COLIMA
GOBIERNO DEL ESTADO

GREENHOUSE GAS INVENTORY OF THE STATE OF COLIMA

BASE YEAR 2015

IMADES
Instituto para el Medio Ambiente y Desarrollo Sustentable del Estado de Colima

UNDER2°
SECRETARIAT THE °CLIMATE GROUP

CECYTCOL
Consejo Estatal de Ciencia y Tecnología del Estado de Colima

Consultoría en Ingeniería de Proyectos

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The collaboration with The Climate Group aims and impulses the incorporation of mitigation strategies into de State Action Plan of the State of Colima, and showcases the policy framework towards 2050 to avoid dangerous climate change.

The counterpart of the funding was given by the State Council of Science and Technology of Colima (CECYTCOL, by its acronym in Spanish), in order to promote the environmental culture with a scientific and technological formation.

Acknowledgments

Editorial

INSTITUTO PARA EL MEDIO AMBIENTE Y DESARROLLO SUSTENTABLE DEL ESTADO DE COLIMA

Executive summary

The State of Colima is one of the thirty-one states of Mexico. With 0.3% of Mexico's territory, the 5,627 km^2 make it the fourth smallest state of the country, but the size is compensated by its importance. Colima has one of the most important ports in the country, where big quantities of goods are mobilized internationally, has installed up to 2,700 MW for electric generation, and has multiple natural protected areas and up to 123 endemic animal species, which at least 5 are endemic to the state.

In order to keep improving the state and ensure a good life quality for the more than 711 thousand citizens, the government, in its three orders, has been working in different environmentally-related projects. One of these is the conservation and creation of carbon sinks with actions like reforestations. This year, 72,070 trees will be planted in coordination with the National Forestry Commission of México and the State of Colima; protection of 22,468 hectares of continental natural areas; and the establishment of a biotic-cultural corridor which connects 14.5 million hectares of land to preserve the species of different states of the central-occidental region.

A second action was the creation of a mitigation and adaptation law, which provides the basis for the elaboration of programs and strategies focused in decreasing the vulnerability of the economic activities, the natural areas and the population in front of climate change.

Also, the state government is working towards sustainable transportation. Last year, the Sustainable Mobility Law of the State of Colima was approved, setting a pathway to promote the use of cleaner technologies in public and private sectors, no motorized and other eco-friendly ways of transportation. With this, there are already 3 new bike ways that are the beginning of a 324.62 km bikeway network. Along with his action, last year 180 efficient taxis were introduced to reduce the pollutant emissions, and this year were proved 2 new buses to introduce low carbon units for collective public transportation.

Now, with the help of the Under2 Coalition Future Fund, the government of the State of Colima is able to make the Update of the Greenhouse Gas Inventory of the state of Colima, which is essential to recognize the sources of our state's emissions in order to develop an objective and effective strategy of mitigation, as well as provide a real data to support those projects where the lack of background information has stopped them to become actual actions.

As part of the Under2 Coalition and human beings, the mitigation in the most pollutant sectors is a priority, the inventory will give a base line and the contribution of each sector which will appoint the best path to reach the goal of maintaining the global temperature below the 2°C threshold. Doing this, the State of Colima is looking forward a future where the people can have a good quality of life, which involves health, resilience capacity, conservation of ecosystems, savings in energy bought and generation, identification of economic potentials and climate change risks decrease.

Acronym summary

By its meaning in English

FAOSTAT	Food and Agriculture Organization of the United Nations Statistics
IPCC	Intergovernmental Panel on Climate Change
UNFCCC	United Nations Framework Convention on Climate Change
UN Environment	United Nations Environment Program
WMO	World Meteorological Organization

By its meaning in Spanish

CANACEM	National Chamber of Cement Cámara Nacional del Cemento
CECYTCOL	State Council of Science and Technology of the State of Colima Consejo Estatal de Ciencia y Tecnología del Estado de Colima
CFE	Federal Electricity Commission Comisión Federal de Electricidad
CINPRO	Project Engineering Consulting Consultoría en Ingeniería de Proyectos
COA	Annual Operating Form Cédula de Operación Anual
CONAFOR	National Forestry Commission Comisión Nacional Forestal
CONAGUA	National Water Comission Comisión Nacional del Agua
CRE	Energy Regulatory Commission Comisión Reguladora de Energía
DENUE	National Statistical Directory of Economic Units Directorio Estadístico Nacional de Unidades Económicas

IMADES	Institute for the Environment and Sustainable Development of the State of Colima Instituto para el Medio Ambiente y Desarrollo Sustentable del Estado de Colima
INECC	National Institute of Ecology and Climate Change Instituto Nacional de Ecología y Cambio Climático
INEGEI	National Inventory of Greenhouse Gas Emissions Inventario Nacional de Emisiones de Gases y Compuestos de Efecto Invernadero
INFOMEX (PNT)	National Transparency Platform Plataforma Nacional de Transparencia
OEIDRUS	State Information Office for Sustainable Rural Development Oficina Estatal de Información para el Desarrollo Rural Sustentable
SAGARPA	Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación
SCT	Ministry of Communications and Transportation Secretaría de Comunicaciones y Transporte
SEMARNAT	Ministry of Environment and Natural Resources Secretaría de Medio Ambiente y Recursos Naturales
SEMOV	Secretariat of Mobility of the State of Colima Secretaría de Movilidad del Estado de Colima
SENER	Ministry of Energy Secretaría de Energía
SIAP	Agrifood and Fisheries Information Service Servicio de Información Agroalimentaria y Pesquera
SIE	Energy Information System Sistema de Información Energética

Summary

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1. Introduction

Global warming is a phenomenon which consists in the planet upper temperature rising because of the concentration of certain atmospheric pollutants, called Greenhouse Gases (GHG). Some of these pollutants are carbon dioxide (CO_2), methane (CH_4) and hydrofluorocarbons (HFCs), among others controlled by the Kyoto Protocol. When the atmospheric balance is broken by anthropogenic causes, the ones generated by humans as the energy generation, the industry, mining and other activities using and transforming natural resources, the socioeconomic affairs and the countries development increase their importance in order to maintain the ecosystem. (UNEP/UNFCCC, 2002)

In response to this situation, in 1988, it was created the Intergovernmental Panel on Climate Change (IPCC) by the United Nations Environment Programme (UN Environment) and the World Meteorological Organization (WMO). Among their most important activities, one of them is the promotion of the realization of Emissions Inventories which evaluates the current situation and propose alternatives for its mitigation. Mexico, for its part, has realized the National Inventory of Greenhouse Gas Emissions (INEGEI) following the establishment in the United Nations Framework Convention on Climate Change (UNFCCC), which gathers estimations of the emissions by source and sink of the period from 1990 to 2010.

