a more specific accounting of diesel oil fuel use than the SENER data and provides data for the years 1993 through 1995. The energy content of these fuels was found by multiplying the volume of these fuels combusted each year by the energy content (in TJ per barrel), using the net energy content values per year published by SENER in *Balance Nacional de Energía 2007*.[17] The fuel consumption values for residual fuel oil and diesel fuel oil were back-cast for the years 1990 to 1992

[13] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466. Previous editions available at same site.
[14] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466
[15] SENER. 2008. "Balance Nacional de Energía 2007." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=48#prop2008
[16] Historical fossil fuel consumption at power generation plants was obtained directly from Secretaría de Energía (SENER) in response to Nuevo Leon's letter of inquiry. March 2007.
[17] SENER. 2008. "Balance Nacional de Energía 2007." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=48#prop2008

by assuming a constant share of total generation for each fossil fuel generation source. Electricity generation prior to 2003 was estimated by multiplying the energy content by the heat value (TJ/GWh) for 2003.

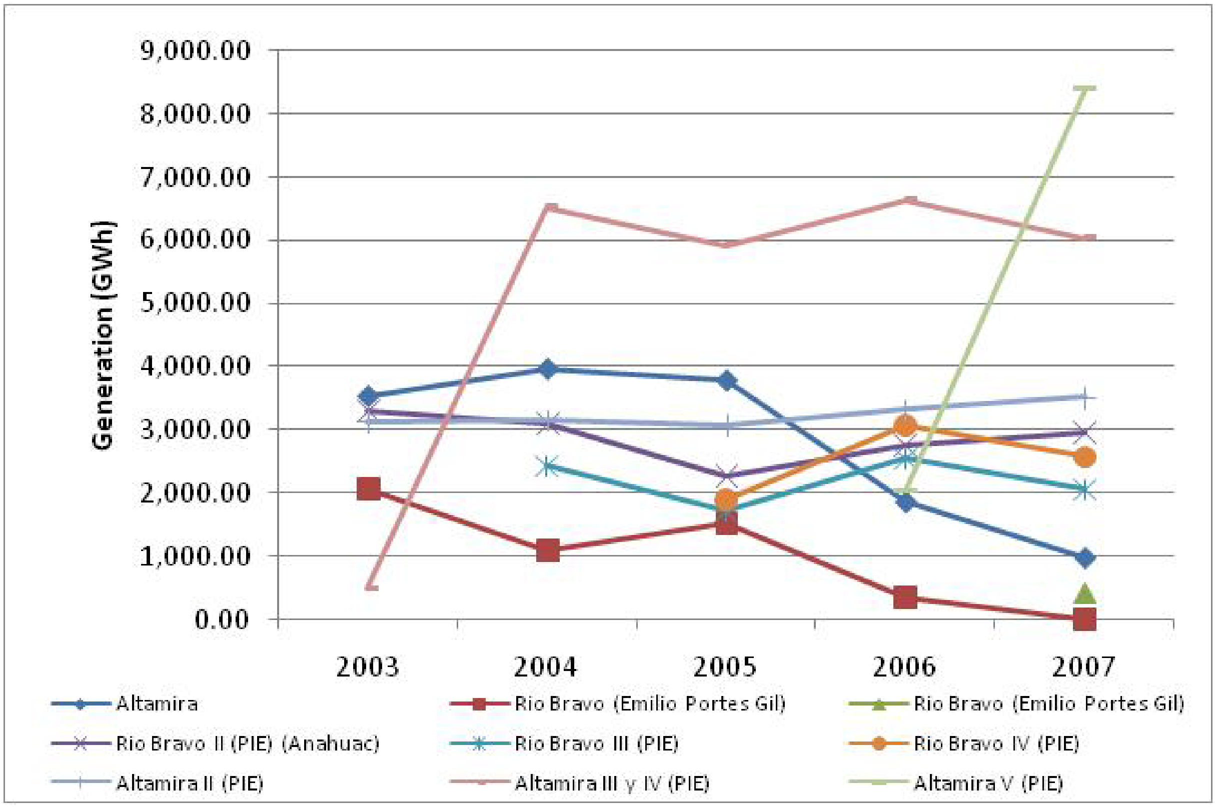
Renewable energy*:* information provided to CCS by SENER indicated that there is one small hydroelectric facility that accounted for 54 GWh of electricity generation in 2007. As SENER's *Electricity Sector Outlook 2008-2017* does not provide any information on these facilities; it was assumed that 54 GWh of electricity from hydro-power was generated in each year over the historic inventory.

Table A-2. Summary of Electricity Generation Characteristics by Plant, 2007

Plant name	Generator type	Fuel type	Gross capacity (MW)	Gross generation (GWh)	Fuel consumption (TJ)
Altamira	CT	Fuel oil/Natural gas	800	981	13,762.40
Rio Bravo (Emilio Portes Gil)	CT	Fuel oil	511	4	81.26
Rio Bravo (Emilio Portes Gil)	CC	Natural gas	511	424	3,282.85
Rio Bravo II (PIE) (Anahuac)	CC	Natural gas	495	2,957	22,894.78
Rio Bravo III (PIE)	CC	Natural gas	495	3,523	27,277.07
Rio Bravo IV (PIE)	CC	Natural gas	1036	6,052	46,858.03
Altamira II (PIE)	CC	Natural gas	495	2,063	15,972.92
Altamira III y IV (PIE)	CC	Natural gas	500	2,576	19,944.86
Altamira V (PIE)	CC	Natural gas	1121	8,391	64,967.90

CT: conventional thermoelectric, CC: combined cycle

Figure A-1. Electricty Generation by Plant, 2003-2007



PIE: Productores Independientes de Energía (Independent Power Producers)

Production-based Reference Case Forecast Methodology

The production-based forecast utilized SENER projections on fuel use, electricity sales, and planned capacity to generate the production-based forecast. The specific forecast methodology for each fuel-type is described below:

Natural gas: the electricity supply sector natural gas consumption projection for the years 2008 through 2017 is provided in the *Natural Gas Market Outlook 2008-2017* report.[18] The 2008 through 2017 average annual increase of 3.5% was applied for each year after 2018. However, based on the available capacity (no additional capacity planned through 2017),[19] it is evident that there will not be sufficient generation capacity to increase natural gas consumption after 2017. Therefore, natural gas consumption in the electricity supply sector for 2018 through 2025 is assumed equal the amount of natural gas needed to power the facilities at the assumed 80% capacity factor. The 2007 heat rate for the

[18] SENER. 2009. "Prospectiva del Mercadode Gas Natural 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466
[19] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466.

existing facilities, as calculated in the historic GHG inventory, is applied to fuel used at the existing facilities to estimate generation.

Other fossil fuels: the data provided by SENER on the consumption of residual fuel oil and diesel oil for 1996 through 2008 was the primary source from which the forecast assumptions on these fuels are based.[20] According to the *Electricity Sector Outlook*, there was no diesel fuel used for electricity generation in 2007. Therefore, CCS assumed that diesel oil is no longer used in the electricity sector. The amount of residual fuel oil combusted for electricity generation is assumed to remain constant until 2015, when the Altamira combustion turbine is retired. Since the cessation of operations at the Altamira facility reduce the electric capacity at facilities using residual fuel oil by 82%, it is assumed that the primary energy from residual fuel oil combustion reduces by 82% in 2015. The 2007 heat rate for the existing facilities, as calculated in the historic GHG inventory, is applied to fuel used at the existing facilities to estimate generation.

Renewable energy: the hydroelectric generation in Tamaulipas is not reported in SENER's *Electricity Sector Outlook 2008-2017*.[21] Therefore, it is assumed that the annual electricity generated at the hydroelectric facility for 2018 through 2025 is equal to the generation total for the year 2007 (54 GWh).

Table A-3 and Figure A-2 display the fossil fuel consumption by fuel type over the historic inventory and reference case forecast periods (1990-2025). Hydro-derived electricity is not included in these visuals, as these are just the fossil-based energy sources used to generate electricity. Table A-4 and Figure A-3 display the electricity generation over this period for all fuel types. These visuals show that natural gas became the primary fossil fuel source for electricity generation in Tamaulipas during the 2000 to 2005 period, while the amount of electricity generated through hydroelectric energy remains constant throughout the entire inventory and forecast period. The peaks occurring in years 2008 through 2015 in Figures A-2 and A-3 are higher than the 2018-2025 level of fossil fuel consumption and electricity generation. The 2018-2025 values are lower than the peaks in previous years due to the reduction in generation capacity that occurs when the Altamira combustion turbine is retired in 2015.

Table A-3. Production-based Inventory and Forecast – Fossil Fuel Consumption (TJ)

Year	Natural gas	Fuel oil	Diesel oil	Total Consumption
1990	11,577	37,216	11	48,805
1995	13,162	44,454	7	57,624
2000	33,007	59,594	638	93,239
2005	137,984	48,429	134	186,547
2010	227,942	7,904	-	235,846
2015	274,284	1,388	-	275,672
2020	264,819	1,388	-	266,207
2025	264,819	1,388	-	266,207

[20] Historical fossil fuel consumption at power generation plants was obtained directly from Secretaría de Energía (SENER) in response to Nuevo Leon's letter of inquiry. March 2007.
[21] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466.

Figure A-2. Production-based Inventory and Forecast – Fossil Fuel Consumption

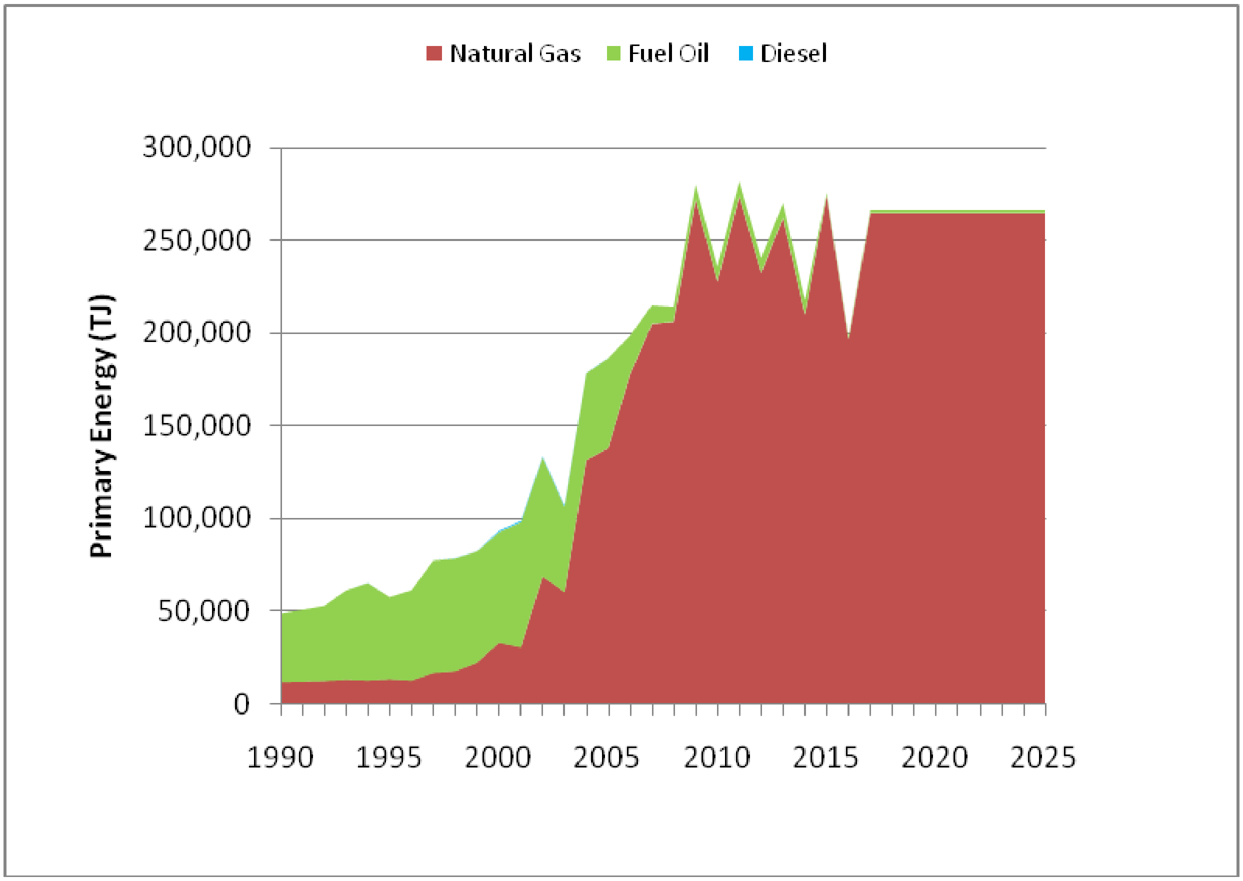
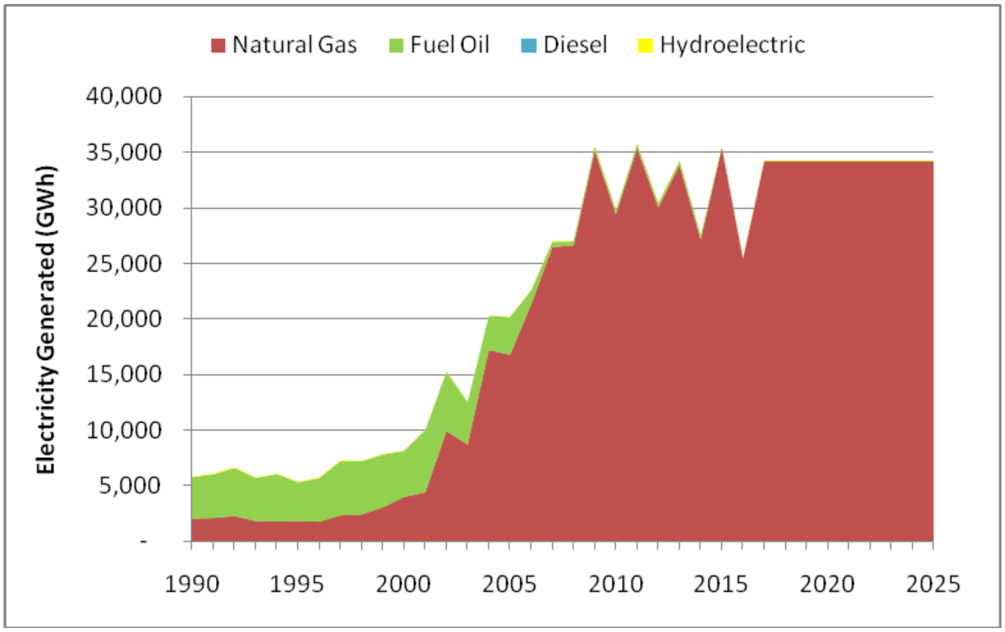


Table A-4. Production-based Inventory and Forecast – Electricity Generation (GWh)

Year	Natural gas	Fuel oil	Diesel oil	Hydroelectric	Total Production
1990	2,027	3,750	0.6	66	5,843
1995	1,806	3,510	0.3	51	5,368
2000	3,980	4,135	22	45	8,182
2005	16,784	3,401	6	54	20,245
2010	29,440	389	0	54	29,883
2015	35,425	68	0	54	35,548
2020	34,203	68	0	54	34,325
2025	34,203	68	0	54	34,325

Figure A-3. Total Electricity Generation – by Fuel Type



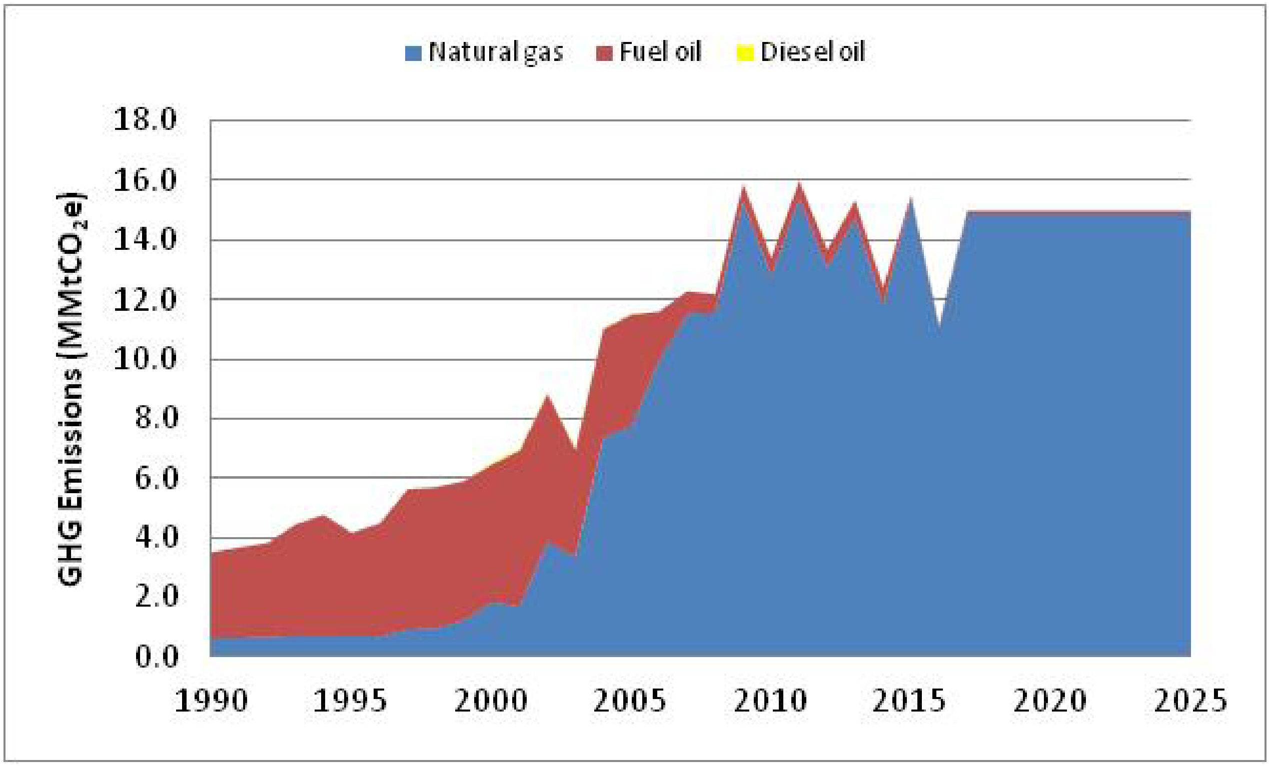
Production-based Inventory and Reference Case Forecast Results

The methods described in the previous two sections provide details on how CCS utilized existing data and official projections to estimate the energy content of fuels used for 1990 through 2025. The production-based historic and projected GHG emissions are displayed in Table A-5 and Figure A-4. The contribution of each fuel type to the GHG emissions estimates are in line with the fossil energy consumption, in that GHG emissions from natural gas dominate the total production-based GHG emission estimates after the 2000 to 2005 time frame.

Table A-5. Production-based GHG Emissions from the Electricity Supply Sector ($MMtCO_2e$)

Year	Natural gas	Fuel oil	Diesel oil	Total Production-based Emissions
1990	0.65	2.89	$8.0*10^{-4}$	3.54
1995	0.74	3.45	$5.0*10^{-4}$	4.19
2000	1.85	4.63	$4.7*10^{-3}$	6.53
2005	7.75	3.76	0.01	11.5
2010	12.8	0.61	0.00	13.4
2015	15.4	0.11	0.00	15.5
2020	14.9	0.11	0.00	15.0
2025	14.9	0.11	0.00	15.0

Figure A-4. Production-based GHG Emissions from the Electricity Supply Sector



Consumption -based Inventory Methodology

The consumption-based inventory accounts for emissions resulting from electricity consumed in Tamaulipas, including emissions from imported electricity, but excluding emissions from electricity produced in, but exported from, the state.

(A-1) *Consumption-based Electricity (GWh) = In-State Sales + Losses*

The consumption-based inventory is primarily based on electricity sales data reported in SENER's *Electricity Sector Outlook 2008-2017* and previous editions.[22] It is assumed that the same mix of generation sources applies to in-state sales (consumption) of electricity. These source-specific breakdowns of electricity consumption were multiplied by the heat rates (TJ/GWh) found in the production-based inventory to yield the energy content used in the emissions calculations.

[22] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466. Previous editions available at same site.

The amount of electricity imported for the years 1993 through 2007 was reported by SENER's *Electricity Sector Outlook* reports. As this generation took place in the United States, the average emission factor for electricity generated in the ERCOT subregion (Texas) – as reported by The Climate Registry – was used to calculate the GHG emissions associated with imported electricity. Information on imports from other states in Mexico was not available. It is noted in SENER's *Electricity Sector Outlook* reports that there is transmission capacity connecting the electricity grid in Tamaulipas to other Mexican states. As the quantity of electricity produced after major capacity additions in 2002 exceeds the amount of electricity consumed in Tamaulipas by a wide margin, it is assumed that Tamaulipas was a net exporter of electricity in those years. For the years that Tamaulipas was (or is projected to be) a net exporter of electricity, the amount of electricity exported was adjusted by taking the difference between gross electricity production and the sum of electricity sold and electricity loss.

There are significant losses of electricity due to T&D loss and theft. While a small amount of loss from T&D is normal (e.g. 3% from the transmission network and 5% used at electricity generation facilities), a scholarly report from Rice University in Houston, TX claims that total loss for the national electricity system in Mexico may exceed 25%.[23] However, it was determined that the loss rate for CFE was a more realistic representation of electricity loss in Tamaulipas. The CFE loss rate was applied to total generation in each year to estimate the amount of electricity lost. For years where there is no loss rate available (1990-1999), it is assumed that the loss rate was the average of the annual loss rate for 2000-2009 (10.7%). Interstate exports were estimated by assuming that any excess electricity would be explained by interstate exports.

Considering that electricity T&D loss is inherent to the electricity supply system, it is necessary to account for T&D losses in the consumption-based inventory. In the production-based inventory, T&D loss and theft are captured within the estimates of total generation, so no separate accounting is necessary. Emissions due to exported electricity are not accounted for in the consumption-based inventory, but will be reported as an adjunct result. Emissions from exports and loss are estimated by assuming the same ratio of fuel-specific consumption to total fuel consumption for each year as the production-based inventory.

Consumption-based Reference Case Forecast Methodology

The consumption-based forecast is driven by the expected change in electricity consumption in Tamaulipas. The electricity consumption for Mexico's Northeast region is projected by SENER's *Electricity Sector Outlook 2008-2017*. The electricity consumption for Tamaulipas is indexed to the projection of the Northeast region for the years 2008 through 2017. The average annual increase of 4.6% was applied each year to estimate total consumption for 2018 through 2025. Then, the source-specific breakdowns were multiplied by the 2007 heat rates (TJ/GWh) calculated from the historic GHG production-based inventory to yield the energy content used in the emissions calculations.

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[23] Hartley, Peter and Eduardo Martinez-Chombo. 2002. "Electricity Demand and Supply in Mexico." Rice University, Houston, TX. Available at: http://www.rice.edu/energy/publications/docs/Hartley_ElectricityDemandSupplyMexico.pdf.

Consistent with the historical GHG inventories, forecast electricity production exceeds electricity sales from 2008 through 2025. Projections of electricity exported from other Mexican states to Tamaulipas were not available. Therefore, it was necessary to make an assumption regarding electricity exports and T&D losses in order to reconcile the production-based and consumption-based reference case forecasts.

It was assumed that the percentage of electricity lost would be equal to the 2000-2009 average annual loss rate (10.7%). This was chosen as conservatively low estimate of transmission and distribution loss that is consistent with the amount of electricity reported to be lost through the high voltage transmission network. Hence, by 2025, it is assumed that the State or Federal government will have identified and mitigated the losses not associated with T&D. The amount of electricity exported annually during the forecast period was calculated by subtracting electricity loss and consumption from production. Emissions from loss and exports are estimated by multiplying the ratio of fuel-specific consumption to total fuel consumption for each year (i.e. Natural Gas TJ / Total TJ; as generated by the production-based forecast) by the total primary energy used to generate exported or lost electricity.

Table A-6 and Figure A-5 display the disposition of electrical power in the State, including in-state consumption, imports, loss, and exports. Figure A-6 shows the primary energy consumption through the historic inventory and reference case forecast period that was used to calculate the GHG emission estimates.

Consumption-based Inventory and Reference Case Forecast Results

The methods described in the previous two sections provide details on how CCS utilized existing data and official projections to estimate the energy content of fuels used for 1990 through 2025. The consumption-based historic and projected GHG emissions are displayed in Table A-7 and Figure A-7. Figure A-7 breaks down the contribution of each fuel type to the in-state consumption component of the consumption-based inventory and reference case forecast, and also includes a dashed line to show the impact of electricity exports on GHG emissions, although GHG emissions from electricity exports are not included in the consumption-based inventory and reference case forecast. Emissions from electricity losses are embedded in the fuel source emissions in Figure A-7. Figure A-8 shows consumption-based GHG emissions by component, and is intended to display the impact of GHG emissions from electricity exports, imports, and loss, relative to emissions directly resulting from consumption of electricity generated in Tamaulipas. The peaks occurring in years 2008 through 2015 in Figure A-5, A-7, and A-8 are higher than the 2018-2025 level of exported electricity and corresponding GHG emissions. The 2018-2025 values are lower than the peaks in previous years due to the reduction in generation capacity that occurs when the Altamira combustion turbine is retired in 2015.

