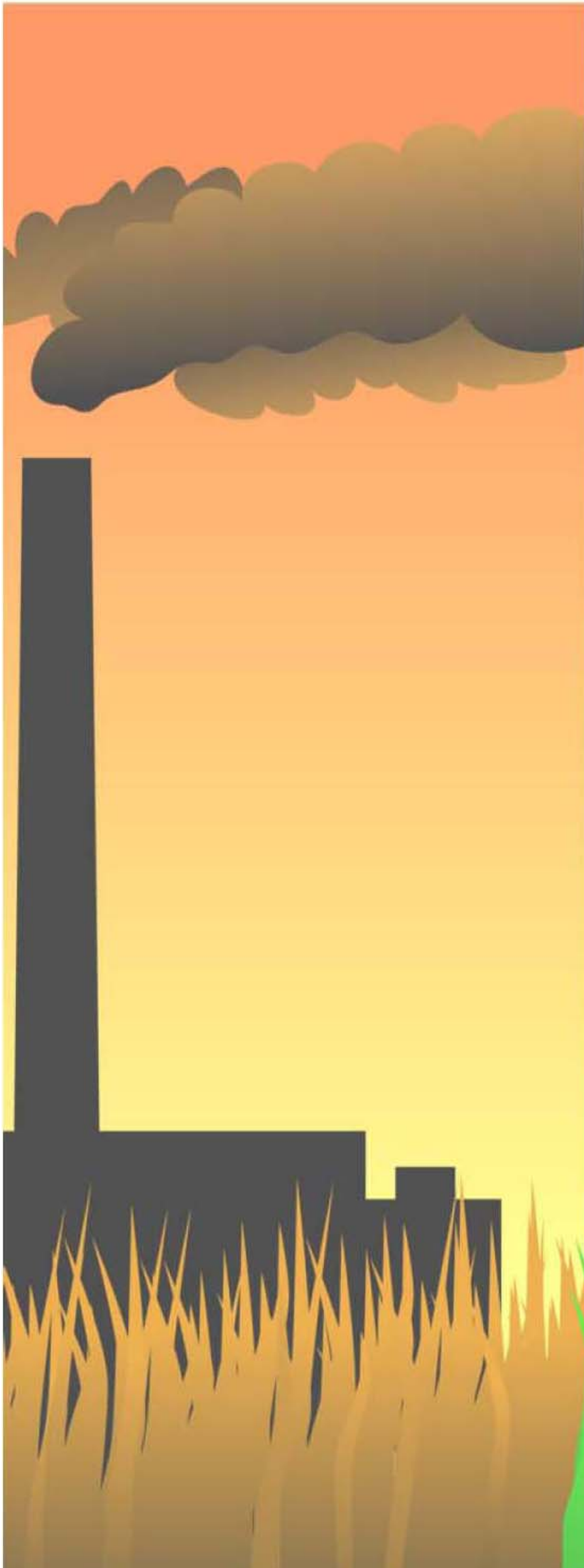

BORDER ENVIRONMENT COOPERATION COMMISSION

Center for Climate Strategies

Helping States and the Nation Tackle Climate Change

GREENHOUSE GAS EMISSIONS IN BAJA CALIFORNIA AND REFERENCE CASE PROJECTIONS 1990-2025

IN COLLABORATION WITH THE GOVERNMENT OF BAJA CALIFORNIA STATE

JUNE 2010

Greenhouse Gas Emissions in Baja California and Reference Case Projections 1990-2025.

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This report is a preliminary assessment of the State's greenhouse gas (GHG) emissions from 1990 to 2005 and a forecast of emissions through 2025. The inventory and forecast estimates serve as a starting point to assist the State with an initial comprehensive understanding of Baja California's current and possible future GHG emissions.
This report is essential for the development of the State Climate Action Plan (SCAP). The inventory and projections cover the six types of gases included in Mexico's national GHG emissions inventory and commonly reported in international reporting under the Kyoto Protocol: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). Emissions of these GHGs are presented using a common metric, CO2 equivalents (CO2e).

1. Greenhouse gas – Baja California, México – Statistics (1990-2005)
2. Greenhouse gas - Baja California, México – Projections (2025)
3. Greenhouse gas – Baja California, México – State Climate Action Plan
4. Greenhouse gas – Environmental Aspects – Baja California, México

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Table of Contents

Page

Acknowledgements iii
Acronyms and Key Terms ix
Executive Summary xiii
Summary of Preliminary Findings 1
  Introduction 1
Baja California Greenhouse Gas Emissions: Sources and Trends 3
  Historical Emissions 3
    Overview 3
    A Closer Look at the Two Major Sectors: Electricity Supply and Transportation 9
  Reference Case Projections 10
  Key Uncertainties and Next Steps 12
  Approach 13
    General Methodology 13
    General Principles and Guidelines 16
Appendix A. Electricity Supply and Use A-1
Appendix B. Residential, Commercial, and Industrial (RCI) Fuel Combustion B-1
Appendix C. Transportation Energy Use C-1
Appendix D. Industrial Processes and Product Use D-1
Appendix E. Fossil Fuel Industries E-1
Appendix F. Agriculture F-1
Appendix G. Waste Management G-1
Appendix H. Forestry and Land Use H-1
Appendix I. INE'S recommendations for the next GHG Emissions Inventories Update I-1

Tables

Table ES-1. Baja California Historical and Reference Case GHG Emissions, by Sector xvi
Table 1. Baja California Historical and Reference Case GHG Emissions, by Sector 5
Table 2. Correspondence between INE and Baja California GHG Sectors 7
Table 3. Key Annual Growth Rates for Baja California, Historical and Projected 12
Table 4. Key Data Sources and Methods and Comparison to National Inventory Methods 14
Table A-1. Emission Factors used for Inventory and Forecast A-5
Table A-2. Summary of Electricity Generation Characteristics by Plant, 2007 .... A-6
Table A-3. Planned Natural Gas Capacity Additions and Assumed Characteristics A-9
Table A-4. Production-based Inventory and Forecast – Fossil Fuel Consumption (TJ) A-11
Table A-5. Production-based Inventory and Forecast – Electricity Generation (GWh) A-12
Table A-6. Production-based GHG Emissions from the Electricity Supply Sector ($MMtCO_2e$) A-13
Table A-7. State-Wide Electrical Power Disposition (GWh) A-15
Table A-8. Total GHG Emissions Associated with Electricity Consumption ($MMtCO_2e$) A-17
Table B-1. Emissions Factors for RCI Fuels (kg/TJ) B-2
Table B-2. Growth Rates used in RCI Forecast B-3
Table B-3. Historical Energy Used in RCI Sector, TJ B-5
Table B-4. GHG Emissions RCI Sector ($MMtCO_2e$) B-7
Table B-5. GHG Emissions Distribution in RCI Sector B-7
Table B-6. Historical Electricity Sales Annual Growth Rates B-8
Table C-1. Activity Factors by Transportation Mode C-2
Table C-2. Annual Growth Rates C-3
Table C-3. Emissions Factors for Onroad Transportation powered by Gasoline C-4
Table C-4. GHG Emissions from Transportation ($MMtCO_2e$) C-6
Table C-5. GHG Emissions Distribution in the Transportation Sector C-6
Table C-6. Percentage Change in GHG Emissions for Selected Time Intervals C-6
Table D-1. GHG Emissions Results from RETC (Metric Tons of CO2e) D-3
Table D-2. Approach to Estimating Inventory Emissions D-6
Table D-3. Approach to Estimating Projections for 2005 through 2025 .... D-6
Table D-4. Historic and Projected GHG Emissions for Industrial Processes ($MMtCO_2e$) D-7
Table D-5. GHG Emission Distribution for Industrial Processes D-8
Table D-6. HCFC Emissions from Refrigeration and Air Conditioning D-8
Table D-7. Clinker Content in National Production of Cement D-8
Table E-1. Comparison of Emission Using Competing Methods for Year 2005 .... E-2
Table E-2. Fossil Fuel Industry Emission Factors E-3
Table E-3. Approach to Estimating Historical/Projected Emissions from Fossil Fuel Systems . E-4
Table E-4. Historical and Projected Emissions for the Fossil Fuel Industry in $MMtCO_2e$ E-5
Table E-5. Historical and Projected Distribution of Emissions by Source E-5
Table F-1. Livestock Populations F-2
Table F-2. Default Manure Management Systems Distribution for Latin America F-4
Table F-3. MCF for Manure Management Systems by Climate Zone F-5
Table F-4. Nitrous Oxide Emission Factors Applied to Manure Management Systems F-5
Table F-5. Inventory Crop Production in Metric Tons F-6

Table F-6. Fertilizer Application Data....F-6
Table F-7. Growth Rates Applied to Livestock Population....F-8
Table F-8. Growth Rates Applied to Crop Production....F-8
Table F-9. Forecast Livestock Populations 2005-2025....F-9
Table F-10. Forecast Crop Production 2005-2025, Metric Tons....F-9
Table F-11. GHG Emissions from Agriculture ($MMtCO_2e$)....F-11
Table F-12. GHG Emission Distribution in the Agriculture Sector....F-11
Table F-13. GHG Mean Annual Growth Rate for Selected Time Intervals....F-11
Table G-1. Destruction of Methane at Valle Verde Landfill, 2009-2025....G-3
Table G-2. Waste Composition Inputs (% of Waste Landfilled)....G-3
Table G-3. Treatment Fractions and IPCC Emission Factors for Domestic Wastewater....G-7
Table G-4. Baja California GHG Emissions from Waste Management ($MMtCO_2e$)....G-8
Table G-5. Gross GHG Emission Distribution in the Waste Management Sector....G-9
Table H-1. Forest Land Description and Coverage....H-3
Table H-2. Factors Used to Estimate Carbon Gain in Baja California Forest....H-3
Table H-3. Forest Area to Carbon Content Conversion Factors....H-5
Table H-4. Biomass Conversion and Expansion Factors....H-5
Table H-5. Surface Area of Woody Perennial Crops in Baja California....H-7
for 1990 and 2006....H-7
Table H-6. Woody Crop Area to Carbon Content Conversion Factors....H-7
Table H-7. Forestry and Land Use Flux and Reference Case Projections ($MMtCO_2e$)....H-8
Table H-8. Alternative Forested Landscape Flux ($MMtCO_2e$)....H-9

Figures

Figure ES-1. Historical Baja California and National Gross GHG Emissions per Capita and per Unit of Economic Output xvii
Figure ES-2. Baja California Gross Consumption-Based GHG Emissions by Sector, ... xviii
1990-2025 xviii
Figure ES-3. Sector Contributions to Gross Emissions Growth in Baja California, 1990-2025: Reference Case Projections ($MMtCO_2e$ Basis) xix
Figure 1. Historical Baja California and Mexico Gross GHG Emissions per Capita and per Unit Gross Product in Dollars 6
Figure 2. Gross GHG Emissions by Sector, 2005, Baja California and Mexico 7
Figure 3. Baja California Gross GHG Emissions by Sector, 2005 8
Figure 4. Baja California Gross GHG Emissions by Sector, 1990-2025 10
Figure 5. Sector Contributions to Gross Emissions Growth in Baja California, 1990-2025 11
Figure A-1. Share of Gross Electricity Generation by Fuel Type, 2007 ..... A-7
Figure A-2. Electricty Generation by Plant, 2003-2007 ..... A-7
Figure A-3. Production-based Inventory and Forecast – Fossil Fuel Consumption A-11
Figure A-4. Total Electricity Generation – by Fuel Type: 1990 - 2025 ..... A-12
Figure A-5. Production-based GHG Emissions from the Electricity Supply Sector A-13
Figure A-6. State-Wide Electrical Power Disposition A-16
Figure A-7. Consumption-based Inventory and Forecast – Fossil Energy Use A-16
Figure A-8. Total Consumption-Based Electricity Supply GHG Emissions A-17
Figure A-9. Consumption-based Electricity Supply GHG Emissions – by Component A-18
Figure B-1. GHG Emissions in RCI Sector B-6
Figure B-2. 2005 Electricity Sector Sales by Sub-sector B-8
Figure B-3. GHG Emissions from Residential Sector Fuel Combustion B-9
Figure B-4. GHG Emissions from Commercial Sector Fuel Combustion B-9
Figure B-5. GHG Emissions from Industrial Sector Fuel Combustion B-10
Figure C-1. Transportation Gross GHG Emissions by Fuel, 1990-2025 ..... C-7
Figure D-1. GHG Emissions from Industrial Processes 1990-2025 ..... D-7
Figure E-1. Oil and Gas Production by Region E-1
Figure E-2. Fossil Fuel Industry Emission Trends ($MMtCO_2e$) E-5
Figure F-1. Climate Zone Distribution in Baja California F-4
Figure F-2. GHG Emissions from Agriculture 1990-2025 ..... F-10
Figure G-1. Wastewater Treatment Systems and Discharge Pathways G-5
Figure G-2. Baja California, Mexico Gross GHG Emissions from Waste Management, 1990-2025 ..... G-8

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

CDM - Clean Development Mechanism

CFCs – Chlorofluorocarbons

CH_4 – Methane

CHP – Combined Heat and Power

CFE - Comisión Federal de Electricidad

CO_2 – Carbon Dioxide

CO_2e – Carbon Dioxide equivalent

CONAFOR – Comisión Nacional Forestal

CONAGUA - Comisión Nacional del Agua

CRE - Comisión Reguladora de Energía

EAF – Electric Arc Furnace

EIIP – Emission Inventory Improvement Program

FAO - Food and Agriculture Organization

FOD - first order decay

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 y Geografía

IPCC – Intergovernmental Panel on Climate Change

kg – Kilogram

kWh – Kilowatt-hour

lb – Pound

LF – Landfill

LFC - Luz y Fuerza del Centro

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

LPG – Liquefied Petroleum Gas

MCF - methane conversion factor

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

NMVOCs - non-methane volatile organic compounds

ODS – Ozone-Depleting Substance

OEIDRUS - Oficina Estatal de Información para el Desarrollo Rural Sustentable

PEMEX - Petróleos Mexicanos

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

RETC - Registro de Emisiones y Transferencias de Contaminantes (stands for the Registry of Emissions and Pollutant Releases)

SEMARNAT – Secretaría de Medio Ambiente y Recursos Naturales

SIE – Sistema de Información Energética

SF_6 – Sulfur Hexafluoride

SIACON -- Sistema de Información Agropecuaria de Consulta

SIT – State Greenhouse Gas Inventory Tool

SNIEG - Sistema Nacional de Información Estadística y Geográfica

SPA - Secretaría de Protección al Ambiente del gobierno del Estado de Baja California

SWDS - Solid waste disposal sites

T&D – Transmission and Distribution

t – Metric ton (equivalent to 1.102 short tons)

TJ - Terajoules

UNFCCC - Framework for Climate Change Convention

US – United States

US EPA – United States Environmental Protection Agency

VS – Volatile solids

WECC - Western Electricity Coordinating Council

WW – Wastewater

yr – Year

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Executive Summary

The Border Environment Cooperation Commission (BECC) which main objective is to support environmental projects to improve the environment and human health in the U.S.-Mexico border, have been implementing diverse actions to support border Mexican states to develop their State Climate Action Plan (SCAP). One the most important results of the SCAP is the Greenhouse Gases (GHG) emissions inventories and projections. With this objective in mind, BECC procured the services of the Center for Climate Strategies (CCS) for the preparation of this report in coordination with the Secretaría de Protección al Ambiente del gobierno del Estado de Baja California (SPA) a preliminary assessment of the State's greenhouse gas (GHG) emissions from 1990 to 2005 and a forecast of emissions through 2025. The inventory and forecast estimates serve as a starting point to assist the State with an initial comprehensive understanding of Baja California's current and possible future GHG emissions.

Baja California'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 Baja California-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 Baja California, 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 emissions 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 Baja California accounted for approximately 16.1 million metric tons (MMt) of *gross production-based*[4] CO_2e emissions in 2005, an amount equal to about 2.4% of Mexico's gross GHG emissions in 2005 excluding carbon sinks, such as accumulation of carbon stocks in forested land. Baja California's gross consumption-based GHG emissions increased by 112% from 1990 to 2005, while national emissions rose by only 31%

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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.

from 1990 to 2005. The growth in Baja California's emissions from 1990 to 2005 is primarily associated with electricity consumption and transportation activities.[5]

Initial estimates of carbon sinks within Baja California's forests 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 0.35 $MMtCO_2e$ were sequestered in Baja California forest biomass in 2005; however, this excludes any losses associated with forest land conversion due to a lack of data. Inclusion of the forest sink leads to *net-production* emissions of 15.8 $MMtCO_2e$ in Baja California for 2005.

Figure ES-1 compares the State's and Mexico's gross production emissions per capita and per unit of economic output.[6] On a per capita basis, Baja California emitted about 4.78 metric tons (t) of gross CO_2e in 1995, less than the 1995 national average of 5.96 tCO_2e. Since 1995, Baja California's per capita emissions increased to 5.67 tCO_2e in 2005, while national per capita emissions for Mexico grew to 6.35 tCO_2e in 2005. Baja California's emissions have grown faster than the national rate; however, population has grown even faster. Therefore, per capita emissions in the state have not reached the national level. Baja California's economic growth exceeded emissions growth for the 1995-2000 period leading to declining estimates of GHG emissions per unit of state product. However, emissions per unit of state product remain fairly constant between 2000 and 2005.

As illustrated in Figure ES-2 and shown numerically in Table ES-1, under the reference case projection, Baja California's gross GHG emissions continue to grow and are projected to reach 27.0 $MMtCO_2e$ by 2025. This would be an increase of 282% over 1990 levels. As shown in Figure ES-3, the transportation sector is projected to be the largest contributor to future emissions growth in Baja California, followed by emissions in the electricity sector. The electricity supply sector experienced a rapid growth in emissions due to the expansion of infrastructure to include two natural gas combined cycle unit starting in 1999.

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 Baja California'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

[5] Comparison with national results were drawn from *México 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.
[6] Historic population available from Instituto Nacional de Estadística y Geografía (INEGI). Population projection was available from Comisión Nacional de Población (CONAPO).

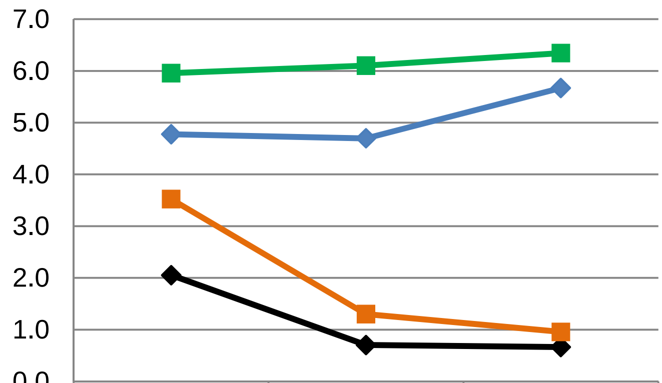
emission estimates and/or methods and suggested next steps for refinement of the inventory and reference case projection.

Table ES-1. Baja California Historical and Reference Case GHG Emissions, by Sector

(Million Metric Tons CO2e)	1990	1995	2000	2005	2010	2015	2020	2025
Energy Consumption Based	**5.9**	**8.3**	**10.5**	**13.7**	**16.4**	**18.3**	**20.7**	**23.6**
Electricity Consumption Based	**1.16**	**1.97**	**3.35**	**5.46**	**6.19**	**6.63**	**7.83**	**9.57**
Electricity Production Based	1.70	2.46	2.81	5.96	6.87	7.73	8.87	9.70
Gas/Diesel Oil	0.01	0.02	0.21	0.01	0.01	0.01	0.01	0.01
Natural Gas	0.00	0.00	0.63	5.75	6.87	7.72	8.86	9.69
Residual Fuel Oil	1.68	2.44	1.97	0.20	0.00	0.00	0.00	0.00
Imported Electricity	-0.54	-0.49	0.54	-0.49	-0.69	-1.10	-1.03	-0.13
Res/Comm/Ind (RCI)	**1.09**	**1.33**	**1.44**	**1.33**	**1.86**	**1.97**	**2.12**	**2.28**
Gas/Diesel Oil	0.09	0.13	0.15	0.20	0.26	0.30	0.34	0.39
Liquefied Petroleum Gases	0.79	0.78	0.69	0.71	0.74	0.80	0.87	0.94
Natural Gas	0.20	0.19	0.26	0.27	0.69	0.73	0.78	0.83
Residual Fuel Oil	0.00	0.22	0.33	0.16	0.16	0.14	0.13	0.12
Solid Biofuels: Wood/Wood Waste	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.005
Transportation	**3.63**	**4.93**	**5.69**	**6.86**	**8.28**	**9.57**	**10.60**	**11.64**
Road Transportation - Gasoline	2.08	3.46	3.76	4.53	5.45	6.27	6.88	7.50
Road Transportation - Diesel	1.16	0.78	0.79	1.42	1.83	2.17	2.45	2.73
Road Transportation - LPG	0.00	0.00	0.12	0.15	0.08	0.07	0.07	0.07
Aviation	0.32	0.43	0.54	0.48	0.64	0.75	0.87	0.98
Marine Vessels	0.05	0.25	0.47	0.28	0.26	0.29	0.31	0.33
Rail	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.03
Fossil Fuel Industry	**0.00**	**0.00**	**0.00**	**0.01**	**0.05**	**0.05**	**0.05**	**0.05**
NG Transmission - pipeline	0.00	0.00	0.002	0.002	0.002	0.002	0.002	0.002
NG Trans. – compressor storage	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04
NG Distribution	0.00	0.00	0.00	0.003	0.009	0.01	0.01	0.01
Industrial Processes	**0.30**	**0.41**	**0.65**	**0.76**	**0.91**	**1.11**	**1.30**	**1.49**
Cement Manufacture	0.24	0.31	0.49	0.53	0.70	0.84	0.99	1.13
Limestone and Dolomite Use	0.05	0.08	0.13	0.17	0.13	0.15	0.18	0.20
ODS Substitutes	0.01	0.02	0.03	0.05	0.08	0.11	0.13	0.16
Waste Management (Gross)	**0.40**	**0.50**	**0.60**	**0.72**	**0.61**	**0.80**	**1.01**	**1.20**
Domestic Wastewater	0.17	0.21	0.25	0.28	0.32	0.36	0.41	0.46
Solid Waste Disposal Site	0.20	0.24	0.30	0.37	0.22	0.37	0.53	0.66
Open Burning	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.08
Landfill Carbon Storage	-0.06	-0.08	-0.09	-0.12	-0.14	-0.16	-0.18	-0.19
Agriculture	**0.43**	**0.43**	**0.47**	**0.49**	**0.53**	**0.58**	**0.63**	**0.68**
Enteric Fermentation	0.22	0.24	0.26	0.28	0.31	0.34	0.38	0.42
Manure Management	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Managed Soils	0.20	0.18	0.21	0.20	0.21	0.23	0.24	0.25
Forestry and Land Use	**-0.23**	**-0.21**	**-0.23**	**-0.26**	**-0.22**	**-0.22**	**-0.22**	**-0.22**
Forest (carbon flux)	-0.26	-0.24	-0.25	-0.25	-0.24	-0.24	-0.24	-0.24
Perennial Tree Agric. (carbon flux)	-0.02	0.00	-0.02	-0.02	-0.04	-0.04	-0.04	-0.04
Forest Fires (non-CO2 emissions)	0.05	0.04	0.03	0.01	0.05	0.05	0.05	0.05
Gross Emiss. Consumption Based	**7.05**	**9.60**	**12.23**	**15.63**	**18.48**	**20.77**	**23.60**	**26.97**
increase relative to 1990	*0%*	*36%*	*73%*	*122%*	*162%*	*194%*	*235%*	*282%*
Emission Sinks	**-0.32**	**-0.32**	**-0.34**	**-0.36**	**-0.38**	**-0.39**	**-0.41**	**-0.43**
Net Emissions (incl. forestry*) Consumption Based	**6.73**	**9.28**	**11.88**	**15.27**	**18.10**	**20.37**	**23.19**	**26.54**
increase relative to 1990	*0%*	*38%*	*76%*	*127%*	*169%*	*203%*	*244%*	*294%*