The GHG Inventory is developed through the IPCC 2006 guidelines for the energy, industrial processes and use of products (IPPU), agriculture, forestry and other land use (AFOLU) and waste sectors.

Each sector is disaggregated by subsector. Each subsector is calculated depending of the type of information obtained of the State, through the level 1, 2 or 3 of the methodologies of the IPCC 2006.

The results were obtained depending of each sector and subsector for the GHG CO_2, N_2O, CH_4, HFC, PFC, SF6 and black carbon. The results in the inventory are shown as equivalent CO_2 (CO_2e). The Figure 1 shows the contribution percentages of each one of the GHG inventory of Colima sectors. The total of the emissions was 18,137 Gg/year of CO_2e for the year 2015 in the State of Colima.

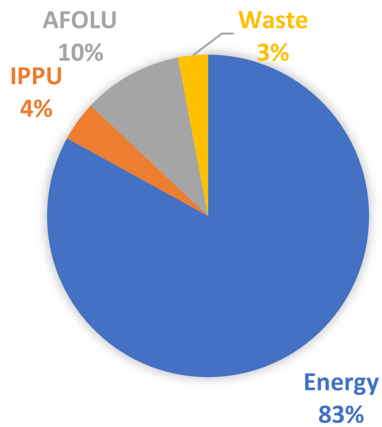


Figure 1. Contribution percentages of each GHG inventory category.

The energy sector is the one which contributes the most to CO_2 emissions, with 83%, followed by the AFOLU sector with a 10%, the IPPU sector with a 4% and the waste sector with the 3%. The results of the GHG inventory show the sectors with the bigger GHG contribution, which can help to implement specific mitigation actions at shorts and longs terms. In the Chart 1 are shown the CO_2e emissions for each sector.

Chart 1. CO_2e emissions in Gg/year for 2015 in the State of Colima.

Sector	2015
Energy	15,070
IPPU	724
AFOLU	1,879
Waste	464
State	**18,137**

The Figure 2 shows the distribution of the CO_2e emissions at municipal level in the state of Colima. The municipalities with the biggest amounts of emissions were Manzanillo, Tecomán, Colima and Minatitlán.

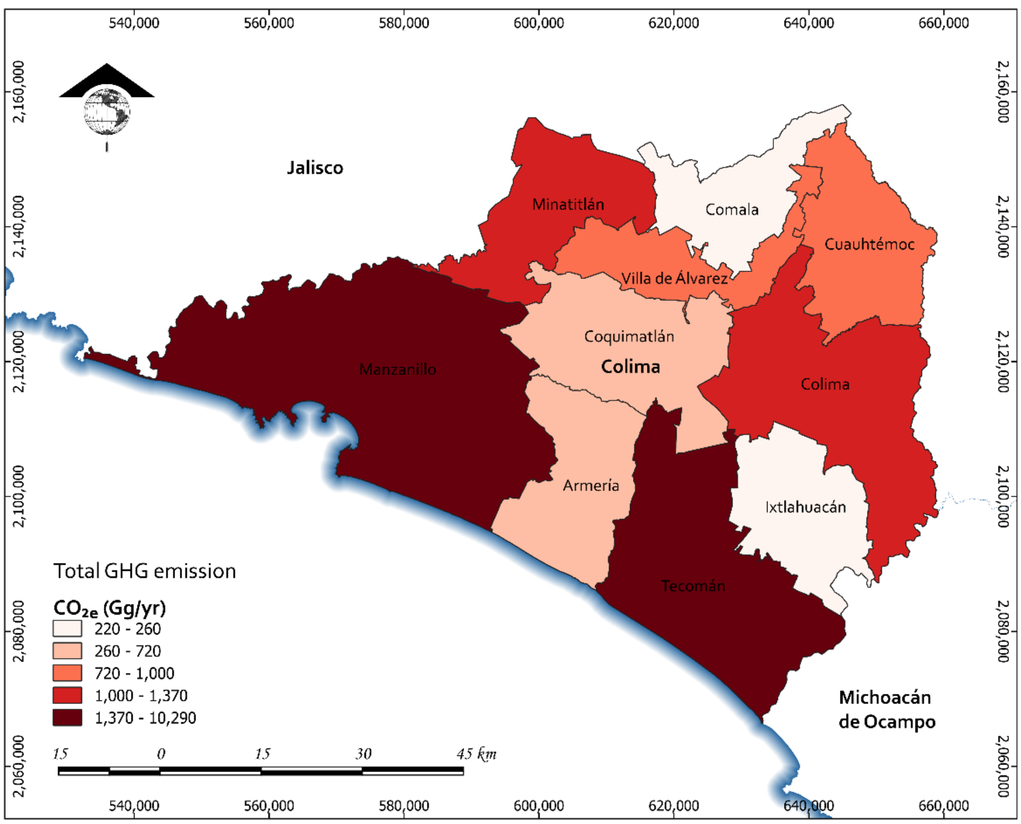


Figure 2. CO_2e emissions distribution at municipal level in the State of Colima.

One of the considerations realized for the present document is the calculation of the uncertainty per each subsector and sector involved. This was realized through the method 1 and 2 of the IPCC 2006 guidelines. It is estimated that the inventory has a global mixed uncertainty of 8.9%.

2. Background

The State of Colima has three inventories of criteria pollutants: 2005, 2008 and 2013. Those were elaborated by SEMARNAT-INECC as part of the National Inventory of GHG Emissions of Mexico (INEGEI). It is important to notice that since the inventory realized in 2008, GHG pollutants as CO_2, CH_4, N_2O and black carbon were considered.