Table A-6. State-Wide Electrical Power Disposition (GWh)

	Consumption-based Inventory			
Year	TM Consumption	Import	Loss	Export
1990	3,432	0	623	1,787
1995	4,651	5	573	149
2000	6,483	9	867	840
2005	7,775	0	2,194	10,275
2010	9,167	0	3,188	20,716
2015	11,574	0	3,792	20,182
2020	14,458	0	3,661	16,206
2025	18,104	0	3,661	12,560

Figure A-5. State-Wide Electrical Power Disposition

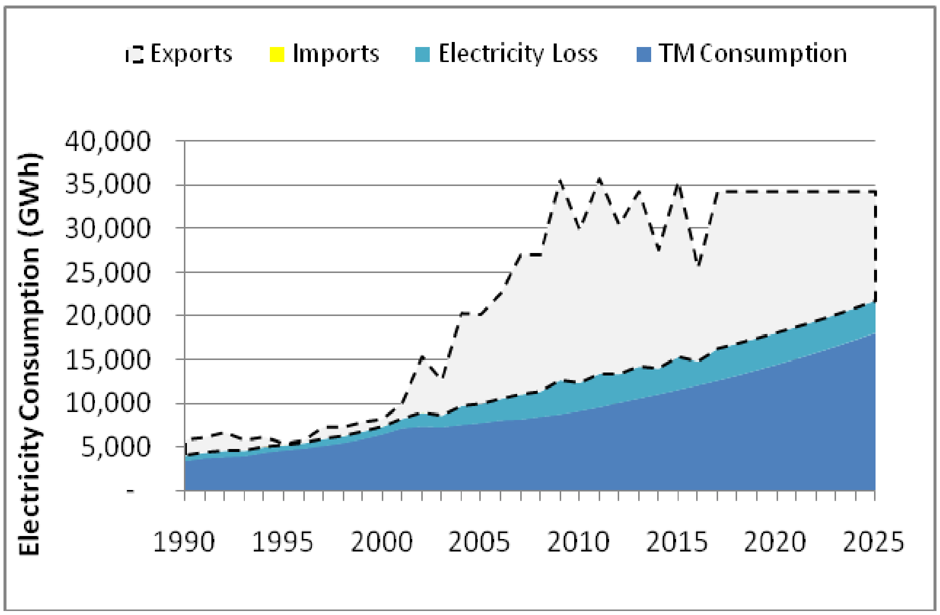


Figure A-6. Consumption-based Inventory and Forecast - Fossil Energy Use

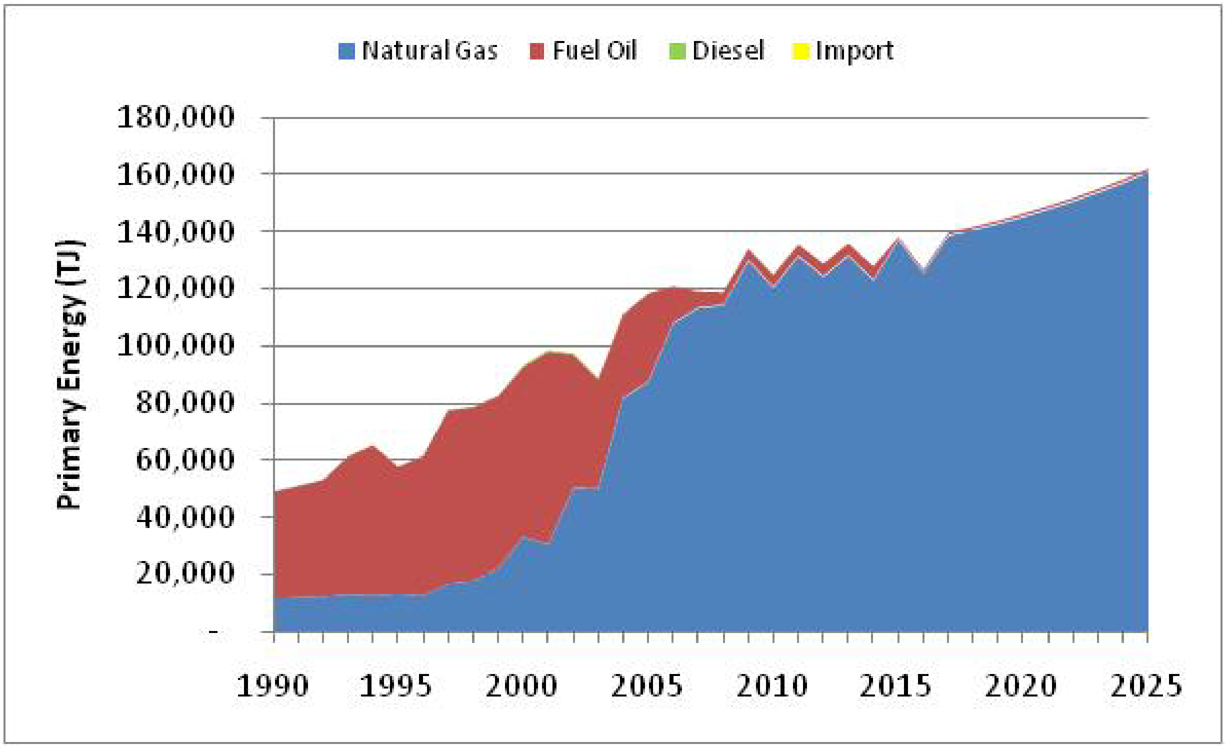


Table A-7. Total GHG Emissions Associated with Electricity Consumption ($MMtCO_2e$)

Year	TM Consumption	Imports	Loss	Total Consumption-based Emissions	Exports
1990	2.61	0.00	0.38	2.98	1.08
1995	3.43	0.04	0.45	3.92	0.12
2000	4.20	0.07	0.69	4.97	0.67
2005	4.42	0.00	1.25	5.28	5.85
2010	4.11	0.00	1.43	5.55	7.87
2015	5.05	0.00	1.65	6.70	8.81
2020	6.31	0.00	1.60	7.91	7.07
2025	7.90	0.00	1.60	9.50	5.48

Figure A-7. Total Consumption-Based Electricity Supply GHG Emissions

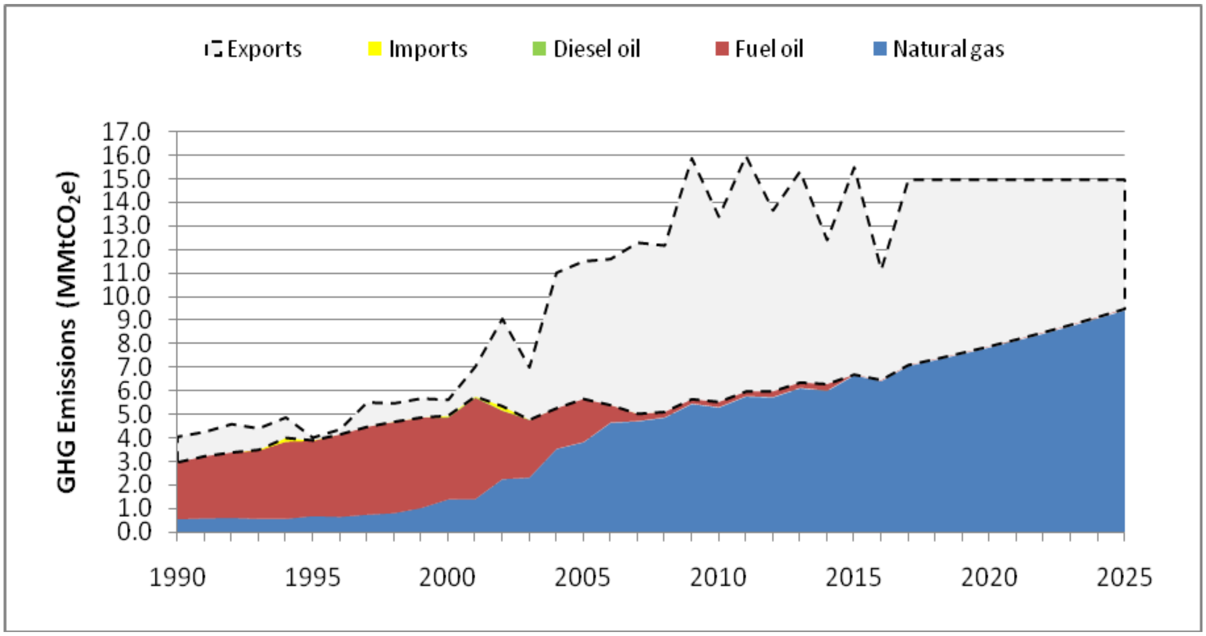
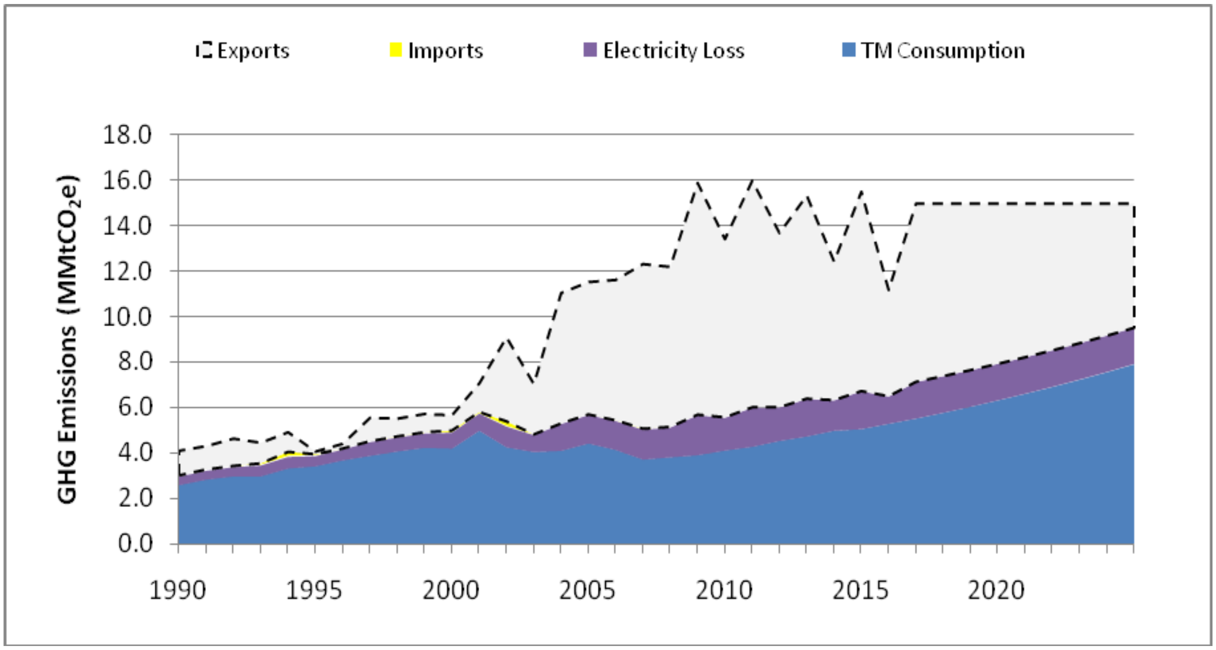


Figure A-8. Consumption-based Electricity Supply GHG Emissions – by Component



Key Uncertainties and Future Research Needs

Key sources of uncertainty underlying the estimates above and opportunities for future research are as follows:

- The generation and consumption (sales) for Tamaulipas, as portrayed in the historical data and projections provided by SENER, show that Tamaulipas has an excess supply and is an exporter of electricity. However, there were no data sources available to CCS that identified the quantity and destination of exported electricity. The only information available regarding the trade of electricity between Mexican states is the transmission capacity (existing and future) between states. Therefore, the amount of exported electricity had to be calculated. The quantity of exported electricity is based on projected electricity consumption, production, and an assumed loss factor.
- Electricity sales are fluid by nature. Therefore, as there are no data available for interstate imports and exports of electricity, it was necessary to project imports and exports on a net basis. While Tamaulipas is projected to be a net exporter of electricity through the forecast period, it is possible that some portion of electricity production will be imported.
- Electricity on-site usage and transmission and distribution loss estimates were assumed during the historic inventory period, and are based on national loss rates estimated from CFE. Over the forecast period, the loss rate is assumed to be equal to the average annual loss rate from 2000-2009. Improvements to these estimates could help to get more accurate emissions associated with imported electricity.
- The information in the SENER electricity and natural gas forecast reports did not provide sufficient information to discern the level of imports and exports in the future, especially from and to other states in Mexico. Projected updates to grid interconnections are reported in SENER's *Electricity Sector Outlook* reports. However, this information is only sufficient to prove or disprove whether there is sufficient grid capacity to transfer electricity between Tamaulipas and the U.S. or another Mexican state. The actual quantities of exports and imports are based on calculations future generation, sales, and assumed losses. More sophisticated market analysis may prove useful in assessing the future contribution of exports and imports to the GHG emissions contribution of the electricity supply sector in Tamaulipas.
- The quantity of exported electricity is based on projected electricity consumption, production, and the aforementioned loss factor. Electricity sales are fluid, by nature. Therefore, as there is no data available for interstate imports and exports of electricity, it was necessary to project imports and exports on a net basis. While Tamaulipas is projected to be a net exporter of electricity, it is possible that some electricity will be imported, also. By accounting for interstate imports and exports on a net basis, potential emissions from imported electricity (which would have a different emissions profile from electricity generated within Tamaulipas) are not included in the consumption-based inventory.

- The SENER reports that provided the electricity and natural gas data (historical and projected) display the gross generation at the largest power plants in Tamaulipas. CCS was not able to identify gross generation and the type of fuel combusted at smaller, privately owned facilities in Tamaulipas. Therefore, it is possible that CCS has underestimated the amount of electricity produced in Tamaulipas. This underestimation would lead to an overestimation in the electricity imported, and the corresponding emissions from that electricity. Since the production-based inventory uses the primary energy from fuel supplied to the Electricity Supply sector, CCS believes that the emissions estimates from electricity produced in Tamaulipas are accurate. Complete data providing total generation at all facilities in Tamaulipas, the type of fuel combusted at each facility, and the net imports of electricity from other Mexican states would increase the precision of the consumption-based emissions estimate and the elements therein (specifically, emissions from imports and loss).
- There are uncertainties associated with the statewide fuel mix, emission factors, and conversion factors (to convert electricity from a heat input basis to electricity output) that should be reviewed and revised with data that is specific to Tamaulipas power generators.
- For combined heat and power facilities that generate and sell electricity to the power grid, fuel use associated with these facilities is aggregated by fuel and sector and, therefore, cannot be broken out easily so that they can be reported under the electricity supply and use sector. Future work could include an assessment to determine how best to isolate emissions associated with combined heat and power facilities.
- Fuel price changes influence consumption levels and, to the extent that price trends for competing fuels differ, may encourage switching among fuels, and thereby affect emissions estimates. Unanticipated events that affect fuel prices could affect the electricity forecast for Tamaulipas.
- Population and economic growth are the principal drivers for fuel use. The reference case projections are based on the estimates of electric generation requirements in reported by SENER's *Electricity Sector Outlook* reports. Electricity demand forecasts by other sectors could help to refine the forecast for Tamaulipas.

Appendix B. Residential, Commercial, and Industrial (RCI) Fuel Combustion

Overview

Activities in the RCI[1]subsectors produce CO_2, CH_4, and N_2O emissions when fuels are combusted to provide space heating, water heating, process heating, cooking, and other energy end-uses. This appendix covers fuel combustion only for these subsectors. In 2005, direct total GHG emissions from RCI fuel combustion of oil, natural gas, liquefied petroleum gas (LPG), coal, and wood were 3.2 $MMtCO_2e$ of which 78% was emitted by industrial sources, 18% by residential sources, and 4% by commercial sources. Non-combustion emissions relating to residential, commercial, and industrial activity may be found in the agriculture, waste, industrial processes, and forestry sector appendices.

Emissions and Reference Case Projections

The 2006 IPCC Guidelines offer three approaches for estimating emissions from fossil fuel combustion by stationary sources. Based on available information, a Tier 1 approach was selected. [2]

The 2006 IPCC Guidelines estimate carbon emissions in terms of the species which are emitted. During the combustion process, most carbon is immediately emitted as CO_2. However, some carbon is released as carbon monoxide (CO), CH_4 or non-methane volatile organic compounds (NMVOCs). Most of the carbon emitted as these non-CO_2 species eventually oxidizes to CO_2 in the atmosphere. In the case of fuel combustion, the emissions of these non-CO_2 gases contain very small amounts of carbon compared to the CO_2 estimate and, at Tier 1, it is more accurate to base the CO_2 estimate on the total carbon in the fuel. This is because the total carbon in the fuel depends on the fuel alone, while the emissions of the non-CO_2 gases depend on many factors such as technologies, or maintenance, which, in general, are not well known.

The Tier 1 method is fuel-based, since emissions from all sources of combustion can be estimated on the basis of the quantities of fuel combusted and average emission factors. Tier 1 emission factors are available for CO_2, CH_4, and N_2O. The quality of these emission factors differs between gases. For CO_2, emission factors mainly depend upon the carbon content of the fuel. Combustion conditions (including combustion efficiency, and carbon retained in slag and ashes) are relatively unimportant. [3] Therefore, CO_2 emissions can be estimated fairly accurately based on the total amount of fuels combusted and the average carbon content of the fuels. Emission factors for CH_4 and N_2O, however, depend on the combustion technology and operating conditions and vary significantly, both between individual combustion installations and over time. Due to this variability, the use of average emission factors for these gases will

[1] The industrial sector includes some emissions associated with agricultural energy use and natural gas consumed as lease and plant fuel. Emissions associated with pipeline fuel use are included in Appendix E.
[2] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Chapter 1, page 1.6. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf
[3] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Chapter 1, page 1.6. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf

introduce relatively large uncertainties.[4] Fortunately, CH_4 and N_2O contribute very little to the total CO_2e emissions from combustion processes. Emissions estimates from wood combustion include only N_2O and CH_4. CO_2 evolved from wood is considered a biogenic source and is not included in this inventory. Carbon dioxide emissions from biomass combustion are assumed to be "net zero", consistent with Intergovernmental Panel on Climate Change (IPCC) methodologies, and any net loss of carbon stocks due to biomass fuel use should be accounted for in the land use and forestry analysis. N_2O and CH_4 emissions in this inventory are reported in CO_2 equivalents (CO_2e).

In order to capture the difference in CH_4 and N_2O emissions, default emission factors in the 2006 IPCC Guidelines are listed in separate tables according to four subsectors: 1) energy industries, 2) manufacturing industries and construction, 3) commercial and institutional, and 4) residential and agriculture/forestry/fishing farms.[5] The emissions factors used for this inventory and forecast are summarized in Table B-1, followed by a brief description of the methods and activity data used to develop the inventory and reference case projections.

Table B-1. Emissions Factors for RCI Fuels (kg/TJ)

Source	Fuel Type	CO_2	N_2O	CH_4
Commercial	Liquefied Petroleum Gases	63,100	0.1	5
Industrial	Diesel Oil	74,100	0.6	3
	Liquefied Petroleum Gases	63,100	0.1	1
	Liquefied Petroleum Gases (Agriculture)	63,100	0.1	5
	Natural Gas	56,100	0.1	1
	Residual Fuel Oil	77,400	0.6	3
Residential	Liquefied Petroleum Gases	63,100	0.1	5
	Natural Gas	56,100	0.1	5
	Solid Biofuels: Wood	112,000	4	300

Diesel

Diesel consumption in the RCI sector for 1993-2007 as well as projected estimates for 2008-2009 were obtained directly from SENER.[6] SENER attributed all diesel consumption to the industrial subsector. Prior to 1993, consumption was extrapolated backwards linearly to 1990. Forecast values were derived by calculating the mean annual growth rate (3.8%) from the 2004-

[4] This paragraph is quoted with minor editing from Chapter 1, Volume 2 of 2006 IPCC Guidelines for National Greenhouse Gas Inventories, page 1.6. http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf

[5] Default emission factor tables are found in Chapter 2, Volume 2 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.

[6] Diesel consumption information was prepared by SENER for the Agencia de Protección al Medio Ambiente y Recursos Naturales (APMARN) de Nuevo León.

2009 SENER dataset and applying that to the years 2010-2025. The growth rates applied for this fuel and all the other fuels in the sector are summarized in Table B-2.

Residual Fuel Oil

Residual fuel oil consumption in the RCI sector was estimated by subtracting electricity sector fuel oil sales from state total fuel oil sales from 1990-2007.[7] Forecast values were derived by calculating the mean annual growth rate (-13.2%) for 1990-2005 and applying that to the years 2008-2025.

Table B-2. Annual Growth Rates used in RCI Forecast

Source	Fuel Type	Annual Growth Rate
Commercial	Liquefied Petroleum Gases	1.6%
Industrial	Diesel Oil	3.8%
	Liquefied Petroleum Gases	3.6%
	Liquified Petroleum Gases (Agriculture)	2.8%
	Natural Gas	0.3%
	Residual Fuel Oil	-13.2%
Residential	Liquefied Petroleum Gases	-0.7%
	Natural Gas	4.0%
	Solid Biofuels: Wood	1.3%

Liquefied Petroleum Gas

State consumption of LPG and forecast consumption were obtained from SENER.[8] Fuel consumption information by state was published for 1996-2005. Consumption by subsector including residential, commercial, and industrial were published by region. The regional percentages were multiplied by the total state consumption for all three subsectors combined to estimate state subsector consumption. Consumption for prior years back to 1990 was estimated by back-casting from reported consumption. Official SENER LPG consumption projections were available for 2006-2016. For the remaining forecast years through 2025, LPG consumption in each subsector was assumed to grow at the same rate as SENER's projection (the 2009-2016 mean annual growth rate). For residential this is -0.7% per year; industrial, 0.3% per year; and commercial, 1.6% per year.

LPG consumption for industrial uses ancillary to agricultural production was also reported and is included here as part of the industrial subsector. Many activities in the agricultural sector require the use of fuel energy such as the operation of tractors and machinery. However, segregated

[7] Sistema de Información Energética - productos petroliferos, accessed from http://sie.energia.gob.mx/sie/bdiController.

[8] SENER: *Prospectiva del Mercado de Gas LP 2006-2015*, *Prospectiva del Mercado de Gas LP 2007-2016*, and *Prospectiva del Mercado de Gas LP 2008-2017* Accessed from http://www.sener.gob.mx/webSener/index.jsp.

information relating to the consumption of energy in the agricultural sector was only available for LPG. The latter is not representative of primary energy consumption in the agricultural sector as the predominant form of energy is diesel used in tractors and heavy machinery. Diesel fuel consumption by vehicles (e.g. tractors and trailers) is captured under Transportation: Road/Diesel (see Appendix C).

Natural Gas

State consumption of natural gas and forecast consumption data were obtained from SENER.[9] Fuel consumption segregated by subsector was available at the state level for industry for 1998-2007. Aggregate natural gas consumption for residential, commercial, and transportation was reported for the state for 2000-2007. National data from SENER indicate that the majority of this aggregate consumption is from residential use.[10] Hence, all of the consumption from this aggregate was assigned to the residential subsector. Consequently the commercial sector has very little consumption assigned to it. Consumption values for prior years back to 1990 were estimated by back-casting the reported consumption. SENER's official natural gas consumption projections were available for 2009-2017. For remaining forecast years up to 2025, state total consumption was assumed to grow at the same rate as SENER's projection (the 2009-2017 mean annual growth rate). For the industrial subsector this is 0.3%. For residential, commercial, and transportation this is 4.0%. In Tamaulipas the industrial subsector dominates natural gas consumption. In 2005, the reported consumption from residential, commercial, and transportation is only 6.8% of the natural gas consumption from the industrial subsector.

Solid Biofuels: Wood

The use of wood fuel by the residential subsector was derived from two sources of information. The 2000 Censo de Población y Vivienda (Population and Housing Census) provided the breakdown of households according to the type of fuel consumed for cooking. This source was used to determine the fraction of homes with wood fuel stoves (6.4%) and infer the share of the population that relies on wood fuel for cooking. SENER provided the average annual wood fuel use per capita for 1996 and 2006 (in natural gas equivalents).[11] Wood fuel use was assumed to decrease linearly between 1996 and 2006. The years 1990-1995 were held constant at the 1996 level. Energy use from wood fuel was calculated by multiplying the percentage of residents who use wood fuel times the average annual wood fuel use per capita. Forecast values were derived by calculating the mean annual growth rate (1.3%) for 1990-2005 and applying that to the years 2006-2025. Only CH_4 and N_2O emissions associated with wood combustion are reported here as any CO_2 emitted would be considered biogenic.

Results

Energy use in the RCI sector totaled 51,807 terajoules (TJ) in 2005. Energy consumption values are shown in Table B-3.

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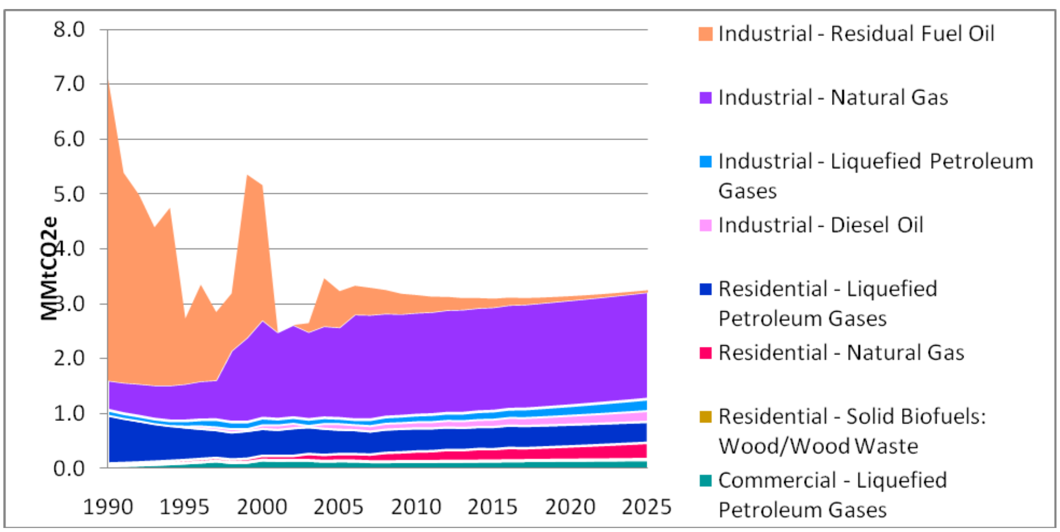
[9] SENER: *Prospectiva del Mercado de Gas Natural 2007-2016* and *Prospectiva del Mercado de Gas LP 2008-2017*. Accessed from http://www.sener.gob.mx/webSener/index.jsp.
[10] SENER: *Prospectiva del Mercado de Gas Natural 2007-2016* and *Prospectiva del Mercado de Gas LP 2008-2017*. Accessed from http://www.sener.gob.mx/webSener/index.jsp.
[11] SENER: *Prospectiva del Mercado de Gas Natural 2007-2016, Cuadro 23.* Accessed from http://www.sener.gob.mx/webSener/index.jsp.