Gross Emiss. Production Based	7.59	10.09	11.68	16.13	19.16	21.86	24.64	27.10
Increase relative to 1990	*0%*	*33%*	*54%*	*112%*	*152%*	*188%*	*224%*	*257%*
Emisiones Netas (incl. forestal*) Production Based	**7.28**	**9.77**	**11.34**	**15.76**	**18.79**	**21.47**	**24.22**	**26.67**
Incremento relativo a 1990	*0%*	*34%*	*56%*	*117%*	*158%*	*195%*	*233%*	*267%*

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



	1995	2000	2005
Baja California GHG/Capita (tCO2e/capita)	4.78	4.70	5.67
Mexico GHG/Capita (tCO2e/capita)	5.96	6.10	6.35
Baja California GHG/dollar (kgCO2e/$)	2.05	0.70	0.66
Mexico GHG/dollar (kgCO2e/$)	3.52	1.30	0.96

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

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

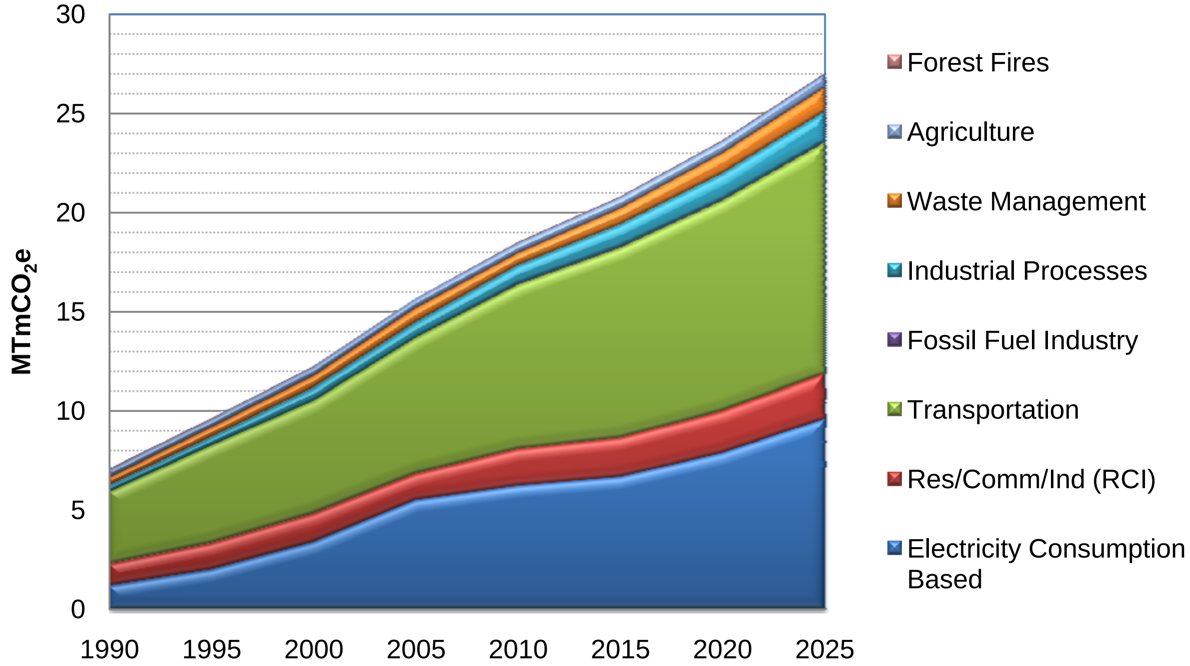
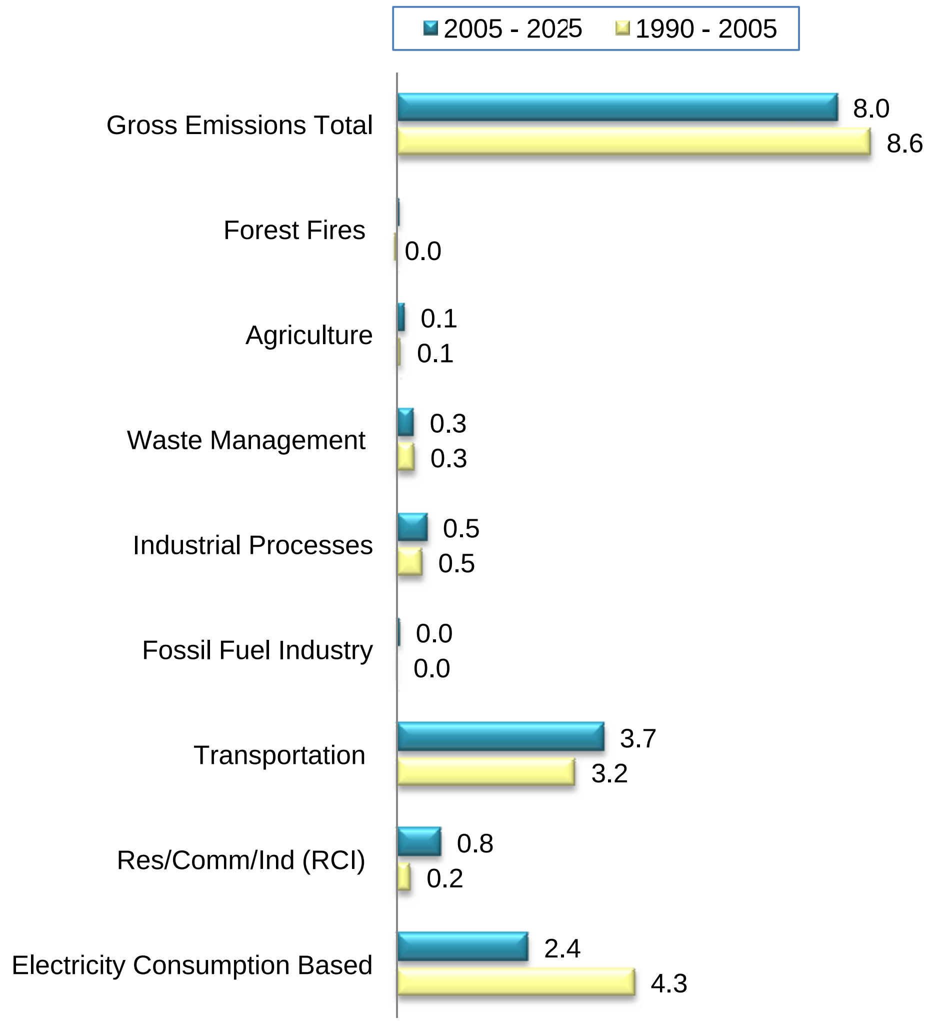


Figure ES-3. Sector Contributions to Gross Emissions Growth in Baja California, 1990-2025: Reference Case Projections (MMtCO$_2$e Basis)



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.

Summary of Preliminary Findings

Introduction

The Border Environment Cooperation Commission (BECC) which main objective is to support environmental projects to improve the environment and human health in the U.S.-Mexico border, have been implementing diverse actions to support border Mexican states to develop their State Climate Action Plan (SCAP). One the most important results of the SCAP is the Greenhouse Gases (GHG) emissions inventories and projections. With this objective in mind, BECC procured the services of the Center for Climate Strategies (CCS) for the preparation of this report in coordination with collaboration of the Secretaría de Protección al Ambiente del gobierno del Estado de Baja California (SPA). SPA contributed with leadership and coordination to the development of the inventory and forecast to serve as input to climate action activities within the framework of the Plan Estatal de Acción Climática de Baja California (PEAC-BC). 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 Baja California'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 Baja California-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 Baja California, 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.[8]

[8] 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).

It is important to note that the preliminary emissions estimates reflect the *GHG emissions associated with the electricity sources used to meet Baja California'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.*

Baja California Greenhouse Gas Emissions: Sources and Trends

Table 1 provides a summary of GHG emissions estimated for Baja California 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) net 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 Baja California accounted for approximately 16.1 million metric tons (MMt) of CO_2e emissions, an amount equal to about 2.4% of Mexico GHG emissions (based on 2005 national emissions).[9] Baja California's gross GHG emissions are rising at a slightly higher rate than those of the nation as a whole (gross emissions exclude carbon sinks, such as forests). Baja California's gross GHG emissions increased 112% from 1990 to 2005, while national emissions rose by 31% from 1990 to 2005.

Figure 1 illustrates the State's emissions per capita and per unit of economic output.[10] On a per capita basis, Baja California emitted about 4.78 metric tons (t) of gross CO_2e in 1995, less than the 1995 national average of 5.55 tCO_2e. Since 1995, Baja California's per capita emissions increased to 5.55 tCO_2e in 2005, while national per capita emissions for Mexico grew to 6.35 tCO_2e in 2005. Although Baja California's emissions have grown faster than the national rate, population has grown faster than the national rate as well, and per capita emissions in the state have not reached the national level. Baja California's economic growth exceeded emissions

[9] Comparison with national results were drawn from the official publication titled: *México 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 respectively. 2005 emissions were derived from these values at 655,477 gigagrams.
[10] Retrieved June, 2008 from: http://www.inegi.gob.mx/est/contenidos/espanol/cubos/default.asp?c=1413.

growth for the 1995-2000 period leading to declining estimates of GHG emissions per unit of state product. However, emissions per unit of state product remained fairly constant from 2000 to 2005.

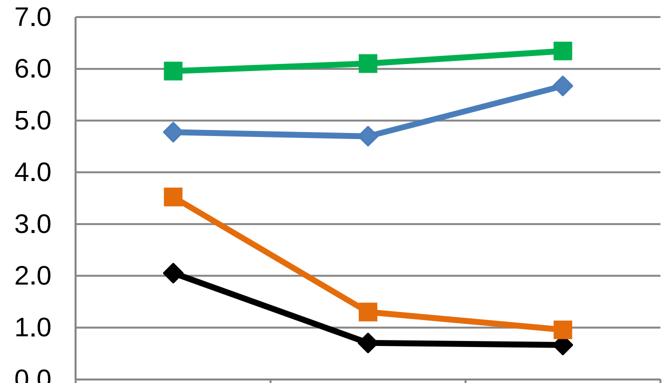
Figure 2 compares gross GHG emissions for Baja California to emissions for Mexico in 2005 according to GHG sectors used by Instituto Nacional de Ecología (INE). The principal source of Baja California's GHG emissions is energy use. Energy use includes activities such as power generation, transportation, 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 Baja California. At the national level, the energy sector accounted for 63% of gross GHG emissions in 2005.

Table 1. Baja California Historical and Reference Case GHG Emissions, by Sector[a]

(Million Metric Tons CO2e)	1990	1995	2000	2005	2010	2015	2020	2025
Energy Consumption Based	**5.9**	**8.3**	**10.5**	**13.7**	**16.4**	**18.3**	**20.7**	**23.6**
Electricity Consumption Based	**1.16**	**1.97**	**3.35**	**5.46**	**6.19**	**6.63**	**7.83**	**9.57**
Electricity Production Based	1.70	2.46	2.81	5.96	6.87	7.73	8.87	9.70
Gas/Diesel Oil	0.01	0.02	0.21	0.01	0.01	0.01	0.01	0.01
Natural Gas	0.00	0.00	0.63	5.75	6.87	7.72	8.86	9.69
Residual Fuel Oil	1.68	2.44	1.97	0.20	0.00	0.00	0.00	0.00
Imported Electricity	-0.54	-0.49	0.54	-0.49	-0.69	-1.10	-1.03	-0.13
Res/Comm/Ind (RCI)	**1.09**	**1.33**	**1.44**	**1.33**	**1.86**	**1.97**	**2.12**	**2.28**
Gas/Diesel Oil	0.09	0.13	0.15	0.20	0.26	0.30	0.34	0.39
Liquefied Petroleum Gases	0.79	0.78	0.69	0.71	0.74	0.80	0.87	0.94
Natural Gas	0.20	0.19	0.26	0.27	0.69	0.73	0.78	0.83
Residual Fuel Oil	0.00	0.22	0.33	0.16	0.16	0.14	0.13	0.12
Solid Biofuels: Wood/Wood Waste	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.005
Transportation	**3.63**	**4.93**	**5.69**	**6.86**	**8.28**	**9.57**	**10.60**	**11.64**
Road Transportation - Gasoline	2.08	3.46	3.76	4.53	5.45	6.27	6.88	7.50
Road Transportation - Diesel	1.16	0.78	0.79	1.42	1.83	2.17	2.45	2.73
Road Transportation - LPG	0.00	0.00	0.12	0.15	0.08	0.07	0.07	0.07
Aviation	0.32	0.43	0.54	0.48	0.64	0.75	0.87	0.98
Marine Vessels	0.05	0.25	0.47	0.28	0.26	0.29	0.31	0.33
Rail	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.03
Fossil Fuel Industry	**0.00**	**0.00**	**0.00**	**0.01**	**0.05**	**0.05**	**0.05**	**0.05**
NG Transmission - pipeline	0.00	0.00	0.002	0.002	0.002	0.002	0.002	0.002
NG Trans. – compressor storage	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04
NG Distribution	0.00	0.00	0.00	0.003	0.009	0.01	0.01	0.01
Industrial Processes	**0.30**	**0.41**	**0.65**	**0.76**	**0.91**	**1.11**	**1.30**	**1.49**
Cement Manufacture	0.24	0.31	0.49	0.53	0.70	0.84	0.99	1.13
Limestone and Dolomite Use	0.05	0.08	0.13	0.17	0.13	0.15	0.18	0.20
ODS Substitutes	0.01	0.02	0.03	0.05	0.08	0.11	0.13	0.16
Waste Management (Gross)	**0.40**	**0.50**	**0.60**	**0.72**	**0.61**	**0.80**	**1.01**	**1.20**
Domestic Wastewater	0.17	0.21	0.25	0.28	0.32	0.36	0.41	0.46
Solid Waste Disposal Site	0.20	0.24	0.30	0.37	0.22	0.37	0.53	0.66
Open Burning	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.08
Landfill Carbon Storage	-0.06	-0.08	-0.09	-0.12	-0.14	-0.16	-0.18	-0.19
Agriculture	**0.43**	**0.43**	**0.47**	**0.49**	**0.53**	**0.58**	**0.63**	**0.68**
Enteric Fermentation	0.22	0.24	0.26	0.28	0.31	0.34	0.38	0.42
Manure Management	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Managed Soils	0.20	0.18	0.21	0.20	0.21	0.23	0.24	0.25
Forestry and Land Use	**-0.23**	**-0.21**	**-0.23**	**-0.26**	**-0.22**	**-0.22**	**-0.22**	**-0.22**
Forest (carbon flux)	-0.26	-0.24	-0.25	-0.25	-0.24	-0.24	-0.24	-0.24
Perennial Tree Agric. (carbon flux)	-0.02	0.00	-0.02	-0.02	-0.04	-0.04	-0.04	-0.04
Forest Fires (non-CO2 emissions)	0.05	0.04	0.03	0.01	0.05	0.05	0.05	0.05
Gross Emiss. Consumption Based	**7.05**	**9.60**	**12.23**	**15.63**	**18.48**	**20.77**	**23.60**	**26.97**
increase relative to 1990	*0%*	*36%*	*73%*	*122%*	*162%*	*194%*	*235%*	*282%*
Emission Sinks	**-0.32**	**-0.32**	**-0.34**	**-0.36**	**-0.38**	**-0.39**	**-0.41**	**-0.43**
Net Emissions (incl. forestry*) Consumption Based	**6.73**	**9.28**	**11.88**	**15.27**	**18.10**	**20.37**	**23.19**	**26.54**
increase relative to 1990	*0%*	*38%*	*76%*	*127%*	*169%*	*203%*	*244%*	*294%*

Gross Emiss. Production Based	**7.59**	**10.09**	**11.68**	**16.13**	**19.16**	**21.86**	**24.64**	**27.10**
Increase relative to 1990	*0%*	*33%*	*54%*	*112%*	*152%*	*188%*	*224%*	*257%*
Emisiones Netas (incl. forestal*) Production Based	**7.28**	**9.77**	**11.34**	**15.76**	**18.79**	**21.47**	**24.22**	**26.67**
Incremento relativo a 1990	*0%*	*34%*	*56%*	*117%*	*158%*	*195%*	*233%*	*267%*

Figure 1. Historical Baja California and Mexico Gross GHG Emissions per Capita and per Unit Gross Product in Dollars[11]



	1995	2000	2005
Baja California GHG/Capita (tCO2e/capita)	4.78	4.70	5.67
Mexico GHG/Capita (tCO2e/capita)	5.96	6.10	6.35
Baja California GHG/dollar (kgCO2e/$)	2.05	0.70	0.66
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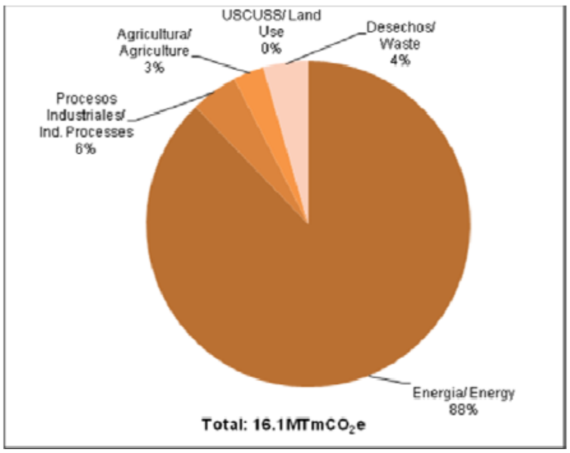
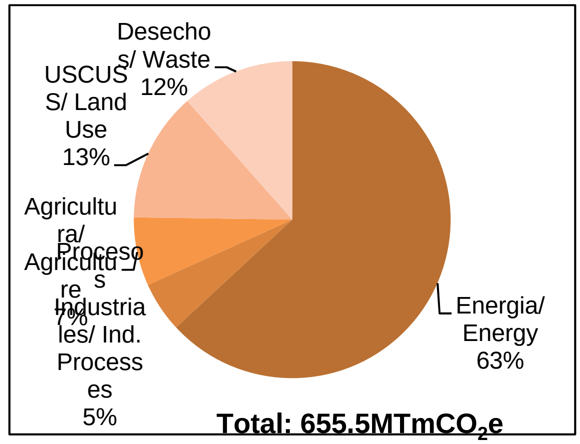
[11] Economic activity expressed in 2006 values. Information retrieved from INEGI, Banco de Información Económica.

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

Baja California[12]



Mexico



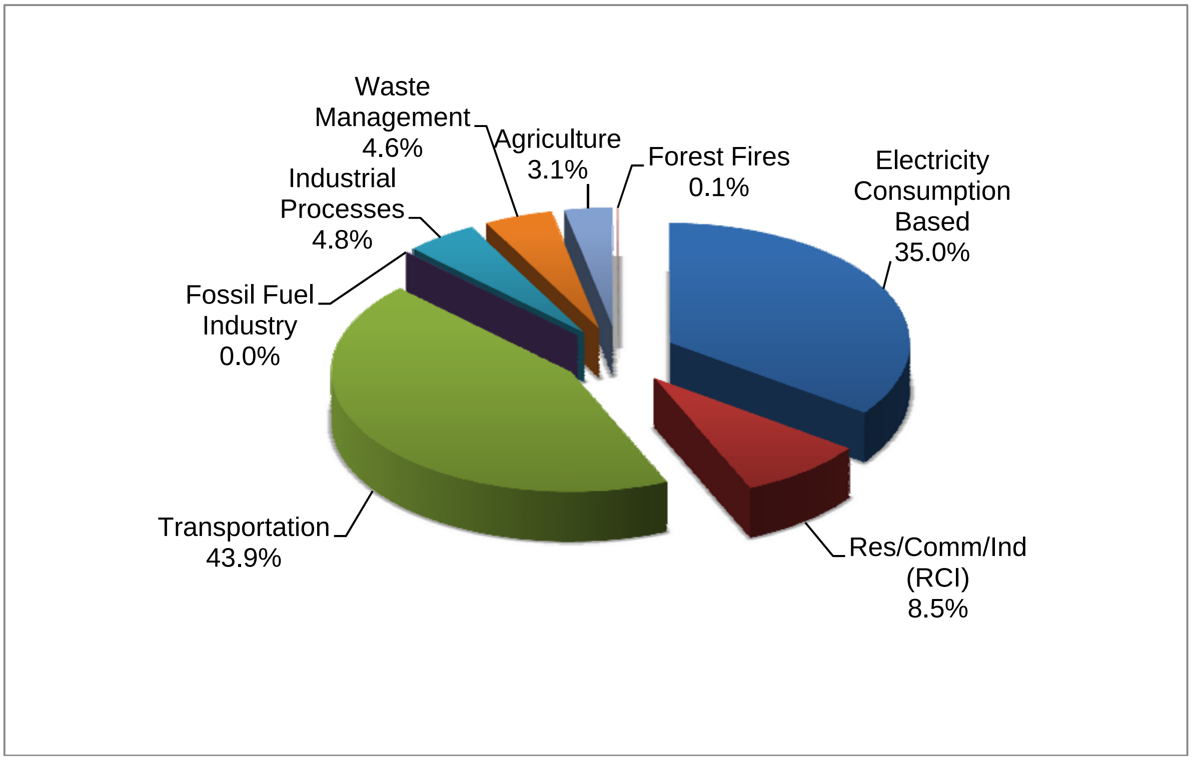
Summary results in this inventory and forecast for Coahuila are presented with additional disaggregation of emission sources in comparison with the summary results of the *Inventario Nacional de Emisiones de Gases de Efecto Invernadero* prepared by INE. Table 2 provides correspondence between the Coahuila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

Table 2. Correspondence between INE and Baja California GHG Sectors

INE	Baja California
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)

[12] 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. Baja California Gross GHG Emissions by Sector, 2005



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

Electricity Supply Sector

In 2007, two combined cycle plants (Presidente Juarez and Mexicali) generated 46% of the state's electricity using natural gas; 5% of the state's electricity was generated from residual fuel oil; 1% from diesel oil; 2% of electricity was imported from the U.S. from power marketer Coral Power L.L.C., San Diego Gas & Electric, and Sempra Energy Solutions.[13] The remaining 46% of the state's electricity comes from a renewable energy geothermal plant (Cerro Prieto).

There is expected to be a 107 MW geothermal facility on-line in 2011, with 93 MW of capacity retiring in that same year. The interconnection with the United States is expected to be terminated in 2013. At the same time, over the coming years, Baja California will open up transmission with Sonora. However, since the amount of electricity generated in Baja California is far greater than the electricity sold over these years, it is assumed that after 2013, Baja California will not import electricity via this new transmission line, using this connection solely to export electricity to other states in Mexico.

Electricity consumption accounted for about 35% of Baja California's gross GHG emissions in 2005 at 5.5 $MMtCO_2e$. Emissions associated with electricity consumption are estimated to grow to around 9.6 $MMtCO_2e$ in 2025. An important area for future research is whether the geothermal energy sources contribute any geogenic carbon dioxide emissions that would not be considered to occur naturally, and hence should be incorporated into the inventory.

Transportation Sector

Transportation activities accounted for about 44% of Baja California's gross GHG emissions in 2005. The sector was divided into five subsectors as follows: a) road vehicles fueled by gasoline, b) road vehicles fueled by diesel, c) road vehicles fueled by liquefied petroleum gas (LPG), d) airplanes fueled by jet fuel, e) marine vessels fueled by diesel, and f) locomotives.

In 2005, transportation emissions totaled 6.9 $MMtCO_2e$, of which 66% resulted from gasoline combustion by light-duty road vehicles, 21% resulted from diesel combustion by heavy-duty road vehicles, 7% from jet fuel combustion by airplanes, and the remaining 6% from marine diesel, liquefied petroleum gas, and locomotive diesel.