The State of Colima has done one GHG inventory; base year 2005, with a projection to 2010. This was realized for the State Climate Change Actions Program elaborated in 2013.

3. Study area description

Colima is a state of constant economic development. It has competitive advantages because of its privileged geographical position, the dynamic population, its solid and growing infrastructure, its enormous natural richness, as well as the growing commercial, agro-industrial, port and extractive activities, which contribute to a diversified economy. During 2015, according to the National Institute of Statistic and Geography (INEGI), the population in the state was up to 711,235 habitants. About 89% of the population resides in urban zones and 11% in rural zones (INEGI, 2016a).

Figure 3. Map of the State of Colima, Mexico. From: INEGI, 2015

3.1. Geographical conditions

The state of Colima is one of the smallest entities of the country; it has the twenty-ninth place in territorial extension. It has a surface of 5,455 Km2 and a littoral of 160 Km of length along the Pacific Ocean. Geographically, the Revillagigedo Archipelago (205 Km^2) is part of Colima; it is formed by the Socorro Islands (160 Km^2), Clarion (35 Km^2), San Benedicto and Roca Partida; it is located 716 Km the west of Manzanillo Port. The state is constituted by 10 municipalities: Armería, Colima, Comala, Coquimatlán, Cuauhtémoc, Ixtlahuacán, Manzanillo, Minatitlán, Tecomán and Villa de Álvarez. In Figure 3, it can be seen a representative map of the State of Colima, with its adjoining to other states. (INEGI, 2016 b)

3.2. Meteorological conditions

The estate is located west of the Mexican Republic; on the west coast of the Pacific Ocean, between the Meridians 103º 29’ to 104º 35' of longitude to the west of Greenwich and the parallels 18º 41' to 19º 31 of latitude at the north. Colima borders on the North with the State of Jalisco, on the East with the States of Michoacán and again with Jalisco, on the west it borders again with Jalisco and on the South with the Pacific Ocean. (INEGI, 2016 c)

In the state of Colima, 86% of its territory has a warm sub humid climate, 12.5% dry and semi-dry climate, 1.5% is located on the slopes of the volcano and has a tempered sub-humid climate (Figure 4). (INEGI, 2016c)

In the State, the average annual temperature is 25 °C, the highest temperature exceeds 30 °C and the minimum temperature is 18 °C. The rains occur during the summer season with a total annual rainfall of approximately 900mm. (INEGI, 2016c)

The climate favors the cultivation of corn, sorghum, sugar cane, coconut palm, tamarind, rice, tomato, lemon and papaya, among others.

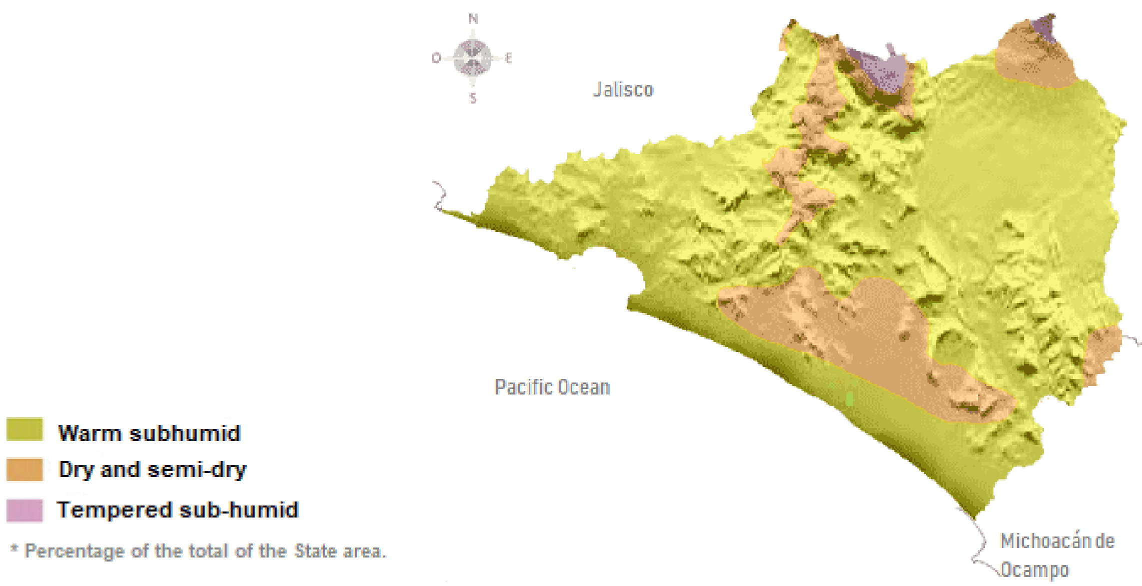


Figure 4. Representative map of the Meteorological Conditions in the State of Colima.

3.3. Economic conditions

In economic terms, the Gross Domestic Product (GDP) in 2015 at 2013 prices was 177 thousand 365 million dollars, with a contribution of 0.6% at the national level, which places it at the 32nd place nationwide:68.9% comes from tertiary activities, 26.5% from secondary activities and 4.6% from primary activities. (INEGI, 2018)

As for the sectors, it was observed for 2015 that the largest contributions were from construction (12.9%), property companies (12.7%), retail (11.2%) and transport, post and storage (10.6%) sectors. (Figure 5).