Table B-3. Historical Energy Used in RCI Sector, TJ

Source	Fuel Type	1990	1995	2000	2005
Commercial	Liquefied Petroleum Gases	628	1,388	2,161	1,953
Industrial	Diesel Oil	20	338	999	1,485
	Liquefied Petroleum Gases	228	950	1,551	1,224
	Liquefied Petroleum Gases (Agriculture)	1,250	598	407	312
	Natural Gas	9,522	11,886	31,654	29,402
	Residual Fuel Oil	70,174	15,281	31,445	8,459
Residential	Liquefied Petroleum Gases	13,500	9,057	7,474	6,744
	Natural Gas	501	718	1,135	1,943
	Solid Biofuels: Wood	235	264	291	285
Total		**96,059**	**40,480**	**77,116**	**51,807**

Figure B-1 and Tables B-4 and B-5 provide a summary profile of GHG emissions for the entire RCI sector. In 2005, total RCI GHG emissions were 3.2 million metric tons of carbon dioxide equivalent ($MMtCO_2e$), of which 78% is associated with fuel combustion in the industrial subsector, 18% is from the residential subsector, and 4% is from the commercial subsector. In 2005, industrial natural gas consumption accounted for 51% of total RCI energy use, followed by industrial consumption of residual fuel oil (21%), and residential LPG consumption (13)%.

Figure B-1. GHG Emissions in RCI Sector



By 2025, total RCI GHG emissions are projected at 3.3 $MMtCO_2e$ of which 74% are from industrial fuel combustion, 21% from residential fuel combustion, and 5% from commercial fuel combustion. Overall, RCI emissions are driven by the combustion of natural gas and residual fuel oil in the industrial subsector and by LPG in the residential subsector. Natural gas consumption was reported as an aggregate total in the state for the residential and commercial subsectors and the transportation sector. In addition to the commercial natural gas consumption included in this aggregate, it is likely that some commercial consumption is included in the industrial subsector consumption. More detailed data from state agencies or fuel suppliers would be necessary to clarify this.

Table B-4. GHG Emissions RCI Sector ($MMtCO_2e$)

Source	Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Commercial	Liquefied Petroleum Gases	0.04	0.09	0.14	0.13	0.11	0.12	0.14	0.15
Industrial	Diesel Oil	0.00	0.03	0.07	0.11	0.12	0.14	0.17	0.21
	Liquefied Petroleum Gases	0.01	0.06	0.10	0.08	0.10	0.12	0.18	0.21
	Liquefied Petroleum Gases (Agriculture)	0.08	0.04	0.03	0.02	0.02	0.03	0.00	0.00
	Natural Gas	0.54	0.67	1.79	1.66	1.86	1.89	1.92	1.94
	Residual Fuel Oil	5.50	1.20	2.46	0.66	0.32	0.16	0.08	0.04
Residential	Liquefied Petroleum Gases	0.87	0.59	0.48	0.44	0.42	0.40	0.39	0.38
	Natural Gas	0.03	0.04	0.07	0.11	0.17	0.20	0.24	0.29
	Solid Biofuels: Wood	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
Total		**7.10**	**2.73**	**5.16**	**3.23**	**3.16**	**3.10**	**3.14**	**3.25**

Table B-5. GHG Emissions Distribution in RCI Sector

Source	Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Commercial	Liquefied Petroleum Gases	1%	3%	3%	4%	4%	4%	4%	5%
Industrial	Diesel Oil	0%	1%	1%	3%	4%	5%	6%	6%
	Liquefied Petroleum Gases	0%	2%	2%	2%	3%	4%	6%	7%
	Agriculture - LPG	1%	1%	1%	1%	1%	1%	0%	0%
	Natural Gas	8%	25%	35%	51%	59%	61%	61%	60%
	Residual Fuel Oil	77%	44%	48%	21%	10%	5%	3%	1%
Residential	Liquefied Petroleum Gases	12%	21%	9%	13%	13%	13%	12%	12%
	Natural Gas	0.4%	2%	1%	3%	5%	6%	8%	9%
	Solid Biofuels: Wood	0.3%	0.9%	0.5%	0.8%	0.9%	1.0%	1.0%	1.1%

Although emissions associated with the generation of electricity that is consumed by the RCI subsectors are accounted for in the electricity generation sector (see Appendix A), it is useful to know the distribution of electricity use between the RCI subsectors to inform possible future approaches for mitigating energy use and thus GHG emissions. In 2005, the industrial sector accounted for the majority of electricity use (60%), followed by the residential (32%) and commercial subsectors (8%). Table B-6 shows historic growth rates for electricity sales by RCI sector. The proportion of each RCI subsector's sales to total sales was used to allocate emissions associated within the electricity supply sector to each of the RCI subsectors. Figure B-2 illustrates the 2005 breakdown of electricity sales by RCI subsector.

Figure B-2. 2005 Electricity Sector Sales by Sub-sector

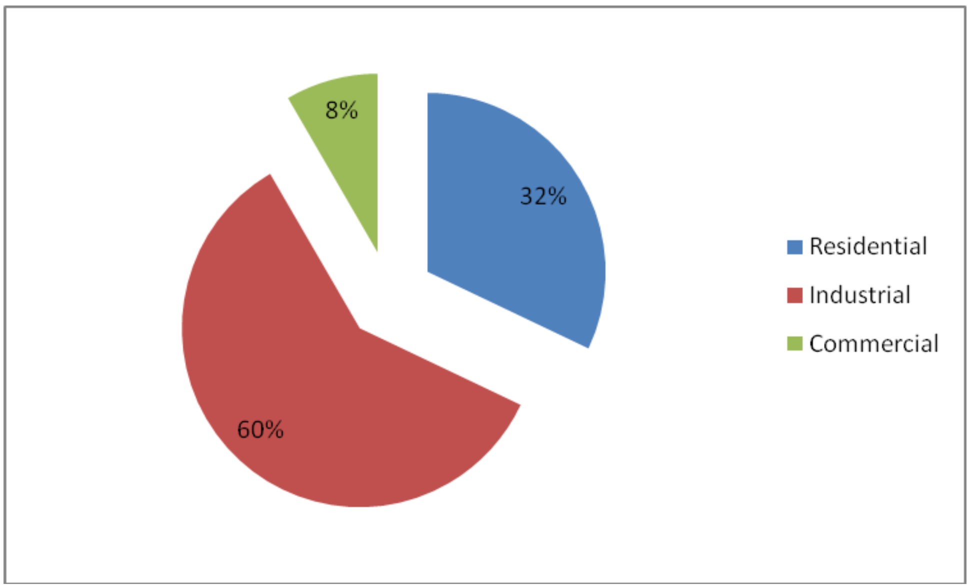


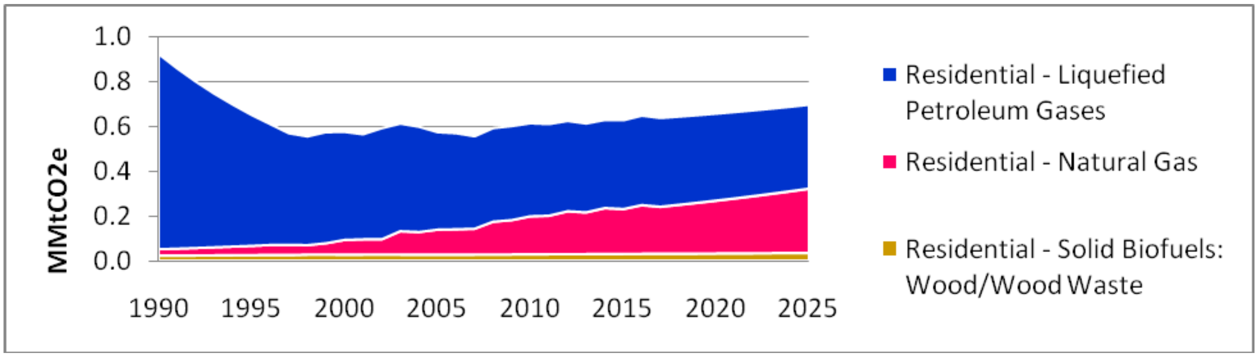
Table B-6. Historical Electricity Sales Annual Growth Rates

Sector	1990-2005*
Residential	6.0%
Commercial	2.5%
Industrial	6.1%
Total	**5.6%**

* 1990-2005 compound annual growth rates calculated from electricity sales by year from SENER.

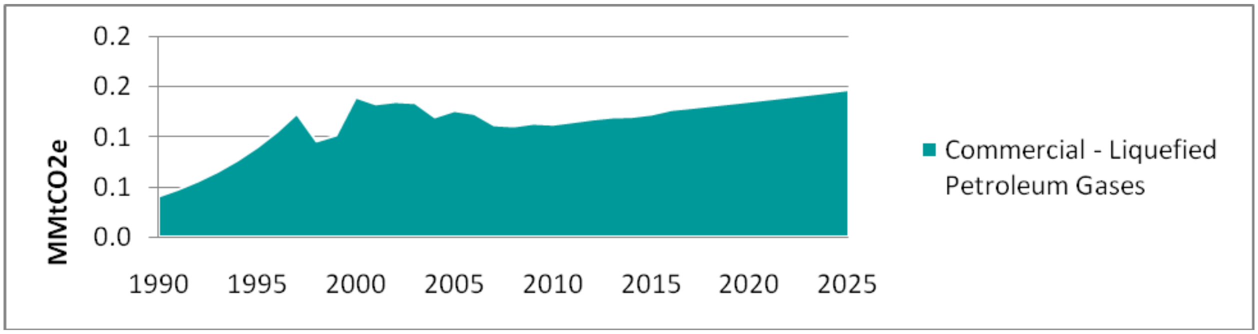
Emissions from residential sources were driven by the combustion of LPG, which represented 76% of total residential emissions in 2005. Emissions relating to the combustion of wood fuels and natural gas represented 1% and 3% of the total, respectively. Historical and projected residential GHG emission trends are shown in Figure B-3. It is unclear why emissions declined most years between 1990 and 2005. Improved stove efficiency may account for some of the reduction in consumption. From 2005 through 2025, residential emissions are estimated to increase by 21%. Emissions growth is driven by residential combustion of natural gas while emissions associated with residential LPG are expected to decline slightly. Emissions associated with residential wood combustion are estimated to remain steady.

Figure B-3. GHG Emissions from Residential Sector Fuel Combustion



Emissions from commercial sources amounted to 0.1 $MMtCO_2e$ in 2005 and were driven by the combustion of LPG, which is associated with stoves. It seems plausible that the restaurant business utilizes LPG in significant quantities. If that is the case, then emissions values for the commercial sector are expected to be larger. Additional work is warranted to better profile this sector. Historical and projected commercial GHG emission trends are shown in Figure B-4. From 2005 through 2025, commercial emissions are estimated to increase by 17%, or about 0.8% per year.

Figure B-4. GHG Emissions from Commercial Sector Fuel Combustion

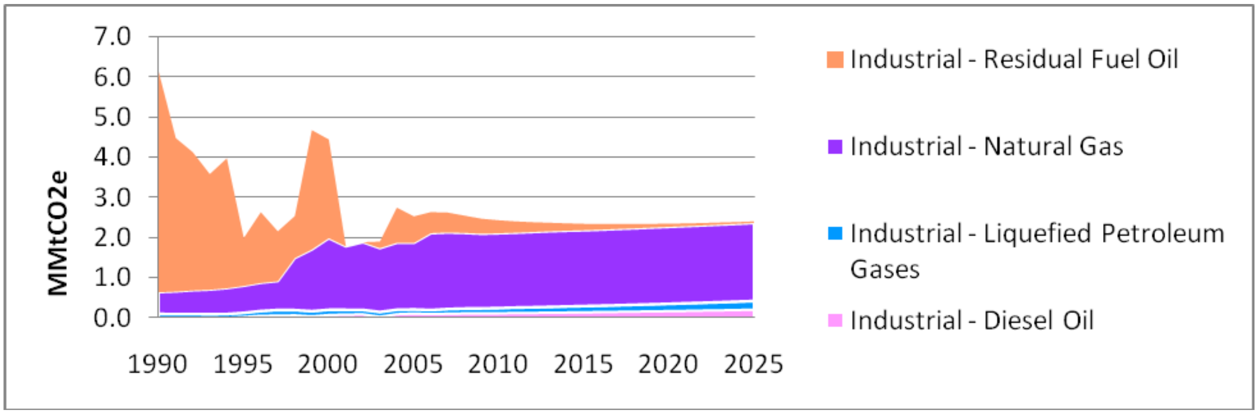


In 2005, emissions from industrial sources were driven by the combustion of natural gas (57%) followed by residual fuel oil (15%) and diesel oil (4%). The contribution of LPG combustion to total emissions was 3%. Historical and projected industrial greenhouse gas emission trends are shown in Figure B-5. Residual fuel oil consumption was estimated by subtracting electricity sector fuel oil sales from state total fuel oil sales from 1990-2007.[12] It was assumed that the difference was attributable to industrial uses. Forecast values were derived by calculating the

[12] Sistema de Información Energética - productos petroliferos, accessed from http://sie.energia.gob.mx/sie/bdiController.

mean annual growth rate (-13%) for 1990-2005 and applying that to the years 2008-2025. High volatility in residual fuel oil consumption in recent years heavily influenced projected consumption rates. Forecast values may be higher if recent declines in residual fuel oil consumption prove to be an anomaly (see additional information under Key Uncertainties).The LPG consumption data included a breakout of combustion associated with agricultural industry. LPG was the only fuel for which data were available to extract agricultural consumption from the rest of industrial consumption.

Figure B-5. GHG Emissions from Industrial Sector Fuel Combustion



Key Uncertainties and Next Steps

Segregated RCI activity data per state, per fuel and per subsector were not always available. Several assumptions were made during the activity data segregation process in an attempt to assess RCI emissions. Reported diesel and residual fuel oil consumption was attributed to the industrial subsector. For diesel consumption in particular, some of this is likely to be consumed within the commercial sector.

Additionally, natural gas consumption information was combined into one value for the residential, commercial, and transportation subsectors. Nationally most natural gas consumption is in the residential sector, hence the aggregate = values for natural gas consumption in Tamaulipas were attributed to the residential subsector. In future work, better sector-level break-out might be possible with the use of bottom-up data from surveys of fuel suppliers.

Residual fuel oil consumption was estimated by subtracting electricity sector fuel oil sales from state total fuel oil sales. This consumption was assumed to occur in the industrial subsector. High volatility in residual fuel oil consumption contributes significant uncertainty to consumption forecasts for this fuel. Additional state industrial consumption data are needed to improve the forecast.

LPG was the only fuel for which agricultural uses were delineated. However, other fuels are likely used in agricultural industries, particularly diesel, and these may be accounted for in other appendices. Future research may be needed to determine the quantity that is consumed by agriculture versus other industries.

Some fuel consumption was forecast, and in some cases back-cast, based on historical consumption. The use of economic indicators could improve consumption forecasts, rather than relying strictly on historical growth rates, and would allow the capture of economic cycles including recessions and growth bursts. Historical economic indicators back to 1990 would also prove helpful for back-casts and could capture fuel consumption expansion and contraction that accompanied periods of growth and recession. Currently, state-specific economic indicators are only available for the years 1993-2007, so are not able to inform the back-cast from 1990-1993 for diesel and residual fuel oil consumption. There was a recession in the early 1990's so diesel and residual fuel oil consumption may be lower than what is estimated. Additional state-specific economic indicators are needed to improve the back-cast as well as the forecast.

Appendix C. Transportation Energy Use

Overview

This appendix summarizes emissions from energy consumption associated with each of the following sources: road transportation, marine vessels, rail engines, and aviation. The fossil fuels combusted in these sources produce carbon dioxide (CO_2) in addition to small amounts of methane (CH_4) and nitrous oxide (N_2O). In 2007, CO_2 accounts for almost 97% of greenhouse gas emissions followed by N_2O (3%) and CH_4 (0.5%) emissions on a carbon dioxide equivalent (CO_2e) basis.

Inventory and Reference Case Projections

Methodology

Based on the information available, emissions were estimated on a fuel consumption basis. According to the 2006 Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories*, emissions are expressed in terms of mass of greenhouse gas per unit of energy consumed. Because the method estimates emissions in terms of energy consumption (e.g. joules), fossil fuel sales data were converted from units of volume to units of energy according to the energy content of each fuel. Emissions were calculated as follows:

$$Emission = \Sigma\ [Fuel_a \ x\ EF_a \ x\ GWP]$$

Where:

Emission = greenhouse gas emissions by species in kilograms (kg) of carbon dioxide equivalent (CO_2e)

$Fuel_a$ = fuel sold in terajoules (TJ)

EF_a = emission factor (kg/TJ). This is equal to the carbon content of the fuel multiplied by the atomic weight ratio of carbon dioxide to carbon (44/12)[1]

a = type of fuel (e.g. petrol, diesel, natural gas, LPG etc)

GWP = global warming potential (from the IPCC Second Assessment Report or SAR)

Fuel consumption information was obtained from Petróleos Mexicanos (PEMEX) and Tamaulipas's Secretaría de Energía (SENER) for each year.[2] Because of limited information on rail diesel consumption, national data were allocated to Tamaulipas, based on the proportion of total national rail line length in Tamaulipas. Table C-1 lists all transportation sources and their

[1] Emission factors for mobile combustion sources are listed in Chapter 3, Volume 2 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
[2] Sistema de Información Energética, con información de Petróleos Mexicanos, http://sie.energia.gob.mx/sie/bdiController.

corresponding activity data. Additional details of the emissions estimation methods are provided by sector below.

Table C-1. Activity Factors by Transportation Mode

GHG Source Sector	Activity Data	Data Source
Road Transportation - Gasoline	State of Tamaulipas: fuel consumption, 1990-2007	Secretaría de Energía: Sistema de Información Energética, with information from Petróleos Mexicanos.
Road Transportation - Diesel	State of Tamaulipas: fuel consumption, 1990-2007	Secretaría de Energía: Sistema de Información Energética, with information from Petróleos Mexicanos.
Road Transportation - LPG	State of Tamaulipas: fuel consumption, 1996-2007	Secretaría de Energía: Prospectiva del mercado de gas LP 2007 - 2016
Road Transportation – Natural Gas	State of Tamaulipas: fuel consumption, 1996-2007	Secretaría de Energía: Prospectiva del mercado de Gas Natural 2007 - 2016
Marine Vessels	National marine diesel consumption, 1990-2002 National marine diesel consumption, 2003-2007 Tons of freight cabotage[3] at Mexican ports, 2000-2002	Instituto Nacional de Ecología: Inventario Nacional de Emisiones de Gases de Efecto Invernadero 1990-2002 Secretaría de Energía: Prospectiva de Petrolíferos 2008 – 2017 Secretaría de Comunicaciones y Transportes: Anuario Estadístico 2000-2007
Aviation	State of Tamaulipas: fuel consumption, 1990-2007	Secretaría de Energía de Tamaulipas: Sistema de Información Energética, con información de Petróleos Mexicanos.
Rail	National rail diesel consumption, 1990-2002 National rail diesel consumption, 2003-2007 Length of existing railways for Mexico and Tamaulipas	Instituto Nacional de Ecología: Inventario Nacional de Emisiones de Gases de Efecto Invernadero 1990-2002 Secretaría de Energía: Prospectiva de Petrolíferos 2008 – 2017 Secretaría de Comunicaciones y Transportes: Longitud de Vías Férreas Existentes Por Entidad Federativa Según Tipo de Vía[4]

[3] Cabotage refers to the transport of goods between two points within the same country.
[4] Secretaría de Comunicaciones y Transportes: " Longitud De La Red Carretera Y Ferroviaria Por Mesoregión Y Entidad Federativa" Disponible en: http://Dgp.Sct.Gob.Mx/Fileadmin/User_Upload/Estadistica/Indicadores/Infra-Comytrans/Io5.Pdf
y "Distribución Porcentual De La Infraestructura De Transportes Y Comunicaciones Por Entidad Federativa Según Modo De Transporte Y Servicio De Comunicaciones". Disponible en: http://dgp.sct.gob.mx/fileadmin/user_upload/Estadistica/Indicadores/Infra-ComyTrans/IO4.pdf

Greenhouse gas emission forecasts were estimated based on fuel consumption forecasts for 2007-2017 from SENER's *Prospectiva de Petrolíferos 2008-2017* and *Prospectiva del Mercado de Gas LP 2008–2017*. The growth trends for the latter part of the projection period (2011-2017) are assumed to continue through 2025. Forecast mean annual growth rates are listed in Table C-2. Due to a lack of projection data specific to Tamaulipas, national projections were used for gasoline and diesel. Projections for LPG and jet fuel are specific to the Northeastern Region of Mexico.

Table C-2. Compounded Annual Growth Rates

Source	2007-2010	2010-2015	2015-2020	2020-2025
Road Transportation - Gasoline	2.6%	2.8%	1.9%	1.7%
Road Transportation - Diesel	1.8%	3.4%	2.5%	2.2%
Road Transportation - LPG	-25.5%	-1.4%	0.0%	0.0%
Road Transportation – Natural Gas	14.5%	14.9%	8.6%	6.2%
Aviation	-12.8%	3.0%	2.8%	2.5%
Marine Vessels	2.0%	2.3%	1.3%	1.4%
Rail	2.0%	2.3%	1.3%	1.4%

Road Transportation

Annual consumption of gasoline and diesel in Tamaulipas for 1990-2007 was obtained from SENER. For diesel onroad transportation, estimates of marine and rail diesel (estimates discussed below) were subtracted from the total transportation diesel values for each year. Transportation LPG and natural gas consumption was not available for Tamaulipas; therefore, consumption was estimated based on data in SENER's *Prospectiva del Mercado de Gas LP 2007–2016* and *Prospectiva del Mercado de Gas Natural 2007–2016* . For LPG, the proportion of transportation LPG to total LPG consumption for the northeastern region of Mexico was applied to total LPG consumption in Tamaulipas. The same method was used to estimate transportation natural gas consumption in Tamaulipas.

Emissions due to gasoline combustion by onrad transportation were calculated using a combination of emissions factors. The default CO_2 emission factor from the 2006 IPCC guidelines was used in conjunction with CH_4 and N_2O emissions factors reported in the INEGEI base on the national vehicle age distribution. The latter emissions factors change overtime in function of vehicle age and control technology and were available for the period 1990-2002. For the period 2003-2025., it was assumed that the CH_4 and N_2O emissions factors were the same as for year 2002. It is important to highlight that the emission factor for CO_2 is not sensitive to the use of control technology (catalytic converter). Table C-3 shows the set of emission factors utilized in this report.

Table C-3. Emissions Factors for Onroad Transportation powered by Gasoline

INEGEI (CH_4, N_2O); 2009 IPCC 2006 (CO_2); all values in (kg/TJ)			
Year	CO_2	CH_4	N_2O
1990	69,300	46.8	1.5
1991	69,300	46.8	1.5
1992	69,300	46.8	1.5
1993	69,300	45.39	1.767
1994	69,300	43.895	2.05
1995	69,300	43.242	2.174
1996	69,300	42.205	2.371
1997	69,300	40.685	2.659
1998	69,300	38.681	3.039
1999	69,300	36.719	3.41
2000	69,300	34.215	3.885
2001	69,300	31.74	4.354
2002	69,300	29.686	4.743

Marine Vessels

Marine diesel consumption was not available for Tamaulipas. Therefore, consumption was estimated for this fuel by allocating national usage to the state level. National marine fuel consumption for 1990-2002 was taken from the national GHG inventory. Consumption values were grown from 2002 to 2007 using daily marine diesel consumption values from SENER's *Prospectiva de Petrolíferos 2008-2017*. National consumption was allocated to Tamaulipas using the proportion of national marine cargo cabotage at Tamaulipas ports. Cabotage refers to the transport of goods between two points within the same country. Transnational cargo was not included per IPCC guidelines. Marine cargo data were available for 2000-2007. Tamaulipas cabotage proportions for 1990-1999 were assumed to be the same as the proportion estimated for 2000.

Marine residual fuel consumption for Tamaulipas was not available. The consumption of marine residual fuel is small compared to marine diesel consumption. There may be a small amount of marine fuel oil included in the total fuel oil consumption reported under the RCI sector.

Aviation

Jet fuel consumption in Tamaulipas for 1990-2007 was obtained from SENER. Consumption of aviation gasoline in Tamaulipas was not available. However, aviation gasoline only accounts for about 1% of total aviation fuel consumption in Mexico.[5] Therefore, emissions from this fuel were assumed to be negligible.