The fastest growing source through the 1990-2005 time period was marine vessels with a mean annual growth rate of 12% (with most growth occurring from 1990 to 1994), followed by road transportation gasoline (5%). In 2025, total transportation emissions are expected to be on the order of 11.7 $MMtCO_2e$ representing a 221% increase from 1990. Road transportation emissions are expected to account for 88% of total transportation emissions in 2025. Aviation emissions are expected to account for 8% in 2025.

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

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, Baja California gross GHG emissions continue to grow steadily, climbing to about 27.0 MMtCO_2e by 2025, 282% above 1990 levels. This equates to an annual rate of growth of 3.9% 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 transportation and electricity supply sectors. Table 3 summarizes the growth rates that drive the growth in the Baja California reference case projections, as well as the sources of these data.

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

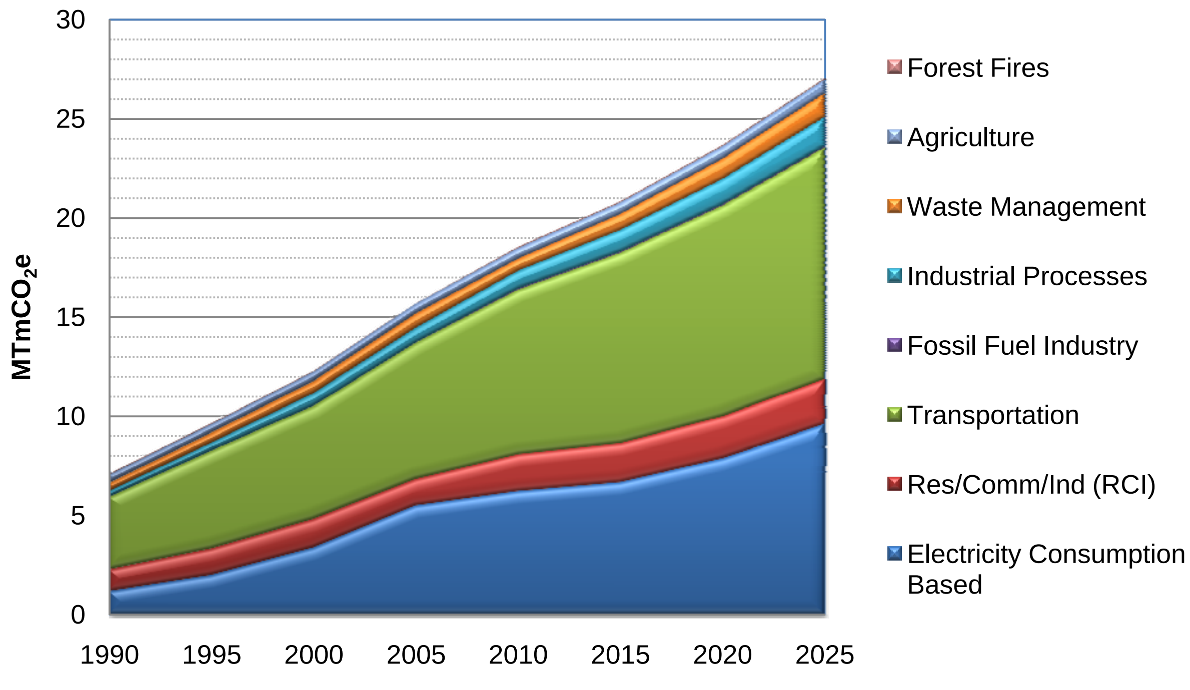
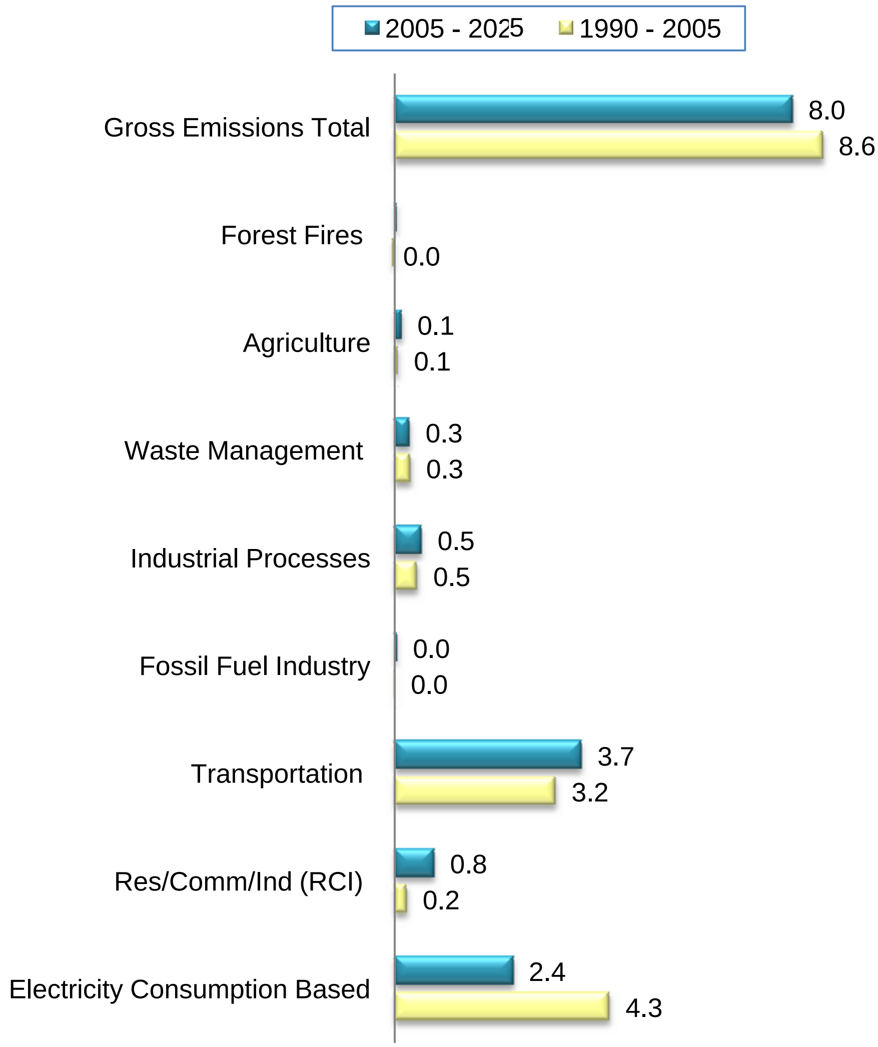


Figure 5. Sector Contributions to Gross Emissions Growth in Baja California, 1990-2025



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 Baja California, Historical and Projected

Activity Data	Rate Period	Mean Annual Rate (%)	Sources
Population	1990-2005 2005-2025	3.65 3.28	Historical population, INEGI Projected population, CONAPO
Electricity Demand	1990 - 2007 2008 - 2017	5.8 3.2	SENER: *Prospectiva del Sector Eléctrico 2008-2017*
Diesel	1990 - 2007	3.6	Sistema de Información Energética, PEMEX
Gasoline	1990 - 2007	5.7	Sistema de Información Energética, PEMEX
Jet Kerosene	1990 - 2006	2.8	Sistema de Información Energética, PEMEX
Vehicle Registration	1990 - 2004	10.6	INEGI. Estadísticas de vehículos de motor registrados en circulación
Livestock Population	1990 - 2005	-0.3	SIACON
Crop Production	1990 - 2005	8.0	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 net CO_2 flux for agricultural soils; and add net CO_2 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 Baja California with a general understanding of Baja California'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 Baja California.

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 Baja California 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[14] and its guidelines for States.[15] 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.[16]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.

[14] 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.
[15] PNUD, FMAM, INE. Manejo del Proceso de Elaboración del Inventario Nacional de Gases de Efecto Invernadero. http://www.ine.gob.mx/cpcc-estudios-cclimatico.
[16] 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 Baja California, 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 Baja California. 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 Baja California. 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 Baja California. This entails accounting for the electricity sources used by Baja California 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 Baja California, 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
- Appendix I. INE'S recommendations for the next GHG Emissions Inventories Update

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 over the 1990-2025 period associated with the generation of electricity supplied by Baja California's electric utility and distributed by the Comisión Federal de Electricidad (CFE) a. This Appendix also describes the data sources, key assumptions, and methodology used to develop an inventory of GHG emissions over the 1990-2007 period for the electric power sector in the state, 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 released by the electricity supply sector in Baja California rely heavily on historical and projected electricity generation and fuel use released 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 for all sectors in this report, consumption-based emission estimates are used.

The following topics are covered in this Appendix:

- *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 Baja California 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 Baja California 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 Baja California GHG inventory and forecast for the electric power sector.
- *Key uncertainties and future research needs:* this section reviews 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 Baja California 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.

Geothermal energy, considered a renewable resource, is a significant source for the generation of electricity in Baja California. While no specific guidance from the IPCC is available, some GHG emission inventories (including the California Air Resources Board 1990-2004 GHG Emissions Inventory and the USEPA 1990-2005 GHG Emissions Inventory) do include fugitive CO_2 emissions from geothermal energy electricity generation projects. CO_2 emissions from geothermal projects are site-specific and technology-dependent. The Climate Registry's Electric Power Sector Reporting Protocol provides guidance for estimating fugitive CO_2 emissions based on technology type (binary versus non-binary). Binary facilities do not emit CO_2, while the emission factor for non-binary plants is 90.7 kg CO_2/MWh.[17] Based on a lack of site-specific data on the geothermal project in Baja California, CCS chose not to include fugitive CO_2 emissions from electricity generation by geothermal sources in the GHG emissions inventory and reference case forecast for Baja California.

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. 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 emissions 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 Baja California power producers, while the consumption-based inventory includes emissions from imported electricity and excludes emissions from exported electricity. As Baja California is a net exporter of electricity in most years, the production-based inventory estimates are higher than the estimates for the consumption-based inventory. The consumption-based inventory and forecast assume some loss through transmission & distribution (T&D) and theft.

[17] The Climate Registry. "Electric Power Sector Protocol for the Voluntary Reporting Program." Version 1.0. June 2009. Available at: http://www.theclimateregistry.org/downloads/2009/05/Electric-Power-Sector-Protocol_v1.0.pdf

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 Baja California. 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 Baja California and other Mexican border states was provided by SENER;[18]
- *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.*[19] This report provides historical data dating back to 1996, as well as projected natural gas consumption in the electricity supply sector through 2017;
- *Planned electric 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;
- *State electricity generation data:* this information was obtained from the Instituto Nacional de Estadística y Geografía (INEGI), and a SENER publication titled *Electricity Sector Outlook 2008-2017*. INEGI provides historical sector-wide generation data for years 1990-2000. SENER provides historical data, by facility, for 2003-2007, 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;[20]
- *Energy content of petroleum products:* this information was obtained from México Federal Government, Ministry of Energy -- Secretaría de Energía (SENER) -- publications titled *Balance Nacional de Energía 2007* and previous editions;[21]
- *Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emission factors:* for all fuels, these emission factors were based on default values listed on Tables 2.2, 2.3, 2.4,

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[18] 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.
[19] SENER. 2009. "Prospectiva del Mercado de Gas Natural 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466
[20] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466
[21] SENER. 2008. "Balance Nacional de Energía 2007." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=48#prop2008

2.5, Chapter 2, Volume 2, of the 2006 Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories*;[22]

- *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.[23]

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 Baja California, 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 (combustion efficiency, carbon retained in slag and ash, etc.) may vary by a small amount based on the age and condition of the combustion unit. 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.[24] All imported electricity to Baja California is assumed to be generated using Natural Gas, as Natural Gas is the most common electricity generation fuel used in California.

[22] 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

[23] 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

[24] 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

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

Fuel Type	EF CO_2 (kg/TJ)	EF N_2O (kg/TJ)	EF CH_4 (kg/TJ)
Natural Gas	56,100	0.1	1
Fuel oil	77,400	0.6	3
Diesel Oil	77,400	0.6	3
Imports	56,100	0.1	1

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 Baja California from 1996 to 2008.[25] The second set of historic records detailed diesel oil and residual fuel oil consumption within the electricity supply sector in Baja California, expressed in Terajoules (TJ) for the period 1996 through 2008.[26] 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.[27] Imported flows of electricity to Baja California are through 9 interconnections existing between the U.S. and Mexico; these interconnections are managed by the Servicio Eléctrico Nacional (SEN) and the Western Electricity Coordinating Council (WECC).

The forecasts of GHG emissions from the electricity supply sector are based on official forecast estimates of electricity sales, official forecast estimates of natural gas combustion within the electricity supply sector, and information on planned additional generation capacity in Baja California. 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 Baja California electricity generation facilities to estimate the total electricity generated within the borders of Baja California from 1990 to 2007. The following steps were taken 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 Baja California.

<u>Electricity generation</u>: the generation of electricity at Baja California electricity generation facilities is reported by INEGI, and in SENER's *Electricity Sector Outlook 2008-2017*

[25] SENER. 2009. "Prospectiva del Mercado de Gas Natural 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466
[26] 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.
[27] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466

and previous editions.[28] The total generation for 1990-2000 is available from INEGI. The fuel-specific generation is found by using the 2003 ratios of fuel-specific generation to total generation. Generation totals for 2001 and 2002 are interpolated from the 2000 and 2003 estimates. From the SENER 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, two combined cycle plants (Presidente Juarez and Mexicali) generated 46% of the state's gross electricity production using natural gas; 5% from residual fuel oil; 1% from diesel oil; 2% of electricity was imported from the U.S. from power marketer Coral Power L.L.C., San Diego Gas & Electric, and Sempra Energy Solutions.[29] The remaining 46% of the state's electricity comes from a renewable energy geothermal plant (Cerro Prieto). Summaries of the 2007 data are displayed in Table A-2 and Figure A-1. Figure A-2 is a representation of the generation at these facilities from 2003 to 2007.

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

Plant name	Generator type	Fuel type	Rated capacity (MW)	Generation (GWh)	Fuel consumption (TJ)
Presidente Juarez (Rosarito)	CT	Fuel oil	320	621	263
Presidente Juarez (Rosarito)	CC	Natural gas	496	3,100	58,132
Presidente Juarez (Tijuana)	GT	Diesel oil	210	132	219
Cerro Prieto (I, II, III)	GEO	N/A	720	5,592	N/A
Mexicali (PIE)	CC	Natural gas	489	2,428	45,530

CT: conventional thermoelectric, CC: combined cycle, GT: gas turbine, GEO: geothermal-electric

[28] 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.
[29] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466

Figure A-1. Share of Gross Electricity Generation by Fuel Type, 2007

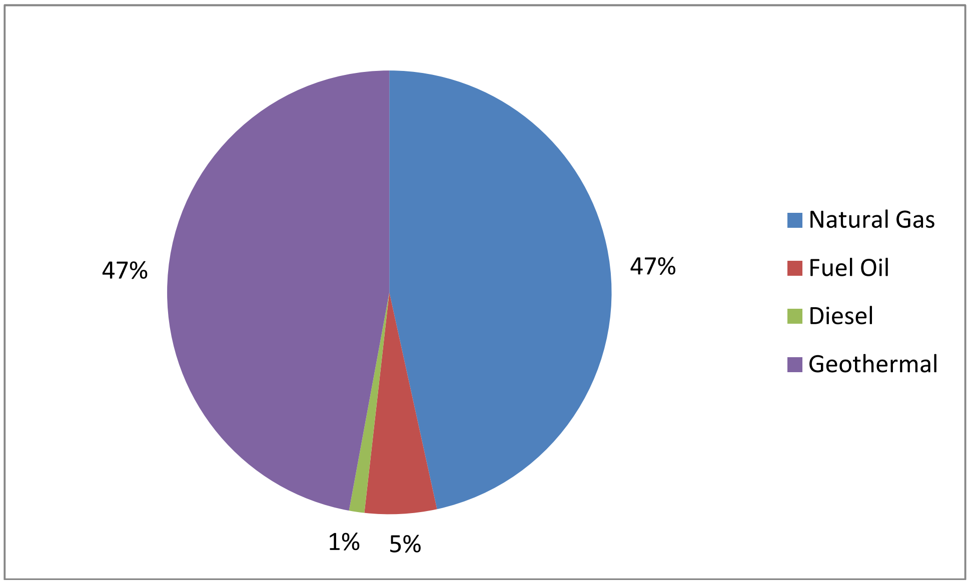
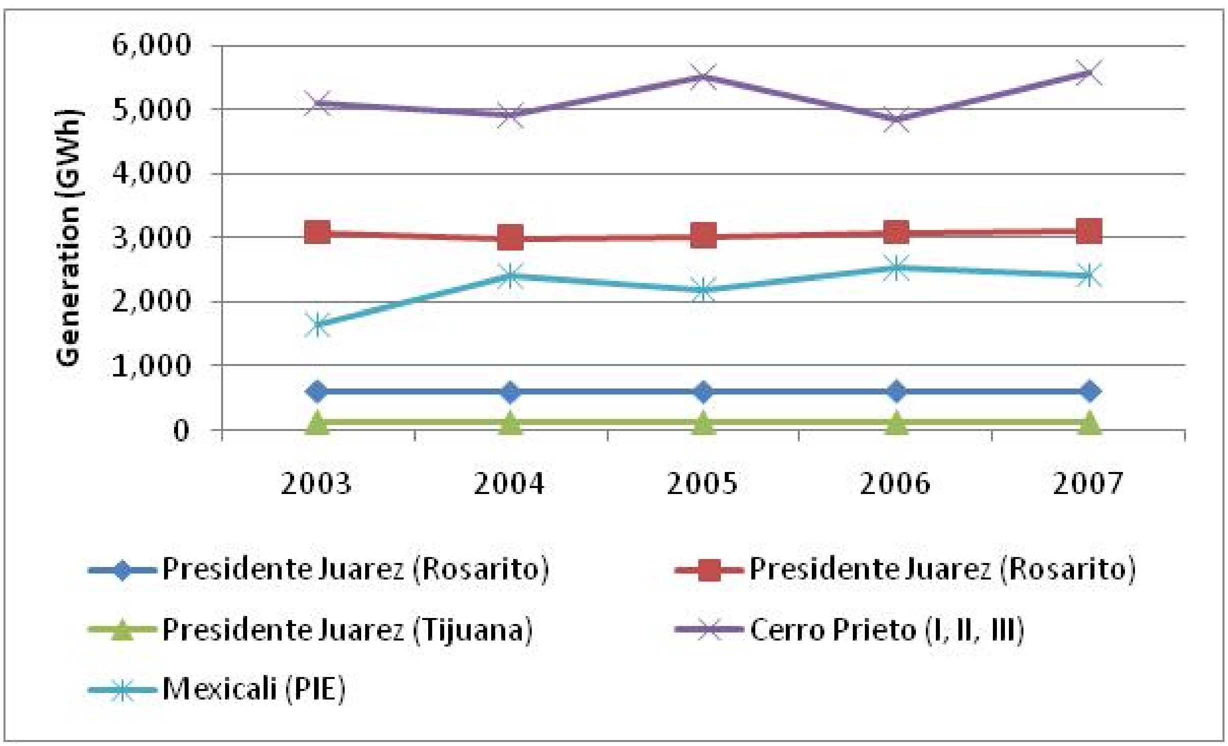


Figure A-2. Electricty Generation by Plant, 2003-2007



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*.[30] The historical data in these reports show that there was no natural gas combusted in the electricity supply sector prior to 2000. Therefore, back-casting of these data was unnecessary. 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 Baja California. The consumption data for residual fuel oil and diesel oil for the years 1996 through 2008 were provided directly to CCS by SENER.[31] 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*.[32] The fuel consumption values for residual fuel oil were back-cast for the years 1990 to 1995 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: geothermal energy provides a significant source of renewable energy for electricity generation in Baja California. SENER's *Electricity Sector Outlook 2008-2017* and previous editions provide the total amount of electricity generated from geothermal energy in Baja California for the years 1993 through 2007. The electricity generation for the years 1990 through 1992 was assumed to equal the generation in 1993.

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.[33] The 2008 through 2017 average annual increase of 3.7% was applied for each year after 2018.

[30] SENER. 2008. "Balance Nacional de Energía 2007." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=48#prop2008
[31] 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.
[32] SENER. 2008. "Balance Nacional de Energía 2007." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=48#prop2008
[33] SENER. 2009. "Prospectiva del Mercado de Gas Natural 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466

However, based on the available and planned capacity (shown in Table A-3),[34] it is evident that there will not be sufficient capacity to increase natural gas consumption after 2021. Therefore, natural gas consumption in the electricity supply sector for 2022 through 2025 is assumed to grow on a constrained basis due to the installed natural gas generation capacity. The resulting average annual increase from 2022 through 2025 is 1.7%. 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.

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.[35] In 2008, it was reported that zero residual fuel oil was burned in the electricity supply sector. Prior to 2008, there was residual fuel oil used at the Presidente Juarez Rosarito facility's combustion turbine. Based on SENER data that show zero residual fuel oil combustion for the electricity supply sector in 2008, it is assumed that this combustion turbine was decommissioned in 2008. According to the *Electricity Sector Outlook*, the Rosarito facility will begin operating a 93 MW combined cycle natural gas generator in 2011. There are no reported changes to diesel fuel capacity. Therefore, CCS assumed that the amount of diesel fuel burned in 2008 will stay constant through 2025. The heat rate for diesel fuel in 2007 from the historic GHG inventory is used to estimate generation for 2008 through 2025.

Table A-3. Planned Natural Gas Capacity Additions and Assumed Characteristics[36]

Plant Type	Year	Capacity (MW)	Gross Efficiency	Capacity Factor	Own-Use	Heat Rate (TJ/GWh)	Estimated Generation (GWh)
Gas Turbine	2009	124	39.4%	0.125	1.5%	9.27	134
Combined Cycle	2009	277	51.4%	0.8	2.9%	7.21	1,885
Conversion (CT to CC)	2011	93	51.4%	0.8	2.9%	7.21	633
Combined Cycle	2012	280	51.4%	0.8	2.9%	7.21	1,905
Combined Cycle	2016	280	51.4%	0.8	2.9%	7.21	1,905

[34] Table displays planned added capacity, as well as assumed generation, based on typical power plant characteristics. Capacity data and characteristic assumptions taken from: SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466.
[35] 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.
[36] SENER. 2009. "Prospectiva del Sector Eléctrico 2008-2017." Available at: http://www.sener.gob.mx/webSener/portal/index.jsp?id=466.

Renewable energy: the projection of electricity generated at the geothermal facility in Baja California is reported for 2008 through 2017 by SENER's *Electricity Sector Outlook 2008-2017*.[37] In 2011, one unit with a rated capacity of 107 MW will be added at the Cerro Prieto geothermal power plant, while one unit at Cerro Prieto with a rated capacity of 93 MW will be taken off-line in 2011. This net increase in capacity in 2011 is believed to provide sufficient capacity to meet the electricity generation projections presented in SENER's *Electricity Sector Outlook 2008-2017.* It is assumed that the annual electricity generated at the geothermal facility for 2018 through 2025 is equal to the generation total for the year 2017.

The *Electricity Sector Outlook* report also states that the interconnection with the United States will be terminated in 2013. At the same time, over the coming years, Baja California will open up transmission with Sonora. However, since the amount of electricity generated in Baja California is far greater than the electricity sold over these years, it is assumed that after 2013, Baja California will not import electricity via this new transmission, using this connection solely to export electricity to other states in Mexico. Although it is unlikely that this assumption will hold completely true and zero electricity will be imported after 2013 from other Mexican states, a lack of projections on exports and imports from SENER make it necessary to assess imports and exports on a "net" basis, which – in the case of Baja California – indicates that there will be a net exportation of electricity throughout the forecast period.

Table A-4 and Figure A-3 display the fossil fuel consumption by fuel type over the historic inventory and reference case forecast periods (1990-2025). Geothermal-derived electricity is not included in these visuals, as these are just the fossil-based energy sources used to generate electricity. Table A-5 and Figure A-4 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 Baja California during the 2000 to 2005 period, while the amount of electricity generated through geothermal energy remains roughly constant throughout the entire inventory and forecast period.