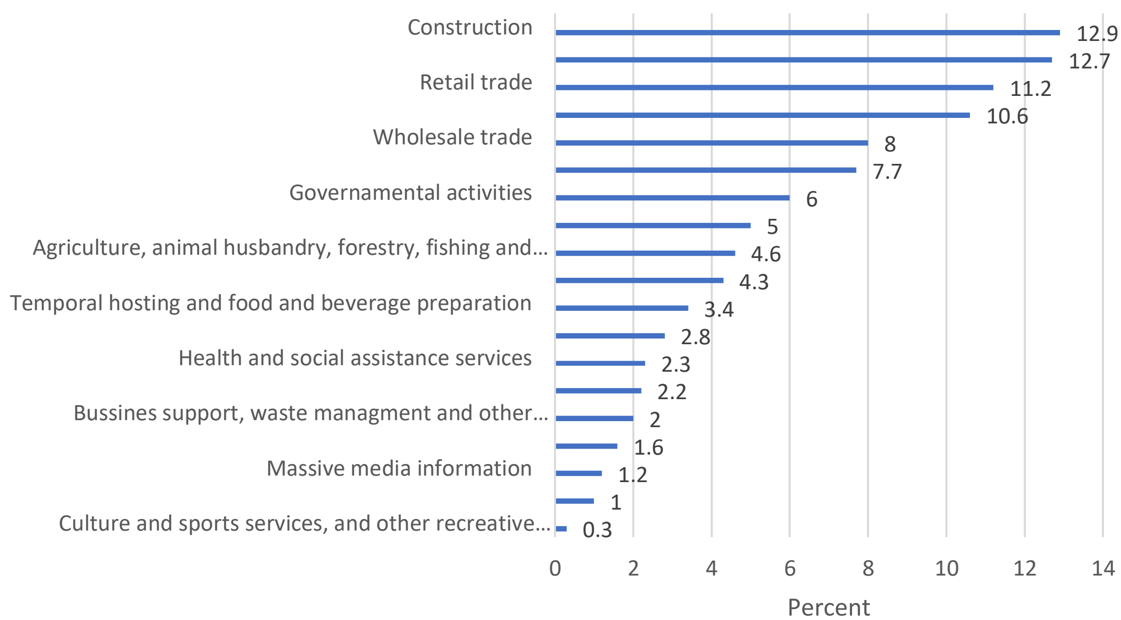


Figure 5. Gross Domestic Product of Colima. From: INEGI, 2018

4. Objectives

4.1. General objective

Elaborate the Greenhouse Gas (GHG) Inventory of the state of Colima, base year 2015; as a useful tool for decision making, scientific research and the identification of opportunities to mitigate the impacts generated in the entity as well as globally.

4.2. Specific objectives

- Elaborate the GHG Inventory of the state of Colima, base year 2015, following the INECC and 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
- Obtain a municipal level resolution for the Inventory of Greenhouse Gases of the State of Colima.
- Estimate emissions by categories, according to the 2006 IPCC: Energy, Industrial Processes and Product Use (IPPU), Waste, Agriculture, Forestry and Other Land Use (AFOLU).
- Develop uncertainty calculations that include activity data and emission factors for the greenhouse gas inventory of the state of Colima.

5. Calculation methodology

The calculation of greenhouse gas emissions was made for the four categories considered by the 2006 IPCC guidelines:

i. Energy (generation, industry, transport, residential, commercial and agriculture).
ii. Industrial process and use of products (IPPU) (production and use of minerals, production of metals, chemical industry, some processes such as food and beverages, and finally, in the production and consumption of halocarbons and sulfur hexafluoride).
iii. Agriculture, forestry and other land uses (AFOLU).
iv. Waste (disposal of municipal solid waste and management, treatment of municipal and industrial wastewater, and waste incineration).

The greenhouse gases that were estimated are those included in ANNEX A of the Kyoto Protocol plus black carbon:

1. Carbon dioxide (CO_2)
2. Methane (CH_4)
3. Nitrous oxide (N_2O)
4. Hydrofluorocarbons (HFC)
5. Perflourocarbons (PFC)
6. Sulfur hexafluoride (SF_6) y
7. Black carbon

As well as the equivalent carbon dioxide (CO_2e), for which the global warming potentials (GWP) of each one of the 100-year greenhouse gases reported in the 5th IPCC Report will be used (IPCC, 2006).

5.1. Estimation methods

The methodology used was that of the Intergovernmental Panel on Climate Change (IPCC) 2006. The most common methodological approach is to combine information on the scope to which a human activity takes place (called activity data or AD) with the coefficients that quantify the emissions or removals per unit activity, called emission factors (EF). Therefore, the basic equation is:

$$Emissions = AD \times EF \qquad \text{Equation 1}$$

5.2. Global warming potentials

The determination of carbon dioxide equivalent emissions (CO_2e) was made by quantifying CO_2, CH_4, N_2O, HCFC-141b, HCFC-22, SF6 and black carbon emitted taking into account the global warming potentials (GWP) of each of the greenhouse gases for 100 years reported in the 5th IPCC Report. Chart 2 shows the GWP used to calculate CO_2 equivalent emissions (CO_2e).

Chart 2. Global Warming Potentials of Greenhouse Gases.

Gas	Global warming potentials for 100 years
CO_2	1
CH_4	28
N_2O	265
HCFC-141b	725
HCFC-22	1,810
SF_6	23,500
Black carbon	900

From: https://www.ipcc.ch/publications_and_data/ar4/wg1/es/tssts-2-5.html

6. Methodological Option and Identification of Key Categories

6.1. Standardization and Validation of Information

Consultancy in Project Engineering and the Institute for the Environment and Sustainable Development of the State of Colima (IMADES) obtained the necessary information for the development of the project, through information requests to the corresponding agencies and institutions, in addition to official information available on the internet useful for the project.

The collected information was standardized to Excel format, to form a database by category. Later, the transcription of information was verified and unit validation was performed, as well as its contrast with the original source. In the case of energy consumption, there were multiple sources of information for the same subcategory, which is why it was considered the most disaggregated and complete for each type of fuel.

6.2. Identification of key categories; decision tree

For the analysis of the key categories, method 1 that describes the IPCC 2006 methodology was used.

Through the use of the decision three included in the IPCC 2006 methodology, the analysis of the information obtained was carried out, as well as the research of local, national and international emission factors, as well as the use of the emissions model, as the case may be. These decision trees provided the level of measurement to be taken by sector and category calculated.

The level represents the methodological complexity. In general, three levels are presented. Level 1 is the basic method (Tier 1), Level 2 is intermediate (Tier 2), and Level 3 is the most demanding in terms of complexity and data requirements (Tier 3). (IPCC, 2006 a)

For the specific case of the motor transport sector, there is specific activity data for the State. The emission factors were calculated through the MOVES-Mexico model, with which were obtained emission factors specific to the State, resulting in the method of calculation level 3 (Tier 3). Figures 6, 7, 8 and 9 show the trees of general decision that were used for the selection of the level of measurement of each category and subcategory.