[5] Instituto Nacional de Ecología: Inventario Nacional de Emisiones de Gases de Efecto Invernadero 1990-2002.

Jet fuel consumption for 2007 was significantly lower than in previous years (3.6 TJ in 2007 compared to 527 TJ in 2006 and 560 TJ in 2005). The consumption data is based on fuel sales, and fuel bought in one year could actually be consumed in another year. Therefore, the 2008 fuel sales value was obtained from SENER (735 TJ), and the 2007 consumption was estimated as the average of fuel sales for 2006, 2007, and 2008 (422 TJ).

Railways

Rail diesel consumption was not available for Tamaulipas. Therefore, consumption was estimated for this fuel by allocating national usage to the state level. National rail fuel consumption for 1990-2002 was taken from the national GHG inventory. Consumption values were grown from 2002 to 2007 using daily rail diesel consumption values from SENER's *Prospectiva de Petrolíferos 2008-2017*. National consumption was allocated to Tamaulipas using the proportion of national rail lines in Tamaulipas. Actual activity, such as ton-miles of rail freight would provide more accurate allocation; however, these data are not available.

Results

During inventory years (1990 through 2005), total transportation emissions increased by 98% reaching 7 MMtCO_2e in 2005. In 1990, the largest sources of greenhouse gas emissions were activities relating to onroad gasoline and onroad diesel combustion, accounting for 95% of total transportation GHG emissions in 1990. The fastest growing source through the time period was marine vessels, with an average annual growth rate of 22% from 1990 to 2005, followed by road transportation LPG (20%).

In 2025, total transportation emissions are expected to be on the order of 12 MMtCO_2e representing a 235% increase from 1990. Road transportation emissions are expected to account for 96% of total transportation emissions in 2025. Marine diesel emissions are expected to increase to 1.4% of transportation emissions in 2025 from 0.3% in 1990. Aviation emissions estimated to account for less than 0.3% in 2025, down from 2% in 1990. Rail emissions are expected to account for 1% of total transportation emissions in 2025, down from 2% in 1990

Table C-4 and Figure C-1 summarize greenhouse gas emission estimates by source. The distribution of greenhouse gas emissions by source is presented in Table C-5. Finally, emissions growth rates for selected time intervals are listed in Table C-6.

Table C-4. GHG Emissions from Transportation (MMtCO_2e)

Source	1990	1995	2000	2005	2010	2015	2020	2025
Road Transportation - Gasoline	1.93	2.49	2.92	3.83	4.58	5.27	5.79	6.31
Road Transportation - Diesel	1.38	1.62	2.30	2.67	3.32	3.92	4.43	4.94
Road Transportation - LPG	0.01	0.03	0.14	0.14	0.06	0.05	0.05	0.05
Road Transportation – Natural Gas	0.00	0.00	0.00	0.00	0.02	0.04	0.06	0.08
Aviation	0.08	0.06	0.43	0.04	0.02	0.02	0.03	0.03
Marine Vessels	0.01	0.04	0.08	0.17	0.12	0.14	0.15	0.16
Rail	0.08	0.07	0.07	0.07	0.09	0.10	0.11	0.12
Total	**3.49**	**4.30**	**5.94**	**6.92**	**8.21**	**9.55**	**10.61**	**11.69**

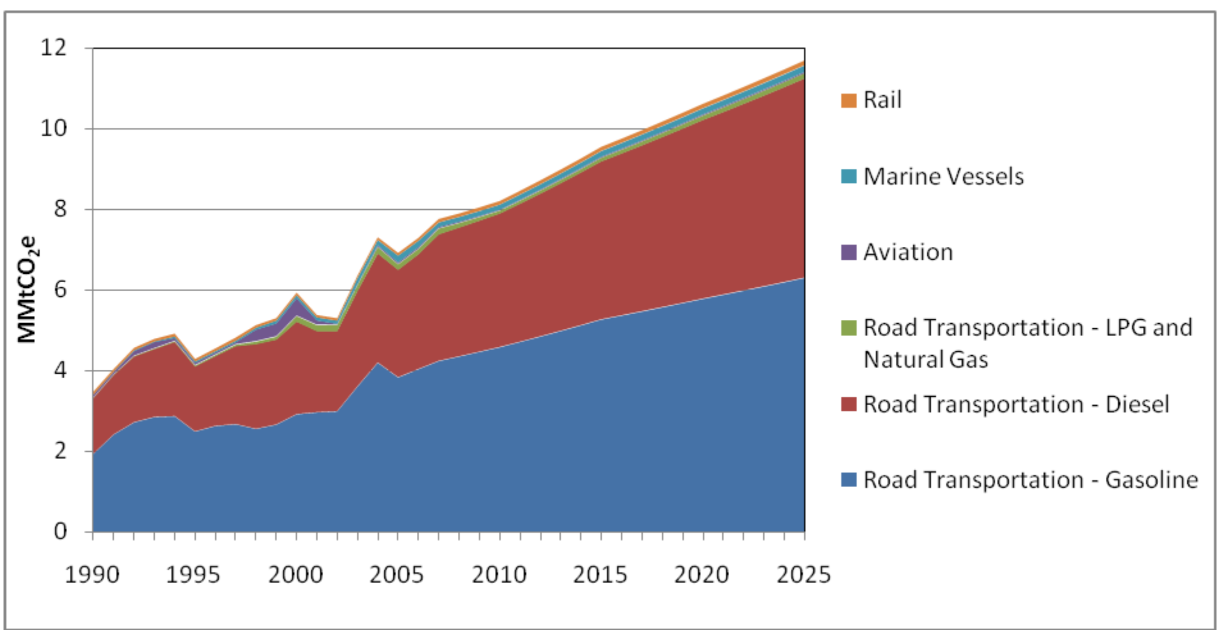
Table C-5. GHG Emissions Distribution in the Transportation Sector

Source	1990	1995	2000	2005	2010	2015	2020	2025
Road Transportation - Gasoline	55.5%	57.9%	49.1%	55.4%	55.8%	55.2%	54.5%	54.0%
Road Transportation - Diesel	39.7%	37.7%	38.7%	38.6%	40.4%	41.1%	41.8%	42.3%
Road Transportation - LPG	0.3%	0.6%	2.4%	2.0%	0.7%	0.5%	0.5%	0.4%
Road Transportation – Natural Gas	0.0%	0.0%	0.0%	0.0%	0.2%	0.4%	0.6%	0.7%
Aviation	2.2%	1.3%	7.2%	0.6%	0.2%	0.2%	0.3%	0.3%
Marine Vessels	0.3%	1.0%	1.4%	2.5%	1.5%	1.4%	1.4%	1.4%
Rail	2.2%	1.5%	1.1%	1.0%	1.1%	1.1%	1.0%	1.0%

Table C-6. Percentage Change in GHG Emissions for Selected Time Intervals

Source	1990-2005	2005-2025	1990-2025
Road Transportation - Gasoline	98%	65%	226%
Road Transportation - Diesel	93%	85%	257%
Road Transportation - LPG	1451%	-62%	482%
Road Transportation – Natural Gas	NA	NA	NA
Aviation	-46%	-25%	-60%
Marine Vessels	1839%	-8%	1675%
Rail	-11%	67%	48%
Total	98%	69%	235%

Figure C-1. Transportation Gross GHG Emissions by Fuel, 1990-2025



Key Uncertainties and Future Research Needs

Per the 2006 IPCC guidelines, fuel energy consumption is the preferred form of activity data.[6] State-level fuel consumption for marine fuels and rail diesel were not available and had to be estimated based on national consumption. Marine residual fuel oil emissions were not estimated for this inventory. Residual fuel is used in large ocean-going vessels of the type likely used for transnational shipping. According to IPCC guidelines, transnational shipping should not be included in the national inventory. There may be a small amount of marine residual fuel included in the total fuel oil estimates in the RCI sector. For rail, national emissions were allocated to Tamaulipas based on the proportion of it total rail line to the national total. More accurate estimates would be derived using estimates of actual rail activity (e.g. tonne-kilometers and/or passenger-kilometers). Based on current estimates, the contribution from the rail sector is very small.

Nitrous oxide and methane emission estimates are based on fuel consumption and on the type of control equipment installed in a vehicle. In order to capture the effect of control technology (e.g. oxidation catalyst) on greenhouse gas emissions, it is necessary to obtain a profile of Tamaulipas's vehicle fleet indentifying the fraction of vehicles with control equipment.

Fuel consumption statistics for aviation fuel have a significant amount of uncertainty because these data are actually based on fuel sales, and for aircraft, fuel is not necessarily consumed in the same state or country in which it is purchased. A more accurate method of estimating aircraft emissions would be based on the number of flights in and out of airports within the state. However, this method requires flight statistics by type of aircraft, which are currently unavailable.

As stated above, national projections were used for gasoline and diesel, and projections for the Northeastern Region of Mexico were used for LPG and jet fuel. Projections specific to Tamaulipas would be preferred, since fuel consumption in Tamaulipas may grow at a different rate than in the rest of Mexico. Significantly, the onroad fuel consumption projections do not factor in changes that are likely to occur in the future to improve the fuel economy of onroad vehicles. The U.S. Corporate Average Fuel Economy (CAFE) standards were revised through the Energy Independence and Security Act (EISA) of 2007 and further fuel economy improvements will be achieved in the U.S. through the national adoption of the California GHG vehicle emission standards through the 2016 model year. It is likely that many of the U.S. vehicles available for purchase in Mexico would be designed to meet these U.S. standards. Even with likely fuel economy improvements, the onroad vehicle sector is one where policies that could be enacted in Tamaulipas or throughout Mexico in the future could result in significant reductions in GHG emissions.

[6] Section 3.2.1.3, Chapter 3, Volume 2 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.

Appendix D. Industrial Processes and Product Use

Overview

Emissions in the industrial processes sector span a wide range of activities, and reflect non-combustion sources of GHG emissions. Combustion emissions for the industrial sector are covered in the Residential, Commercial, and Industrial Fuel Combustion sector. The industrial processes that exist in Tamaulipas, and for which emissions are estimated in this inventory, include the following:

Carbon Dioxide Emissions:

- Limestone and dolomite use *[IPCC category: Other Process Uses of Carbonates]*, which includes all uses that emit CO_2, except cement, lime, and glass manufacturing [1,2]

Ozone depleting substance (ODS) substitutes:

- These are primarily HFCs used in refrigeration and air conditioning applications *[IPCC category: Refrigeration and Air Conditioning]* [3]

Other industrial processes that are sources of non-combustion GHG emissions but were not identified in Tamaulipas include the following:

Carbon dioxide emissions from:

- Non-combustion emissions from cement manufacturing;
- Lime manufacture
- Soda ash manufacture and consumption
- Ammonia & urea production
- Iron & steel production

Methane Emissions from:

- Aluminum production
- Petrochemical production

Nitrous oxide emissions from

- Nitric acid production
- Adipic acid production[4]

HFC, PFC, and SF_6 emissions from:

- Semiconductor manufacturing
- Magnesium production
- Electric power transmission and distribution systems
- Hydrochlorofluorocarbon-22 (HCFC-22) production
- Aluminum production[5]

[1] A primary use of limestone and dolomite includes agricultural soil amendment (to neutralize acidic soils). The agriculture appendix currently does not capture limestone and dolomite consumption; however, if consumption can be determined in future work, then analysis should be performed to reduce the potential for double-counting.
[2] 2006 IPCC, Volume 3, Chapter 2, Section 2.5.
[3] 2006 IPCC, Volume 3, Chapter 7, Section 7.5.
[4] There is no adipic acid production in Mexico according to INE. *Informes del Inventario Nacional de Emisiones de Gases de Efecto Invernadero 1990 – 2002*. 2008.

Evaluation of Registro de Emisiones y Transferencias de Contaminantes (RETC)

RETC stands for the Registry of Emissions and Pollutant Releases. The registry collects information on pollutant transfers to various media (air, water, or soil) during production processes of industrial establishments or activities performed by service establishments (e.g. dry cleaners, baths, hotels, etc.). RETC stores information starting with year 2004, covering 104 federally regulated substances including three GHGs: CO_2, N_2O, and CH_4.[6] Emissions data reported to the RETC were not used directly in this inventory. Rather, the RETC was used to identify industrial sources of GHG within the state.

The use of RETC in this inventory was limited due to a number of reasons. First, RETC provides outputs that combined energy and non-energy emission sources. The focus of the Industrial Processes sector is non-energy emission sources. The IPCC defines energy emissions as those resulting from the intentional oxidation of materials within an apparatus that is designed to provide heat or for use away from the apparatus.[7] Energy emissions are associated with the combustion of fossil fuels in ovens, boilers, furnaces, and engines; energy emissions are reported as part of Electricity Supply, Transportation, Fossil Fuel Industries, and Residential, Commercial, Industrial Fuel Use. The distinction between energy and non-energy emission sources is significant and is best exemplified in the case of cement plants where non-energy emissions (CO_2) result from the gradual decomposition of raw minerals to produce clinker, whereas energy emissions relate to fossil fuel combustion in cement ovens. Second, RETC provides data for only 2004 and 2005. A two-year time series is not sufficient to identify emissions trends from historic activity data. Finally, RETC is a young program that is experiencing tremendous growth. In 2004, the number of participants nationwidetotaled 1,715 and increased to 2,452 in 2005. The large difference in program participation suggests that the 2004 data set is incomplete in comparison with 2005.

In spite of these limitations, RETC was a valuable tool for identifying industrial sources of GHG emissions. Moreover, RETC has the potential to generate reports for energy and non-energy emissions since the registry operates with information from state and federal Cédulas de Operación Anual (environmental permits) detailing the quantity and nature of emission sources. Table D-1 lists businesses that reported GHG emissions to RETC. As mentioned above, values reflect both energy and non-energy related emissions.

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[5] Idem. Aluminum is only produced in the state of Veracruz.
[6] This evaluation of RETC is based on data retrieved prior to June 1, 2009 from http://app1.semarnat.gob.mx/retc/tema/faq.html
[7] 2006 IPCC, Volume 3, Chapter 1, p.1.8

Table D-1. GHG Emissions Results from RETC (Metric Tons CO_2e)

SECTOR/COMPANY	Pollutant	2004	2005
FOOD INDUSTRY			
DULCES FAMOSOS DE MEXICO S. DE R. L .DE C. V.	CO_2		2,970
EMBOTELLADORA DE TAMPICO S.A. DE C.V.	CO_2	2,837	
PASTEURIZADORA FRONTERIZA S.A. DE C.V.	CO_2	208	214
PROTEÍNAS BÁSICAS S.A. DE C.V.	CO_2	73,417	59,430
PRODUCTS COMPOSED OF DIFFERENT MATERIALS			
BISSELL MEXICO S. DE R. L. DE C. V.	CO_2		
INDELPRO S. A. DE C. V.	CO_2		33,088
METAL PRODUCTS			
IMI MANUFACTURING DE MEXICO S.A DE C.V.	CO_2	1,354	
INDUSTRIA FABRICADORA DE ALUMINIO S. DE R.L.D E C.V.	CO_2	76,747	940
INDUSTRIAS INTERLAKE, S.A. DE C.V.	CO_2		13
MODINE TRANSFERENCIA DE CALOR S.A. DE C.V.	CO_2		302
PLASTIC PRODUCTS			
CEBAL AMERICAS DE REYNOSA S. DE R.L DE C.V	CO_2		0.1
AUTOMOTIVE			
DELPHI INTERIOR SYSTEMS DE MÉXICO S.A. DE C.V OPERACIONES RIMIR	CO_2		5,513
TECNOLOGIA MODIFICADA S.A. DE C.V.	CO_2		1
TRW VEHICLE SAFETY SYSTEMS DE MEXICO S.A. DE C.V	CO_2		20
TRW VEHICLE SAFETY SYSTEMS DE MEXICO SA DE CV	CO_2	470	1,005
ALCOHOL AND TOBACCO			
EMBOTELLADORA CIUDAD VICTORIA S.A. DE C.V.	CO_2	4,599	4,136
EMBOTELLADORA MANTE S.A. DE C.V.	CO_2	1,406	2,073
ELECTRONICS			
MOTORES REYNOSA S.A DE C.V.	CO_2	507	811
SONY NUEVO LAREDO S.A. DE C.V. PLANTA CPC	CO_2		3
ELECTRIC GENERATION			
CFE CENTRAL TERMOELECTRICA ALTAMIRA	CO_2	3,236,932	
TRIGEN ALTAMIRA S.A. DE C.V.	CO_2		42,272
METALURGICAL (INCLUDING STEEL)			
AMMEX PRODUCTOS INTERNACIONAL S. DE R.L. DE C.V. PLANTA 7	CO_2		0.02
CASTLIGHT DE MEXICO SA DE CV	CO_2	557	
CIVES ACERO S.A. DE C.V.	CO_2		53
FANSTEEL DE MEXICO S. DE R.L DE C.V.	CO_2	1,083	
OTHER			
IMPRESORA DONNECO INTERNACIONAL	CO_2		
PETROLEUM AND PETROCHEMICAL			
BJ SERVICESCOMPANY MEXICANASADE CV	CO_2	235	
GASODUCTOS DE TAMAULIPAS S. DE R.L. DE C.V.	CH_4	38	
PEMEX EXPLORACION Y PRODUCCION ACTIVO INTEGRAL BURGOS SISTEMA ARCABUZ CULEBRA	CO_2	126,866	324,135
PEMEX EXPLORACION Y PRODUCCION ACTIVO INTEGRAL BURGOS SISTEMA BURGOS	CO_2	69,255	
PEMEX EXPLORACION Y PRODUCCION ACTIVO INTEGRAL BURGOS SISTEMA CULEBRA NORTE	CO_2	136,309	
PEMEX EXPLORACION Y PRODUCCION ACTIVO INTEGRAL BURGOS SISTEMA REYNOSA	CO_2	645,609	
PEMEX EXPLORACION Y PRODUCCION R. N. ACTIVO INT. BURGOS SISTEMA FRANCISCO CANO	CO_2		7,332
PEMEX EXPLORACION Y PRODUCCION R. N. SISTEMA PEÑA BLANCA ACTIVO INTEGRAL BURGOS	CO_2		28,975
PEMEX EXPLORACION Y PRODUCCION R.N. ACTIVO INTEGRAL BURGOS SISTEMA CUERVITO	CO_2		46,952
PEMEX EXPLORACION Y PRODUCCION R.N. ACTIVO INTEGRAL BURGOS SISTEMA CUITLAHUAC	CO_2		24,564

SECTOR/COMPANY	Pollutant	2004	2005
PEMEX EXPLORACION Y PRODUCCION R.N. ACTIVO INTEGRAL BURGOS SISTEMA LAREDO	CO_2		308,826
PEMEX GAS Y PETROQUIMICA BASICA COMPLEJO PROCESADOR DE GAS BURGOS	CO_2	66,891	230,012
PEMEX GAS Y PETROQUIMICA BASICA COMPLEJO PROCESADOR DE GAS REYNOSA	CO_2	165,541	330,714
PEMEX GAS Y PETROQUÍMICA BÁSICA SECTOR MADERO	CO_2		0.4
PEMEX GAS Y PETROQUIMICA BASICA SUPERINTENDENCIA DUCTOS REYNOSA	CH_4	124	
PEMEX REFINACIÓN SECTOR DE DUCTOS MADERO	CO_2	11,981	
PEMEX REFINACION TERMINAL DE ALMACENAMIENTO Y DISTRIBUCION REYNOSA TAM.	CO_2		7
PEMEX REFINACION TERMINAL MARÍTIMA MADERO	CO_2		0.6
REGION NORTE, AIPRA, ÁREA ALTAMIRA, SISTEMA ARENQUE	CO_2		0.7
REGION NORTE, AIPRA, ÁREA ALTAMIRA, SISTEMA ÉBANO	CO_2		10
PAINTS AND INKS	CO_2		
JOHNS MANVILLE INDUSTRIAL S.A.DE C.V.	CO_2		0.00002
PRODUCTOS OXIDADOS DE MEXICO S DE R.L. DE C.V.	CH_4		0.2
APPAREL			
BON WORTH INTERNATIONAL S. DE R.L. DE C.V.	CH_4	0.3	
CHEMICAL			
PETROCEL S.A.	CO_2		323,468
PRODUCTORA DE TEREFTALATOS DE ALTAMIRA S.A. DE C.V.	CO_2		38,484
SHIN ETSU POLYMER MEXICO S.A DE C.V.	CO_2		0.3
SONY NUEVO LAREDO S.A. DE C.V.	CO_2		11
TI GROUP AUTOMOTIVE SYSTEMS S. DE R.L DE C.V	CO_2	4,210	2
TRW DELPLAS S.A. DE C.V	CO_2		23
WELDMEX INDUSTRIES S. DE R.L. DE C.V.	CO_2		70
TEXTILES			
GST AUTOLEATHER DE MEXICO S.A. DE C.V.	CO_2		4,600
NIEN HSING INTERNATIONAL VICTORIA S.A. DE C.V.	CO_2	12,987	
GLASS			
VIDRIO DECORATIVO OCCIDENTAL S.A DE C.V	CO_2		0.3
TOTAL		**4,640,162**	**1,821,031**

Historical Emissions and Reference Case Projections

Greenhouse gas emissions were estimated using the 2006 IPCC Guidelines.[8] Table D-2 identifies for each emissions source category the information needed for input to calculate emissions, the data sources used for the analyses described here, and the historical years for which emissions were calculated based on the availability of data.

Based on statistics from Camara Nacional de Cemento[9] and Servicio Geológico Mexicano[10], CCS determined that there is no cement, lime, or iron and steel production in Tamaulipas. In the absence of consumption data for limestone and dolomite, consumption was assumed to be equal to the in-state production of these minerals. Limestone production data were only available for 2003-2007. Limestone production for 2002 was assumed to be the same as 2003, and 1990-2002 values were estimated by assuming the same trend as found in the national limestone production

[8] 2006 IPCC Guidelines, Volume 3.
[9] Camara Nacional de Cemento statistics. http://www.canacem.org.mx/la_industria_del_cemento.htm.
[10] Servicio Geológico Mexicano. *Anuario Estadístico de la Minería Mexicana Ampliada*. Estadísticas por Producto para Minerales Metálicos y no Metálicos, Capítulo IV.

values from the National GHG inventory. Emissions were calculated using the default 2006 IPCC emission factor of 0.44 tons CO_2 per ton of mineral consumed.

Table D-2. Approach to Estimating Inventory Emissions

Source Category	Time Period for which Data Available	Required Data	Data Source
Limestone and Dolomite Consumption	1994-2007	Mt of limestone and dolomite consumed	Consumption was assumed to be equal to production of from mining. Source: Servicio Geológico Mexicano. *Anuario Estadístico de la Minería Mexicana Ampliada*. Estadísticas por Producto para Minerales Metálicos y no Metálicos, Capítulo IV.
ODS Substitutes	1980-2007	Number of operating vehicles	Instituto Nacional de Estadísticas, Geografía, e Informática. Estadísticas de vehículos de motor registrados en circulación. http://www.inegi.org.mx/inegi/default.aspx

IPCC methods were not used to estimate HFC's from mobile air-conditioning systems. These were calculated using an approach developed for the State of Baja California's 2005 GHG inventory.[11] This approach consists of basing emissions on the number of vehicles operated during each year in the state and the assumption that all vehicles are equipped with air conditioning units. [12] This approach deviates from methodology outlined in Section 7.5.2, Chapter 7, Volume 3 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories;[13] however, it was adopted in the absence of better activity data (e.g. HFCs sales information for the IPCC methodology). The number of mobile air conditioning units was converted to emissions using an emission factor of 166 kg CO_2e pervehicle published by IPCC in a special technical report.[14]

Similarly, ODS substitute emissions from refrigeration and stationary air conditioning were calculated using the approach adopted in Baja California's GHG inventory. This approach consists of basing emissions on the number and size of homes connected to the electricity grid. It is assumed that all homes with electricity have one refrigerator and one stationary air conditioning unit. Homes with two or more rooms were assumed to own two air conditioning units. This approach deviates from methodology outlined in Section 7.5.2, Chapter 7, Volume 3 of the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories[15]; however, it was adopted in the absence of better activity data (e.g. HCFCs sales information). Moreover, this approach assumes that 10% of all units have leaks and 15% of the refrigerant released is composed of HCFC-22. The latter is a hydrochlorofluorocarbon subject to the stipulation of the Montreal Protocol and exempt from

[11] *Inventario de Emisiones de Gases de Efecto Invernadero del Estado de Baja California 2005: Versión Final Secretaría de Protección al Ambiente del gobierno del estado Baja California,* Centro Mario Molina, Diciembre, 2007, pp. 26-27.
[12] Instituto Nacional de Estadística Y Geografía (INEGI). Motor Vehicle Active Registration Statistics.
[13] Retrieved May, 2008 from: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.
[14] IPCC/TEAP, Bert Metz, Lambert Kuijpers, Susan Solomon, Stephen O. Andersen, Ogunlade Davidson, José Pons, David de Jager, Tahl Kestin, Martin Manning, and Leo Meyer (Eds). *Safeguarding the Ozone Layer and the Global Climate System: Issues related to hydrofluorocarbons and perfluorocarbons*. Cambridge University Press: Cambridge, England. 2005 (p. 306) http://www.ipcc.ch/pdf/special-reports/sroc/sroc_full.pdf.
[15] Retrieved May, 2008 from: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

GHG inventory considerations. Emissions associated with HCFC-22 were included in this appendix for the purposes of comparison. Nonetheless, HCFC-22 emissions will not be incorporated in the state summary of GHG emissions.