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

Table A-4. Production-based Inventory and Forecast – Fossil Fuel Consumption (TJ)

Year	Natural gas	Fuel oil	Diesel oil	Total Production
1990	0	21,696	176	21,871
1995	0	31,476	236	31,712
2000	11,221	25,347	2,800	39,368
2005	102,323	2,605	115	105,043
2010	122,268	0	104	122,372
2015	137,511	0	104	137,615
2020	157,797	0	104	157,901
2025	172,559	0	104	172,663

Figure A-3. Production-based Inventory and Forecast – Fossil Fuel Consumption

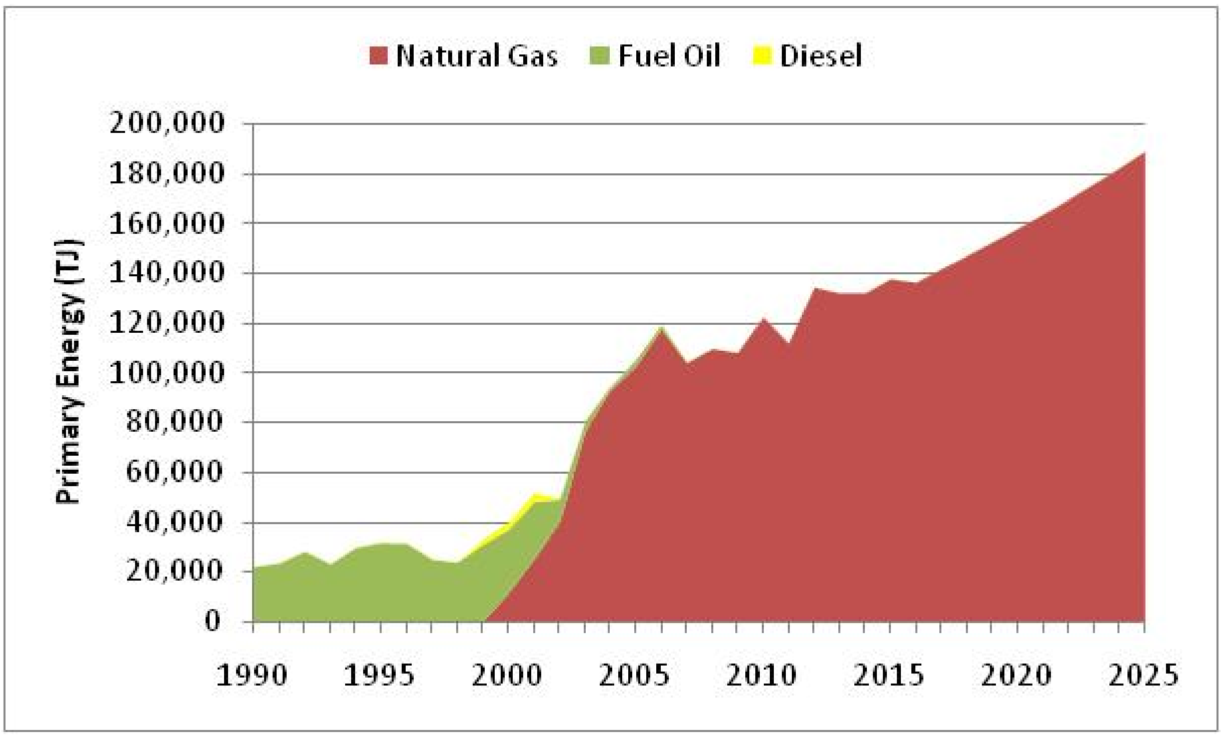
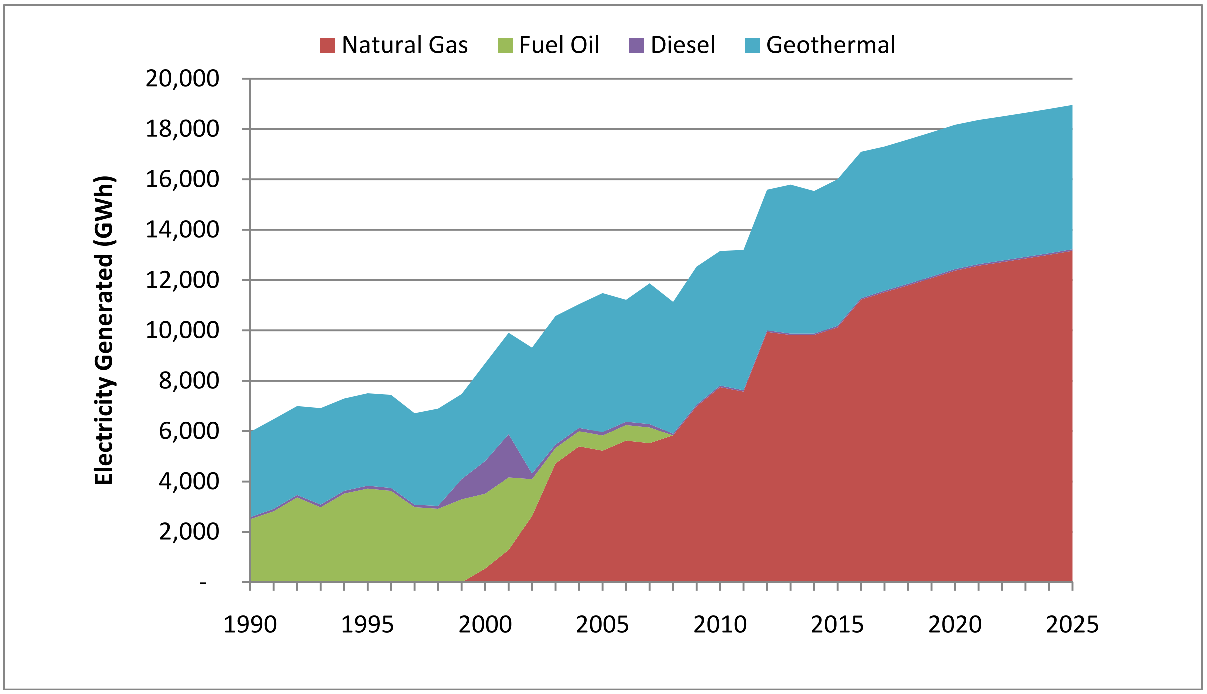


Table A-5. Production-based Inventory and Forecast – Electricity Generation (GWh)

Year	Natural gas	Fuel oil	Diesel oil	Geothermal	Total Production
1990	0	2,506	80	3,387	5,973
1995	0	3,722	110	3,673	7,505
2000	543	2,971	1,299	3,885	8,697
2005	5,225	608	129	5,521	11,483
2010	7,748	0	62	5,347	13,157
2015	10,122	0	62	5,817	16,002
2020	12,377	0	62	5,730	18,169
2025	13,164	0	62	5,730	18,956

Figure A-4. Total Electricity Generation – by Fuel Type: 1990 - 2025



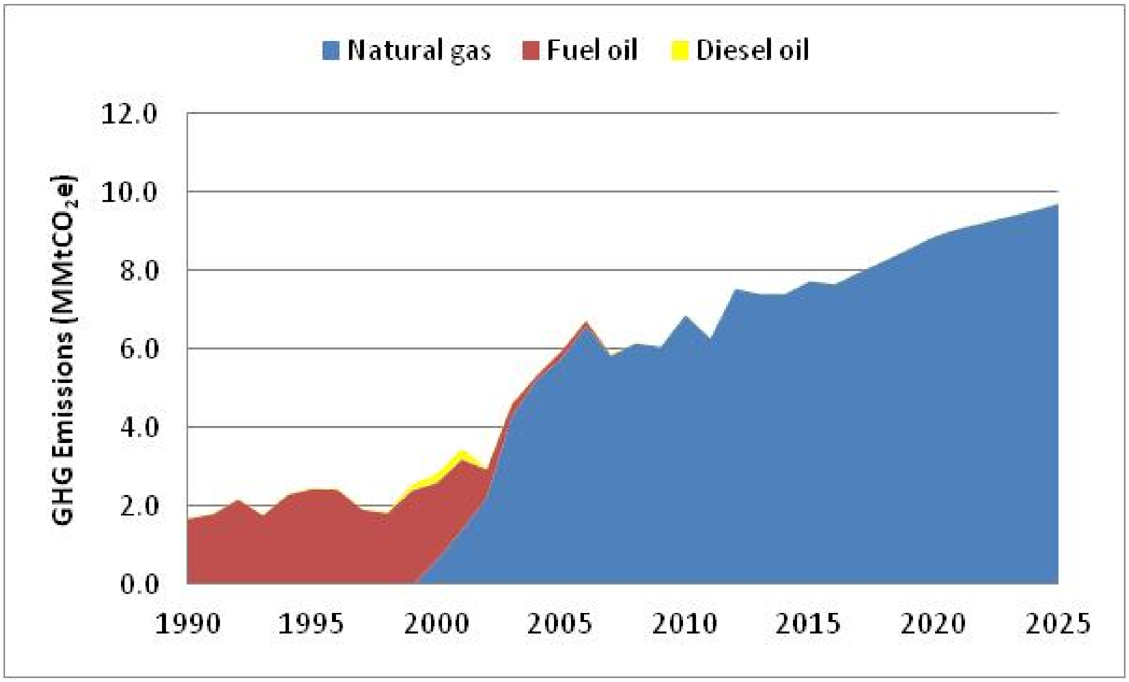
Production-based Inventory and Reference Case Forecast Results

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-6 and Figure A-5. 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-6. Production-based GHG Emissions from the Electricity Supply Sector ($MMtCO_2e$)

Year	Natural gas	Fuel oil	Diesel oil	Total Production-based Emissions
1990	0.00	1.68	0.01	1.70
1995	0.00	2.44	0.02	2.46
2000	0.63	1.97	0.21	2.81
2005	5.75	0.20	0.01	5.96
2010	6.87	0.00	0.01	6.87
2015	7.72	0.00	0.01	7.73
2020	8.86	0.00	0.01	8.87
2025	9.69	0.00	0.01	9.70

Figure A-5. 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 Baja California, including emissions from imported electricity, but excluding emissions from electricity produced in, but exported from, the state.

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

The consumption-based inventory is primarily based on electricity sales data reported by INEGI, and in SENER's *Electricity Sector Outlook 2008-2017* and previous editions.[38] 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.

The amount of electricity imported for the years 1993 through 2007 was reported by SENER's *Electricity Sector Outlook* reports. It was assumed that imported electricity was generated using natural gas. As this generation took place in the United States, the average heat rate for natural gas – as reported by the U.S. Environmental Protection Agency – was used to calculate the energy content of the fuel used to generate the imported electricity.[39] Baja California also exports a significant amount of electricity (nearly 2,000 GWh in some years) to the United States. The amount of electricity exported in the historical inventory is also reported by SENER's *Electricity Sector Outlook* reports.

There are significant losses of electricity due to T&D loss and theft. While a small amount (8% to 10%) of loss from T&D is normal, a scholarly report from Rice University in Houston, TX claims that total loss for the national electricity system in Mexico may exceed 25%.[40] Data from CFE provided to CCS indicates annual loss rates around 10% for the CFE region (all of Mexico other than Mexico City). For the inventory period, electricity loss was estimated by subtracting electricity sales and electricity exports from total production. This method yields loss rates generally between 10% and 20%.

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.

Consumption -based Reference Case Forecast Methodology

The consumption-based forecast is driven by the expected change in electricity consumption in Baja California. The electricity consumption for Mexico's Northwest region is projected by SENER's *Electricity Sector Outlook 2008-2017*. The electricity consumption for Baja California is indexed to the projection of the Northwest region for the years 2008 through 2017. The average annual increase of 3.4% 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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[38] 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.
[39] U.S. EPA. 2006. "National Electric Energy Data System (NEEDS) 2006 Base Case." Section 3: Power System Operations Assumptions. Available at: http://epa.gov/airmarkt/progsregs/epa-ipm/docs/Section-3.pdf.
[40] 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 Baja California were not available. Therefore, it was necessary to make an assumption regarding total production levels or assuming electricity export demands 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 average annual loss in the CFE from 2000-2009, which was 10.6%. This loss rate is assumed to remain constant through 2025. Equation A-1 was used to estimate the amount of electricity exported each year over that period. Emissions from exports and loss are estimated by multiplying the ratio of fuel-specific consumption to total fuel consumption for each year (as generated by the production-based forecast) by the total fossil energy used to generate exported or lost electricity.

Table A-7 and Figure A-6 display the disposition of electrical power in the State; including in-state consumption, imports, loss, and exports. Figure A-7 shows the primary energy consumption through the historic inventory and reference case forecast period that was used to calculate the GHG emissions estimates.

Table A-7. State-Wide Electrical Power Disposition (GWh)

	Consumption-based Inventory			
Year	Total In-State Consumption	Import	Loss	Export
1990	3,538	44	484	1,995
1995	4,081	228	1,733	1,920
2000	7,522	927	2,036	66
2005	8,496	75	2,025	1,037
2010	10,440	0	1,403	1,314
2015	12,025	0	1,707	2,270
2020	14,111	0	1,938	2,120
2025	16,679	0	2,022	255

Figure A-6. State-Wide Electrical Power Disposition

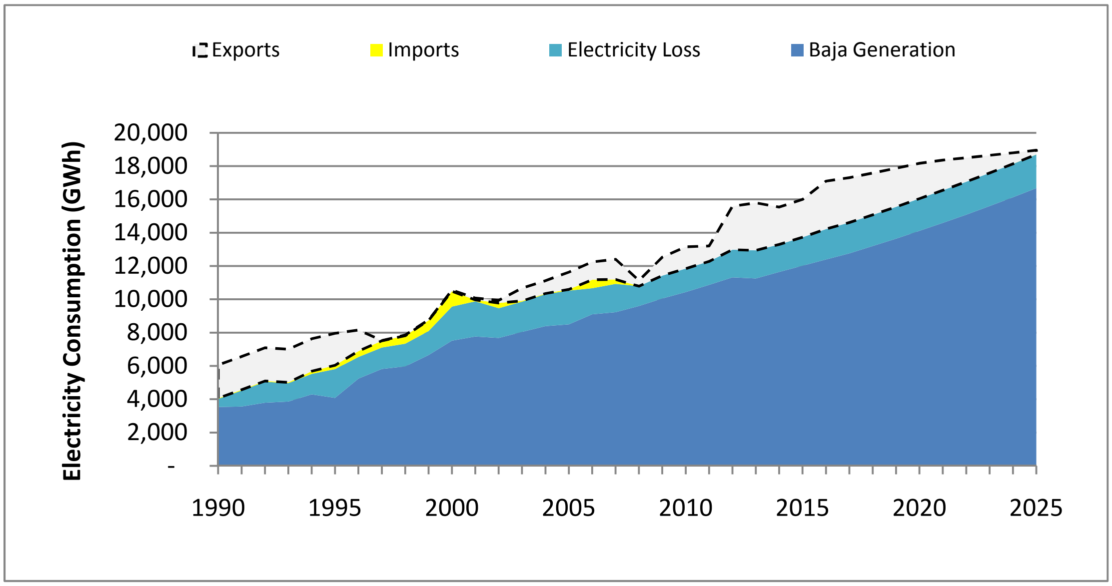
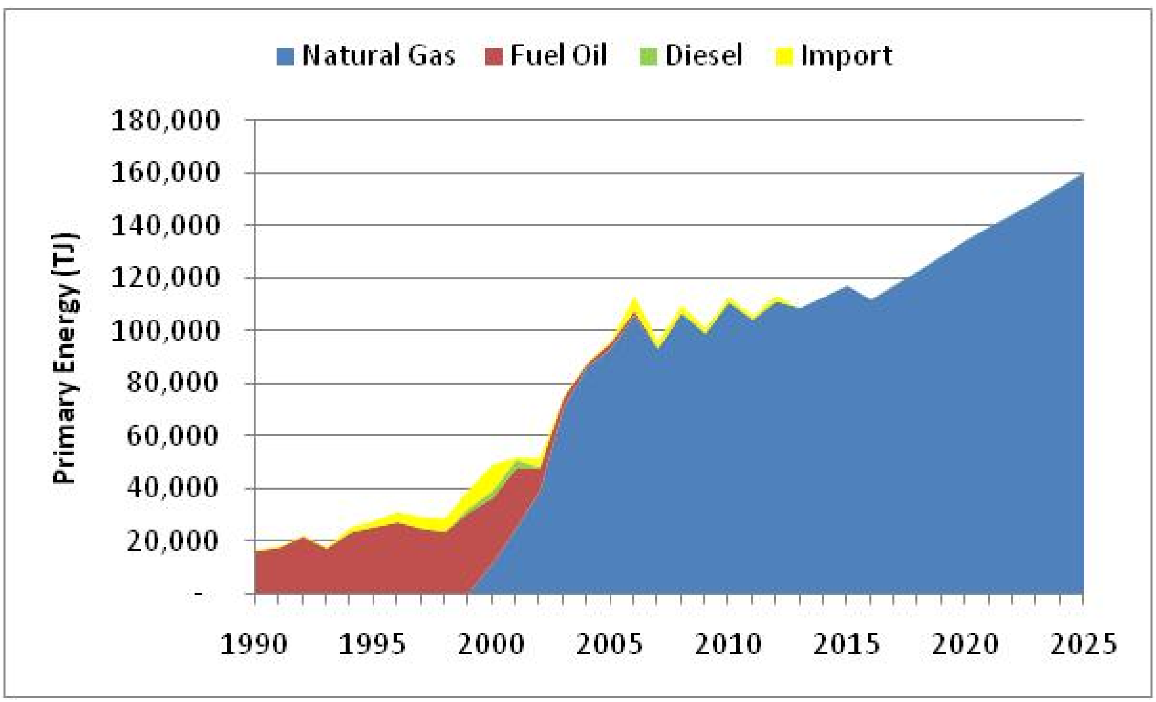


Figure A-7. Consumption-based Inventory and Forecast – Fossil Energy Use



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-8 and Figure A-8. Figure A-8 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-8. Figure A-9 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 Baja California.

Table A-8. Total GHG Emissions Associated with Electricity Consumption ($MMtCO_2e$)

Year	Baja Consumption	Imports	Loss	Total Consumption-based Emissions	Exports
1990	0.76	1.25	0.50	1.29	0.44
1995	0.99	1.95	0.97	2.10	0.50
2000	1.66	1.96	1.13	3.35	0.02
2005	4.37	0.18	1.05	5.46	0.54
2010	5.36	0.00	0.88	6.35	0.63
2015	5.81	0.00	0.79	6.60	1.13
2020	6.89	0.00	0.67	7.56	1.31
2025	8.53	0.00	0.48	9.02	0.68

Figure A-8. Total Consumption-Based Electricity Supply GHG Emissions

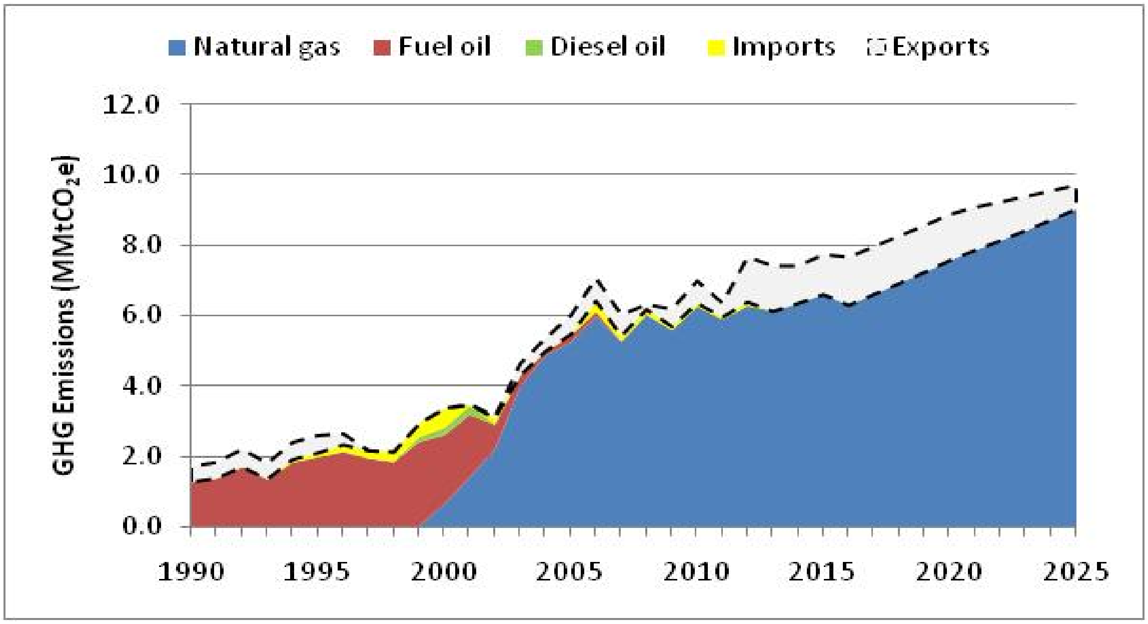
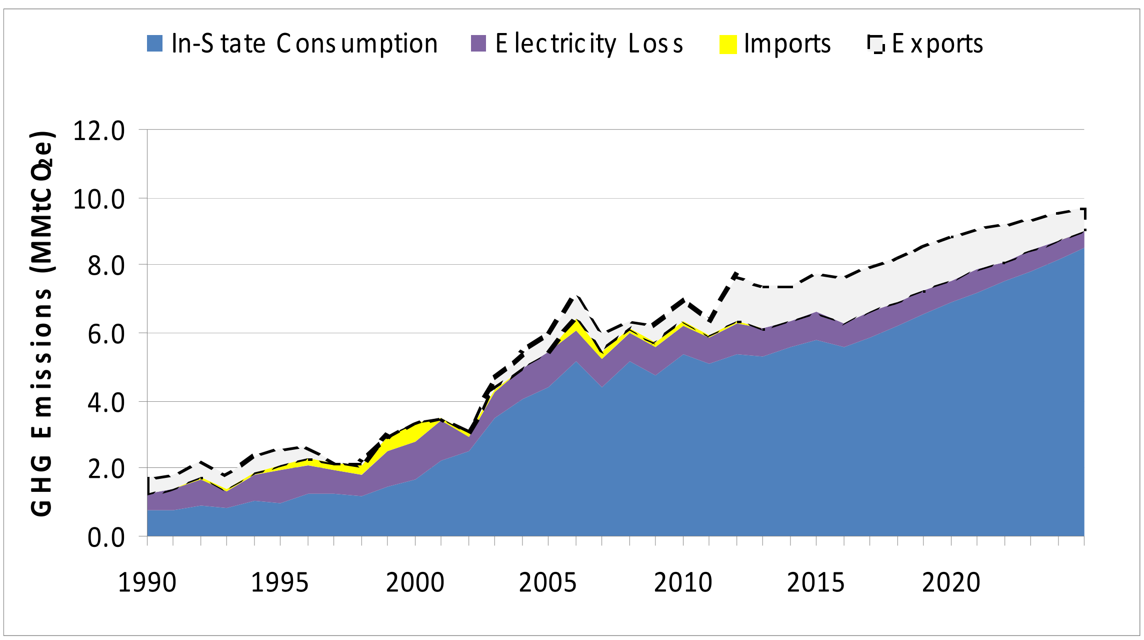


Figure A-9. Consumption-based Electricity Supply GHG Emissions – by Component



Key Uncertainties and Future Research Needs

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

- The 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 Baja California and the U.S. or another Mexican state. The forecasted 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 Baja California.
- The INEGI dataset only provided total gross generation for 1990-2000. CCS estimated the fuel-specific generation by assuming a constant ratio of generation based on previous estimates for this time period that used average heat rates from 2003-2007 to estimate generation. Thus, there is uncertainty in the fuel-specific generation rates for 1990-2002. However, these assumptions do not have an impact on the GHG emission results, as the emission calculations are based on fuel consumption (TJ).
- Population and economic growth are the principal drivers for fuel use. The reference case projections are based on the estimates of electric generation requirements and reported by SENER's *Electricity Sector Outlook* reports. Alternatively, an Autoregressive Integrated Moving Average (ARIMA) model may be used to develop forecast scenarios based on historical data series, where recent years weigh more heavily than past years. The ARIMA model is a combination of an autoregressive model (based on past values), and a moving average model (based on past errors), that can determine an energy growth trend.
- Electricity on-site usage and T&D loss estimates were used to convert gross generation in the forecast to sales to meet the state demand. The on-site usage and transmission and distribution loss estimates are calculated based on reported gross generation, in-state electricity sales, and electricity imports and exports. Improvements to these estimates could help to get more accurate emissions associated with imported electricity.
- 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 Baja California power generators. Key among these is whether geothermal production of power emits fugitive CO_2 that should be added to these preliminary estimates.
- 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 Baja California.