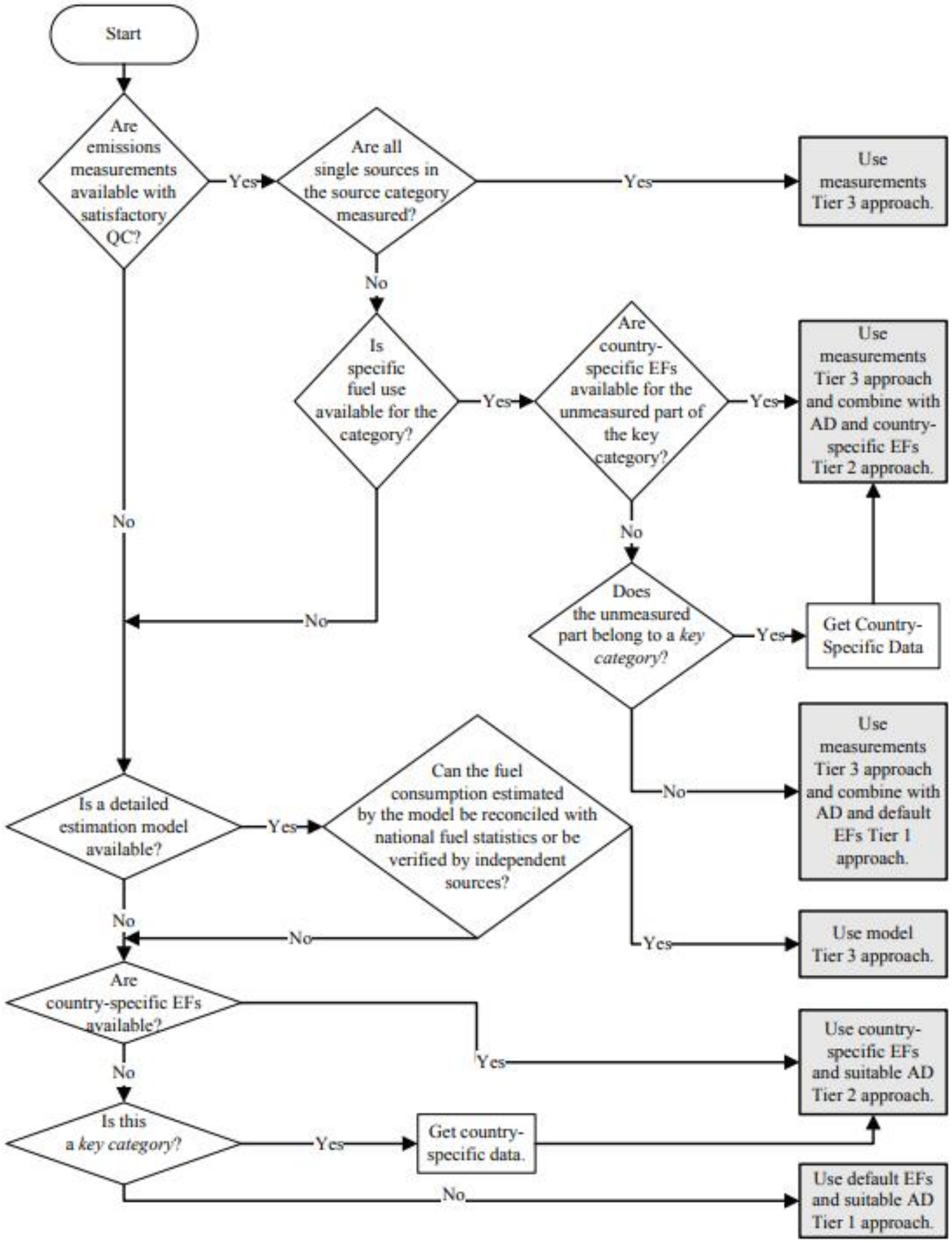


Figure 6. Decision tree to select the estimation method for Energy category. (IPCC, 2006)