Table D-3 lists the data and methods that were used to estimate future activity levels related to industrial process emissions and the annual compound growth rates computed from the data/methods for the reference case projections. Sources of economic forecast data were not identified; therefore, forecasts were based on historical data. Historical data for total manufacturing volume were obtained from Sistema Nacional de Información Estadística y Geográfica (SNIEG).[16]

Table D-3. Approach to Estimating Projections for 2005 through 2025

Source Category	Projection Assumptions	Average Annual Growth Rates			
		2005 - 2010	2010 - 2015	2015 - 2020	2020 - 2025
Limestone and Dolomite Consumption	Based on 2003-2007 manufacturing physical volume from SNIEG	-4.9%	0.4%	0.4%	0.4%
ODS Substitutes	Based on 2003-2006 vehicle registration data from INEGI	3.2%	2.2%	1.9%	1.8%

Results

GHG emissions have been summarized in Figure D-1 and Table D-4. The distribution of emissions in the industrial processes sector is shown for selected years in Table D-5. In 2005, GHG emissions from non-combustion industrial processes were estimated to be about 0.19 $MMtCO_2e$. The largest source of emissions is ODS substitutes from mobile air-conditioning systems. Forecast industrial process and product use emissions are projected to reach 0.27 $MMtCO_2e$ by 2025, of which 93% will be generated by as a result of ODS substitutes

[16] Sistema Nacional de Información Estadística y Geográfica (SNIEG), http://www.inegi.org.mx/inegi/default.aspx?s=est&c=125&e=08.

Figure D-1. GHG Emissions from Industrial Processes 1990-2025

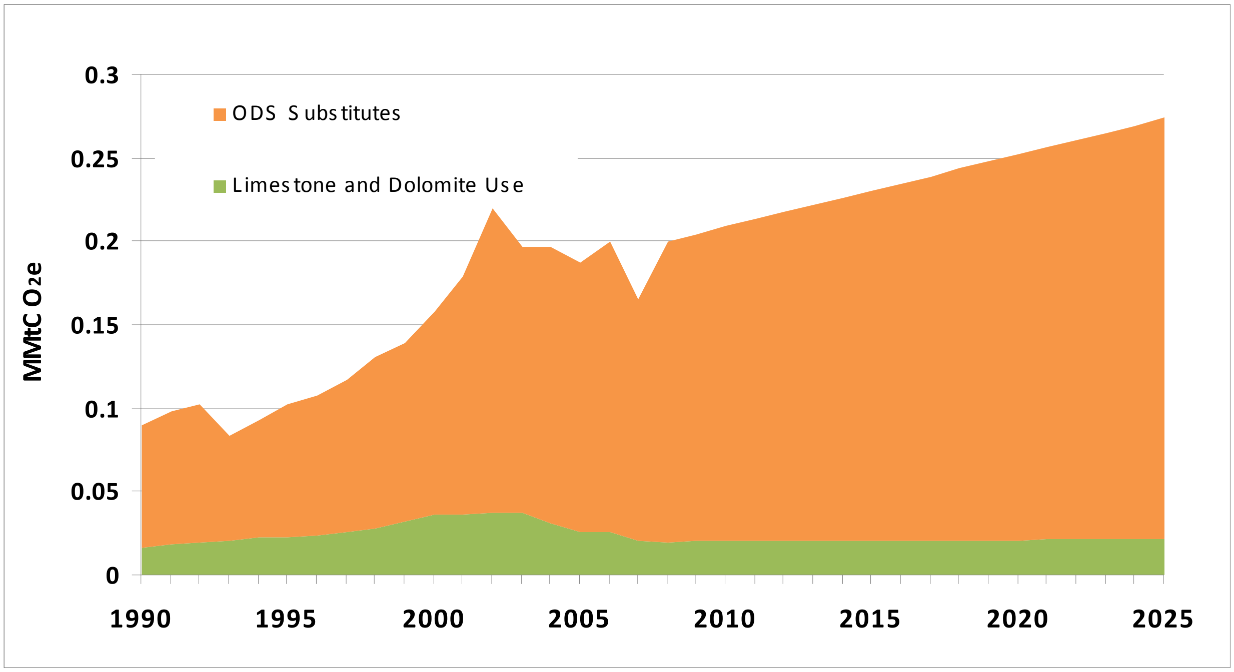


Table D-4. Historic and Projected GHG Emissions for Industrial Processes ($MMtCO_2e$)

Source	1990	1995	2000	2005	2010	2015	2020	2025
Limestone and Dolomite Use	0.02	0.02	0.04	0.03	0.02	0.02	0.02	0.02
ODS Substitutes	0.07	0.08	0.12	0.16	0.19	0.21	0.23	0.25
Grand Total	**0.09**	**0.10**	**0.16**	**0.19**	**0.21**	**0.23**	**0.25**	**0.27**

Table D-5. GHG Emission Distribution for Industrial Processes (Percent)

Source	1990	1995	2000	2005	2010	2015	2020	2025
Limestone and Dolomite Use	22%	20%	25%	16%	10%	9%	8%	7%
ODS Substitutes	78%	80%	75%	84%	90%	91%	92%	93%

Table D-6. HCFC Emissions from Refrigeration and Air Conditioning

Year	1990	1995	2000	2005	2010	2015	2020
Refrigeration (kg HCFC-22)	983	1,105	1,204	1,322	1,390	1,452	1,517
Air Conditioning (kg HCFC-22)	23,488	26,388	28,747	31,577	33,188	34,674	36,226
Total (MMtCO2e)	0.042	0.047	0.051	0.056	0.059	0.061	0.064

Key Uncertainties and Research Needs

Key sources of uncertainty and associated research needs underlying the estimates above are as follows:

- Limestone and dolomite consumption for chemical applications that result in CO_2 release are associated with various segments of industry including agriculture, chemical manufacturing, glass manufacturing, environmental pollution control, and the metallurgical industry. For instance, limestone and dolomite are used to adjust pH in agricultural soils or can be used as flux stones or purifiers in refining metals such as iron. A crude estimate of emission was prepared based on production of these minerals. This approach is provisional while more accurate methods are developed or new activity data are collected from economic statistics and/or industry surveys.

- Significant uncertainty stems from the method adopted to estimate GHG emissions from mobile air-conditioning systems. These were calculated for Tamaulipas according to the approach described in Baja California's 2005 GHG inventory.[17] Although this approach deviates from the methodology outlined in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, it allowed the quantification of ODS substitute emissions. According to the 2006 IPCC guidelines, more accurate estimates can be obtained by collecting information from equipment manufacturers/importers on the total charge of ODS substitutes in the equipment they manufacture or import. Alternatively, sales information can be used to trace sources of emissions more precisely.

- Due to the lack of reasonably specific projection surrogates, historical trend data were used to project emission activity level changes for multiple industrial processes. There is significant uncertainty associated with any projection, including a projection that assumes that past historical trends will continue in future periods. All assumptions on growth should be reviewed by industry experts and revised to reflect their expertise on future trends especially for the cement manufacturing industry, and for limestone and dolomite consumption and ODS substitutes.

- For the electric power transmission and distribution systems and semiconductor industries, future efforts should include a survey of companies within these industries to determine the extent to which they are experiencing SF_6 losses.

[17] *Inventario de Emisiones de Gases de Efecto Invernadero del Estado de Baja California 2005: Versión Final Secretaría de Protección al Ambiente del gobierno del estado Baja California.* Centro Mario Molina. Diciembre, 2007 (26-27)

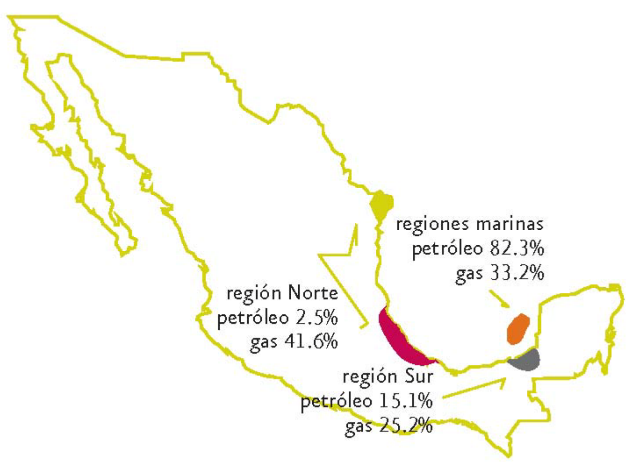
Appendix E. Fossil Fuel Industries

Overview

The GHG emissions associated with the fossil fuel industries sector include fugitive emissions associated with the production, processing, transmission, and distribution of oil and gas as well as fugitive emissions from coal mining.[1]

In Mexico, fossil fuel reserves are predominantly located around the Gulf of Mexico[2] (see Figure E-1). Tamaulipas' location in the Gulf region has encouraged the development of infrastructure supporting oil and natural gas exploration, production, and processing. PEMEX operates one oil refinery in Maderos and two natural gas processing centers around the cities Reynosa and Burgos. Maderos is the oldest refinery in the national oil system and was upgraded in 2002 to raise refining capacity from 155 to 190 thousand barrels per day.[3] The processing center in Burgos became operational in 2004 processing 241 million cubic feet of natural gas and rapidly increasing production to 804 million cubic feet by 2007. In 2007, the share of natural gas processing in Tamaulipas was 23% of the national output.[4] While state-level information relating to natural gas and oil processing was found, natural gas and oil production data was not available during the development of this inventory. It is believed that these activities occur in Tamaulipas. Additional research will be required to develop emission estimates for these segments of the industry.

Figure E-1. Oil and Gas Production by Region[5]



Fuente: Sistema de Información Energética, Sener.
La suma de los parciales puede no coincidir con los totales, debido al redondeo de las cifras.

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[1] Note that emissions from natural gas consumed as lease fuel (used in well, field, and lease operations) and plant fuel (used in natural gas processing plants) are included in Appendix B in the industrial fuel combustion category.
[2] Information on oil and gas reserves were obtained from PEMEX. *Reservas de Hidrocarburos al 1 de Enero de 2009*. Marzo, 2009. http://www.ri.pemex.com/index.cfm?action=content&sectionID=134&catID=12201
[3] http://www.gasandoil.com/goc/company/cnl25012.htm
[4] PEMEX. *Anuario Estadístico.* 2008.
[5] Secretaría de Energía. *Balance Nacional de Energía 2006*. (p.37)

Emissions and Reference Case Projections

Methodology
For the development of emissions in the natural gas and oil systems, CCS considered several possible methods that could be applied based on the nature and availability of activity data. The simplest, Tier 1 method from the *2006 IPCC Guidelines* was considered (Method A). This approach estimates emissions as function of the volume of natural gas marketed in the system and emission factors for developing countries. These emission factors are based estimates from regions outside the Americas and have a large uncertainty range.

Alternatively, the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*[6] offers an approach for North America that improves correlation between activity data and emissions (Method B). Improved correlation is achieved through increased disaggregation of the industry and in many cases by switching to a different parameter of activity data like units of natural gas processing units and length of transmission pipeline. Method B represents a simplified version of the quantification methods developed by GRI study for the US EPA[7]. The full study identified approximately 100 components of natural gas systems that are methane-emission sources. For each component, the study developed an emission factor. To estimate emissions, the emission factors were multiplied by the activity level for each component (e.g., amount of gas produced, numbers of wells, miles of pipe of a given type and operating regime, or hours of operation of a given type of compressor).

The GRI study also served as the basis for the US EPA *State Greenhouse Gas Inventory Tool* (SIT), a tool designed to facilitate the development of state-level GHG emissions inventories (Method C).[8] Similar to Method B, the SIT streamlines the bottom- up approach of the GRI study by grouping industry segments together and correlating emissions to various parameters besides natural gas throughput.

IPCC *Good Practice Guidance* recommends the approach inherent in methods B and C, namely, the correlation of segments of the fossil fuel industry to a diversity of activity data parameters. For the purposes of this inventory, CCS selected Method C because it offers an estimate of emissions based on a wider number of parameters and also provides a consistent basis of comparison with state –level GHG inventories in the US. Two notable exemptions were emission estimates for natural gas production and processing, where CCS relied on 2006 IPCC emission factors (Method A) due to the lack of records detailing the amount of fugitive losses and flaring occurring in Tamaulipas. The median value was selected from the range of default values on Table 4.2.5 of the 2006 IPCC *Guidelines.*

Emissions from the oil industry are also significant in Tamaulipas. CCS compared PEMEX statistics on the volume of petroleum refined at seven historic plants since 1990 with the values

[6] See Chapter 2, Section 2.7.1.2. The document is available from www.ipcc-nggip.iges.or.jp/public/gp/english/
[7] GRI/US EPA (1996). *Methane Emissions from the Natural Gas Industry*. Report No. EPA-600/R-96-080, GRI / United States Environmental Protection Agency.
[8] Additional information about the EPA SIT is found at www.epa.gov/climatechange/emissions/state_guidance.html

reported in the Mexico's third national inventory.[9] The volume of refined oil was consistent in both sources of information and it was also found that the refining plant at Madero processed between 12 to 14% of total crude oil.

For the selection of emission factors, CCS considered three methods: 1996 IPCC *Guidelines*, 2006 IPCC *Guidelines*, and US EPA *State Greenhouse Gas Inventory Tool* (SIT). All three methods calculate emissions in function of the volume of oil processed in each of three segments of the industry: production, refining, and transportation.

There is great uncertainty associated with emission estimates in the oil industry. The 2006 IPCC Guidelines concludes that the level of uncertainty ranges between -40 and +800%.[10] CCS compared emission factors from each competing methods and observed that their values could differ by two orders of magnitude (see Table E-1). In the absence of methods and emissions factors specific developed for Mexico, CCS opted to apply US EPA emission factors to the activity data in Tamaulipas because this approach is consistent with other regional GHG inventories including Arizona, New Mexico, and Nuevo Leon. Another reason is that US EPA offers an emission factor for oil refining activities, whereas the most recent 2006 IPCC *Guidelines* do not. Finally, the emission factor for oil production provides a middle value between default factors of the 1996 and 2006 IPCC *Guidelines*.

Table E-1. Comparison of Emission Factors for the Oil Industry

Segment	1996 IPCC	EPA	2006 IPCC	Units
Production	16.29	588.83	4766.03	kg CH4/1000-barrel
Refining	4.58	5.06	None	kg CH4/1000-barrel
Transportation	4.58	1.34	0.86	kg CH4/1000-barrel

For the development of emissions in the Fossil Fuel Industry sector, CCS combined methods and emission factors that covered the largest number of sources and provided the least amount of uncertainty. Table E-2 shows a selected number of emission factors that in conjunction with activity data drive inventory and forecast emissions.

[9] INE. Informes del Inventario Nacional de Emisiones de Gases de Efecto Invernadero 1990 – 2002. Available at http://www.ine.gob.mx/cpcc-lineas/640-cpcc-inventario-3

[10] Default IPCC values are based on unpublished studies in China, Romania, and Uzbekistan. See 2006 IPCC Guidelines, Volume 2, Chapter 4, Table 4.2.5.

Table E-2. Selected Fossil Fuel Industry Emission Factors

Activity	Emission factors	
Natural gas processing		
Volume of natural gas processed	12.2	Tonnes CH_4 per million cubic meter per year (2006 IPCC-fugitive sources)
Natural gas transmission		
Miles of transmission pipeline	0.6	Tonnes CH_4 per year per activity unit (SIT)
Number of gas compressor stations	964.1	Tonnes CH_4 per year per activity unit (SIT)
Natural gas distribution		
Total miles of distribution pipeline	2.122	Tonnes CH_4 per year per activity unit (SIT)
Total number of services	0.015	Tonnes CH_4 per year per activity unit (SIT)
Petroleum Systems		
Oil refined (1000-barrels)	5.06	Kg CH_4 per year per activity (SIT)
Oil transported (1000-barrels)	1.34	Kg CH_4 per year per activity (SIT)

Natural Gas Industry Emissions

Activities generating GHG emissions in the natural gas system of Tamaulipas include production, processing, transmission and distribution. Key data sources include the Secretaria de Energía (SENER), the Comisión Reguladora de Energía (CRE), and Petróleos Mexicanos (PEMEX).

SENER provided information about natural gas transmission and distribution infrastructure (including pipeline lengths).[11] It also provided data on the number of users serviced by this infrastructure (indicating the number of meters). The earliest reference to natural gas transmission and distribution infrastructure dates back to 1997 from CRE[12]. Due to limited amount of historical records, there is some uncertainty around emissions estimates for the period 1990 to 1997 for this segment of the industry. However, methane losses during transmission and distribution are not significant contributors to total sector emissions. The CRE offered information about companies licensed to build and operate natural gas lines and the date of these concessions.[13] The number of existing and projected natural gas compression stations was obtained from PEMEX.[14] Additionally, the *Anuarios Estadisticos* of PEMEX provided natural gas processing statistics for the period 1990-2007 for the processing centers located in Reynosa and Burgos.

[11] Secretaría de Energía. *Prospectiva del Mercado de Gas Natural*. México: SENER. Information taken from publications dated 2003 to 2007. http://www.sener.gob.mx/webSener/portal/index.jsp?id=48#prop2008

[12] See footnote 6.

[13] A list of permits for natural gas transmission and distribution is available at http://www.cre.gob.mx/articulo.aspx?id=169

[14] From presentation titled "Crecimiento del Mercado de Gas Natural: Retos para la Comercialización".

Oil Industry Emissions

Petroleum refining occurs in Tamaulipas at the Madero refinery. Process volumes were available from *PEMEX'Anuario Estadísticos*.[15] In 2005, the Madero plant refined 141.9 thousand barrels of crude oil or 11% of the national throughput for that year. Statistics on the amount of crude oil produced in the state were not located. Therefore, CCS could not determine emission estimates for this segment of the industry. An assessment of oil production fugitive emissions will require more research and collaboration with the authorities at PEMEX. Fugitive emissions from the transport of crude oil was estimated on the assumption that the amount of oil transported in the state by pipeline, tanker, and truck was equivalent to the volume of oil processed during refining. Emissions for this segment of the industry are negligible in comparison to total fossil fuel industry emissions. A more accurate assessment of oil production fugitive emissions will require more research and collaboration with the authorities at PEMEX.

Coal Industry Emissions

There is no coal production or processing in Tamaulipas.

Emission Forecast

Table E-3 provides an overview of data sources and approaches used to develop historical and forecast fossil fuel sector emission estimates. The forecast is driven by fugitive emissions from the production of natural gas. Tamaulipas hosts two of ten gas processing plants in Mexico which account for 23.8% of national natural gas processing in 2007. SENER estimates that the Burgos gas processing plant will reach peak capacity production in 2011 at 1,876 million cubic feet per day[16]. This represents an increase of 678% from 2004, the year when the Burgos plant became operational. This is a very large increase of projected production that will need to be revised in future inventory and forecast updates.

Due to the large investment involved in building natural gas transmission infrastructure, the forecast assumed no transmission pipeline additions to what existed in 2005. However, PEMEX projects the installation of 3 new compressor stations by the year 2014. Also, the distribution network and the number of users were assumed to grow annually at 3.9% until 2010, at the same rate as the growth in the number of homes equipped with gas stoves from 1990 to 2000.[17] This vigorous growth accounts for rapid development of the natural gas sector in Mexico and across the Border Region in particular. CCS assumed that forecast emissions would grow at the same rate as population (0.91%) for the period 2011-2025.[18]

The forecast for petroleum systems was prepared using SENER's projected growth in the national crude oil market. SENER projects a 0.8% mean annual growth rate for the period 2008 – 2017.

[15] PEMEX. Anuarios Estadísticos, 2001 & 2006. http://www.pemex.com/index.cfm?action=content&sectionID=2&catid=2624&contentID=2633
[16] SENER. Prospectiva del Mercado de Gas Natural 2008-2017. 2007. (p. 142)
[17] Instituto Nacional de Estadísticas, Geografía e Informática. 1990. *Censos Generales de Población y Vivienda.* Instituto Nacional de Estadísticas, Geografía e Informática. 2000. *Censos Generales de Población y Vivienda.*
[18] Consejo Nacional de la Población. http://www.conapo.gob.mx/

Table E-3. Approach to Estimating Historical/Projected Emissions from Fossil Fuel System

Activity	Approach to Historical Emissions		
	Required Data	Data Source	Available Data and Key Assumptions
Natural gas production	Volume of natural gas produced	Not available	None
Natural gas processing, venting and flaring	Volume of natural gas processed	PEMEX	1990 through 2007
Natural gas transmission	Miles of transmission pipeline	CRE SENER	Permit dated 19/6/98 = 8 km Permit dated 2/6/99 = 627 km Permit dated 12/9/02 = 114 km Permit dated 26/9/02 = 58 km
	Number of gas transmission compressor stations	PEMEX	Prior to 2000 = 0 Projected to 2014 = 3
	Number of storage stations	Not present in Tamaulipas	
Natural gas distribution	Miles of distribution pipeline	CRE SENER	Permit dated 17/11/97 = 366 km Permits issued 05-06 = 1664 km
	Number of services	CRE SENER	Permit dated 17/11/97 = 366 km Permits issued 05-06 = 1664 km
Oil refining	Volume of petroleum refined	PEMEX	Barrels of oil refined 1990-2005
Oil transportation	Volume of crude oil transported	Not available	Assumed to be equal to barrels of oil refined 1990-2005
Coal mining	Tonnes of production	Not present in Tamaulipas	

Results

Table E-4 displays the estimated emissions from the fossil fuel industry in Tamaulipas over the period 1990 to 2025. Natural gas production is the major contributor to inventory and forecast emissions. This trait may change when oil and natural gas production values become available. The relative contributions to sector total emissions are shown in Table E-5. Figure E-2 displays process-level emission trends from the fossil fuel industry, on a million-metric-tons-of-carbon-dioxide-equivalent ($MMtCO_2e$) basis.

Table E-4. Historical and Projected Emissions for the Fossil Fuel Industry in $MMtCO_2e$

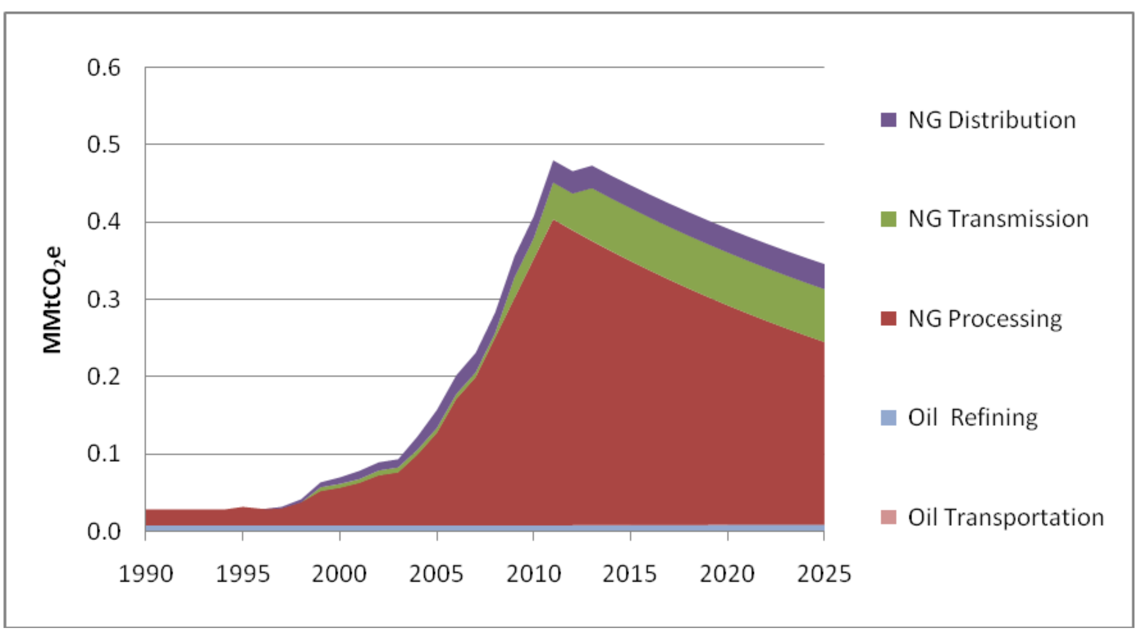
Source	1990	1995	2000	2005	2010	2015	2020	2025
NG Production	ND	ND	ND	ND	ND	ND	ND	ND
NG Processing	0.02	0.02	0.05	0.12	0.34	0.34	0.28	0.24
NG Transmission	0.00	0.00	0.01	0.01	0.03	0.07	0.07	0.07
NG Distribution	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03
Oil Production	ND	ND	ND	ND	ND	ND	ND	ND
Oil Refining	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Oil Transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.03**	**0.03**	**0.07**	**0.16**	**0.41**	**0.45**	**0.39**	**0.35**

ND = No data was available. Totals may not add up due to rounding

Table E-5. Historical and Projected Distribution of Emissions by Source

Source	1990	1995	2000	2005	2010	2015	2020	2025
NG Production	ND	ND	ND	ND	ND	ND	ND	ND
NG Processing	73.3%	76.3%	70.0%	76.2%	84.5%	76.3%	72.4%	68.3%
NG Transmission	0.0%	0.0%	7.3%	4.2%	6.7%	15.3%	17.5%	19.8%
NG Distribution	0.0%	0.0%	12.0%	14.9%	7.0%	6.6%	7.9%	9.4%
Oil Production	ND	ND	ND	ND	ND	ND	ND	ND
Oil Refining	21.1%	18.8%	8.4%	3.8%	1.5%	1.4%	1.7%	2.0%
Oil Transportation	5.6%	5.0%	2.2%	1.0%	0.4%	0.4%	0.4%	0.5%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Figure E-2. Fossil Fuel Industry Emission Trends ($MMtCO_2e$)



Key Uncertainties

Key sources of uncertainty underlying the estimates above are as follows:

- Fugitive emissions from natural gas production were not estimated. Considerable effort is required to make an assessment of emissions based on operational records at each production well.
- Fugitive emissions from oil production were not estimated. Considerable effort is required to make an assessment of emissions based on state level production statistics.
- IPCC methodologies assess that the inherent uncertainty of Tier 1 methods for natural gas production and processing is in the range of ±70. On the other hand, US EPA emission factors are based on U.S industry-wide averages. Until fugitive emissions are disclosed based on plant specific operation and maintenance records and local studies (at least specific to Mexican states), significant uncertainties remain around natural gas and oil systems emission estimates.
- The assumptions used for the projections do not reflect all potential future changes that could affect GHG emissions, including future capital expenditures, potential changes in regulations and emissions-reducing improvements in oil and gas production, processing, and pipeline technologies.