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

Overview

Activities in the RCI[41] sectors 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, coal, and wood were 1.4 $MMtCO_2e$ of which 54% was emitted by industrial sources, 34% by residential sources, and 12% 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.[42]

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.[43] 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

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[41] 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.

[42] 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

[43] 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.[44] 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.[45] 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
	Agriculture - Liquefied Petroleum Gases	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, was obtained directly from SENER.[46] 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 (2.7%) from the 1994-2009 SENER dataset and applying that to the years 2010-2025. The growth rates applied for this

[44] 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

[45] 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.

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

fuel and all the other fuels in the sector are summarized in Table B-2.

Residual Fuel Oil
For each year from 1990-2007, residual fuel oil consumption in the RCI sector was estimated by subtracting state electricity sector annual fuel oil sales from state total annual fuel oil sales.[47] Forecast values were derived by calculating the mean annual growth rate (-2.1%) for 2003-2006 and applying that to the years 2008-2025.

Table B-2. Growth Rates used in RCI Forecast

Source	Fuel Type	Growth Rate
Commercial	Liquefied Petroleum Gases	2.5%
Industrial	Diesel Oil	2.7%
	Liquefied Petroleum Gases	3.0%
	Liquefied Petroleum Gases - Agriculture	2.1%
	Natural Gas	1.2%
	Residual Fuel Oil	-2.1%
Residential	Liquefied Petroleum Gases	0.6%
	Natural Gas	1.9%
	Solid Biofuels: Wood	2.9%

Liquefied Petroleum Gas
State consumption of liquefied petroleum gas (LPG) and forecast consumption were obtained from SENER.[48] 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 state consumption 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 0.6%; industrial, 3.0%; and commercial, 2.5%.

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 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

[47] SIE - productos petrolíferos.
[48] 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.

consumption by vehicles (tractors, trailers, etc.) is captured under Transportation: Road/Diesel (see Appendix C).

Natural Gas

State consumption of natural gas and forecast consumption data were obtained from SENER.[49] 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.[50] 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 1.2%. For residential, commercial, and transportation this is 1.9%. In Baja California the industrial subsector dominates natural gas consumption. The reported consumption from residential, commercial, and transportation is only 3% 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 (0.7%). SENER provided the average annual wood fuel use for one person for 1996 and 2006 (in natural gas equivalents).[51] 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 average annual wood fuel use. Forecast values were derived by calculating the mean annual growth rate (2.9%) 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 20,372 terajoules (TJ) in 2005. Energy consumption values are shown in Table B-3.

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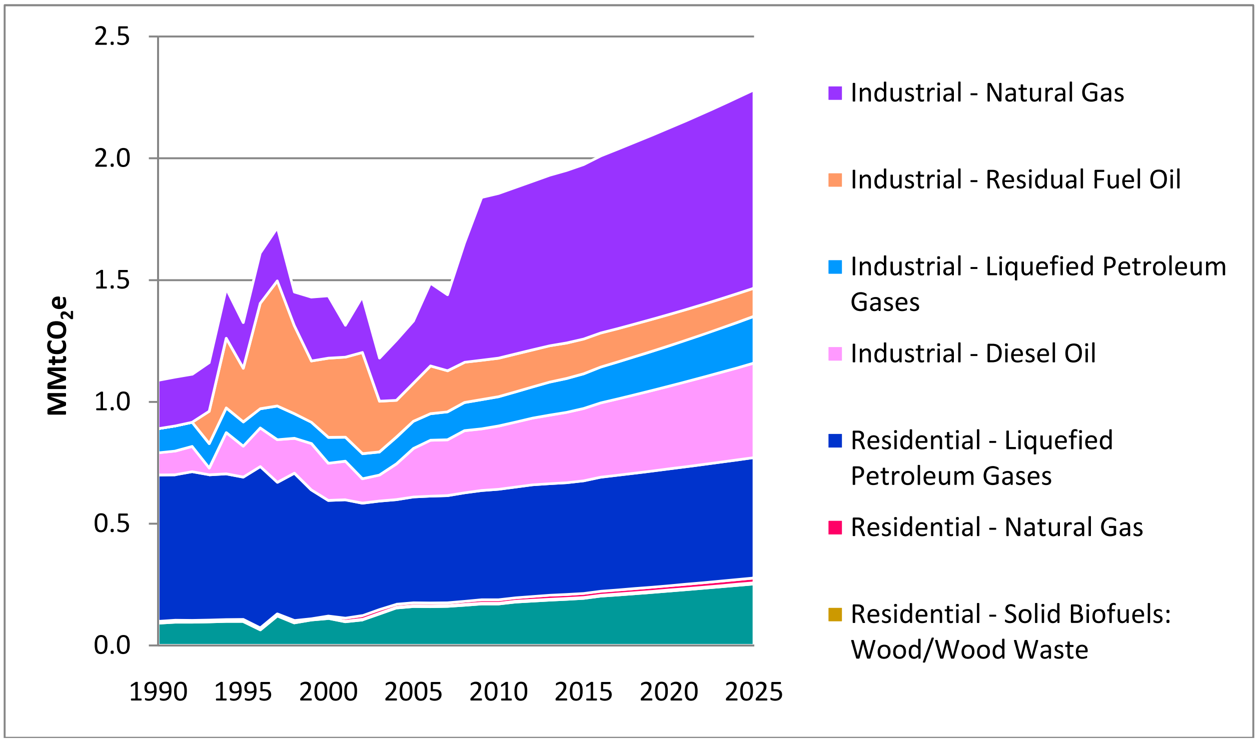
[49] SENER: *Prospectiva del Mercado de Gas Natural 2007-2016* and *Prospectiva del Mercado de Gas LP 2008-2017*. Accessed from http://www.sener.gob.mx/webSener/index.jsp.
[50] SENER: *Prospectiva del Mercado de Gas Natural 2007-2016* and *Prospectiva del Mercado de Gas LP 2008-2017*. Accessed from http://www.sener.gob.mx/webSener/index.jsp.
[51] 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	1,413	1,520	1,712	2,469
Industrial	Diesel Oil	1,215	1,690	2,035	2,657
	Liquefied Petroleum Gases	1,056	1,073	1,189	1,372
	Liquefied Petroleum Gases - Agriculture	498	487	476	384
	Natural Gas	3,523	3,324	4,541	4,533
	Residual Fuel Oil	0	2,812	4,150	1,989
Residential	Liquefied Petroleum Gases	9,289	9,038	7,339	6,723
	Natural Gas	78	131	131	216
	Solid Biofuels: Wood	19	24	27	29
Total		**17,114**	**20,077**	**21,599**	**20,372**

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 1.3 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) of which 55% is associated with fuel combustion in the industrial subsector, 33% is from the residential subsector, and 12% is from the commercial subsector. In 2005, residential LPG consumption accounted for 32% of total RCI energy use, followed by industrial natural gas consumption (20%) and industrial consumption of diesel (15%).

Figure B-1. GHG Emissions in RCI Sector



By 2025, total RCI GHG emissions are projected at 2.3 $MMtCO_2e$ of which 67% are from industrial fuel combustion, 23% are from residential fuel combustion, and 11% are from commercial fuel combustion. Overall, RCI emissions are driven by the combustion of natural gas and diesel fuel in the industrial subsector and by LPG in the residential subsector. The combustion of LPG in the commercial subsector and LPG and residual fuel oil in the industrial subsector also represent large contributors to GHG emissions in this sector. 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	0.09	0.10	0.11	0.16	0.17	0.19	0.22	0.25
Industrial	Diesel Oil	0.09	0.13	0.15	0.20	0.26	0.30	0.34	0.39
	Liquefied Petroleum Gases	0.07	0.07	0.08	0.09	0.09	0.11	0.13	0.16
	Agriculture - Liquefied Petroleum Gases	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.04
	Natural Gas	0.20	0.19	0.26	0.26	0.68	0.72	0.77	0.81
	Residual Fuel Oil	0.00	0.22	0.33	0.16	0.16	0.14	0.13	0.12
Residential	Liquefied Petroleum Gases	0.60	0.58	0.47	0.43	0.45	0.46	0.48	0.49
	Natural Gas	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
	Solid Biofuels: Wood	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.005
Total		**1.09**	**1.33**	**1.44**	**1.33**	**1.86**	**1.97**	**2.12**	**2.28**

Table B-5. GHG Emissions Distribution in RCI Sector

Source	Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Commercial	Liquefied Petroleum Gases	8%	7%	8%	12%	9%	10%	10%	11%
Industrial	Diesel Oil	8%	10%	11%	15%	14%	15%	16%	17%
	Liquefied Petroleum Gases	6%	5%	5%	7%	5%	6%	6%	7%
	Agriculture - Liquefied Petroleum Gases	3%	2%	2%	2%	2%	2%	1%	2%
	Natural Gas	18%	14%	18%	20%	37%	37%	36%	36%
	Residual Fuel Oil	0%	17%	23%	12%	9%	7%	6%	5%
Residential	Liquefied Petroleum Gases	55%	44%	33%	32%	24%	23%	23%	21%
	Natural Gas	0.9%	0.8%	0.7%	0.8%	0.5%	1%	0.9%	0.9%
	Solid Biofuels: Wood	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%

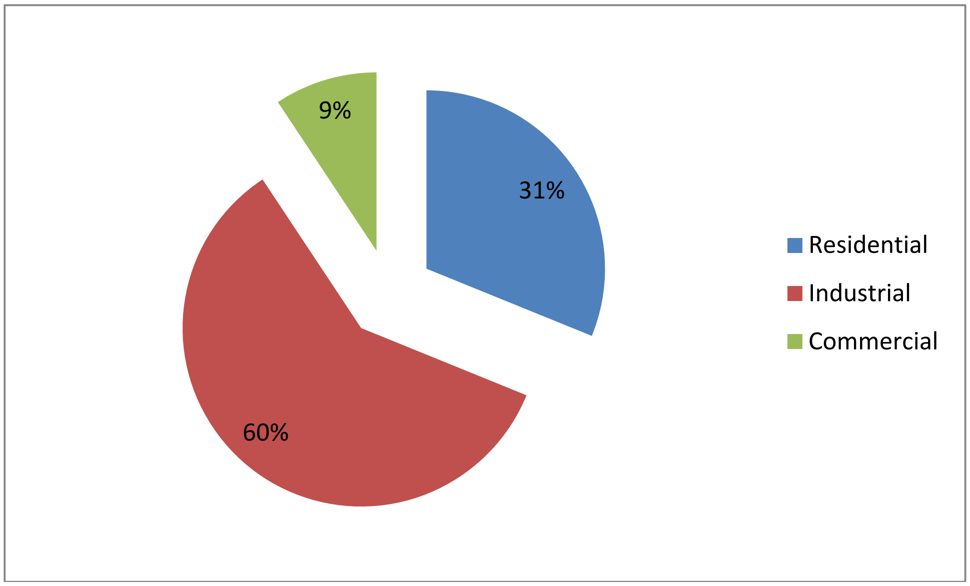
Table B-6 shows historic growth rates for electricity sales by RCI sector. The proportion of each RCI sector's sales to total sales was used to allocate emissions associated within the electricity supply sector to each of the RCI sectors. These emissions are not accounted for in this sector, but in the electricity supply sector. Figure B-2 illustrates the 2005 breakdown of electricity sales by RCI sub-sector.

Table B-6. Historical Electricity Sales Annual Growth Rates

Sector	1990-2005*
Residential	4.7%
Commercial	1.5%
Industrial	8.5%
Total	**6.0%**

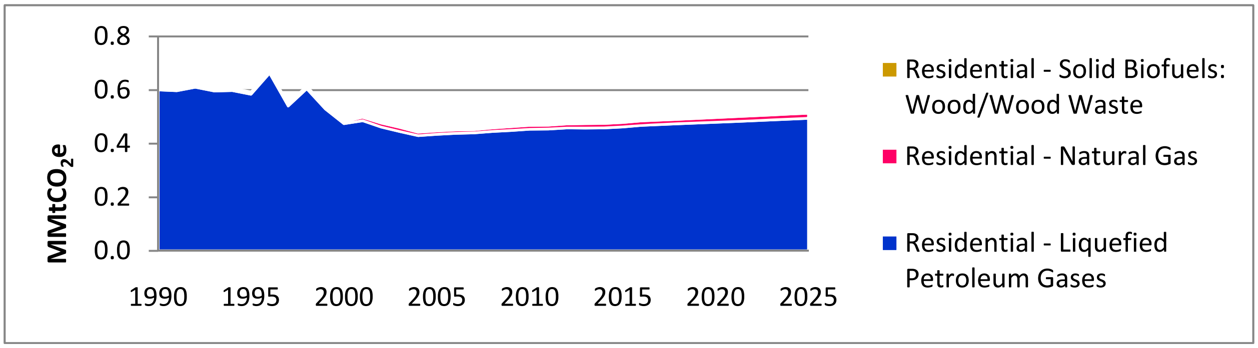
* 1990-2005 compound annual growth rates calculated from electricity sales by year from SENER.

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



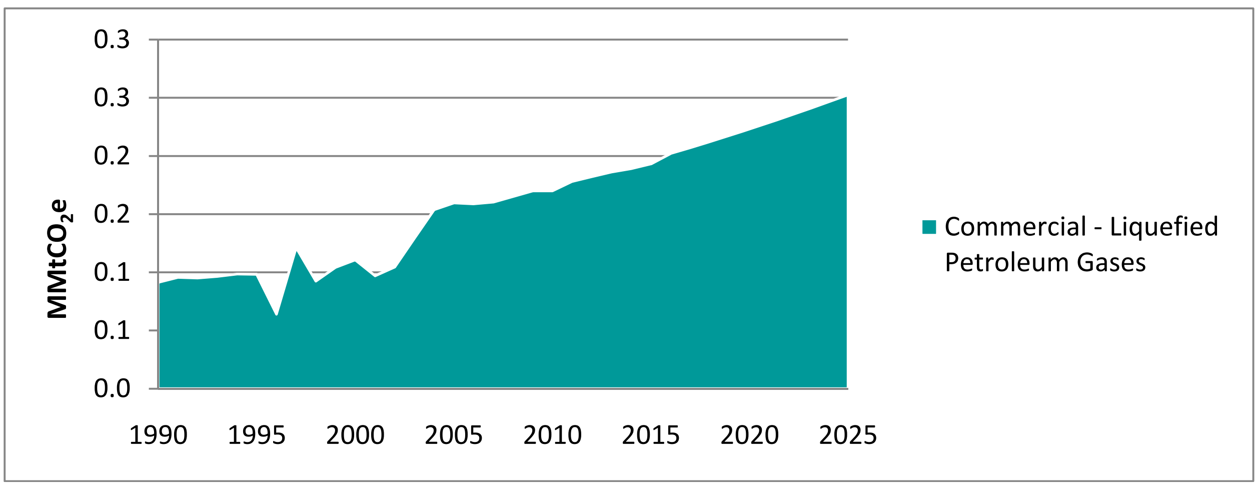
RCI emissions from residential sources were driven by the combustion of LPG, which represented 97% of total residential emissions in 2005. Emissions relating to the combustion of wood fuels and natural gas represented 2.3% and 0.7% of the total, respectively. Historical and projected residential GHG emission trends are shown in Figure B-3. It is unclear why emissions declined for 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 15%, or about_0.7% per year. Emissions growth is driven by residential combustion of LPG while emissions associated with residential natural gas and wood combustion are estimated to grow only slightly above 2005 levels.

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



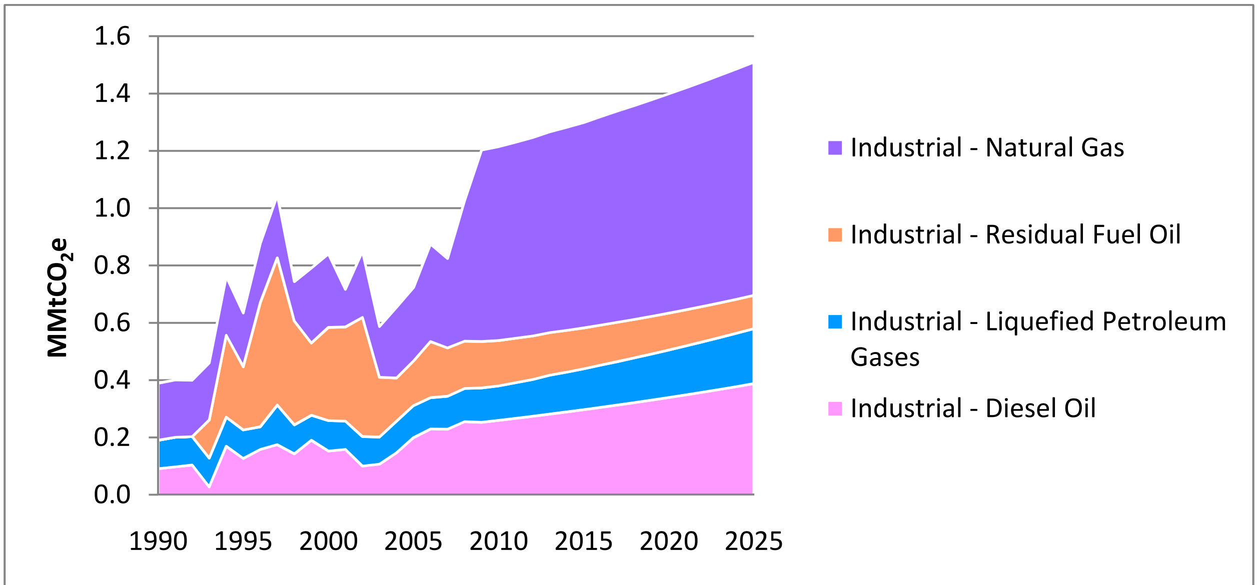
Emissions from commercial sources amounted to 0.2 $MMtCO_2e$ in 2005 and were driven by the combustion of LPG, which is associated with stoves. It seems plausible that the restaurant business utilizes LPG in significant quantities. If that is the case, then emissions values for the commercial sector 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 58%, or about 2.3% per year.

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



Emissions from industrial sources were driven by the combustion of natural gas (36%) followed by diesel oil (27%) and residual fuel oil (22%). The contribution of LPG combustion to total emissions was about 12%. Historical and projected industrial GHG emission trends are shown in Figure B-5. 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. From 2005 through 2025, industrial emissions are estimated to increase by 109%, or about 3.8% per year. Natural gas consumption forecasts were based on SENER projections (see Emissions and Reference Case Projections). SENER projects large growth in the industrial consumption of natural gas: hence the large increase in natural gas consumption in Figure B-4. Forecasts based on historical consumption would be lower (see additional information under Key Uncertainties).

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 Baja California 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.

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.

Other forecasts were based strictly on SENER projections (LPG and natural gas). SENER projects large growth in industrial consumption of natural gas. The historical industrial natural gas consumption from 1990-2005 had a 1.7% annual growth rate. If the reference case forecasts had been based on historical trends rather than SENER projections then the 2025 consumption would be approximately 25% lower. Some of the uncertainty in the forecast can be attributed to differences in projection rates.

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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). Carbon dioxide accounts for approximately 97% of greenhouse gas emissions followed by nitrous oxide (2.5%) and methane (0.5%) emissions on a carbon dioxide equivalent 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)[52]

$_a$ = 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 Baja California's Secretaría de Energía (SENER) for each year.[53] Because of limited information on marine vessel and rail diesel consumption, national data were allocated to Baja California for these sources. Marine diesel was allocated based on the proportion of marine freight tonnage at Baja California ports. Rail diesel was allocated based on the proportion of total national rail line length in Baja California. Table C-1 lists all transportation sources and their corresponding

[52] 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
[53] Sistema de Información Energética, con información de Petróleos Mexicanos, http://sie.energia.gob.mx/sie/bdiController.

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 Baja California: fuel consumption, 1990-2007	Secretaría de Energía: Sistema de Información Energética, with information from Petróleos Mexicanos.
Road Transportation - Diesel	State of Baja California: fuel consumption, 1990-2007	Secretaría de Energía: Sistema de Información Energética, with information from Petróleos Mexicanos.
Road Transportation - LPG	State of Baja California: fuel consumption, 1996-2007	Secretaría de Energía: Prospectiva del mercado de gas LP 2007 - 2016
Marine Vessels	National marine diesel consumption, 1990-2002 National marine diesel consumption, 2003-2007 Tons of freight cabotage[54] 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 Baja California: fuel consumption, 1990-2007	Secretaría de Energía de Baja California: 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 Baja California	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 [55]

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[54] Cabotage refers to the transport of goods between two points within the same country.
[55] 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 from SENER's *Prospectiva de Petrolíferos 2008-2017* and *Prospectiva del Mercado de Gas LP 2008–2017*. Forecast annual growth rates are listed in Table C-2. Due to a lack of projection data specific to Baja California, national projections were used for gasoline and diesel. Projections for LPG and jet fuel are specific to the Northwestern Region of Mexico.

Table C-2. 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	-19.6%	-1.6%	0.0%	0.0%
Marine Vessels	2.0%	2.3%	1.3%	1.4%
Aviation	11.7%	3.4%	2.8%	2.5%
Rail	2.0%	2.3%	1.3%	1.4%

Road Transportation

Annual consumption of gasoline and diesel in Baja California 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 consumption was not available for Baja California; therefore, consumption was estimated based on data in SENER's *Prospectiva del Mercado de Gas LP 2007–2016*. The proportion of transportation LPG to total LPG consumption for the northwestern region of Mexico was applied to total LPG consumption in Baja California.

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 Baja California. 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 Baja California using the proportion of national marine cargo cabotage at Baja California 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. Baja California cabotage proportions for 1990-1999 were assumed to be the same as the proportion estimated for 2000.

Marine residual fuel consumption for Baja California 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 Baja California for 1990-2007 was obtained from SENER. Consumption of aviation gasoline in Baja California was not available. However, aviation gasoline only accounts for about 1% of total aviation fuel consumption in Mexico.[56] Therefore, emissions from this fuel were assumed to be negligible.

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

Railways

Rail diesel consumption was not available for Baja California. 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 Baja California using the proportion of national rail lines in Baja California. 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 89% reaching levels of about 6.9 $MMtCO_2e$ in 2005. In 1990, the largest sources of greenhouse gas emissions were activities relating to onroad gasoline and onroad diesel combustion, accounting for 89% of total transportation GHG emissions in 1990.