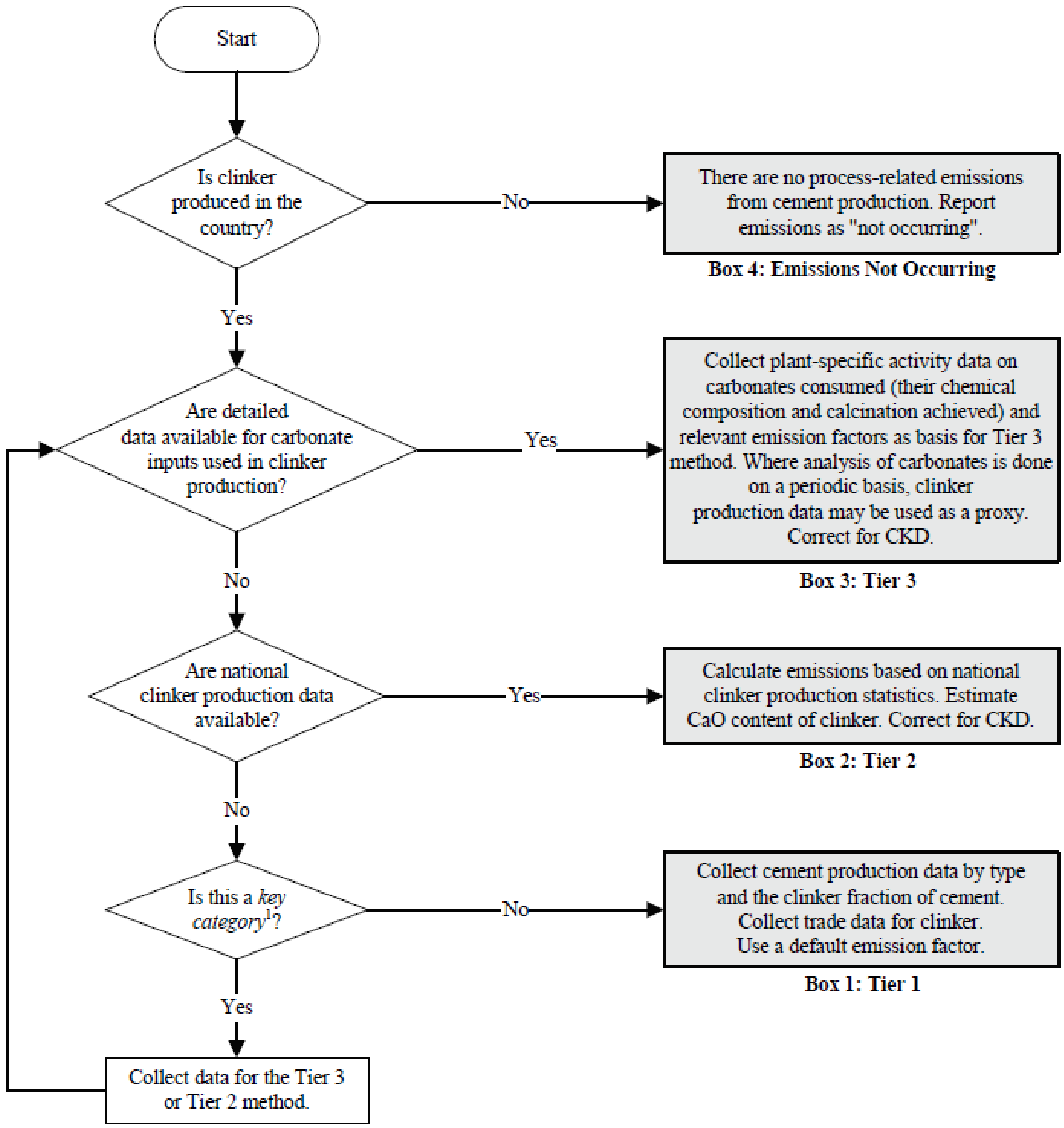


Figure 7. Decision tree to select the estimation method for IPPU category. (IPCC, 2006)

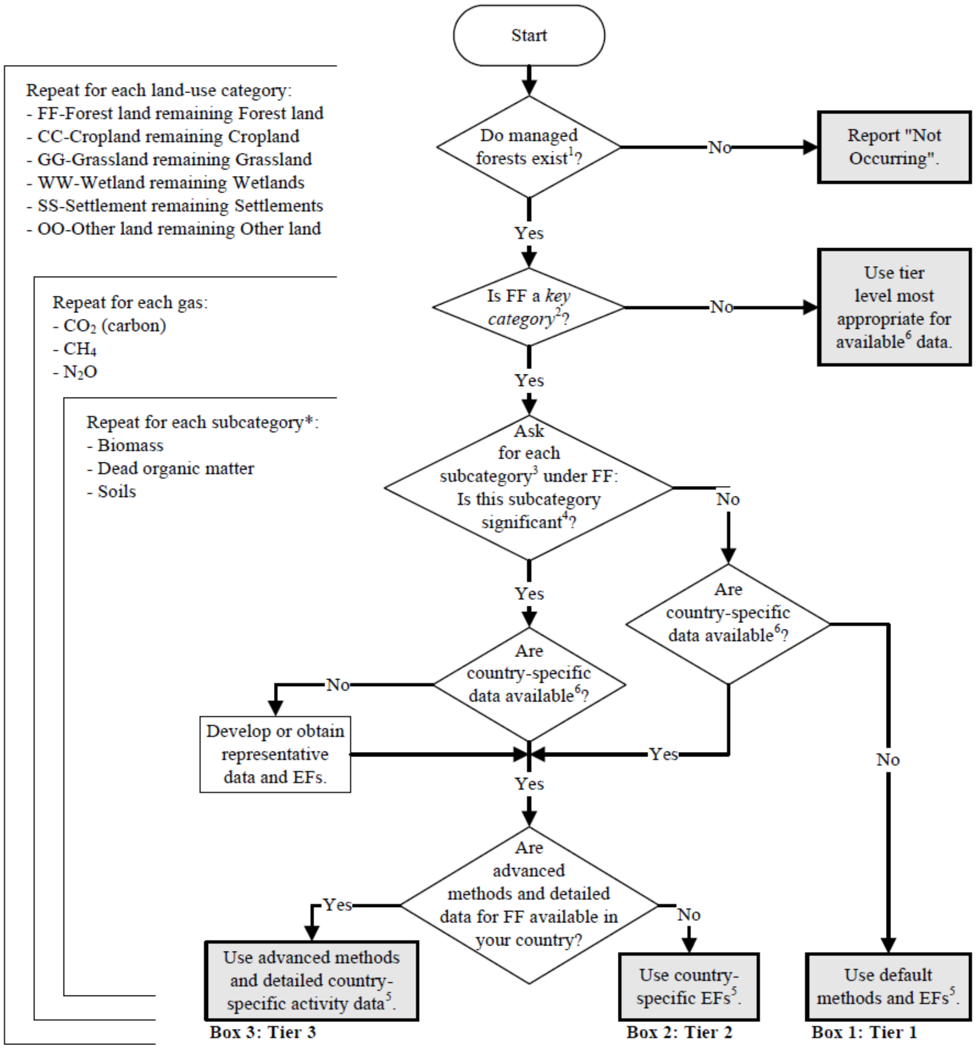


Figure 8. Decisions tree to identify the correct level of calculation for lands which stay with the same use. The example shows the forestry lands which stay as it. AFOLU. (IPCC, 2006)