Appendix F. Agriculture

Overview

The emissions covered in this appendix refer to non-energy methane (CH_4) and nitrous oxide (N_2O) emissions from livestock and crop production. Emissions and sinks of carbon in agricultural soils due to changes in cultivation practices are also covered. CO_2 emissions can also occur as a result of urea, lime and dolomite application. Energy emissions (combustion of fossil fuels in agricultural equipment) are included in the residential, commercial, and industrial (RCI) sector estimates (see Appendix B). Other CO_2 emissions or sequestration as a result of livestock and crop production are considered to be biogenic, and therefore per IPCC guidelines, are not included in GHG emission estimates.

The primary GHG sources and sinks - livestock production, agricultural soils, and crop residue burning are further subdivided as follows:

- *Enteric fermentation:* CH_4 emissions from enteric fermentation are the result of normal digestive processes in ruminant and non-ruminant livestock. Microbes in the animal digestive system break down food and emit CH_4 as a by-product. More CH_4 is produced in ruminant livestock because of digestive activity in the large fore-stomach.
- *Manure management:* CH_4 and N_2O emissions from the storage and treatment of livestock manure (e.g., in storage piles, compost piles or anaerobic treatment lagoons) occur as a result of manure decomposition. The environmental conditions of decomposition drive the relative magnitude of emissions. In general, the more anaerobic the conditions are, the more CH_4 is produced because decomposition is aided by CH_4-producing bacteria that thrive in oxygen-limited conditions. In contrast, N_2O emissions are increased under aerobic conditions. The 2006 IPCC guidelines segregate this source sector as follows:
    - CH_4 emissions due to manure management;
    - Direct N_2O emissions due to manure management;
    - Indirect N_2O emissions due to leaching of nitrogen following manure application;
    - Indirect N_2O emissions due to volatilization of nitrogen (e.g. as ammonia) following manure application with subsequent nitrogen deposition, denitrification, and N_2O emissions.
- *Agricultural soils:* The management of agricultural soils can result in N_2O emissions and net fluxes of carbon dioxide (CO_2) causing emissions or sinks. In general, soil amendments that add nitrogen to soils can also result in N_2O emissions. Nitrogen additions drive underlying soil nitrification and denitrification cycles, which produce N_2O as a by-product. The 2006 IPCC guidelines segregate this source sector as follows:
    - Direct N_2O emissions due to managed soils;
    - Indirect N_2O emissions due to nitrogen volatilization and subsequent atmospheric deposition;
    - Indirect N_2O emissions due to leaching & runoff.

Note: Agricultural soils can store or release soil carbon, if these soil carbon pools are disturbed and oxidized; when oxidized, the soil carbon is released as CO_2. Agricultural soil carbon flux is considered part of the land use category, and therefore is discussed in the land use and forestry appendix.

- *Aggregate sources and non- CO_2 emissions sources on land:* These include all agricultural sources which result in CH_4 and N_2O emissions that do not fall into the above categories. The 2006 IPCC guidelines segregate this source sector as follows:
  - Urea application (which is also addressed under agricultural soils above as a nitrogen fertilizer): CO_2 is emitted during urea decomposition in soils;
  - Liming: CO_2 is emitted as a result of pH adjustment in acidic soils;
  - Residue burning: CH_4 and N_2O emissions are produced when crop residues are burned (CO_2 that is emitted is considered biogenic and not reported).

Emissions and Reference Case Projections

Inventory Data

Enteric fermentation. Methane emissions for 1990 through 2005 were estimated using a Tier 1 method described the 2006 Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories* (2006 IPCC).[1] This method multiplies annual methane emission factors specific to each type of ruminant animal to activity data (livestock population by animal type). The activity data were provided by SIACON[2] and are summarized in Table F-1. This methodology, as well as the others described below, is based on international guidelines developed by sector experts for preparing GHG emissions inventories.[3]

Table F-1. Livestock Populations

Livestock Category		1990	1995	2000	2005
Dairy Cows	Vacuno lechero	0	198467	214130	256463
Other Cattle	Otros vacunos	863,926	568,125	410,930	406,722
Buffalo	Búfalo				
Sheep	Ovinos	130,135	123,883	119,515	104,465
Goats	Caprinos	1,184,191	1,158,310	507,264	615,623
Camels	Camelidos				
Horses	Equinos				
Mule/Asses	Mulas y asnos				
Deer	Ciervos				
Alpacas	Alpacas				
Swine	Porcinos	144,928	59,873	56,878	77,845
Poultry	Aves de corral	7,170,412	9,351,893	13,390,490	13,895,387
Rabbits	Conejo				

[1] GHG emissions were calculated using a Tier 1 method described in Volume 4, Chapter 10 of the 2006 Intergovernmental Panel on Climate Change *Guidelines for National Greenhouse Gas Inventories*, published by the National Greenhouse Gas Inventory Program of the IPCC, available at (http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html.

[2] Sistema de Información Agropecuaria de Consulta (SIACON), a national database that stores agriculture and animal farming statistics. Document in Spanish. *Sistema de Información Agroalimentaria y de Consulta 1980-2006*. 2007. http://www.oeidrus-tamaulipas.gob.mx/cd_anuario_06/SIACON_2007.html

[3] Revised 2006 IPCC *Guidelines for National Greenhouse Gas Inventories* and *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, published in 2000 by the National Greenhouse Gas Inventory Program of the IPCC, available at: (http://www.ipcc-nggip.iges.or.jp/public/gp/english/).

Manure management. 2006 IPCC guidelines were used to estimate methane and nitrous oxide emissions using activity data on Tamaulipas livestock populations from 1990 to 2005. The activity data were retrieved from Sistema de Información Agropecuaria de Consulta (SIACON; see Table F-1).

To calculate CH_4 emissions due to manure management, population values are multiplied by an estimate for typical animal mass and a volatile solids (VS) production rate to estimate the total VS produced. The VS estimate for each animal type is then multiplied by a maximum potential CH_4 emissions factor and a weighted methane conversion factor (MCF) to derive total CH_4 emissions. The MCF adjusts the maximum potential methane emissions based on the types of manure management systems employed in Tamaulipas.

The emission factors were derived from a combination of regional expert studies[4] and state practices in manure management. Default IPCC emission and conversion factors were used for all emission sources in this sector with input information relating to livestock population by type, geographic area, and climate region. The geographic area category selected for Tamaulipas was Latin America and climate region categories selected were warm (>26 degrees C) and temperate (15-25 degrees C) assigned to 98% and 2% of livestock population by type according to the terrain covered by each climate zone (see Figure F-1). The assumptions of livestock manure managed by system type and the associated methane conversion factors are shown in Tables F-2 and F-3 below. Manure management system distribution and methane conversion factors were assumed to remain constant through the inventory and forecast years.

Direct N_2O emissions due to manure management are derived by using the same animal population values above multiplied by the typical animal mass and a total Kjeldahl nitrogen (K-nitrogen) production factor. The total K-nitrogen is multiplied by a non-volatilization factor to determine the fraction that is managed in manure management systems. The unvolatilized portion is then divided into fractions that get processed in either liquid (e.g. lagoons) or solid waste management systems (e.g. storage piles, daily spread, dry lot). Table F-4 shows the N_2O emission factor per manure management system.

Indirect N_2O emissions due to leaching are derived by taking the mass of nitrogen excreted per animal per manure management system multiplied by the fraction of nitrogen released through leaching and runoff. The product is then multiplied by a N_2O emission factor. Indirect N_2O emissions due to volatilization are derived by taking the mass of nitrogen excreted per animal per manure management system multiplied by the fraction of nitrogen released through volatilization. The product is then multiplied by a N_2O emission factor. The volatilization N_2O emissions factor is 0.01 kg N_2O-N/kg N, while the emission factor for leaching is 0.0075 kg N_2O-N/kg N.

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[4] Study results are summarized in Table 10-A-4 in Volume 4, Chapter 10, of the 2006 IPCC *Guidelines for National Greenhouse Gas Inventories.*

Figure F-1. Climate Zone Distribution in Tamaulipas

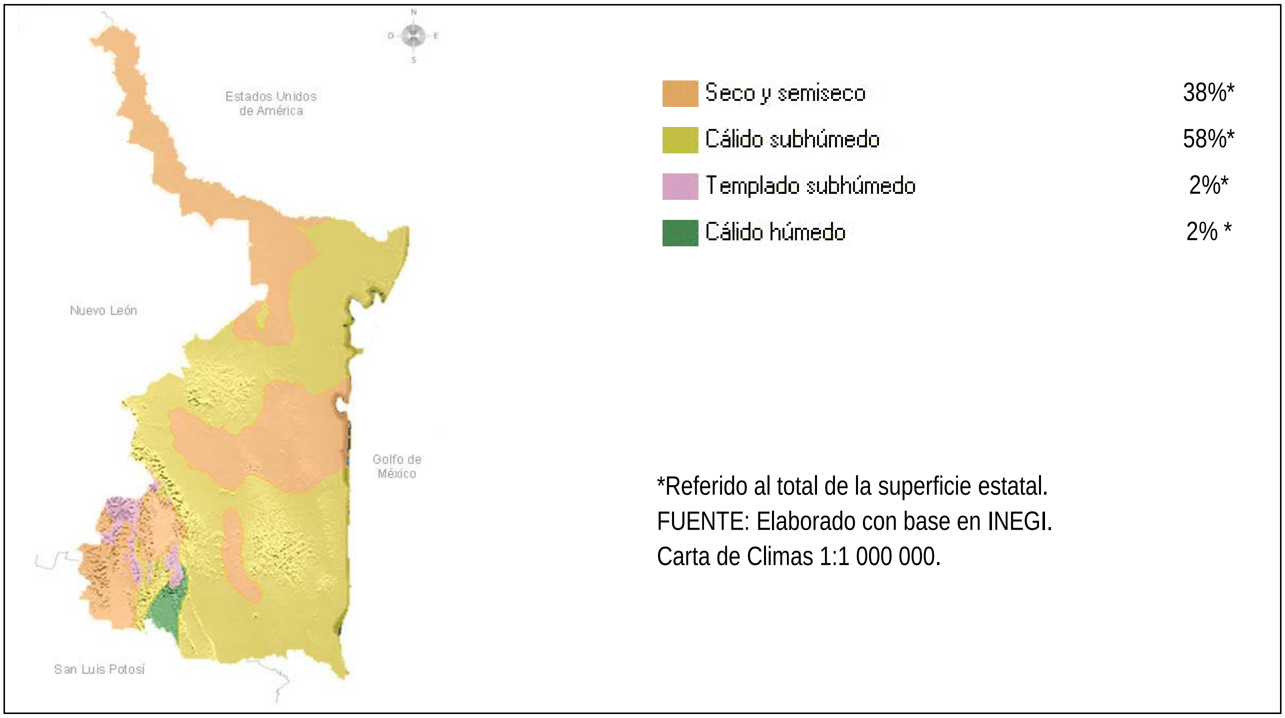


Table F-2. Default Manure Management Systems Distribution for Latin America

Livestock	Burned for fuel	Daily Spread	Digester	Dry Lot	Liquid Slurry	Other	Pasture, Range, Paddock	Solid Storage
Breeding Swine		2.0%	0.0%	20.5%	4.0%	44.5%		25.0%
Broilers						100.0%		
Dairy Cows	0.0%	62.0%	0.0%	0.0%	1.0%	0.0%	36.0%	1.0%
Goats						100.0%		
Horses						100.0%		
Layers (dry)						100.0%		
Layers (wet)						100.0%		
Market Swine		2.0%	0.0%	41.0%	8.0%	39.0%		10.0%
Mule/Asses						100.0%		
Other Cattle	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	99.0%	0.0%
Sheep						100.0%		
Turkeys						100.0%		

Table F-3. MCF for Manure Management Systems by Climate Zone

Livestock	Climate	Burned for fuel	Daily Spread	Digest-er	Dry Lot	Liquid Slurry	Other	Pasture, Range, Paddock	Solid Storage
Breeding Swine	Temperate		0.5%	10.0%	1.5%	42.0%	1.0%		4.0%
	Warm		1.0%	10.0%	2.0%	78.0%	1.0%		5.0%
Broilers	Temperate						1.5%		
	Warm						1.5%		
Dairy Cows	Temperate	10.0%	0.5%	10.0%	1.5%	42.0%	10.0%	1.5%	4.0%
	Warm	10.0%	1.0%	10.0%	2.0%	78.0%	1.0%	2.0%	5.0%
Goats	Temperate						1.5%		
	Warm						2.0%		
Horses	Temperate						1.5%		
	Warm						2.0%		
Layers (dry)	Temperate						1.5%		
	Warm						1.5%		
Layers (wet)	Temperate						78.0%		
	Warm						80.0%		
Market Swine	Temperate		0.5%		1.5%	42.0%	1.0%		4.0%
	Warm		1.0%		2.0%	78.0%	1.0%		5.0%
Mule/ Asses	Temperate						1.5%		
	Warm						2.0%		
Other Cattle	Temperate	10.0%	0.5%	10.0%	1.5%	42.0%	1.0%	1.5%	4.0%
	Warm	10.0%	1.0%	10.0%	2.0%	78.0%	1.0%	2.0%	5.0%
Sheep	Temperate						1.5%		
	Warm						2.0%		
Turkeys	Temperate						1.5%		
	Warm						1.5%		

Table F-4. Nitrous Oxide Emission Factors Applied to Manure Management Systems

Management System	Emission Factor (kg N_2O-N/kg N excreted)
Daily Spread	0
Digester	0
Dry Lot	0.02
Lagoon	0
Liquid Slurry	0.005
Other	0.001
Pit	0.002
Pit >1 month	0.002
Solid Storage	0.005

Agricultural soils. The decomposition of crop residues and nitrogen fixing crops add nitrogen to the nitrification and de-nitrification cycle in the soil, which produces N_2O as a by-product. The amount of nitrogen in crop soils was calculated as the product of crop dry matter harvested annually, the ratio of plant dry matter to crop dry matter, the nitrogen fraction of the plant dry matter, and the default nitrogen emission factor. In Table F-5, nitrogen fixing crops are beans and pulses.

Table F-5. Crop Production Inventory in Metric Tons[5]

Crop		1990	1995	2000	2005
N-fixing forages	Forrajes fijadores de N	0	0	0	0
Non-N-fixing forages	Forrajes no fijadores de N	24,730	16,736	22,030	58,140
Beans & pulses	Frijoles y legumbres	23,726	14,907	4,237	2,276
Grains	Granos				
Perennial grasses	Hierbas perennes	8,429	526,281	258,850	798,022
Grass-clover mixtures	Mezcla de hierba y trébol	0	0	0	0
Root crops, other	Raíces, otros	0	300	1,870	0
Tubers	Tubérculos	0	0	0	0
Alfalfa	Alfalfa	289	3,330	200	647
Rice	Arroz	20,145	6,793	7,883	6,449
Oats	Avena	0	0	0	0
Peanut (w/pod)	Cacahuetes (c/ vaina)	0	111	229	30
Barley	Cebada	1,729	212	202	480
Rye	Centeno	0	0	0	0
Dry bean	Frijoles	0	0	0	0
Non-legume hay	Heno no leguminoso	0	0	0	0
Maize	Maíz	663,322	818,782	283,144	713,668
Millet	Mijo	0	0	0	0
Potato	Patatas	20	0	0	0
Soyabean	Soja	72,188	33,131	50,822	94,246
Sorghum	Sorgo	1,892,624	1,154,765	2,275,346	2,162,216
Wheat	Trigo	27,733	29,863	628	0

Application of synthetic fertilizer also adds nitrogen to the nitrification and de-nitrification cycle in the soil and contributes the release of N_2O in the atmosphere. Emissions from the application of fertilizer to agricultural lands were based on data from the International Fertilizer Industry Association.[6] Table F-6 shows the estimate of N applied for each year.

Table F-6. Fertilizer Application Data

Parameter	1990	1995	2000	2005
Quantity (kg N)	99,581,739	78,891,682	95,438,427	71,394,480

Additions of nitrogen to the soil from organic fertilizers was calculated as the amount of total nitrogen available from reclaimed manure less the amount of this nitrogen dedicated for the purposes of feed, fuel or construction. In the case of Tamaulipas, it was assumed no manure went to feed, fuel, or construction.

[5] Sistema de Información Agropecuaria de Consulta (SIACON), a national database that stores agriculture and animal farming statistics. Document in Spanish. *Sistema de Información Agroalimentaria y de Consulta 1980-2006*. 2007. http://www.oeidrus-tamaulipas.gob.mx/cd_anuario_06/SIACON_2007.html

[6] International Fertilizer Industry Association (http://www.fertilizer.org/ifa/ifadata/search). Data on N applied by state for 1990-2005.

Nitrogen input to soils from the deposition of urine and dung by grazing animals on pasture, range and paddock was calculated as the fraction of nitrogen in manure that is left unmanaged on fields as a result of grazing. Table F-3 identifies the default fraction of manure left unmanaged.

In regard to cultivation of histosols which can also result in N_2O emissions, it was determined that the cultivation of these highly organic soils did not apply to Tamaulipas, because histosols only exist in boreal regions. Similarly, no consideration was given to flooding and draining of organic soils because such practice does not occur in the state.

Aggregate sources and non-CO_2 emissions sources on land. These include urea (applied as a source of N) and lime and dolomite which are used to neutralize acidic soils. All three amendments emit CO_2, which results from the breakdown of each compound. No data have been identified for Tamaulipas to estimate emissions from these additional amendments. Urea could be one of the commercial fertilizers captured within the total N represented in Table F-6 above; however, detailed information on the types of fertilizers applied was not available.

Residue burning. Agricultural burning can result in emissions of both N_2O and CH_4. Data on acres burned in Tamaulipas could not be found, and therefore emissions from residue burning were not calculated. When estimates of the tons or acres of Tamaulipas crops burned are found, these emissions will be included in the analysis.

Forecast Data

Forecast estimates were based on livestock population and crop production trends from 1990-2005. The resulting growth rates used to estimate 2005 through 2025 emissions are listed in Tables F-7 and F-8. Note that a negative growth indicates a decrease in livestock population or crop production. Based on these growth rates, forecast livestock and crop production activity were estimated through the year 2025. Forecast livestock population and crop production values are shown in Tables F-9 and F-10.

Livestock population figures are used to estimate emissions from manure management, and enteric fermentation. Population figures are also used to estimate organic additions and animal waste deposits on the land, which are used in the calculations of N_2O emissions from agricultural soils. The crop production figures are used to estimate the crop residues left on the soil, which also gets factored into the ag soils N_2O emissions calculation. N fertilizer applications also contribute to the calculation of N_2O emissions from ag soils. The fertilizer estimate (-1.0% annual growth) is forecast based on the change in N fertilizer application between 1995 and 2005.

Table F-7. Annual Growth Rates Applied to Livestock Population

Type	Type	Rate (%)	Period of Measurement
Dairy Cows	Vacuno lechero	3.7%	2000-2005
Other Cattle	Otros vacunos	-0.2%	2000-2005
Buffalo	Búfalo		
Sheep	Ovinos	-1.5%	2000-2005
Goats	Caprinos	3.9%	2000-2005
Camels	Camelidos		
Horses	Equinos		
Mule/Asses	Mulas y asnos		
Deer	Ciervos		
Alpacas	Alpacas		
Swine	Porcinos	6.5%	2000-2005
Poultry	Aves de corral	0.7%	2000-2005
Rabbits	Conejo		

Table F-8. Growth Rates Applied to Crop Production

Crop Name		Mean Annual Growth	
English	Spanish	Rate (%)	Period of Measurement
N-fixing forages	Forrajes fijadores de N		
Non-N-fixing forages	Forrajes no fijadores de N	0.0%	N/A*
Beans & pulses	Frijoles y legumbres	-11.7%	2000-2005
Grains	Granos		
Perennial grasses	Hierbas perennes	0.0%	N/A*
Grass-clover mixtures	Mezcla de hierba y trébol		
Root crops, other	Raíces, otros		
Tubers	Tubérculos		
Alfalfa	Alfalfa	0.0%	N/A*
Rice	Arroz	-3.9%	2000-2005
Oats	Avena		
Peanut (w/pod)	Cacahuetes (c/ vaina)	-33.6%	2000-2005
Barley	Cebada	0.0%	N/A*
Rye	Centeno		
Dry bean	Frijoles		
Non-legume hay	Heno no leguminoso		
Maize	Maíz	0.0%	N/A*
Millet	Mijo		
Potato	Patatas		
Soyabean	Soja	0.0%	N/A*
Sorghum	Sorgo	-1.0%	2000-2005
Wheat	Trigo		
* In some cases, data from year to year fluctuated dramatically, and no distinct growth trend could be seen. In these cases, no growth was assumed.			

Table F-9. Forecast Livestock Populations 2005-2025

Livestock Type		2005	2010	2015	2020	2025
Dairy Cows	Vacuno lechero	256,463	307,165	367,891	440,622	527,732
Other Cattle	Otros vacunos	406,722	402,557	398,435	394,355	390,317
Buffalo	Búfalo		0	0	0	0
Sheep	Ovinos	104,465	97,087	90,231	83,859	77,936
Goats	Caprinos	615,623	747,129	906,727	1,100,417	1,335,482
Camels	Camelidos		0	0	0	0
Horses	Equinos		0	0	0	0
Mule/Asses	Mulas y asnos		0	0	0	0
Deer	Ciervos		0	0	0	0
Alpacas	Alpacas		0	0	0	0
Swine	Porcinos	77,845	106,541	145,815	199,568	273,134
Poultry	Aves de corral	13,895,387	14,419,321	14,963,011	15,527,201	16,112,664
Rabbits	Conejo					

Table F-10. Forecast Crop Production 2005-2025, Metric Tons

Crop		2005	2010	2015	2020	2025
N-fixing forages	Forrajes fijadores de N	0	0	0	0	0
Non-N-fixing forages	Forrajes no fijadores de N	58,140	58,140	58,140	58,140	58,140
Beans & pulses	Frijoles y legumbres	1,223	657	353	190	1,223
Grains	Granos	0	0	0	0	0
Perennial grasses	Hierbas perennes	798,022	798,022	798,022	798,022	798,022
Grass-clover mixtures	Mezcla de hierba y trébol	0	0	0	0	0
Root crops, other	Raíces, otros	0	0	0	0	0
Tubers	Tubérculos	0	0	0	0	0
Alfalfa	Alfalfa	647	647	647	647	647
Rice	Arroz	5,276	4,316	3,531	2,889	5,276
Oats	Avena	0	0	0	0	0
Peanut (w/pod)	Cacahuetes (c/ vaina)	4	0	0	0	4
Barley	Cebada	480	480	480	480	480
Rye	Centeno	0	0	0	0	0
Dry bean	Frijoles	0	0	0	0	0
Non-legume hay	Heno no leguminoso	0	0	0	0	0
Maize	Maíz	713,668	713,668	713,668	713,668	713,668
Millet	Mijo	0	0	0	0	0
Potato	Patatas	0	0	0	0	0
Soyabean	Soja	94,246	94,246	94,246	94,246	94,246
Sorghum	Sorgo	2,054,711	1,952,550	1,855,470	1,763,216	2,054,711
Wheat	Trigo	0	0	0	0	0

Results

During inventory years (1990 through 2005), total agricultural emissions decreased by 24% down to 1.80 million metric tons of carbon dioxide equivalents ($MMtCO_2e$) in 2005. In 1990, the top two emitting sources were enteric fermentation, and agricultural soils. Enteric fermentation and agricultural soil accounted for 49 and 50%, respectively, of total greenhouse gas emissions in 1990. All major emissions categories declined between 1990 and 2005.

During forecast years (2005 through 2025), total agriculture emissions are projected to increase by 31% attaining levels around 2.36 million metric tons of carbon dioxide equivalents. In 2025, the top two emitting source sectors are again expected to be enteric fermentation and agricultural soils. Enteric fermentation accounts for 56% of total greenhouse gas emissions in 2025, and agricultural soils make up 42%. Enteric fermentation showed the most growth between 2005 and 2025, although manure management grew at a slightly faster rate.

Figure F-2 and Table F-11 summarize greenhouse gas emission estimates by source sector. The distribution of greenhouse gas emissions by source is presented in Table F-12. Finally, mean annual growth rates for selected time intervals are listed in Table F-13.