The fastest growing source through the 1990-2005 time period was marine vessels with an annual growth rate of 11.9% (with most growth occurring from 1990 to 1994), followed by road transportation gasoline (5.3%). In 2025, total transportation emissions are expected to be on the order of 11.6 $MMtCO_2e$ representing a 221% increase from 1990. Road transportation emissions are expected to account for 77% of total transportation emissions in 2025. Aviation emissions are expected to account for 8% in 2025, down from 9% 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	2.08	3.46	3.76	4.53	5.45	6.27	6.88	7.50
Road Transportation - Diesel	1.16	0.78	0.79	1.42	1.83	2.17	2.45	2.73
Road Transportation - LPG	0.00	0.00	0.12	0.15	0.08	0.07	0.07	0.07
Marine Vessels	0.05	0.25	0.47	0.28	0.26	0.29	0.31	0.33
Aviation	0.32	0.43	0.54	0.48	0.64	0.75	0.87	0.98
Rail	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.03
Total	**3.63**	**4.93**	**5.69**	**6.86**	**8.28**	**9.57**	**10.60**	**11.64**

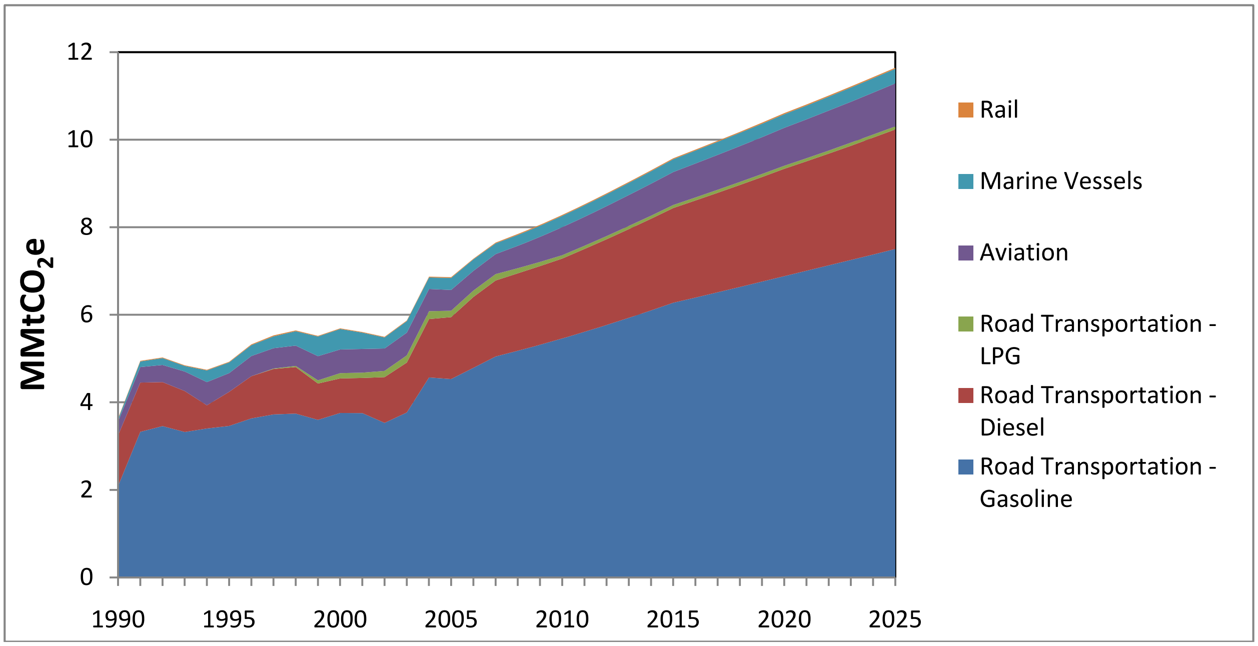
Table C-5. GHG Emissions Distribution in the Transportation Sector

Source	1990	1995	2000	2005	2010	2015	2020	2025
Road Transportation - Gasoline	57.4%	70.2%	66.0%	66.0%	65.9%	65.5%	64.9%	64.4%
Road Transportation - Diesel	32.0%	15.8%	13.9%	20.6%	22.1%	22.6%	23.1%	23.4%
Road Transportation - LPG	0.0%	0.0%	2.1%	2.1%	0.9%	0.7%	0.7%	0.6%
Marine Vessels	1.4%	5.0%	8.2%	4.0%	3.1%	3.0%	2.9%	2.9%
Aviation	8.8%	8.7%	9.5%	6.9%	7.7%	7.9%	8.2%	8.4%
Rail	0.5%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%

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

Source	1990-2005	2005-2025	1990-2025
Road Transportation - Gasoline	117%	66%	260%
Road Transportation - Diesel	22%	93%	135%
Road Transportation - LPG	NA	-52%	NA
Marine Vessels	440%	21%	554%
Aviation	50%	106%	209%
Rail	-11%	67%	48%
Total	**89%**	**70%**	**221%**

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.[57] 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 Baja California 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 Baja California's vehicle fleet indentifying the fraction of vehicles with control equipment.

As stated above, national projections were used for gasoline and diesel, and projections for the Northwestern Region of Mexico were used for LPG and jet fuel. Projections specific to Baja California would be preferred, since Baja California's fuel consumption may grow at a different rate than in the rest of Mexico.

[57] 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.

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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 greenhouse gas (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 Baja California, and for which emissions are estimated in this inventory, include the following:

Carbon Dioxide Emissions:

- Non-combustion emissions from cement manufacturing *[IPCC category: Cement Production]* [58];
- 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 [59,60]

Ozone depleting substance (ODS) substitutes:

- These are primarily hydrochlorofluorocarbons (HFCs) used in refrigeration and air conditioning applications *[IPCC category: Refrigeration and Air Conditioning]* [61]

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

Carbon dioxide emissions from:

- 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[62]

HFC, PFC, and SF_6 emissions from:

- Semiconductor manufacturing
- Magnesium production

[58] 2006 IPCC, Volume 3, Chapter 2, Section 2.2.
[59] 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.
[60] 2006 IPCC, Volume 3, Chapter 2, Section 2.5.
[61] 2006 IPCC, Volume 3, Chapter 7, Section 7.5.
[62] There is no adiptic acid production in Mexico according to Instituto Nacional de Ecología. 2008. *Informes del Inventario Nacional de Emisiones de Gases de Efecto Invernadero 1990 – 2002*.

- Electric power transmission and distribution systems
- Hydrochlorofluorocarbon-22 (HCFC-22) production
- Aluminum production[63]

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 contains information for years 2004 and 2005 and covers 104 federally regulated substances including three GHGs: carbon dioxide, nitrous oxide, and methane. 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 combine 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.[64] 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 calcination of raw minerals to produce clinker, whereas energy emissions relate to fossil fuel combustion in cement ovens. Additionally, RETC only provides data for a limited number of years, namely 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 totaled 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.

[63] Idem. Aluminum is only produced in the state of Veracruz.
[64] 2006 IPCC, Volume 3, Chapter 1, p.1.8

Table D-1. GHG Emissions Results from RETC (Metric Tons of CO2e)

Subsector/Company	2004	2005
Food Industry		
INDUSTRIAL DE GRASAS Y DERIVADOS, S.A. de C.V.		
Carbon dioxide	7,859	2,923
Alcohol & Tobacco		
CERVECERIA CUAUHTEMOC MOCTEZUMA S.A. DE C.V.		
Carbon dioxide	35,342	35,860
Lime & Limestone		
CEMEX MÉXICO S.A. DE C.V. PLANTA ENSENADA		
Carbon dioxide	399,547	405,758
FABRICAS MONTERREY SA de CV PLANTA ENSENADA		
Carbon dioxide		4,695
Other		
CERVECERIA CUAUHTEMOC MOCTEZUMA (water treatment)		
Carbon dioxide	1,289	1,713
Methane		110
INDUSTRIAS P KAY DE MEXICO SA DE CV		
Carbon dioxide		6
PIONEER SPEAKERS, S.A. de C.V.		
Carbon dioxide		0
POWER SONIC, S.A. DE C.V.		
Carbon dioxide		0
SENSIENT IMAGING TECHNOLOGIES S.A. DE C.V.		
Carbon dioxide		0
TECNICAS MEDIOAMBIENTALES WINCO S.A. DE C.V.		
Carbon dioxide		40
Chemical Industry		
CALINOR S.A. DE C.V.		
Carbon dioxide	112	112
KAMIMEX S.A DE C.V		
Carbon dioxide	523	461
PRAXAIR MEXICO S. DE R.L. DE C.V.		
Carbon dioxide	441	441
PULIDOS INDUSTRIALES S.A. de C.V.		
Carbon dioxide	10,425	
Grand Total	**455,540**	**452,119**

Historical Emissions and Reference Case Projections

Greenhouse gas emissions were estimated using the 2006 IPCC Guidelines.[65] 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.

[65] 2006 IPCC Guidelines, Volume 3.

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.[66] 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. This approach deviates from the methodology outlined in Section 7.5.2, Chapter 7, Volume 3 of the 2006 IPCC Guidelines;[67] however, it was adopted in the absence of better activity data (e.g., HFCs sales information). The number of mobile air conditioning units was converted to emissions using an emission factor of 166 kg CO_2e per vehicle published by IPCC in a special technical report.[68] Emissions from stationary refrigeration units were not included in this inventory because these operate with HCFC-22, a non-reportable GHG under the Kyoto Protocol, but regulated under the Montreal Protocol .[69]

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[70]; 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 GHG inventory considerations. Emissions associated with HCFC-22 were included in this appendix for the purposes of comparison with Baja California's GHG inventory. Nonetheless, HCFC-22 emissions will not be incorporated in the state summary of GHG emissions.

Cement production for 2000-2008 was estimated based on national production and the number of cement manufacturing plants in the state. National production data were not available for 1990-1999. For these years, production was estimated based on the state population and the estimate of per capita cement consumption for 2000 from Camara Nacional de Cemento. 2006 IPCC methodologies require the identification of the clinker concentration in a given cement blend. Based on national cement statistics covering the period 1994-2008, the weighted average concentrations of clinker per cement blend was determined. Prior to 1994, the average

[66] *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.

[67] The IPCC method is based on data on chemical sales by application.

[68] 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.

[69] In the 2005 inventory by Centro Mario Molina, emissions from stationary refrigeration are assumed to be HCFC-22, a hydrochlorofluorocarbon subject to the stipulation of the Montreal Protocol and exempt from GHG inventory considerations.

[70] Retrieved May, 2008 from: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

concentration of clinker was applied. Table D-7 summarizes the analysis of clinker content by cement blend. Finally, the amount of clinker produced is multiplied by the default 2006 IPCC emission factor (0.52 metric tons CO_2 per metric ton of clinker) to calculate emissions.

Limestone and dolomite consumption includes all uses except cement manufacturing. Strictly following the IPCC methodology, limestone and dolomite used in lime manufacturing and glass manufacturing would also be subtracted and reported separately. However, due to a lack of state-level data for lime and glass manufacturing, consumption in these processes is included in the limestone and dolomite consumption category. Limestone and dolomite consumption data were unavailable; therefore, consumption was assumed to equal in-state production of these minerals minus limestone used for cement manufacturing (to avoid double-counting).[71]

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 values from the National GHG inventory. Limestone production for 2006 and 2007 were significantly lower than the previous three years, resulting in negative values when the cement values were subtracted. Therefore, consumption was assumed to be equal to the average production values for 2003-2005. Limestone production was multiplied by the default 2006 IPCC emission of 0.44 metric tons CO_2 per metric ton of mineral) to obtain emissions.

[71] IPCC default values were used to estimate limestone consumption in cement manufacturing. Cement is assumed to contain 75% clinker, clinker is assumed to be 65% lime, and 100% of the lime is assumed to come from limestone.

Table D-2. Approach to Estimating Inventory Emissions

Source Category	Time Period for which Data Available	Required Data	Data Source
Cement Manufacture	2000-2008	Metric tons (Mt) of clinker produced and masonry cement produced each year	National cement production and the inventory of manufacturing plants by state retrieved from Camara Nacional de Cemento statistics. http://www.canacem.org.mx/la_industria_del_cemento.htm
Limestone and Dolomite Consumption	2003-2007	Mt of limestone and dolomite consumed minus estimated limestone consumption from cement manufacturing	Consumption was assumed to be equal to the production of limestone from mining. CCS is developing methods to better assess limestone and dolomite consumption in the state. Source: Servicio Geológico Mexicano. 2008. *Anuario Estadístico de la Minería Mexicana Ampliada, 2007*. Estadísticas por Producto para Minerales Metálicos y no Metálicos, Capítulo IV.
Iron and Steel Production	NA	Mt of crude steel produced by production method	This activity was identified in *Inventario de Emisiones de Gases de Efecto Invernadero del Estado de Baja California 2005*; however, production data were not found, or emissions data reported in RETC.
ODS Substitutes	1980-2007	Vehicle fleet	Instituto Nacional de Estadísticas, Geografía, e Informática. Estadísticas de vehículos de motor registrados en circulación. http://www.inegi.org.mx/inegi/default.aspx

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 construction materials consumption and total manufacturing volume were obtained from Sistema Nacional de Información Estadística y Geográfica (SNIEG).[72]

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
Cement Manufacture	Based on 2003-2007 construction materials consumption from SNIEG	5.7%	3.8%	3.2%	2.7%
Limestone and Dolomite Consumption	Based on 2003-2007 manufacturing physical volume from SNIEG	-2.9%	3.1%	2.7%	2.4%
ODS Substitutes	Based on 2003-2007 vehicle registration data from INEGI	8.6%	5.8%	4.5%	3.7%

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

Results

In 2005, GHG emissions from non-combustion industrial processes were about 0.88 million metric tons of carbon dioxide equivalent ($MMtCO_2e$). The largest source of emissions is cement production, followed by limestone consumption. Forecast industrial process and product use emissions are projected to reach 1.7 $MMtCO_2e$ by 2025, of which 90% will be generated by as a result of cement manufacturing.

Figure D-1 provides a graphic representation of emissions. Most notably, activity data relating to limestone and dolomite use show a divergent trend during the years for which historical data were available (2003-2007).

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.

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

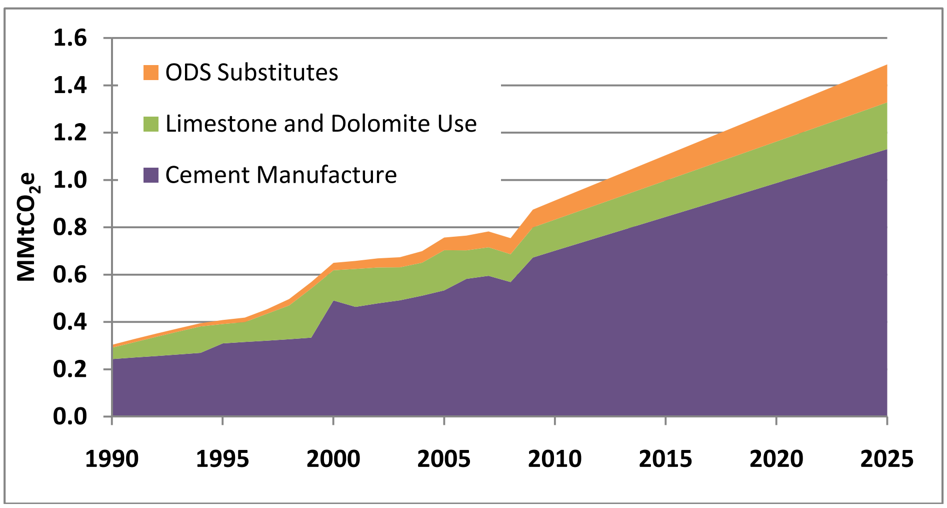


Table D-4. Historic and Projected GHG Emissions for Industrial Processes ($MMtCO_2e$)

Source	1990	1995	2000	2005	2010	2015	2020	2025
Cement Manufacture	0.24	0.31	0.49	0.53	0.70	0.84	0.99	1.13
Limestone and Dolomite Use	0.05	0.08	0.13	0.17	0.13	0.15	0.18	0.20
ODS Substitutes	0.01	0.02	0.03	0.05	0.08	0.11	0.13	0.16
Grand Total	**0.30**	**0.41**	**0.65**	**0.76**	**0.91**	**1.11**	**1.30**	**1.49**

Table D-5. GHG Emission Distribution for Industrial Processes

Source	1990	1995	2000	2005	2010	2015	2020	2025
Cement Manufacture	80.2%	75.7%	75.6%	70.5%	76.8%	76.4%	76.2%	76.0%
Limestone and Dolomite Use	15.8%	20.0%	19.7%	22.5%	14.4%	13.9%	13.5%	13.3%
ODS Substitutes	4.0%	4.2%	4.7%	7.0%	8.8%	9.7%	10.3%	10.8%

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

Year	1990	1995	2000	2005	2010	2015	2020
Refrigeration (kg HCFC-22)	130	165	194	222	234	244	255
Air Conditioning (kg HCFC-22)	3,045	3,873	4,561	5,216	5,482	5,727	5,984
Total (MMtCO2e)	0.005	0.007	0.008	0.009	0.010	0.010	0.011

Table D-7. Clinker Content in National Production of Cement

Año	National production by cement blend in metric tons					Clinker content (weighted average)
	Portland Gris (96% clinker)	Blanco (28.8% clinker)	Mortero (64% clinker)	Other (64.4% clinker)	Clinker (100% clinker)	
1994	30,243,326	516,684	720,232	113,625	220,619	94.1%
1995	24,033,981	441,975	645,663	173,169	793,455	94.0%
1996	26,440,746	466,440	1,140,024	127,125	1,447,276	93.8%
1997	27,679,233	530,803	1,316,355	158,327	1,073,967	93.4%
1998	28,608,786	568,795	1,549,994	187,670	592,846	93.1%
1999	29,738,734	642,632	1,420,243	156,321		93.1%
2000	31,518,759	613,075	1,096,005	201,128		93.5%
2001	30,177,359	636,394	1,319,868			93.3%
2002	30,897,412	623,680	1,850,420			93.0%
2003	31,143,454	632,386	1,817,561			93.0%
2004	32,374,824	680,380	1,937,238			92.9%
2005	34,571,534	773,499	2,106,583			92.8%
2006	37,180,967	843,869	2,337,166			92.7%
2007	37,757,921	864,999	2,590,337			92.6%
2008	36,608,126	823,449	2,679,457			92.5%
Elaborated by CCS from typical clinker composition (2006 IPCC) and industry production data (INEGI, Encuesta Industrial Mensual (EIM)).						

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 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 method does not account for crushed limestone consumed for road construction or other uses that do not result in CO_2 emissions. This approach is provisory while more accurate methods are developed or new activity data is collected from economic statistics and/or industry surveys.

- Since emissions from industrial processes are determined by the level of production and the production processes of a few key industries there is relatively high uncertainty regarding future emissions from the industrial processes category as a whole. Future emissions depend on the competitiveness of Baja California manufacturers in these industries, and the specific nature of the production processes used in Baja California. Forecast emissions based on economic data or industry performance data are usually more reliable that those based on historic trends. The use of relevant economic data in this analysis will likely paint a better picture of forecast emissions.

- Significant uncertainty stems from the method adopted to estimate GHG emissions from mobile air-conditioning systems. These were calculated according to the approach described in Baja California's 2005 GHG inventory.[73] 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 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.

[73] *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)

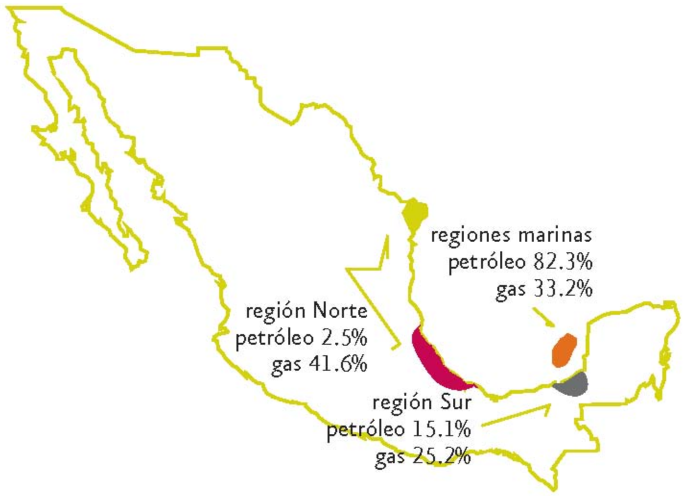
- For the electricity T&D and semiconductor industries, future efforts should include a survey of companies within these industries to determine the extent to which they are experiencing SF_6 losses.

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.[74] In Baja California, GHG emissions are limited to the transmission and distribution of natural gas. It is unlikely that other sources of emissions would occur because Baja California does not have coal deposits, or oil and natural gas reserves[75] . Mexico's petroleum rich areas are located around the Gulf of Mexico as illustrated in Figure E-1 below.

Figure E-1. Oil and Gas Production by Region[76]



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

Emissions and Reference Case Projections

Methodology

For the development of natural gas emissions estimates, CCS considered several possible methods that could be applied based on the nature and availability of activity data. A 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 recommended for developing countries that are based on regions outside the Americas with a

[74] 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.
[75] Information on oil and gas reserves was 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
[76] Secretaría de Energía. *Balance Nacional de Energía 2006*. (p.37)

large uncertainty range (-40 to 250%).[77] This approach was utilized by the authors of the *Inventario Nacional de Emisiones de Gases de Efecto Invernadero* (INEGEI).

Alternatively, the *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*[78] 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[79]. 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 State Greenhouse Gas Inventory Tool (SIT), a tool commissioned by the US EPA to facilitate the development of state-level GHG emissions inventories (Method C).[80] 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 for two reasons: a) it provides a consistent basis of comparison with state –level GHG inventories in the US; and b) it reflects that Baja California is a relatively developed region and that its natural gas infrastructure is new.

CCS conducted a comparison of emissions estimated by these various methods (see Table E-1). The values using Method A represent higher end emissions where regulatory and operational controls are few to none. The values derived from methods B and C are consistent with each other and reflect emissions where the natural gas system is well maintained and highly reliable. Table E-2 list Method C emission factors by occurring activity in Baja California.

Table E-1. Comparison of Emission Using Competing Methods for Year 2005

Source	Method A	Method B	Method C	Units
Emissions from transmission	5507.5	2319.5	2029.3	Metric tons of CH4
Emissions from distribution	3191.6	199.9	389.3	Metric tons of CH4

[77] 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.
[78] See Chapter 2, Section 2.7.1.2. The document is available from www.ipcc-nggip.iges.or.jp/public/gp/english/
[79] GRI/US EPA (1996). *Methane Emissions from the Natural Gas Industry*. Report No. EPA-600/R-96-080, GRI / United States Environmental Protection Agency.
[80] Additional information about the EPA SIT is found at www.epa.gov/climatechange/emissions/state_guidance.html

Table E-2. Fossil Fuel Industry Emission Factors

Activity	Emission factors	
Natural gas transmission		
Transmission pipeline	0.6	tons CH4 per year per mile
Gas storage compressor stations	964.1	tons CH4 per year per station
Natural gas distribution		
Distribution pipeline	0.541	tonnes CH4 per year per mile
Total number of services	0.015	tonnes CH4 per year per activity unit

Natural Gas Industry Emissions

Key information sources for the activity data were the Secretaria de Energía (SENER), and the Comisión Reguladora de Energía (CRE). SENER provided information about natural gas transmission and distribution infrastructure (including pipeline lengths, and the number of planned and operating storage units).[81] It also provided data on the number of users serviced by this infrastructure (indicating the number of meters). The CRE offered information about companies licensed to build and operate natural gas lines and the date of these concessions.[82] Information obtained by means of these data sources was sparse and largely derived from permit descriptions where projected information was listed (e.g., number of services at the end of the 5-year concession); it is possible therefore that emission are slightly over-estimated. Table E-3 summarizes activity data used in estimating natural gas industry emissions. Please note that some information on the table was not provided on an annual basis but in periods of five years. A linear interpolation was applied to obtain annual values.

Oil Industry Emissions

As described above, there is no oil production or refinement in Baja California.

Coal Industry Emissions

There is no coal production or processing in Baja California.

Emission Forecast

Several assumptions were made in the preparation of the forecast. Due to the large investment involved in building natural gas transmission infrastructure, the forecast assumed no transmission pipeline or storage stations beyond already existed in 2008. On the other hand, the distribution network and the number of natural gas customers were assumed to grow annually at 2.4% from 2009 to 2025, the same rate as the growth in population for the same time period.[83]

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[81] 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

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

[83] Source: II Conteo de Población y Vivienda 2005 with projections by Consejo Nacional de Población (CONAPO).

In short, the forecast is driven by moderate growth in population and economic activity, and the consequent expansion of the natural gas distribution system.