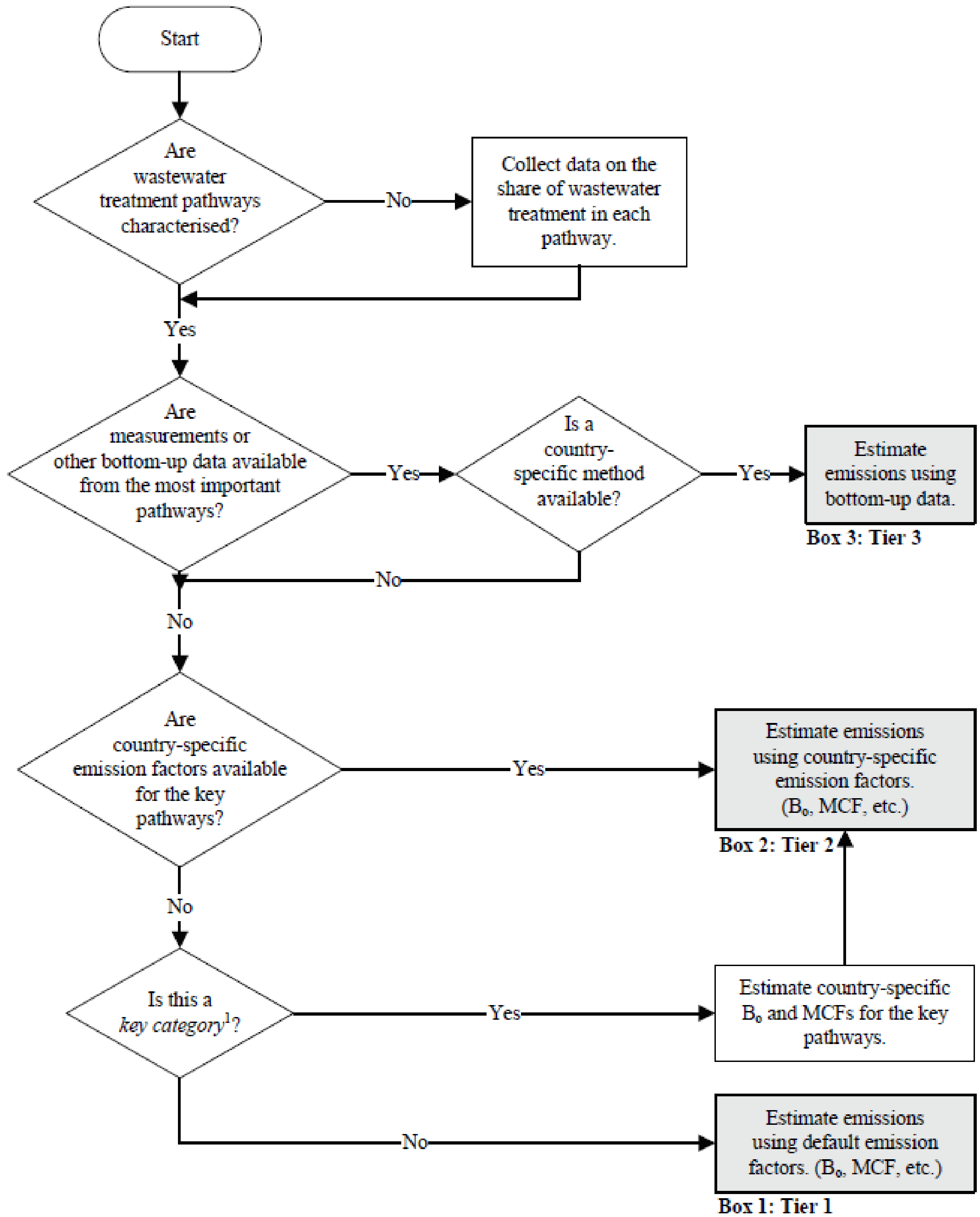


Figure 9. Decisions tree to calculate the CH4 emissions from domestic wastewater. Waste. (IPCC, 2006). The example shows the Waste. (IPCC, 2006)

The results of this election are shown in Chart 3, where the level of calculation is shown.

Chart 3. Calculation level in the inventory per category and subcategory for the GHG Inventory of the State of Colima, base year 2015.

Category- subcategory code/ name	Source	Methodology	Tier/ Level	Emission factor source	Activity data source
1A1 Energy industries	1A1ai Electricity generation	IPCC 2006	2	CO_2 National, other IPCC-2006	COA
	1A1aiii Energy generation plants	IPCC 2006	2	IPCC 2006	
1A2 Manufacturing and construction industries	1A2a Iron and steel	IPCC 2006	2	CO_2 National, other IPCC-2006	COA
	1A2c Chemistry substances	IPCC 2006	2	CO_2 National, other IPCC-2006	COA
	1A2e Food, beverage and tobacco industries	IPCC 2006	2	CO_2 National, other IPCC-2006	COA
	1A2f non-metallic minerals	IPCC 2006	2	CO_2 National, other IPCC-2006	COA
	1A2m non-specified industries	IPCC 2006	2	CO_2 National, other IPCC-2006	COA
1A3 Transport	1A3a Civil aviation	IPCC 2006	1	CO_2 National, other IPCC-2006	SCT
	1A3b Road transportation	MOVES	3	MOVES	Inquiry
	1A3c Railways	IPCC 2006	1	CO_2 National, other IPCC-2006	SCT
	1A3d Navigation	IPCC 2006	1	CO_2 National, other IPCC-2006	SCT
1A4 Other sectors	1A4a Commercial / Institutional	IPCC 2006	2	CO_2 National, other IPCC-2006	SENER, CRE
	1Ab Residential	IPCC 2006	2	CO_2 National, other IPCC-2006	SENER, CRE
	1A4c Agriculture/Silviculture	IPCC 2006	2	CO_2 National, other IPCC-2006	SENER, CRE
2A Mineral industry	2A1 Cement production	IPCC 2006	1	default	COA
	2A4 Other uses of carbonates in processes	IPCC 2006	1	default	COA
2C Metal industry	2C1 Production of iron and steel	IPCC 2006	1	default	COA
2F Use of substitute products for substances that deplete the ozone layer	2F1 Refrigeration and air conditioning	IPCC 2006	1	default	COA