Figure F-2. GHG Emissions from Agriculture 1990-2025

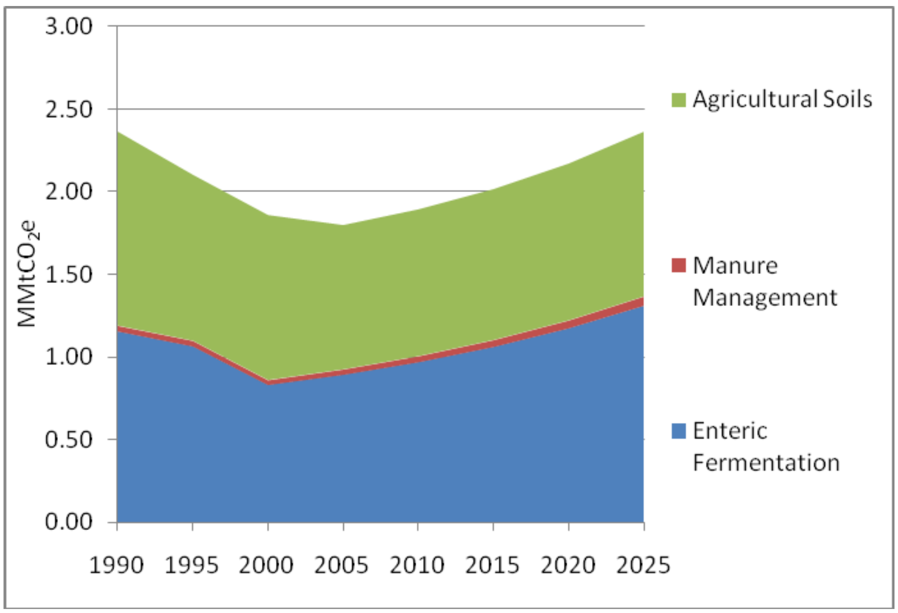


Table F-11. GHG Emissions from Agriculture ($MMtCO_2e$)

Source Sector	1990	1995	2000	2005	2010	2015	2020	2025
Enteric Fermentation	1.16	1.07	0.83	0.89	0.97	1.06	1.18	1.31
Manure Management	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.06
Agricultural Soils	1.17	1.00	0.99	0.87	0.89	0.91	0.95	0.99
Residue Burning	Not Estimated							
Total	**2.36**	**2.10**	**1.86**	**1.80**	**1.89**	**2.01**	**2.17**	**2.36**

Table F-12. GHG Emission Distribution in the Agriculture Sector

Source	1990	1995	2000	2005	2010	2015	2020	2025
Enteric Fermentation	49.0%	50.8%	44.9%	49.8%	51.3%	52.8%	54.2%	55.6%
Manure Management	1.4%	1.6%	1.6%	1.8%	1.9%	2.0%	2.2%	2.3%
Agricultural Soils	49.6%	47.7%	53.6%	48.4%	46.8%	45.2%	43.6%	42.1%

Table F-13. GHG Mean Annual Growth Rate for Selected Time Intervals

Agriculture	1990-2005	2005-2025	1990-2025
Enteric Fermentation	-1.7%	1.9%	0.4%
Manure Management	-0.3%	2.8%	1.4%
Agricultural Soils	-2.0%	0.7%	-0.5%

Key Uncertainties

In order to reduce uncertainty associated with greenhouse gas emissions from enteric fermentation processes, it is recommended that an enhanced characterization of the livestock population be developed. In the case of Tamaulipas, "other cattle" (non-dairy cows) accounts for 61% of the ruminant population. This broad category could be broken down into subcategories (e.g. calves, bulls, etc) and by the number of cattle in pasture versus on feedlots. Then emission factors specific to each of the subcategories could be applied. At a minimum, the following information is required to develop livestock subcategory specific emission factors: 1) feed intake estimate, 2) average animal weight, 3) animal activity index, 4) feeding conditions, and 5) mean winter conditions. Additional effort put into this source category will significantly impact a large share of total enteric fermentation emissions.

For manure management, no information was identified to indicate that any of the State's confined animal operations was employing controls to reduce methane emissions, such as anaerobic digesters. The forecast also assumes that none of these projects will be implemented prior to 2025. To the extent that this assumption is incorrect, future methane emissions from manure management are over-estimated.

Emissions from the application of fertilizer to agricultural lands were calculated from estimates of fertilizer application from the International Fertilizer Industry Association. Since the application of fertilizers varies significantly from crop to crop, it is recommended that nitrogen additions be segregated by crop and by fertilizer type, if possible (including different commercial fertilizers and organic fertilizers, like manure). This information combined with fertilized area by crop will result in decreased uncertainty.

Agricultural residue burning is not considered in this analysis because of a lack of data. Emissions factors do exist for the GHG emissions of burning various crop residues; however data on the acreage of crop residue burnings in Tamaulipas does not exist. If that information could be found it would improve the analysis. Prescribed burning is not typically a significant source (less than 1% of total) of ag emissions in most US states, but, nonetheless, it does contribute to overall GHG emissions.

A final contributor to the uncertainty in the emission estimates is the forecast assumptions. Mean annual growth rates were derived from historical trends during the period 1990 through 2005; however, historical data were inconsistent. The early nineties experienced very high livestock population and crop production values which declined sharply by 2000. Even during high yield years, values oscillated sharply from one year to the next. The fluctuation of values may indicate poor quality data. In cases where data from year to year fluctuated dramatically, and no distinct growth trend could be seen, no growth was assumed. This is done to make a conservative estimate, with relatively few dramatic increases and decreases in animal population or crop yield estimates. Input from in-state agricultural experts could improve the forecast estimates.

Appendix G. Waste Management

Overview

Greenhouse gas (GHG) emissions from waste management include:

- Solid waste disposal – methane (CH_4) emissions from solid waste disposal sites (SWDS), accounting for potential CH_4 that is flared or captured for energy production (this includes both open and closed landfills):[1]
- Incineration and open burning of waste – CH_4, carbon dioxide (CO_2), and nitrous oxide (N_2O) emissions from the combustion of solid waste (e.g. residential open burning); and
- Wastewater (WW) treatment and discharge – CH_4 and N_2O from domestic wastewater and CH_4 from industrial wastewater treatment facilities.

Inventory and Reference Case Projections

Solid Waste Disposal

For solid waste management, SWDS emplacement data were obtained from studies conducted by the Secretaría de Desarrollo Social (SEDESOL) compiled and available through the Sistema Nacional de Información Ambiental y Recursos Naturales (SNIARN).[2] This database provided the annual mass of municipal solid waste (residuos sólidos urbanos) by state for the period 1998-2006. Historic population values were used to model emplacement starting in 1960; similarly, population projections were used to determine future municipal waste generation rates. Population projections through 2025 were obtained from the Comisión Nacional de la Población (CONAPO). Emissions were modeled using the first order decay (FOD) model from the 2006 IPCC guidelines.[3]

The term “generation” typically refers to all waste entering the waste stream, which would include waste incineration, landfilling, recycling, and composting. However, as Tamaulipas does not track solid waste managed via incineration, recycling, composting, or other methods, it is assumed that all waste generated (entering the waste stream) decomposes at SWDS according to the FOD model, whether the waste is disposed of in a regulated or non-regulated SWDS. Waste treated through open burning is assumed to not enter the waste stream and is therefore not subtracted from the total waste generation (i.e. solid waste managed via open burning is not captured within the SNIARN solid waste generation estimates).

[1] CCS acknowledges that N_2O and CH_4 emissions are also produced from the combustion of landfill gas; however, these emissions tend to be negligible for the purposes of developing a state-level inventory for policy analysis. Note also that the CO_2 emitted from landfills is considered to be of biogenic origin (e.g. forest products waste, food waste, yard waste); hence, these emissions are excluded from the estimates of CO_2e from waste generation

[2] Secretaría de Medio Ambiente y Recursos Naturales. *Sistema Nacional de Información Ambiental y Recursos Naturales*. Dimensión Ambiental, Residuos. Based on municipal studies conducted by SEDESOL. Online at: http://www.semarnat.gob.mx/informacionambiental/Pages/index-sniarn.aspx

[3] IPCC. *2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 5: Waste*. Online at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

The classification of industrial waste (desechos de manejo especial) exists in the Mexican legislation;[4] however, in practice, municipal solid waste (desechos sólidos urbanos) and industrial waste (desechos de manejo especial) are consolidated at disposal sites. Consequently, no additional/separate emissions were estimated for industrial waste, since these emissions are already counted as part of emissions from municipal solid waste sites.

Information on the classification of landfills (i.e. managed vs. unmanaged) was not available. Therefore, CCS accepted the IPCC defaults for methane correction factor (MCF, 0.6) and oxidation factor (0%). The MCF accounts for the fact that waste at unmanaged sites tends to decompose in an aerobic environment, producing less methane per unit of waste than waste at managed sites, where waste decomposes in an anaerobic manner. The oxidation factor takes into account the amount of methane that is oxidized (converted from methane to CO_2 before it enters the atmosphere). The default oxidation factor of 0% was accepted by CCS due to the expectation that many sites don't have substantial soil cover, thereby reducing the likelihood of oxidation at the surface. It is important to note here that the CO_2 emitted from SWDS is considered to be of biogenic origin (e.g. forest products waste, food waste, yard waste); hence, these emissions are excluded from the estimates of CO_2e from SWDS.

According to the United Nations Framework for Climate Change Convention (UNFCCC) Clean Development Mechanism (CDM) project database,[5] there are no landfill gas capture projects currently in place or planned in the near future in Tamaulipas. Therefore, no correction for methane recovery was made to the inventory or forecast.

Another factor used by the IPCC Waste Model to compute methane emissions at SWDS is the composition of waste at the SWDS. IPCC provides default waste composition for North America. Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) also provided national-level waste composition data for Mexico. However, the UNFCCC reports on the Valle Verde (Baja California), Ciudad Juarez (Chihuahua), and Monterrey II (Nuevo Leon) Landfill Gas CDM projects provide SWDS-specific waste composition data, based on a survey of waste going into the respective SWDS. It is assumed that these data are more representative of the waste composition for northern Mexico (including Tamaulipas) and were used along with the MX national data to derive average waste composition inputs for the IPCC model. The share of waste composition for each waste type in Tamaulipas was calculated by taking the average of the MX national, Valle Verde, Ciudad Juarez, and Monterrey II share of total waste composition for each waste type. Table G-1 displays the waste composition input options, including the average of the four available waste composition data sets (used for this inventory and forecast). This table also shows that the waste composition selected for Tamaulipas is reasonably similar to the IPCC default and Mexico national data.

[4] Ley General par la Prevención y gestión Integral de los Residuos, Articulo 5.
[5] UNFCCC, 2009. CDM Project Search. http://cdm.unfccc.int/Projects/projsearch.html. Reference retrieved from Climate Action Reserve. *Protocolo de Reporte de Proyectos en Rellenos Sanitarios en México Recolección y Destrucción del Metano de los Rellenos Sanitarios; Versión 1.0*. March 2009.

Table G-1. Waste Composition Inputs (% of Waste Landfilled)

Waste Type	MX National	Valle Verde Landfill	Ciudad Juarez Landfill	Monterrey II Landfill	Tamaulipas Assumed Waste Composition	IPCC Default
Food	51.7%	36.7%	43.5%	38.4%	42.6%	33.9%
Garden	0.0%	17.7%	3.6%	4.1%	6.3%	0.0%
Paper	14.4%	12.2%	15.2%	15.3%	14.3%	23.2%
Wood	0.0%	0.7%	1.4%	2.1%	1.1%	6.2%
Textile	1.5%	0.0%	0.0%	6.5%	2.0%	3.9%
Nappies	0.0%	0.7%	0.0%	0.0%	0.2%	0.0%
Plastics, other inert	32.4%	32.0%	36.3%	33.6%	33.6%	32.8%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

As organic wastes are deposited in landfills, some of the carbon in those wastes is not released as landfill gas, and therefore is sequestered long-term in the SWDS. Such sequestration from food and garden wastes is considered in this inventory and forecast. Sequestration of carbon in paper and wood products is considered as long-term sequestration attributed to the forestry sector. As described in the Forestry & Land Use Appendix; this I&F currently does not have information on in-state wood products manufacturing and modeled end use (e.g. paper, lumber, energy, waste). It is likely that much of the forest products waste that is disposed at SWDS in Tamaulipas comes from out of state sources; hence, sequestration in SWDS for these wastes is not counted in this I&F. However, the quantity of carbon sequestered in landfills from food and garden waste is quantified using the aforementioned waste composition inputs for Tamaulipas SWDS and the IPCC Waste Model and represented in the results shown below.

Incineration and Open Burning of Waste

There are two types of solid waste combustion: 1) by incineration, and 2) open burning. The incineration of solid waste is not regulated by the state. Furthermore, open burning is common but not recorded. Open burning of solid waste is assumed to be most common in rural areas, where residents do not have access to solid waste management services. Waste generation and disposal data specific to rural and urban areas are not available, leading CCS to make assumptions necessary to complete the estimation of emissions from this source.

CONAPO produced a projection of population for each state in Mexico, including detail on population in areas considered rural (less than 2,500 people in a population center). The CONAPO data provided projections of rural population for the years 2005 through 2025.[6] Rural population for 1990 through 2004 was calculated by multiplying the ratio of rural:total population by the total population for each year reported by Instituto Nacional de Estadística, Geografía, e Informática (INEGI).[7] The per-capita MSW generation estimates from the solid

[6] State population projections were obtained from CONAPO for 2006 to 2025. Source: http://www.conapo.gob.mx/00cifras/5.htm.
[7] INEGI. Historic state population for years 1990, 1995, 2000, 2005. Source: http://www.inegi.org.mx/inegi/default.aspx.

waste disposal source sector were multiplied by the rural population to produce an estimate of waste generated and assumed to be combusted through open burning in each year. Emissions from open burning were calculated using the Tamaulipas activity data, developed using the methods described above, and IPCC emission factors.[8]

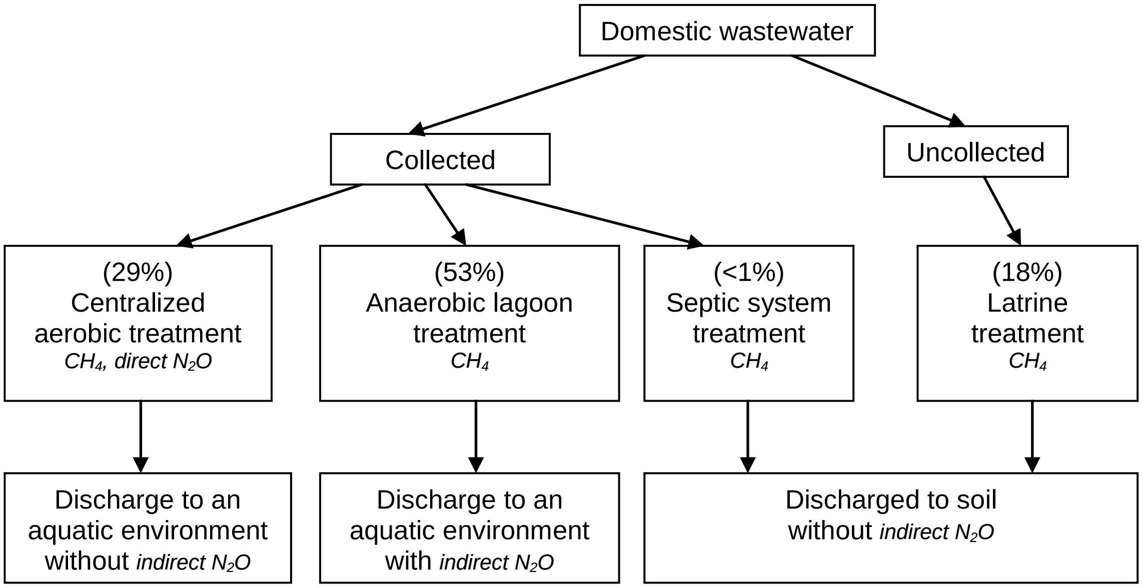
Wastewater Treatment and Discharge

GHG emissions from domestic and industrial wastewater treatment were also estimated. For domestic wastewater treatment, emissions are calculated using 2006 IPCC guidelines, and are based on state population, fraction of each treatment type (e.g. aerobic treatment plant, anaerobic lagoon, septic system, or latrine treatment), and emission factors for N_2O and CH_4.[9] The key IPCC emission factors are shown in Table G-2.

The percentage of Tamaulipas residents on city sewer is 82%, according to 2005 housing statistics published by INEGI,[10] and it is presumed that 18% of domestic wastewater generation is uncollected.[11] Comisión Nacional del Agua (CONAGUA) provided in-state wastewater treatment capacity by treatment system. This information was used to break down the population, whose wastewater is collected by city sewers, by each type of treatment system.[12] Three assumptions were made in the process of allocating wastewater flow to each treatment/discharge pathway; 1) all wastewater collected by a sewer system is treated by a wastewater treatment facility, 2) uncollected wastewater is treated in latrines, and 3) direct nitrous oxide emission occur in centralized aerobic treatment plants, and indirect nitrous oxide emissions occur from the discharge of wastewater effluent from anaerobic treatment systems to aquatic environments. Figure G-1 shows wastewater treatment system and discharge pathways for Tamaulipas with the fraction of effluent associated by each system. Domestic wastewater emissions were projected based on the population growth rate for 2005-2025 (1.00%/yr).[13]

[8] IPCC, 2006. "2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5: Waste." Chapter 5: Incineration and Open Burning of Waste. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_5_Ch5_IOB.pdf.
[9] IPCC, 2006. "2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5: Waste." Chapter 6: Wastewater Treatment and Discharge. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[10] INEGI. *Censos Generales de Población y Vivienda*: http://www.inegi.org.mx/inegi/default.aspx
[11] Retrieved May, 2008 from: http://www.inegi.gob.mx/est/contenidos/espanol/sistemas/conteo2005/iter2005/selentcampo.aspx
[12] Consejo Nacional del Agua, 2007. *Inventario Nacional de Plantas Municipales de Potabilización y de Tratamiento de Aguas Residuales en Operación*. México: CONAGUA.
[13] INEGI. Historic state population for years 1990, 1995, 2000, 2005. Source: http://www.inegi.org.mx/inegi/default.aspx.State population projections were obtained from CONAPO for 2006 to 2025. Source: http://www.conapo.gob.mx/00cifras/5.htm.

Figure G-1. Wastewater Treatment Systems and Discharge Pathways



Municipal Wastewater Treatment. This category accounts for methane and nitrous oxide emissions resulting from municipal wastewater treatment and discharge. The methods used are as follows and emission factors are provided in Table G-2 below:

a. Domestic WW – methane: for each treatment option, methane is calculated as the fraction of the population utilizing the treatment system, the capacity of the system to generate methane based on BOD, population and BOD generation rate per capita. This is described by the formula:

$$Emisiones_{CH4} = \sum_j [U_j \times B_o \times MCF_j] \times P \times BOD \times 325.25$$

Where:
U_j = population fraction connected to treatment system j
Bo= maximum methane generation capacity
MCF_j =methane correction factor
j = treatment system/option
P = population
BOD = BOD per capita per day
325.25 = days in a year

b. Domestic WW – nitrous oxide: nitrous oxide emissions occur in aerobic treatment plants and during the discharge of effluent to aquatic environments. Emissions from aerobic treatment plants is calculated as the fraction of the population serviced by the plant times a default plant emission factor (see 2006 IPCC, Volume 5, Equation 6.9). CCS correlated the treatment categories in operation in the state from CONAGUA publications with the treatment categories described in the IPCC guidance. As part of this exercise, all aerobic treatments systems were correlated under one single IPCC category encompassing all aerobic systems, namely, centralized aerobic plants. For aerobic treatment processes, the equation for estimating N_2O emissions is as follows:

$$N_2O_{PLANT} = P \times T_{PLANT} \times P_{IND\text{-}COM} \times EF_{PLANT}$$

Where:
N_2O_{PLANTS} = total N_2O emissions from plants in inventory year, kg N_2O/yr
P = human population
T_{PLANT} = degree of utilization of aerobic modern, centralized WWT plants, %. This fraction was determined as the ratio of state-wide nitrification/denitrification treatment capacity to total treatment capacity multiplied by the fraction of the population that is connected to the sewer.
$F_{IND\text{-}COMM}$ = factor to allow for co-discharge of industrial nitrogen into sewer; default value 1.25.
EF_{PLANT} = emission factor, 3.2 g N_2O/person/year.

Most nitrous oxide emissions occur from the discharge of wastewater effluent that is ultimately released to aquatic environments. The effluent contains residual levels of nitrogen rich substances that eventually decompose and release nitrous oxide emissions. This estimate is driven by population and the amount of protein consumption per capita:

$$Emissions_{N2O} = P \times Protein \times F_{NPR} \times F_{IND\text{-}COM} \times EF \times (44/28)$$

Where:
P = population
Protein = annual protein consumption rate per capita. Per the Food and Agriculture Organization (FAO), the average rate from 1990 to 2003 for México is 31 kg/person/year.
F_{NPR} = fraction of nitrogen in protein.
$F_{IND\text{-}COM}$ = factor to allow for co-discharge of industrial nitrogen into sewer; default value 1.25
EF = emission factor, the product of B_o and MCF factors
(44/28) = N to N_2O conversion factor.

Table G-2. IPCC Emission Factors for Domestic Wastewater Treatment

Treatment System	N_2O Emission Factor	CH_4 Emission Factors		
		MCF	B_o (kg CH_4/kg BOD)	BOD (g/person/day)
Latrine	n/a	0.5	0.6	40
Anaerobic Lagoon	n/a	0.8	0.6	40
Septic system	n/a	0.5	0.6	40
Centralized, aerobic treatment plant	3.2 g N_2O/person/year[a]	0.3	0.6	40
Effluent discharge to aquatic environment	0.005 kg N_2O-N/kg N[b]	n/a	n/a	n/a

[a] Emission factor for direct nitrous oxide emissions
[b] Emission factor for indirect nitrous oxide emissions

Industrial Wastewater Treatment. For industrial wastewater emissions, IPCC provides default assumptions and emission factors for four industrial sectors: Malt and Beer, Red Meat & Poultry, Pulp & Paper, and Fruits & Vegetables. INEGI provided data on red meat processing.[14] No data were available for malt and beer, pulp and paper, fruit and vegetable and poultry processing. Current industrial production data for red meat were used to estimate emissions for all historic years from 2002-2007, along with the IPCC emission factors for red meat production. Emissions were back-cast to 1990, assuming that activity in each year (1990 through 2001) was equal to the 2002 activity, where no industrial wastewater was processed. Emissions were forecast, assuming that emissions in each year were equal to the 2007 emission estimate.

Results

Figure G-2 and Table G-3 show the emission estimates for the waste management sector. Overall, the sector accounts for 0.96 MMtCO_2e in 2005, and emissions are estimated to be 1.25 MMtCO_2e/yr in 2025. Accounting for SWDS carbon storage yields the net emission estimates of 0.09 MMtCO_2e and 0.11 MMtCO_2e for 2005 and 2025, respectively.

As shown in Table G-4, in 2005, the largest sources in the waste management sector were emissions from SWDS and emissions from domestic wastewater, accounting for 50.1% and 39.1% of total sector emissions. By 2025, the contribution of emissions from SWDS (56.6%) and domestic wastewater emissions (35.2%) will change slightly from 2005. Emissions from open burning account for 10.0% and 7.9% of the total sector emissions in 2005 and 2025, respectively. Emissions from industrial wastewater contributed minimally towards the waste sector emissions; however, data for only red meat production were available. The relative contribution from SWDS decreases at the point where the methane destruction values relative to emissions are highest (2010, 2015).

Key Uncertainties and Future Research Needs

According to the Guidelines of the IPCC, a first order decay model to estimate emission from solid waste disposal sites contains inherent uncertainties, which are described below:

- Decay of carbon compounds to methane involves a series of complex chemical reactions and may not always follow a first-order decay reaction. Higher order reactions may be involved, and reaction rates will vary with conditions at the specific solid waste disposal site (SWDS). Reactions may be limited by restricted access to water and local variations in populations of bacteria;
- SWDS are heterogeneous. Conditions such as temperature, moisture, waste composition and compaction vary considerably even within a single site, and even more between different sites in a country. Selection of ‘average’ parameter values typical for a whole country is difficult; and
- Use of the FOD method introduces additional uncertainty associated with decay rates (half-lives) and historical waste disposal amounts. Neither of these are well understood or thoroughly researched.

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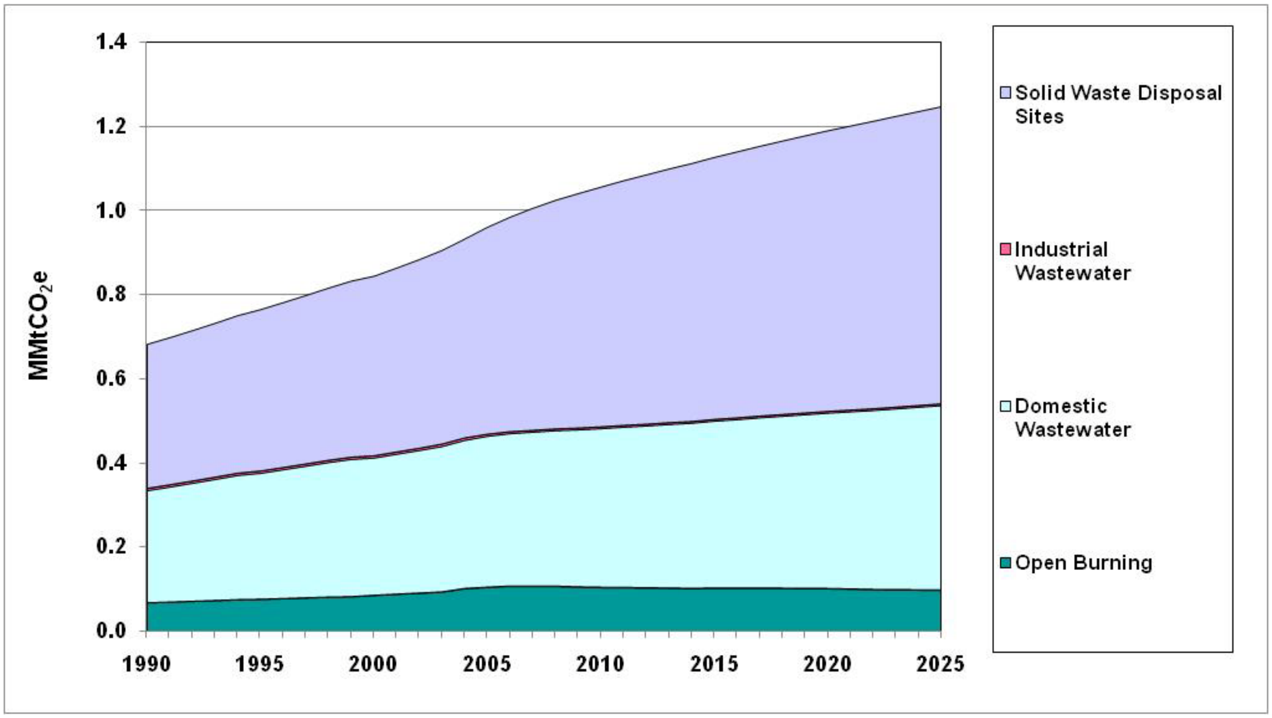
[14] Instituto Nacional de Estadísticas, Geografía e Informática. *Estadísticas de Ganado en Rastros Municipales por Entidad Federativa 2002-2007*. Online at: http://www.inegi.org.mx/est/contenidos/espanol/proyectos/coesme/programas/programa2.asp?clave=063&c=10984.