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

Activity	Approach to Historical Emissions		
	Required Data	Data Source	Available Data
Natural gas production	Number of wells	Not present in Baja California	
Natural gas processing, venting and flaring	Volume of natural gas processed	Not present in Baja California	
Natural gas transmission	Miles of transmission pipeline	CRE/SENER	Permit dated 16/12/98 = 36 km Permit dated 15/12/00 = 217 km Permit dated 27/11/03 = 1.6 km Permit granted 2005-06 = 6.8 km
	Number of gas transmission compressor stations	Not present in Baja California	
	Number of storage stations	SENER	Permit dated 7/8/03 = 2 Units became operational in 2008
Natural gas distribution	Miles of distribution pipeline	SENER	1998-2003 = 0 km 2004-2009 = 281 km
	Number of services	SENER	1998-2003 = 0 2004-2009 = 19,263
Oil systems	Volume of petroleum processed	Not present in Baja California	
Coal mining	Tons of production	Not present in Baja California	

Results

Table E-4 displays the estimated emissions from the fossil fuel industry in Baja California over the period 1990 to 2025. Fugitive emissions from natural gas compressor storage stations are the major contributor to forecast emissions. The relative contribution of sources to sector total emissions is 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 Transmission - pipeline	NA	NA	0.002	0.002	0.002	0.002	0.002	0.002
NG Transmission - compressor storage	NA	NA	0.000	0.000	0.040	0.040	0.040	0.040
NG Distribution	NA	NA	0.000	0.003	0.009	0.010	0.011	0.012
Total	NA	NA	**0.002**	**0.005**	**0.051**	**0.052**	**0.053**	**0.055**

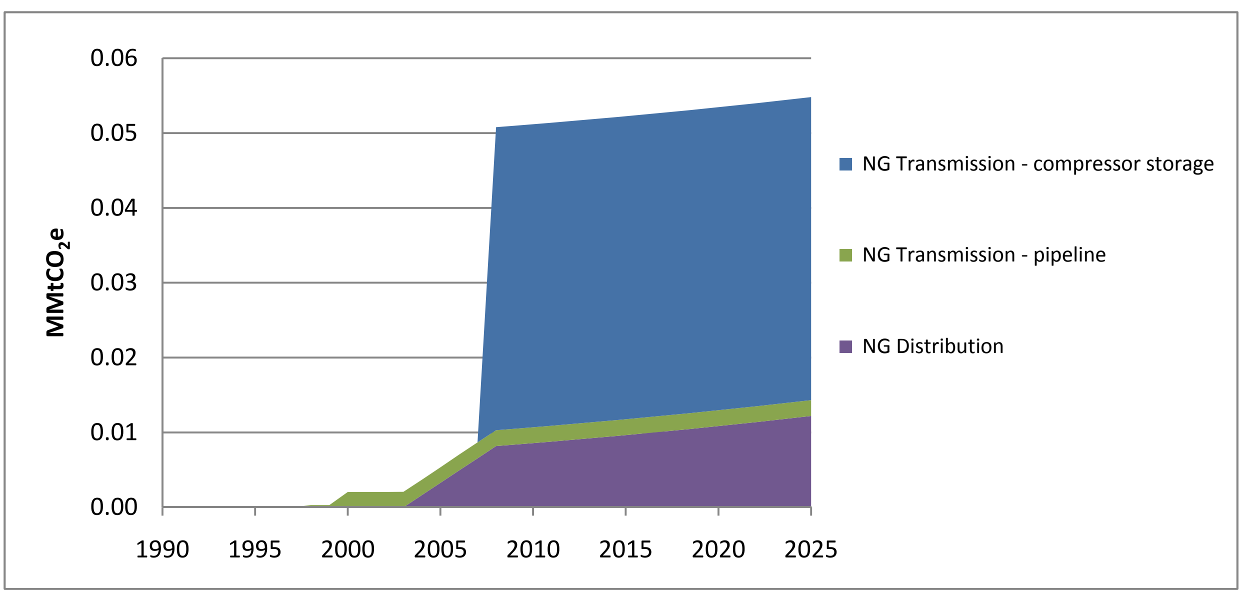
NA indicates that no activity was associated with a source for a given year.

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

Source	1990	1995	2000	2005	2010	2015	2020	2025
NG Transmission - pipeline	NA	NA	100%	39%	4%	4%	4%	4%
NG Transmission - compressor storage	NA	NA	0%	0%	79%	77%	76%	74%
NG Distribution	NA	NA	0%	61%	17%	18%	20%	22%
Total	NA	NA	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

NA indicates that no activity was associated with a source for a given year.

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



Key Uncertainties

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

- Emission factors were 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 both the natural gas transmission and distribution emission estimates. This uncertainty is can be quantified as the difference in emission results between IPCC Tier 1 method and those from US EPA State Inventory Tool.

Source	IPCC	EPA	Units	Difference
Emissions from transmission	5507.5	2029.3	Metric tons of CH4	-63%
Emissions from distribution	3191.6	389.3	Metric tons of CH4	-88%

- 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

Enteric fermentation

Methane emissions for 1990 through 2005 were estimated using a Tier 1 method described in the 2006 Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories* (2006 IPCC).[84] 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[85] 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.[86]

Table F-1. Livestock Populations

Livestock Type		1990	1995	2000	2005
Dairy Cows	Vacuno lechero	0	34,708	50,239	54,327
Other Cattle	Otros vacunos	184,785	159,258	158,325	175,820
Buffalo	Búfalo				
Sheep	Ovinos	5,842	2,389	7,137	26,935
Goats	Caprinos	39,246	44,787	39,945	20,398
Camels	Camelidos				
Horses	Equinos				
Mule/Asses	Mulas y asnos				
Deer	Ciervos				
Alpacas	Alpacas				
Swine	Porcinos	45,296	28,962	22,212	12,231
Poultry	Aves de corral	2,822,898	1,650,979	644,481	1,232,086
Rabbits	Conejo				

84 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.

85 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

86 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 Baja California 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 Baja California.

The emission factors were derived from a combination of regional expert studies[87] 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 Baja California was Latin America and climate region categories selected were warm (>26 degrees C) and temperate (15-25 degrees C) assigned to 93% and 7% 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.

[87] 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 Baja California

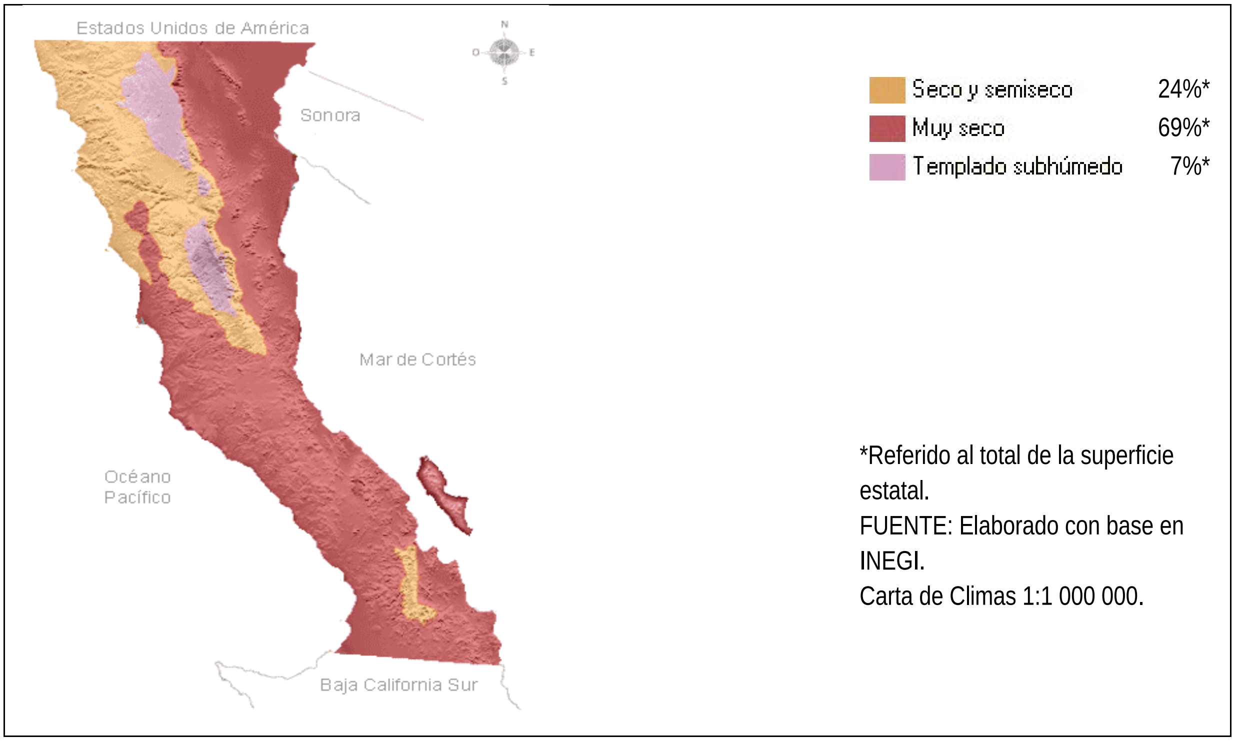


Table F-2. Default Manure Management Systems Distribution for Latin America

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. Inventory Crop Production in Metric Tons[88]

Crop		1990	1995	2000	2005
N-fixing forages	Forrajes fijadores de N	0	0	0	12
Non-N-fixing forages	Forrajes no fijadores de N	153,905	438,128	290,138	728,344
Beans & pulses	Frijoles y legumbres	381	1518	4019.72	4139.09
Grains	Granos	0	0	0	0
Perennial grasses	Hierbas perennes	514,477	400,793	200,869	264,287
Grass-clover mixtures	Mezcla de hierba y trébol	0	0	10	0
Root crops, other	Raíces, otros	20,141	16,463	16,864	10,003
Tubers	Tubérculos	0	0	0	0
Alfalfa	Alfalfa	1,063,371	1,278,000	2,109,783	2,158,030
Rice	Arroz	0	0	0	0
Oats	Avena	0	349	0	954.4
Peanut (w/pod)	Cacahuetes (c/ vaina)	0	1	0	0
Barley	Cebada	30,368	25,962	1,574	11,670
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	7,683	6,583	10,855	2,584
Millet	Mijo	0	0	0	0
Potato	Patatas	15,462	7,861	3,543	924
Soyabean	Soja	0	0	0	0
Sorghum	Sorgo	10,028	19,242	23,705	9,705
Wheat	Trigo	256,642	394,944	535,901	504,514

Application of synthetic fertilizer also adds nitrogen to the nitrification and de-nitrification cycle in the soil and contributes the release of N_2O to the atmosphere. Emissions from the application of fertilizer to agricultural lands were based on data from the International Fertilizer Industry Association.[89] 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)	14,522,061	12,237,721	14,447,387	12,139,995

[88] 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

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

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 Baja California, it was assumed no manure went to feed, fuel, or construction.

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 Baja California, 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 Baja California 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 Baja California could not be found, and therefore emissions from residue burning are assumed to be zero. When estimates of the tons or acres of Baja California 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 are also used in the calculation of N_2O emissions from ag soils. The fertilizer estimate (-0.1% annual growth) is forecast based on the change in N fertilizer application between 1995 and 2005.

Table F-7. Growth Rates Applied to Livestock Population

Livestock Type		Rate (%)	Period of Measurement
Dairy Cows	Vacuno lechero	1.6%	2000-2005
Other Cattle	Otros vacunos	2.1%	2000-2005
Buffalo	Búfalo		
Sheep	Ovinos	0.0%	N/A*
Goats	Caprinos	0.0%	N/A*
Camels	Camelidos		
Horses	Equinos		
Mule/Asses	Mulas y asnos		
Deer	Ciervos		
Alpacas	Alpacas		
Swine	Porcinos	0.0%	N/A*
Poultry	Aves de corral	0.0%	N/A*
Rabbits	Conejo		
* 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-8. Growth Rates Applied to Crop Production

Crop		Mean Annual Growth	
English	Spanish	Rate (%)	Period of Measurement
N-fixing forages	Forrajes fijadores de N	0.0%	N/A*
Non-N-fixing forages	Forrajes no fijadores de N	0.0%	N/A*
Beans & pulses	Frijoles y legumbres	0.6%	2000-2005
Grains	Granos		
Perennial grasses	Hierbas perennes	5.6%	2000-2005
Grass-clover mixtures	Mezcla de hierba y trébol		2000-2005
Root crops, other	Raíces, otros	-9.9%	2000-2005
Tubers	Tubérculos		
Alfalfa	Alfalfa	0.5%	2000-2005
Rice	Arroz		
Oats	Avena	0.0%	N/A*
Peanut (w/pod)	Cacahuetes (c/ vaina)	0.0%	N/A*
Barley	Cebada	0.0%	N/A*
Rye	Centeno		
Dry bean	Frijoles		
Non-legume hay	Heno no leguminoso		
Maize	Maíz	-25.0%	2000-2005
Millet	Mijo		
Potato	Patatas	-23.6%	2000-2005
Soyabean	Soja		
Sorghum	Sorgo	-16.4%	2000-2005
Wheat	Trigo	-1.2%	2000-2005
* 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	54,327	58,748	63,528	68,697	74,287
Other Cattle	Otros vacunos	175,820	195,248	216,823	240,782	267,389
Buffalo	Búfalo					
Sheep	Ovinos	26,935	26,935	26,935	26,935	26,935
Goats	Caprinos	20,398	20,398	20,398	20,398	20,398
Camels	Camelidos					
Horses	Equinos					
Mule/Asses	Mulas y asnos					
Deer	Ciervos					
Alpacas	Alpacas					
Swine	Porcinos	12,231	12,231	12,231	12,231	12,231
Poultry	Aves de corral	1,232,086	1,232,086	1,232,086	1,232,086	1,232,086
Rabbits	Conejo					

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

Crop Type		2005	2010	2015	2020	2025
N-fixing forages	Forrajes fijadores de N	12	12	12	12	12
Non-N-fixing forages	Forrajes no fijadores de N	728,344	728,344	728,344	728,344	728,344
Beans & pulses	Frijoles y legumbres	4,139	4,262	4,389	4,519	4,653
Grains	Granos	0	0	0	0	0
Perennial grasses	Hierbas perennes	264,287	347,727	457,511	601,955	792,003
Grass-clover mixtures	Mezcla de hierba y trébol	0	0	0	0	0
Root crops, other	Raíces, otros	10,003	5,934	3,520	2,088	1,239
Tubers	Tubérculos	0	0	0	0	0
Alfalfa	Alfalfa	2,158,030	2,207,382	2,257,862	2,309,496	2,362,311
Rice	Arroz	0	0	0	0	0
Oats	Avena	954	954	954	954	954
Peanut (w/pod)	Cacahuetes (c/ vaina)	0	0	0	0	0
Barley	Cebada	11,670	11,670	11,670	11,670	11,670
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	2,584	615	146	35	8
Millet	Mijo	0	0	0	0	0
Potato	Patatas	924	241	63	16	4
Soyabean	Soja	0	0	0	0	0
Sorghum	Sorgo	9,705	3,973	1,627	666	273

Crop Type		2005	2010	2015	2020	2025
Wheat	Trigo	504,514	474,964	447,146	420,956	396,301

Results

During inventory years (1990 through 2005), total agricultural emissions increased by 15% reaching levels on the order of 0.49 million metric tons of carbon dioxide equivalents ($MMtCO_2e$). In 1990, the top two emitting sources were enteric fermentation and agricultural soils. Enteric fermentation alone accounted for 52% of total greenhouse gas emissions in 1990. The fastest growing source through the time period was residue burning with total growth of 30% between 1990 and 2005; all other sources had minimal growth.

During forecast years (2005 through 2025), total agriculture emissions are projected to increase by 39% attaining levels around 0.68 million metric tons of carbon dioxide equivalents. In 2025, the top two emitting source sectors are expected to be enteric fermentation and agricultural soils. Enteric fermentation accounts for 62% of total greenhouse gas emissions in 2025. Enteric fermentation is also the fastest growing source through the time period, with a total growth rate of 50% between 2005 and 2025.

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

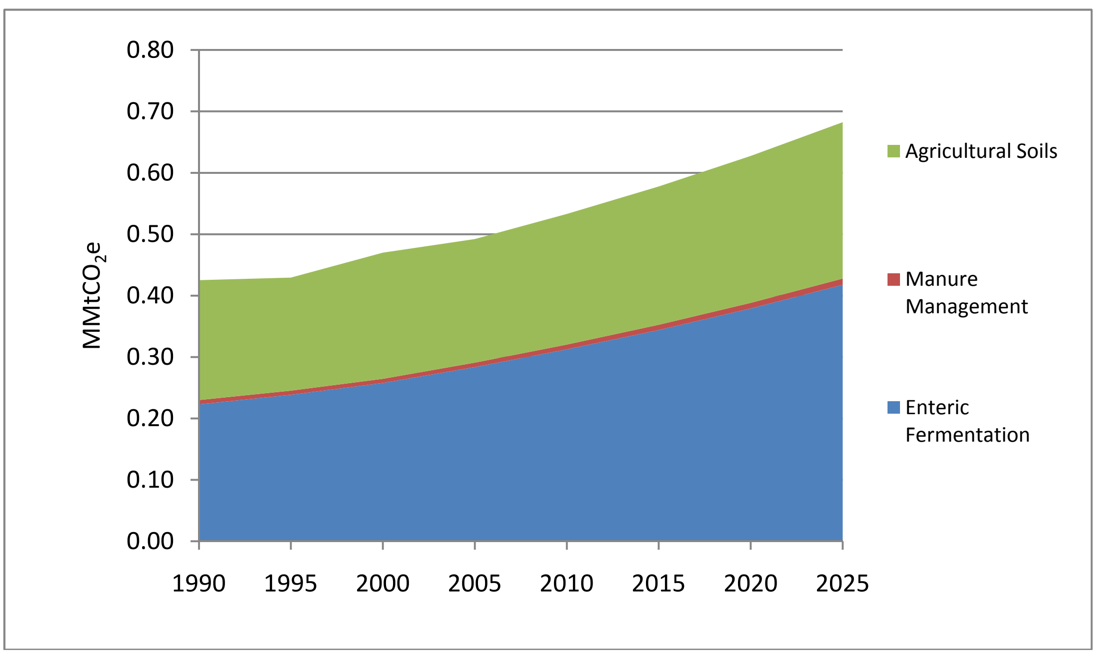


Table F-11. GHG Emissions from Agriculture ($MMtCO_2e$)

Source Sector	1990	1995	2000	2005	2010	2015	2020	2025
Enteric Fermentation	0.22	0.24	0.26	0.28	0.31	0.34	0.38	0.42
Manure Management	0.007	0.007	0.007	0.007	0.008	0.008	0.009	0.010
Agricultural Soils	0.20	0.18	0.21	0.20	0.21	0.23	0.24	0.25
Residue Burning	Not Estimated							
Total	**0.43**	**0.43**	**0.47**	**0.49**	**0.53**	**0.58**	**0.63**	**0.68**

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

Source	1990	1995	2000	2005	2010	2015	2020	2025
Enteric Fermentation	52.2%	55.5%	54.8%	57.6%	58.6%	59.6%	60.4%	61.2%
Manure Management	1.7%	1.6%	1.4%	1.5%	1.5%	1.5%	1.5%	1.5%
Agricultural Soils	45.6%	42.7%	43.5%	40.8%	39.9%	39.0%	38.1%	37.3%

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

Agriculture	1990-2005	2005-2025	1990-2025
Enteric Fermentation	1.6%	2.0%	1.8%
Manure Management	0.1%	1.6%	1.0%
Agricultural Soils	0.2%	1.2%	0.8%

Key Uncertainties and Research Needs

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 Baja California, "other cattle" (non-dairy cows) accounts for 76% of the ruminant population in 2005. 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 burning in Baja California 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 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 2000 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. 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):[90]
- 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, solid waste disposal site (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).[91] 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.[92]

The term "generation" typically refers to all waste entering the waste stream, which would include waste incineration, landfilling, recycling, and composting. However, as Baja California 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).

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[90] 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 CO2e from waste generation

[91] 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

[92] 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;[93] 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),[94] there is one landfill site in Baja California – the Valle Verde landfill – that is a participant in the Clean Development Mechanism (CDM) program, accepting credit for emission reductions for the years 2009 through 2019.[95] CCS accounted for the GHG reductions from methane destruction; however, any offset fossil fuel combustion to generate electricity is not reflected in this chapter but would be accounted for under the Residential, Commercial and Industrial Fuel Combustion Appendix. The CDM report does not provide information on methane destruction prior to 2009 and after 2019. CCS assumes that the project will continue beyond 2019. Therefore, CCS used the average annual change in methane destruction from 2010 through 2019 to estimate the amount of methane destroyed per year for the years 2020 through 2025.[96] The methane destruction value provided by the CDM report for 2019 represents the methane destroyed from January through June of that year. This value was corrected to represent the whole year by multiplying the original 2019 value by two. Table G-1 displays the methane destruction values for the Valle Verde landfill provided by the CDM report, as well as the methane destruction extrapolated by CCS. The GHG reductions through methane destroyed are subtracted from the methane generation forecast made by the FOD equation in the IPCC waste model.

[93] Ley General par la Prevención y gestión Integral de los Residuos, Articulo 5.
[94] 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
[95] UNFCCC, 2006. Clean Development Mechanism Project Design Document Form – Valle Verde Landfill Gas Project. Version 3.1.
[96] The exact start date of the project was not reported in the CDM Report. Therefore, it is assumed that the methane destruction reported for 2009 is the actual value for methane destruction in that year. Therefore, for the purpose of projection through 2025, the 2010 through 2019 average annual change was used.

Table G-1. Destruction of Methane at Valle Verde Landfill, 2009-2025

Year	Methane Destruction – CDM Report (tCH_4/year)	Methane Destruction – CCS Model Inputs (tCH_4/year)
2009	1,376	1,376
2010	11,397	11,397
2011	10,722	10,722
2012	10,168	10,168
2013	9,643	9,643
2014	9,146	9,146
2015	8,675	8,675
2016	8,228	8,228
2017	7,806	7,806
2018	7,405	7,405
2019	2,906[a]	5,812
2020	0	5,496
2021	0	5,196
2022	0	4,913
2023	0	4,646
2024	0	4,393
2025	0	4,154

[a] Represents only the first half of the calendar year.

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 report on the Valle Verde Landfill Gas CDM project provides SWDS-specific waste composition data, based on a survey of waste going into the SWDS. It is assumed that these data are more representative of the waste composition in Baja California and are used as the waste composition inputs for the IPCC model. Table G-2 displays the waste composition input options, including the Valle Verde Landfill, which was used for this inventory and forecast project. This table shows that the waste composition at the Valle Verde landfill is reasonably similar to the IPCC default and Mexico national data.