Figure G-2. Tamaulipas, Mexico Gross GHG Emissions from Waste Management



Source: Based on approach described in text.

Table G-3. Tamaulipas GHG Emissions from Waste Management ($MMtCO_2e$)

Source	1990	1995	2000	2005	2010	2015	2020	2025
Solid Waste Disposal Sites	0.34	0.38	0.43	0.49	0.57	0.62	0.67	0.71
Open Burning	0.07	0.08	0.09	0.11	0.11	0.10	0.10	0.10
Domestic Wastewater	0.27	0.30	0.33	0.36	0.38	0.40	0.42	0.44
Industrial Wastewater	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Total Gross Emissions	**0.68**	**0.77**	**0.85**	**0.96**	**1.06**	**1.13**	**1.19**	**1.25**
Carbon Stored in SWDS	0.06	0.06	0.07	0.09	0.10	0.10	0.11	0.11
Total Net Emissions	**0.63**	**0.70**	**0.77**	**0.87**	**0.96**	**1.03**	**1.09**	**1.14**

Table G-4. Gross GHG Emission Distribution in the Waste Management Sector

Source	1990	1995	2000	2005	2010	2015	2020	2025
Solid Waste Disposal Sites	50%	50%	50%	51%	54%	55%	56%	57%
Open Burning	10%	10%	10%	11%	10%	9%	9%	8%
Domestic Wastewater	39%	39%	39%	37%	36%	35%	35%	35%
Industrial Wastewater	1%	1%	1%	1%	0%	0%	0%	0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Another source of uncertainty is the quality of the activity data. Waste accumulation values that are available from SEMARNAT are based on population and waste generation rates per capita. Actual records of waste accumulation per site were not available for individual SWDS. A comprehensive set of accumulation records would reduce some of the uncertainty associated with SWDS methane emissions. Also, the waste composition data used for Tamaulipas is estimated by taking the average of Mexico national data and three landfills, but may not be representative of the state, although this is the assumption made in this analysis. Additionally, only methane recovery projects recognized by the UNFCCC CDM program were surveyed for this analysis. It is possible in the future that landfill gas at managed landfills in Tamaulipas will be captured and destroyed during the forecast period (e.g. due to increasingly popular carbon offset programs).

Open burning quantities of waste at residential sites were estimated by assuming that the rural portion of the Tamaulipas population conducts open burning. As some of this waste may be deposited at an SWDS or managed in another way, this assumption is likely to lead to an overestimate. However, this overestimate could help correct for the assumption that no open burning (or incineration) takes place in urban areas, which is probably not the case. Emissions from open burning of MSW include biogenic CO_2, which is released from the combustion of paper, wood, food and garden waste, and any other biogenic waste material. However, CH_4 and N_2O emissions due to the combustion of these materials may be significant and are included in the inventory as an anthropogenic GHG source. CO_2, CH_4, and N_2O from fossil-based carbon in sources, such as plastic and tires, are also included. Clearly, this initial estimate of residential open burning emissions can be greatly improved through surveys of solid waste experts in Tamaulipas.

For the domestic wastewater sector, the key uncertainties are associated with the application of IPCC default values for the parameters listed in Table G-3 above. To the extent that additional methane is being generated outside of the anaerobic digestion process, these emissions will be underestimated. Also, it is assumed that no methane collection and destruction is conducted at anaerobic treatment plants (e.g. flaring or other combustion of digester gas). So, to the extent that this is occurring, methane emissions are over-estimated. Potential emissions (primarily N_2O) from treatment plant sludge that is applied to the surface of landfills or otherwise land-applied were not quantified in this inventory.

For industrial wastewater, emissions were only estimated for the red meat industry using state data. There are no data for malt and beer, fruit and vegetable processing, or poultry processing facilities. To the extent that these industries are present in Tamaulipas, the emissions from industrial wastewater will be underestimated.

Appendix H. Forestry and Land Use

Overview

Forestry and land use emissions refer mainly to the net carbon dioxide (CO_2) flux[1] from forests and perennial woody crops in Tamaulipas, which account for about 28% of the state's land area.[2] Currently, there are approximately 1.5 million hectares of forests and 41,000 hectares of perennial woody crops in Tamaulipas. In addition to forest CO_2 flux, additional CO_2 is either emitted or sequestered within urban forests. Additional GHG emissions can occur from other land use practices, including non-farm fertilizer application.

Through photosynthesis, carbon dioxide is taken up by trees and plants and converted to carbon in forest biomass. Carbon dioxide removals and emissions occur during respiration in live trees, decay of dead biomass, and combustion (both forest fires and biomass removed from forests for energy use). In addition, carbon is stored for long time periods when forest biomass is harvested for use in durable wood products. Carbon dioxide flux is the net balance of carbon dioxide removals from and emissions to the atmosphere from the processes described above.

According to the 2006 IPCC guidelines, the Forestry and Land Use Sector includes six land use categories: 1) forest land, 2) cropland, 3) grassland, 4) wetlands, 5) settlements, and 6) other land.[3] Wetlands do not represent a key land use in Tamaulipas. Losses of terrestrial carbon can also occur during conversion of grasslands to agricultural or developed use (i.e. land use change); however, no data were identified to quantify this potential source in Tamaulipas. In this inventory, the forestry and land use sector CO_2 flux is categorized into two primary subsectors:

- *Forest Land Use [IPCC Categories: Forestland Remaining Forestland and Land Converted to Forestland]:* this consists of carbon flux occurring on lands that are not part of the urban landscape. Fluxes covered include net carbon sequestration, carbon stored in harvested wood products (HWP), and emissions from forest fires and prescribed burning.
- *Other Land Use:* these include Perennial Woody Crops [IPCC Category: Cropland Remaining Cropland] which cover carbon flux occurring on croplands that contain perennial woody vegetation, such as oil palm and fruit and nut orchards. Fluxes include biomass accumulation and tree removal.

  Other sources that could be included here if data were available include settlements (including urban forest carbon flux). Net carbon fluxes for grassland and other land are not considered to be significant and data to quantify these are unavailable. Also not included due to a lack of data are carbon fluxes associated with land management changes in crop cultivation, including losses/gains in soil carbon. Finally, as mentioned above, wetlands are not a significant land use in Tamaulipas.

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[1] "Flux" refers to both emissions of CO_2 to the atmosphere and removal (sinks) of CO_2 from the atmosphere.
[2] Sistema Nacional de Información Estadística y Geográfica (SNIEG), http://mapserver.inegi.gob.mx/geografia/espanol/estados/bc/agr_veget.cfm?c=1215&e=02&CFID=1762489&CFTOKEN=31412962
[3] IPCC defines other land as bare soil, rock, ice, and any other land not included in one of the other five land use categories.

Inventory and Reference Case Projections

Forested Landscape

2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC) offers two methods for estimating carbon flux. Based on the information available for Tamaulipas, the "gain-loss" method was adopted which expresses the annual change in carbon stocks in biomass in forested land as the annual increase in carbon stocks due to biomass growth minus the annual decrease of carbon stock due to biomass loss:

$$\Delta C_B = \Delta C_G - \Delta C_L$$

where:

ΔC_B = annual change in carbon stocks in biomass considering the total area, metric tons (t) of carbon (C) per year (yr), tC/yr;

ΔC_G = annual increase in carbon stocks due to biomass growth for each land sub-category, considering the total area, tC/yr;

ΔC_L = annual decrease in carbon stocks due to biomass loss for each land sub-category, considering the total area, tC/yr.

The annual increase in carbon stocks due to biomass growth (ΔC_G) is calculated for each vegetation type as follows:

$$\Delta C_G = \Sigma A_i \bullet G_{wi} \bullet (1+\mathrm{R}) \bullet CF_i$$

where:

A = land area, ha;

G_w = Above-ground biomass growth, t dry mass (d.m.) ha^{-1} yr^{-1};

R = Ratio of below-ground biomass to above-ground biomass, t d.m. below-ground biomass per t d.m. above-ground biomass; and

CF = carbon fraction of dry matter, tC/t d.m.

Estimates for the dead wood and litter carbon pools were not included in these estimates. The default assumption is that the stocks for these pools are not changing over time, if the land remains within the same land-use category.

Forest information was obtained from land surveys conducted in 1990 and 1995 by the United Nations Food and Agriculture Organization (FAO) Global Forest Resources Assessment (FRA).[4] These are summarized in Table H-1 below. In order to supplement missing historical data, land

[4] *FRA 2000 Bibliografía Comentada Cambios en la Cobertura Forestal: México*, Departamento de Montes, Organización de las Naciones Unidas para la Agricultura y la Alimentación, August, 2000.

area values for 1991-1994 were interpolated from the 1990 and 1995 data, and it was assumed that mean annual area for the time period 1996-2025 would remain constant from 1995. The FAO data only provides the total forest area. Forest area was allocated to climate zone and forest types using a 2002 survey from the Secretaría de Medio Ambiente Y Recursos Naturales (SEMARNAT).[5] This survey divides forest land area into bosques and selvas. Bosques were assigned to temperate mountain systems and selvas were assigned to sub-tropical mountain systems based on IPCC criteria.[6]

More recent and more detailed forest land data are available from INEGI.[7] However, the data, available as digital maps, required processing that was beyond the resources of this preliminary I&F project. Due to the relatively small contribution of the forest sector for Tamaulipas, the less precise and less resource intensive set of forest data were chosen for this inventory. An important aspect of the data shown in Table H-1 is the apparent loss of over 10% of the forest land in Tamaulipas during this time. It is not clear whether this apparent large loss of forest land is real or some artifact of the FAO survey data.

Table H-1. Forest Land Description and Coverage

Climate domain (i)	Ecological zone (j)	1990 (ha)	1995 (ha)
Sub-Tropical	Mountain Systems	926,354	818,558
Temperate	Mountain Systems	771,747	699,900
	Totals	**1,698,101**	**1,518,458**

Table H-2 lists the values used for carbon conversion factors, G_w, R and CF taken from the 2006 IPCC guidelines.[8]

[5] SEMARNAT. Compendio de Estadísticas Ambientales, 2002. México, D.F., 2003.
[6] Table 4.5, Chapter 4, Volume 4 of the IPCC guidelines.
[7] Land use and vegetation maps are referenced as: conjunto uso del suelo y vegetación escala 1:250 000, datum ITRF 92, formato SHP, seris I, II y III, clave D1502.
[8] Table 4.9, Chapter 4, Volume 4 of the 2006 IPCC guidelines lists values of above-ground net biomass growth in natural forests expressed as a range of plausible values. For the purposes of a conservative estimate of carbon sinks, lower end values were selected.

Table H-2. Factors Used to Estimate Carbon Gain in Tamaulipas Forest

Factor		Sub-Tropical Value	Temperate Value	Units
Above-ground biomass growth	G_w	0.5	0.9	t d.m. ha^{-1} yr^{-1}
Ratio of below-ground biomass to above-ground biomass	R	0.53	0.28	t d.m. below-ground biomass per t d.m. above-ground biomass
Carbon fraction of dry matter	CF	0.47	0.47	t C/t d.m.

Several factors should be considered when estimating the annual decrease of carbon stocks due to biomass loss (ΔC_L), including harvesting wood products, fuel wood removals from forests, and carbon stock losses due to disturbances such as fires or insect infestations. Carbon stock decreases due to disturbances and wood products harvesting were calculated; however, information relating to fuel wood removals was not available. Consequently, the annual decrease of carbon stocks was calculated as the sum of carbon losses due to disturbances ($L_{disturbance}$) and carbon losses due to wood removals ($L_{removals}$) according to the following equation.

$$\Delta C_L = L_{removals} + L_{disturbance}$$

Data on forest surface area disturbed by fire and disease was obtained from Secretaría de Medio Ambiente y Recursos Naturales, Comisión Nacional Forestal (SEMARNAT).[9] Data on forest diseases were obtained for 1990-2008. Area disturbed by fires for 2009-2025 was estimated as the average of 2004-2008 values. For forest fires, data were obtained for the years 1995 through 2006; values for 1990-1995 were estimated by taking the average of the values for 1995-2005; and values for 2007-2025 were estimated as the average of 2002-2006 values. Carbon stocks losses due to disturbances were calculated using default conversion numbers listed in Table H-3 and calculated as follows:

$$L_{disturbance} = \{A_{disturbance} \bullet B_W \bullet (1+ R) \bullet CF \bullet fd\}$$

where:

$L_{disturbances}$ = annual other losses of carbon, t C/yr;

$A_{disturbance}$ = area affected by disturbances, ha/yr;

B_W = average above-ground biomass of land areas affected by disturbances, t d.m./ha;

R = ratio of below-ground biomass to above-ground biomass, in t d.m. below-ground biomass per t d.m. above-ground biomass;

CF = carbon fraction of dry matter, t C per t d.m.; and

fd = fraction of biomass lost in disturbance.

[9] SEMARNAT, Anuario Estadistico de la Producción Forestal, http://www.semarnat.gob.mx/gestionambiental/forestalysuelos/Pages/anuariosforestales.aspx.

Table H-3. Forest Area to Carbon Content Conversion Factors

Factor		Sub-Tropical Value	Temperate Value	Units
Above-ground biomass	B_w	60	50	t d.m./ha
Ratio of below-ground biomass to above-ground biomass	*R*	0.28	0.53	t d.m. below-ground biomass per t d.m. above-ground biomass
Carbon fraction of dry matter	*CF*	0.47	0.47	t C/t d.m.
Fraction of biomass lost in fire	*fd*	0.90	0.90	NA
Fraction of biomass lost to disease or infestation	*fd*	0.10	0.10	NA

Non-CO_2 emissions from forest fires were also estimated. Methane (CH_4) and nitrous oxide (N_2O) emission factors from the 2006 IPCC Guidelines[10] were applied to the tonnes of biomass burned, as estimated using the factors in Table H-3 above.

Finally, wood harvest volume by type of wood was obtained from the *Anuario Estadistico de la Producción Forestal* from SEMARNAT for the years 1990 through 2005. Carbon loss due to wood harvest was calculated as:

$$L_{removals} = BCEF_{\mathrm{R}} \bullet (1 + R) \bullet CF$$

where: $BCEF_R$ is the biomass conversion and expansion factor, or the mass of above-ground biomass per volume of harvested wood [t biomass per cubic meter (m^3) of wood volume].

The values for $BCEF_R$ are shown in Table H-4 below. Due to lack of data, long-term storage in the resulting durable wood products (i.e., furniture, lumber), was not considered in this inventory.

Table H-4. Biomass Conversion and Expansion Factors

Climate Zone	Forest Type	$BCEF_R$ (t biomass/m^3 wood)
Temperate	Hardwoods	1.55
Temperate	Pines	0.83

Other Land Use

Other than perennial woody crops, data were not identified to estimate GHG emissions from other land uses in Tamaulipas. These other sources/sinks include urban forest carbon flux, use of fertilizers on settlement soils, carbon flux on grasslands and other lands.

Perennial Woody Crops. The only data available for woody perennial crops were total area and harvested area for 1989 to 2006 from Sistema de Informacion Agroalimentaria de Consulta

[10] Emission factors for non-tropical forests from Table 2.5 of Volume 4 (4.7 g CH_4 /kg of biomass and 0.26 g N_2O/kg biomass).

(SIACON). Crop areas for 2007-2025 were held constant at the average of 2002-2006 values. A list of woody crops identified from the SIACON and sample data for the 1990 and 2006 are shown in Table H-5.

Harvested area was assumed to be the surface area of mature trees, while the difference between total area and harvested area was assumed to be the surface area of immature trees. The change in carbon for mature trees ($\Delta C_{B,M}$) was estimated by taking the difference between total biomass for a given year (n) and the total biomass for the previous year (n-1):

$$\Delta C_{B,M} = B_{w,n} \bullet \mathrm{A_n} - B_{w,n-1} \bullet \mathrm{A_{n-1}}$$

where:

A = land area, ha;

B_w = average above-ground biomass, t d.m./ha.

Immature trees were assumed to gain carbon each year, estimated as:

$$\Delta C_{B,I} = G_{w,n} \bullet \mathrm{A}$$

where: G_w = above-ground biomass growth, tonnes d.m. ha^{-1} yr^{-1}.

The total change in carbon for woody crops was then estimated as the sum of the carbon flux for mature trees and immature trees:

$$\Delta C_{B,} = \Delta C_{B,M} + \Delta C_{B,I}$$

Table H-5. Surface Area of Woody Perennial Crops in Tamaulipas in 1990 and 2006

Crop Name		1990 Total Area (ha)	1990 Harvested Area (ha)	2006 Total Area (ha)	2006 Harvested Area (ha)
Aceituna	olive	-	-	625	0
Aguacate	avocado	102	88	46	46
Algarrobo	carob tree	-	-	-	-
Almendra	almond	-	-	-	-
Chabacano	apricot	-	-	-	-
Ciruela	prunes	-	-	-	-
Citricos	citric tree	666	388	-	-
Datil	dates	-	-	-	-
Durazno	peaches	-	-	-	-
Eucalipto	eucalyptus	-	-	-	-
Frutales Varios	various fruits	-	-	-	-
Granada	pomegranate	-	-	-	-
Guayaba	guayaba	-	-	-	-
Higo	fig	-	-	-	-
Limon	lime	1,845	1,145	3,314	3,124
Macadamia	macadamia	-	-	-	-
Mandarina	tangerine	61	4	767	757
Manzana	apple	-	-	-	-
Membrillo	quince	-	-	-	-
Mostaza	mustard	-	-	-	-
Naranja	orange	17,199	12,244	35,217	34,295
Nectarina	nectarine	-	-	-	-
Nuez	walnut	22	22	81.5	81.5
Palma De Ornato	palm	-	-	-	-
Palma De Ornato (planta)	palm	-	-	-	-
Pera	pear	-	-	-	-
Pistache	pistache	-	-	-	-
Toronja (pomelo)	grapefruit (pomelo)	688	617	1,413	1,367
	Total	**20,583**	**14,508**	**41,464**	**39,670**

Table H-6. Woody Crop Area to Carbon Content Conversion Factors

Factor		Value	Units
Above-ground biomass	B_w	63	t d.m. ha^{-1}
Above-ground biomass growth	G_w	2.1	t d.m. ha^{-1} yr^{-1}

Default values for below-ground biomass for agricultural systems are not available. According to IPCC guidelines, the default assumption is that there is no change in below-ground biomass of perennial trees in agricultural systems.[11] Estimates for the dead wood and litter carbon pools were also not included in these estimates. The default assumption is that the stocks for these pools are not changing over time, if the land remains within the same land-use category.

Results

Carbon flux associated with forestry and other land uses are summarized in Table H-7. In 2005, the carbon flux for forested lands and perennial tree agricultural systems was estimated to be a net sequestration of 2.3 MMtCO_2e. The analysis of historical records indicates that: 1) biomass growth in Tamaulipas' forested landscape exceeds the carbon decrease due to disturbances (forest fires) and the harvest of wood products combined, and 2) biomass loss is largely attributed to forest fires.

A notable and potentially significant data gap is the amount of wood harvested for use as a fuel. Also notable in the historical data of Table H-1 is the loss of over 10% of the forest soil carbon sink due to lower estimates of forest area between 1990 and 1995. However, the losses of carbon stocks due to changes in land use from forestry to other use during this period was not estimated. This is due to a lack of data in the post-1995 time-frame on forest land use. Future work should focus on the use of newer and more detailed land use/land cover data to confirm the 1990-1995 rate of forest area loss and to determine whether forest area has continued to decline at a similar rate after 1995. If the carbon stocks associated with the forest area loss between 1990 and 1995 were incorporated into the inventory, the net GHG emissions during those years would likely be positive, not negative as estimated using the currently available data and IPCC methods.

Methane and nitrous oxide emissions from forest fires were estimated to be negligible.

Table H-7. Forestry and Land Use Flux and Reference Case Projections (MMtCO2e)

Subsector	1990	1995	2000	2005	2010	2015	2020	2025
Forest Land Use	-2.5	-2.2	-2.3	-2.3	-2.3	-2.3	-2.3	-2.3
Growth	*-2.9*	*-2.5*	*-2.5*	*-2.5*	*-2.5*	*-2.5*	*-2.5*	*-2.5*
Fires (carbon loss)	*0.04*	*0.01*	*0.01*	*0.01*	*0.02*	*0.02*	*0.02*	*0.02*
Fires (CH_4 and N_2O)	*0.004*	*0.001*	*0.002*	*0.001*	*0.002*	*0.002*	*0.002*	*0.002*
Disease	*0.000*	*0.000*	*0.000*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*
Harvested Wood	*0.30*	*0.27*	*0.18*	*0.23*	*0.18*	*0.18*	*0.18*	*0.18*
Other Land Use	-0.08	0.01	0.01	-0.02	-0.01	-0.01	-0.01	-0.01
Perennial Woody Crops	*-0.08*	*0.01*	*0.01*	*-0.02*	*-0.01*	*-0.01*	*-0.01*	*-0.01*
Total Carbon Flux	**-2.6**	**-2.2**	**-2.3**	**-2.3**	**-2.3**	**-2.3**	**-2.3**	**-2.3**
Total (including CH_4 and N_2O)	**-2.6**	**-2.2**	**-2.3**	**-2.3**	**-2.3**	**-2.3**	**-2.3**	**-2.3**

NOTE: totals may not add exactly due to independent rounding.

[11] While the removal of mature trees probably results in the loss of below-ground biomass, the 2006 IPCC guidelines establish that, for Tier 1 estimates, no change is assumed for below-ground biomass, Section 5.2.1.2 of Volume 4.

Key Uncertainties and Future Research Needs

As stated above, not all IPCC land use categories relevant to Tamaulipas were covered in this inventory due to a lack of data for some categories. For example, losses of terrestrial carbon can also occur during conversion of grasslands to agricultural or developed use; however, no data were identified to quantify this potential source in Tamaulipas. For settlements, future research should include efforts to quantify urban forest terrestrial carbon storage (e.g. using estimates of tree canopy cover as an important input). Information on the use of commercial fertilizers in non-farm applications would allow for estimates to be made of N_2O emissions from settlement soils.

For the forested landscape, detailed data on forest types could not be utilized due to insufficient resources. Based on available data, such as satellite imagery, it may be possible to expand the detail of the inventory for forest lands as well as include the additional land use categories (including urban land area). However, additional resources will be needed to process digital imagery files available from INEGI.[12] As stated under the Results section above, future work should focus on the use of newer and more detailed land use/land cover data to confirm the 1990-1995 rate of forest area loss and to determine whether forest area has continued to decline at a similar rate after 1995. If the carbon stocks associated with the forest area loss between 1990 and 1995 were incorporated into the inventory, the net GHG emissions during those years would likely be positive, not negative as estimated using the currently available data and IPCC methods.

There is much uncertainty associated with the selection of above-ground net biomass growth values. Tables 4.8 and Table 4.9, Chapter 4, Volume 4 of 2006 IPCC guidelines lists values of above-ground net biomass and above-ground net biomass growth in natural forests expressed as a range of plausible values. For the purposes of a conservative estimate of carbon sinks, lower end values were selected. However, this was an assumption that needs verification. The selection of median values results in the carbon sequestration estimates listed in Table H-8. The results show differences of about almost a factor of five. Clearly, data from in-state forest biomass surveys could greatly reduce the uncertainty associated with the use of the IPCC defaults.

Table H-8. Alternative Forested Landscape Flux ($MMtCO_2e$)

Subsector	1990	1995	2000	2005
Forest Land – Lower End Factors	-2.6	-2.2	-2.3	-2.3
Forest Land – Median Value Factors	-11.9	-10.5	-10.6	-10.6

Several processes contributing to the annual decrease of carbon stocks due to biomass loss should be considered, including harvesting of wood products, fuel wood removals from forests, and carbon stock losses due to disturbances such as fires or insect infestations. For Tamaulipas, information regarding the annual decrease of carbon stocks due to fuel wood removals was not available and could have a substantial impact on the estimated carbon flux. Additionally, carbon loss by insect infestation was not considered in these estimates. Finally, carbon storage can occur from harvested wood products, when the harvested biomass is converted to durable wood

[12] Land use and vegetation maps are referenced as: conjunto uso del suelo y vegetación escala 1:250 000, datum ITRF 92, formato SHP, seris I, II y III, clave D1502

products, such as lumber or furniture. Storage of forest carbon can also occur in landfills, when forest products are disposed. Research is needed on the end uses of wood harvested in Tamaulipas in order to adequately characterize the full net flux of forest carbon.