Table G-2. Waste Composition Inputs (% of Waste Landfilled)

Waste Type	MX National	IPCC Default	Valle Verde Landfill
Food	51.7%	33.9%	36.7%
Garden	0.0%	0.0%	17.7%
Paper	14.4%	23.2%	12.2%
Wood	0.0%	6.2%	0.7%
Textile	1.5%	3.9%	0.0%
Nappies	0.0%	0.0%	0.7%
Plastics, other inert	32.4%	32.8%	32.0%
Total	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 Baja California 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 Baja California 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.[97] 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 y Geografía (INEGI).[98] The per-capita MSW generation estimates from the solid waste disposal source sector were multiplied by the rural population to produce an estimate of waste combusted through open burning in each year. Emissions from open burning were calculated using the Baja California activity data, developed using the methods described above, and IPCC emission factors.[99]

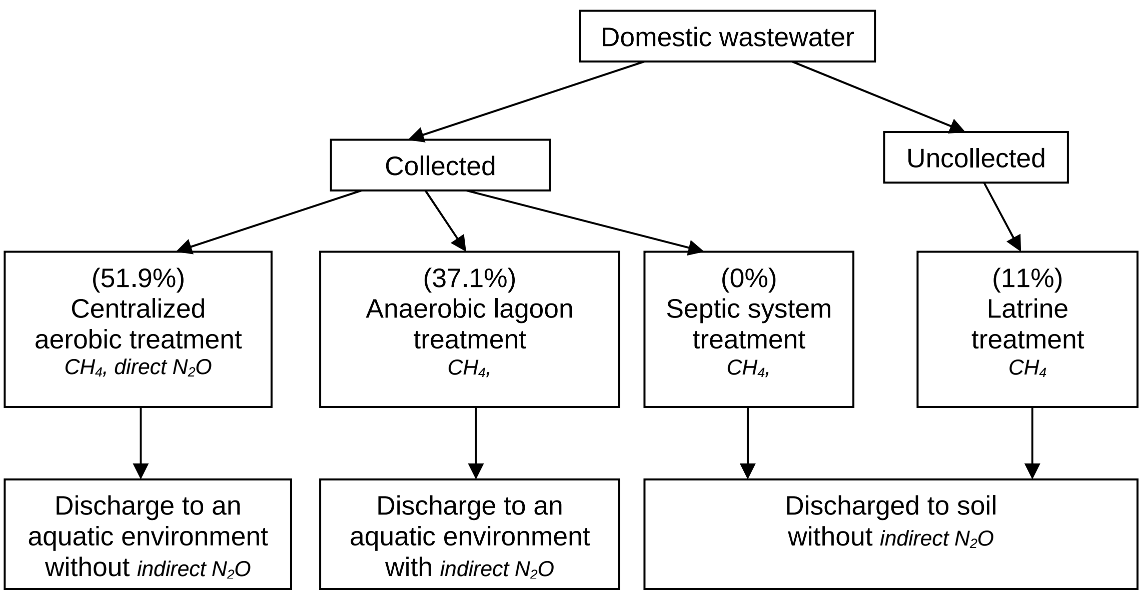
Wastewater Treatment and Discharge

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.[100] The key IPCC emission factors are shown in Table G-3.

[97] State population projections were obtained from CONAPO for 2006 to 2025. Source: http://www.conapo.gob.mx/00cifras/5.htm.
[98] INEGI. Historic state population for years 1990, 1995, 2000, 2005. Source: http://www.inegi.org.mx/inegi/default.aspx.
[99] 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.
[100] 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

The percentage of Baja California residents on city sewer is 89%, according to 2005 housing statistics published by INEGI[101], and it is presumed that 11% of domestic wastewater generation is uncollected.[102] Comisión Nacional del Agua (CONAGUA) provided in-state wastewater treatment capacity by treatment system. This information was used to breakdown the population, whose wastewater is collected by city sewers, by each type of treatment system.[103] Three assumptions were made in the process of allocating wastewater flow to each 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 Baja California with the fraction of effluent associated by each system. Domestic wastewater emissions were projected based on the projected population growth rate for 2005-2025 for a growth rate of 2.45% per year.[104]

Figure G-1. Wastewater Treatment Systems and Discharge Pathways



101 INEGI. *Censos Generales de Población y Vivienda*: http://www.inegi.org.mx/inegi/default.aspx
102 Retrieved May, 2008 from: http://www.inegi.gob.mx/est/contenidos/espanol/sistemas/conteo2005/iter2005/selentcampo.aspx
103 Consejo Nacional del Agua, 2007. *Inventario Nacional de Plantas Municipales de Potabilización y de Tratamiento de Aguas Residuales en Operación*. México: CONAGUA.
104 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.

1) Wastewater treatment – This category accounts for methane and nitrous oxide emissions resulting from municipal and industrial wastewater treatment.

   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:
   Uj = population fraction connected to treatment system j
   Bo= maximum methane generation capacity
   MCFj =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:

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

   Where:
   N_2OPLANTS = total N_2O emissions from plants in inventory year, kg N_2O/yr
   P = human population
   TPLANT = 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.
   FIND-COMM = factor to allow for co-discharge of industrial nitrogen into sewer; default value 1.25.
   EFPLANT = emission factor, 3.2 g N_2O/person/year.

Most nitrous oxide emissions occur by 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-3. Treatment Fractions and 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

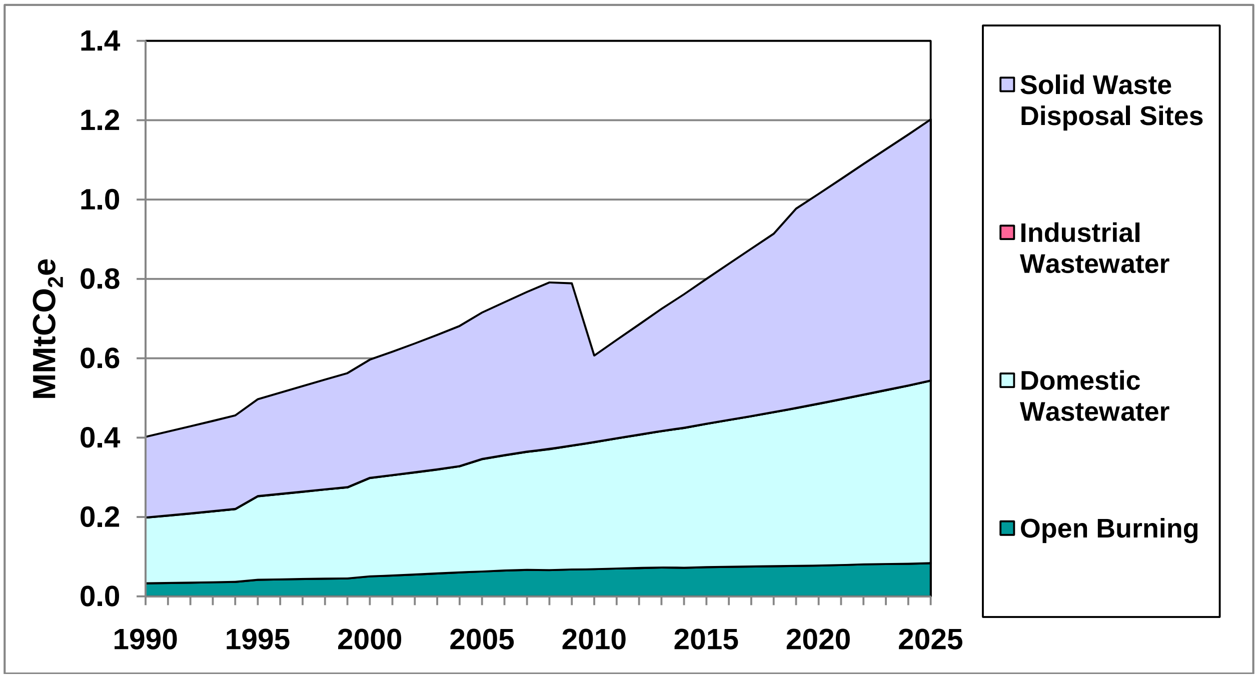
For industrial wastewater emissions, IPCC provides default assumptions and emission factors for four industrial sectors: Malt and Beer, Red Meat & Poultry, Pulp & Paper, and Fruits & Vegetables. INEGI provided data on red meat processing.[105] No data were available for malt and beer, pulp and paper, 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.

105 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.

Results

Figure G-2 and Table G-4 show the emission estimates for the waste management sector. Overall, the sector accounts for 0.72 MMtCO_2e in 2005, and emissions are estimated to be 1.20 MMtCO_2e/yr in 2025. Accounting for SWDS carbon storage yields the net emission estimates of 0.60 MMtCO_2e and 1.01 MMtCO_2e for 2005 and 2025, respectively. The large dip in landfill emissions after 2009 is due to the reduction of methane emissions from the aforementioned Valle Verde CDM landfill gas project.

Figure G-2. Baja California, Mexico Gross GHG Emissions from Waste Management, 1990-2025



Source: Based on approach described in text.

Table G-4. Baja California GHG Emissions from Waste Management (MMtCO_2e)

Source	1990	1995	2000	2005	2010	2015	2020	2025
Solid Waste Disposal Sites	0.20	0.24	0.30	0.37	0.22	0.37	0.53	0.66
Open Burning	0.03	0.04	0.05	0.06	0.07	0.07	0.08	0.08
Domestic Wastewater	0.17	0.21	0.25	0.28	0.32	0.36	0.41	0.46
Industrial Wastewater	0.00	0.00	0.00	4.1E-04	4.6E-04	4.6E-04	4.6E-04	4.6E-04
Total Gross Emissions	**0.40**	**0.50**	**0.60**	**0.72**	**0.61**	**0.80**	**1.01**	**1.20**
Carbon Stored in SWDS	0.06	0.08	0.09	0.12	0.14	0.16	0.18	0.19
Total Net Emissions	**0.34**	**0.42**	**0.50**	**0.60**	**0.47**	**0.64**	**0.84**	**1.01**

As shown in Table G-5, in 2005, the largest sources in the waste management sector were emissions from SWDS and emissions from domestic wastewater, accounting for 52% and 40% of total sector emissions. By 2025, the contribution of emissions from SWDS (55%) and domestic wastewater emissions (38%) will change slightly from 2005. Emissions from open burning account for 9% and 7% 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).

Table G-5. Gross GHG Emission Distribution in the Waste Management Sector

Source	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**
Solid Waste Disposal Sites	50.5%	49.1%	49.9%	51.6%	35.9%	45.6%	52.1%	54.7%
Open Burning	8.2%	8.5%	8.5%	8.8%	11.3%	9.2%	7.7%	7.0%
Domestic Wastewater	41.1%	42.3%	41.5%	39.6%	52.7%	45.1%	40.2%	38.2%
Industrial Wastewater	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

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.
- 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.

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 all waste disposal facilities. A comprehensive set of accumulation records would reduce some of the uncertainty associated with SWDS methane emissions. Also, the waste composition data used for Baja California is representative of a single landfill, but may not be representative of the state as a whole, although this is the assumption made in this analysis. Additionally, the only methane recovery project included was the Valle Verde Landfill Gas project recognized by the UNFCCC CDM program.

It is possible in the future that landfill gas at other managed landfills 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 Baja California population conducts open burning. As some of this waste may be deposited at an SWDS, 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 is 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 Baja California.

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. 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 Baja California, 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[106] from forests and perennial woody crops in Baja California, which account for about 4% of the state's land area.[107] Currently, there are approximately 190,000 hectares of forests and 7,000 hectares of perennial woody crops in Baja California. 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 from 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.[108] Wetlands may represent a significant land use in Baja California. Also, losses of terrestrial carbon can occur during conversion of grasslands to agricultural or developed use (i.e. land use change). However, no data were identified to quantify these potential sources in Baja California. 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

[106] "Flux" refers to both emissions of CO_2 to the atmosphere and removal (sinks) of CO_2 from the atmosphere.
[107] 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
[108] IPCC defines other land as bare soil, rock, ice, and any other land not included in one of the other five land use categories.

cultivation, including losses/gains in soil carbon. Finally, as mentioned above, wetlands are not a significant land use in Baja California.

Inventory and Reference Case Projections

Forest Land Use

2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC) offers two methods for estimating carbon flux. Based on the information available for Baja California, 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:

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

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 tonne 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).[109] In order to supplement missing historical data, land 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).[110] 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.[111] For Baja California, the SEMARNAT survey assigns all forests to the "bosque" category; therefore, all forested land surface area was assumed to be in the temperate mountain system category as shown in Table H-1.

More recent and more detailed forest land data are available from INEGI.[112] 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 Baja California, the less precise and less resource intensive set of forest data were chosen for this inventory. The data in Table H-2 show a loss in forest area of 26,200 hectares between 1990 and 1995. This represents nearly a 12% loss in forest area during this period.

Table H-1. Forest Land Description and Coverage

Climate domain (i)	Ecological zone (j)	1990 (ha)	1995 (ha)
Tropical	Mountain Systems	0	0
Temperate	Mountain Systems	219,700	193,500

Table H-3 lists the values used for carbon conversion factors, G_w, R and CF taken from the 2006 IPCC guidelines.[113]

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

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

[109] *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.
[110] SEMARNAT. Compendio de Estadísticas Ambientales, 2002. México, D.F., 2003.
[111] Table 4.5, Chapter 4, Volume 4 of the IPCC guidelines.
[112] Land use and vegetation maps are referenced as: conjunto uso del suelo y vegetación escala 1:250 000, datum ITRF 92, formato SHP, series I, II y III, clave D1502
[113] Table 4.9, Chapter 4, Volume 4 of 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.

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). [114] 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-4 and calculated as follows:

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

where:

$L_{disturbance}$ = 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, tonne C per t d.m.; and

fd = fraction of biomass lost in disturbance.

[114] SEMARNAT, Anuario Estadístico 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		Value	Units
Above-ground biomass	B_w	50	tonnes d.m. ha^{-1}
Ratio of below-ground biomass to above-ground biomass	*R*	0.53	tonnes d.m. below-ground biomass per tonnes d.m. above-ground biomass
Carbon fraction of dry matter	*CF*	0.47	tonnes C/tonnes d.m.
Fraction of biomass lost in fire	*fd*	0.90	unitless
Fraction of biomass lost to disease or infestation	*fd*	0.10	unitless

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[115] 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 Estadístico 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 estimated GHG emissions from other land uses in Baja California. 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 Información Agroalimentaria de Consulta (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-6.

[115] 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).

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):

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

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 Baja California for 1990 and 2006

Crop Name		1990 Total Area (ha)	1990 Harvested Area (ha)	2006 Total Area (ha)	2006 Harvested Area (ha)
Aceituna	olive	3,497	2,044	5,379	1,619.5
Aguacate	avocado	7	7	48	26
Algarrobo	carob tree	70	70	70	70
Almendra	almond	13	11	1	0
Chabacano	apricot	6	0	1	1
Ciruela	prunes	38	26	1	1
Citricos	citric tree	0	0	0	0
Datil	dates	37	37	196	196
Durazno	peaches	14	9	2	2
Eucalipto	eucalyptus	0	0	135	19
Frutales Varios	various fruits	5	0		
Granada	pomegranate	0	0	5	5
Guayaba	guayaba	0	0	2	0
Higo	fig	17	2	9	9
Limon	lime	174	129	307.5	247.5
Macadamia	macadamia	0	0	0	0
Mandarina	tangerine	14	11	8	5
Manzana	apple	64	60	25	5
Membrillo	quince	6	6	11	8
Mostaza	mustard	11	11	0	0
Naranja	orange	256	196	473	461
Nectarina	nectarine			0	0
Nuez	walnut	23	23	28	20
Palma De Ornato	palm	0	0	0	0
Palma De Ornato (planta)	palm	0	0	14	0
Pera	pear	9	9	9	7
Pistache	pistachio	33	0	2	0
Toronja (pomelo)	grapefruit	29	24	12	9
Uva	grapevine	6,738	6,081	4,236	3,343
	Total	**11,114**	**9,150**	**10,975**	**6,054**

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

Factor		Value	Units
Above-ground biomass	B_w	63	tonnes d.m. ha^{-1}
Above-ground biomass growth	G_w	2.1	tonnes 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.[116] 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 0.27 $MMtCO_2e$. The analysis of historical records indicates that 1) biomass growth in Baja California's 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 is the loss of over 10% of the forest carbon sink due to lower estimates of forest area between 1990 and 1995. Assuming that these area estimates are accurate and that the land was cleared for conversion to other use, the associated loss in carbon stocks are not reflected in the historic emission estimates below for the 1990-1995 time-frame. If the potential losses in carbon stocks were to be included, the results might show lower net sequestration and possibly even positive GHG emissions during this period. In addition, it is not clear whether the losses in forested area shown in Table H-1 above have continued after 1995.

Table H-7. Forestry and Land Use Flux and Reference Case Projections ($MMtCO_2e$)

Subsector	1990	1995	2000	2005	2010	2015	2020	2025
Forested Land	-0.21	-0.20	-0.21	-0.24	-0.19	-0.19	-0.19	-0.19
Growth	*-0.29*	*-0.26*	*-0.26*	*-0.26*	*-0.26*	*-0.26*	*-0.26*	*-0.26*
Fires (carbon loss)	*0.012*	*0.010*	*0.008*	*0.002*	*0.013*	*0.013*	*0.013*	*0.013*
Fires (CH_4 and N_2O)	*0.046*	*0.039*	*0.031*	*0.010*	*0.051*	*0.051*	*0.051*	*0.051*
Disease	*0.0001*	*0.003*	*0.000*	*0.003*	*0.001*	*0.001*	*0.001*	*0.001*
Harvested Wood	*0.020*	*0.002*	*0.000*	*0.000*	*0.003*	*0.003*	*0.003*	*0.003*
Perennial Woody Crops	-0.020	-0.004	-0.019	-0.024	-0.037	-0.037	-0.037	-0.037
Total Carbon Flux	**-0.28**	**-0.24**	**-0.27**	**-0.27**	**-0.27**	**-0.27**	**-0.27**	**-0.27**
Total (including CH_4 and N_2O)	**-0.23**	**-0.21**	**-0.23**	**-0.26**	**-0.22**	**-0.22**	**-0.22**	**-0.22**

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

Key Uncertainties and Future Research Needs

As stated above, not all IPCC land use categories relevant to Baja California 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 Baja California. Future research should

[116] 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.

include efforts to quantify wetlands and 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 wetlands and urban land area). However, additional resources will be needed to process digital imagery files available from INEGI.[117] Future research is also needed to confirm the large losses in forested area from 1990 to 1995 and to determine losses/gains in area since 1995. Any losses of carbon stocks due to clearing and conversion to non-forest use are not included in the current estimates.

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 an order of magnitude. 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$_2$e)

Subsector	1990	1995	2000	2005
Forest Land – Lower End Factors	-0.11	-0.20	-0.21	-0.24
Forest Land – Median Value Factors	-1.05	-1.48	-1.49	-1.51

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 Baja California, 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 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 Baja California in order to adequately characterize the full net flux of forest carbon.

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

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Appendix I. **INE'S recommendations for the next GHG Emissions Inventories Update**

On the correspondence dated August 5, 2010, INE submitted few recommendations to be considered in the next GHG Emissions Inventories update for the Spanish. The following, presents a portion of INE's correspondence including the general comments submitted for the documents reviewed in respect to the six Mexican border states inventories as wells as the recommendations for each specific report.

General Comments on inventories developed by the United States Center for Climate Strategies[118]

Inventories followed the 2006 IPCC methodologies and from INE's standpoint, these were correctly applied, with the exception of the "Land Use, Land Use Changes, and Forestry" category, where CCS recognizes that further work will have to be done to achieve compatibility with the National Greenhouse Gas Emissions Inventory (INEGEI, for its Spanish acronym). Emissions estimated by CCS for this sector are currently negative; in general, they are expected to be positive due to the degree of deforestation and land use changes. We recommend working with the research institutions involved in the national inventory on this category.

To estimate emissions in the electricity supply sector, CCS quantified them based on electricity used plus imported electricity, minus electricity exports. This estimation approach is useful to identify GHG mitigation measures when considering the implications of policies and actions that may impact power plants emissions, both within and outside of the state. To present summaries of total emissions in each state across all categories, estimates of emissions based on electricity use were employed, except when state emissions were compared against INEGEI emissions, as only emissions generated in the geographic area are considered.

General recommendations for the inventories:

- Verify units. The $MMtCO_2e$ to $MTmCO_2e$ units have not been corrected (Use only the international system).
- Verify that units are identified in all the tables and figures.
- Where it says: "Un Análisis Minucioso a *las* Dos Sectores Principales: Suministro Eléctrico y Transporte" *[A Thorough Analysis of the Two Main Sectors: Electrical supply and Transportation],* change to "Un Análisis Minucioso a *los* Dos Sectores Principales: Suministro Eléctrico y Transporte" (approx. pg. 19).
- Change the word segregados [segregated] for desagregados [disaggregated].
- Identify the source of DGPs used and reference year.
- Change the word residuos [*residue*] to desechos [*waste*] on INE's Table 2.
- Change where it says: "INEGI – Instituto Nacional de Estadísticas, Geografía e Informática" to "INEGI – Instituto Nacional de Estadística y Geografía."
- In estimating emissions resulting from electricity imports, the inventories considered that these were generated by a natural gas combined cycle. Clarify for readers that this represents an error, as it fails to consider the contribution of renewable energies or the use of fuel with a higher carbon content in the electricity system. Justify why only the natural gas emission factor is considered as opposed to other fuels.
- In Table A-3, where do they obtain the heat index value? SENER defines it as the equivalent electricity in secondary terms, expressed in (MJ/MWh) with a 3,600 conversion value. Additionally, one more operation needs to be indicated to go from MW to TJ.
- In the "Residential, Commercial, and Industrial (RCI) section, for natural gas, it mentions that aggregate data are available for "residential, commercial, and transportation," though industrial rather than transportation is what's reported in this sector. If transportation does count in the case of natural gas, is it included in the transportation source?
- In RCI, fuel oil is estimated in the residential sector; however, the National Energy Balance indicates that this energy source has not been used in this sector since 1999. Where was this information obtained and what purpose does it serve in this sector?
- Identify complete bibliographic sources and include them in tables and figures if not developed internally. For example: When citing information sources, do not merely state that information is from SENER, INEGI, etc., but also add the document from which information was obtained, or the internet link.
- When adding that information has been requested, indicate from which period is information available and publication date.
- Identify for all emission sources the activity data used or estimated in tables, as well as conversion factors.
- Identify for all sources the emission factors used in tables.

[118] The translation of INE's Recommendation Official Letter was conducted by a certified translator.

- The undifferentiated use of the terms pronóstico [forecast] and proyección [projection] persists throughout the inventory. We recommend identifying them only as projections.
- Use acronyms correctly, such as the case of IPCC; use the same [acronym] throughout the entire inventory.
- Review and correct all acronyms in the document.
- Figures (charts) are labeled in English. For the Spanish version, label them only in Spanish.
- Check the language (some words in footnotes are still in English, they need to be translated). There are word repetitions throughout the inventory, for example "de de," (IPCC IPCC).
- Check the Spanish language.
- Pursuant to the 2006 IPCC methodology, volume 5, page 3.25 says the following:

  "Long term carbon storage in solid waste disposal sites (SWDS) is established as an **informational element** for the Waste Sector. The declared value for waste derived from harvested wood products (paper and cardboard waste, wood, and landscaping and park waste) is equal to variable 1B, $\Delta C_{HWP\ SWDS\ DC}$, i.e. the change in carbon stock in harvested wood products (HWP) related to domestic use disposed in SWDS in the reporting country, as used in Chapter 12, Harvested Wood Products, AFOLU ."

  Therefore, we recommend not adding it to the waste section.

- The value of their emissions is compared to values in the Third Communication; we recommend comparing it to the value reported for 2005 in the Fourth Communication, INEGEI 1990-2006. Total emissions in 2005 were 685.117 MtmCO_2e.

  - Total 685.117 MtmCO_2e
  - Energy 61.2%
  - Processes 8.2%
  - Agriculture 6.6%
  - USCUSS 10.2%
  - Waste 13.8%

<u>Observations – Baja California Inventory</u>

- Explain the text above Table A-4. Inventory and Projection based on Fossil Fuel Production-Use (TIJ). Why was it that only in 2000 was a higher amount of diesel used?
- In Table A-7, explain the amount of electrical energy losses in 1995, since it represents almost half of the total use in the state. Did so much remain uncollected, or was it inefficiency in the system?
- In Table A-8, verify electricity importation amounts, since they do not match the total.
- Appendix B, first paragraph, says: "En el 2005 las emisiones totales de GEI procedentes de la quema de aceite, gas natural, carbono y leña fueron del orden de 1.4 MTmCO2e" ["In 2005 the total of GHG emissions from oil, natural gas, carbon, and wood burning amounted to 1.4 MTmCO2e."] Instead of lubricant oil [aceite] they surely meant petroleum oil
- In Figure B-1 the commercial sector was not included in the graph.
- For Baja California, INE requests a review of TJ data regarding electricity production between 2002 and 2003, since it almost doubles from one year to the other, which we believe not to be normal.
- Along with the above item, verify 2000 to 2005 carbonization rates. The rate is expected to drop as a result of the substitution of fuel oil by natural gas; however, it may happen that a high natural gas consumption rate will increase the carbonization rate, so we must verify it this is indeed the case.