Category- subcategory code/ name	Source	Methodology	Tier/ Level	Emission factor source	Activity data source
2G Manufacturing and use of other products	2G2 SF6 y PFC of other products uses	IPCC 2006	1	Reported by the industrial	COA
3A Livestock	3A1 Enteric fermentation	IPCC 2006	1	default	SAGARPA
	3A2 Manure management	IPCC 2006	1	default	SAGARPA
3B Land	Land converted to forest land	IPCC 2006	3	Specific for Mexico	INEGI-CONAFOR
	Lands converted to Grasslands	IPCC 2006	3	Specific for Mexico	INEGI-CONAFOR
	Lands converted to Settlements	IPCC 2006	3	Specific for Mexico	INEGI-CONAFOR
	Land converted to Agricultural land	IPCC 2006	3	Specific for Mexico	INEGI-CONAFOR
	Lands converted to other lands	IPCC 2006	3	Specific for Mexico	INEGI-CONAFOR
Removals	Forest lands that remain as forest lands	IPCC 2006	3	Specific for Mexico	INEGI-CONAFOR
	Pastures that remain as grasslands	IPCC 2006	3	Specific for Mexico	INEGI-CONAFOR
	Agricultural Lands that remain as Agricultural land	IPCC 2006	3	Specific for Mexico	INEGI-CONAFOR
3C Aggregate sources and non-CO2 emission sources of land	3C1 Biomass burn	IPCC 2006	2	National	CONAFOR
	3C2 Whitewashing	IPCC 2006	1	default	SAGARPA
	3C3 Application of urea	IPCC 2006	1	default	SAGARPA
	3C4 Direct N2O emissions from managed soils	IPCC 2006	1	default	SAGARPA
	3C5 Indirect N2O emissions from managed soils	IPCC 2006	1	default	SAGARPA
	3C6 Indirect emissions of N2O resulting from manure management	IPCC 2006	1	default	SAGARPA
4A Solid waste disposal	Municipal solid waste disposal	Mexican Model of Biogas	3	FE del model	Specific for final disposal sites
4C Incineration and open incineration of waste	Burning waste opencast	IPCC 2006	1	default	INEGI
4D Wastewater treatment and disposal	Municipal Wastewater (treated)	IPCC 2006	2	Nacional	CONAGUA
	Municipal Wastewater (untreated)	IPCC 2006	2	Nacional	CONAGUA
	Industrial Wastewater (treated)	IPCC 2006	1	default	CONAGUA

6.3. Control procedure and inventory quality assurance

A quality control system (QC) is a set of activities that are developed. The QC system is designed to have routine and coherent controls that guarantee the integrity of the data, its correction and its completeness; detect and correct errors, omissions, as well as document and archive the inventory material and the record of all QC activities.

The QC activities contain general methods such as accuracy controls applied to the acquisition of data and calculations, the use of approved standard procedures for calculations of emissions and removals, measurements, estimation of uncertainties, archiving of the information and the declaration. QC activities also include technical reviews of categories, activity data, emission factors, other parameters and estimation methods. (IPCC, 2006 b)

The QC procedure followed in the development of the present inventory was carried out in each of the inventory phases, in Figure 10, the process is shown.

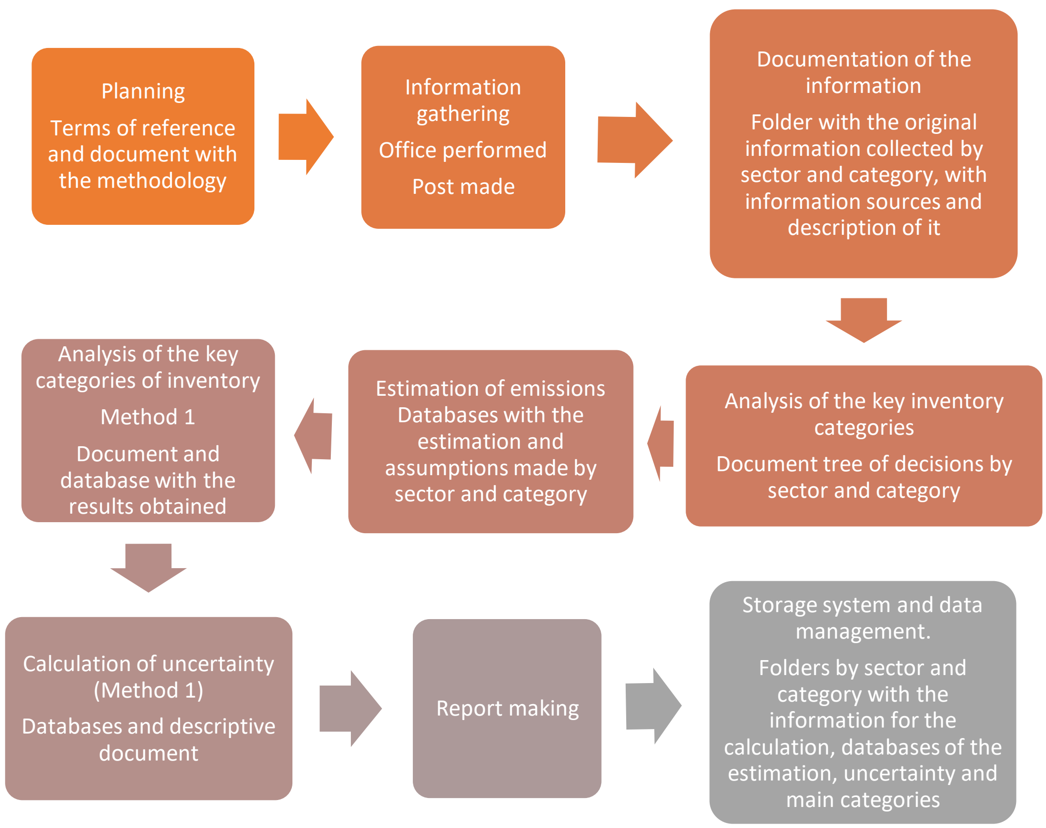


Figure 10. QA/QC procedure for the elaboration of the inventory.

Each phase has its corresponding documentation, which are from databases, documents with procedures, etc.

6.4. Estimation of Uncertainty

The estimation of uncertainty is an essential step in an inventory of gas emissions and removals. It is essential to have the estimation of both the trend, the emission factors, the activity data and other estimation parameters corresponding to each category. In Figure 11, there is a General structure of a generic uncertainty analysis diagram, which was a base in the current inventory. (IPCC, 2006c)

The calculation of uncertainty includes methods intended to:

1. Determine the uncertainties of the individual variables used in the inventory (eg: estimations of emissions from specific categories, emission factors, activity data, etc.);
2. Add the uncertainties of the component to the full inventory;
3. Determine the uncertainty in the trend;
4. Identify significant sources of inventory uncertainty to help prioritize data collection and efforts to improve inventory.

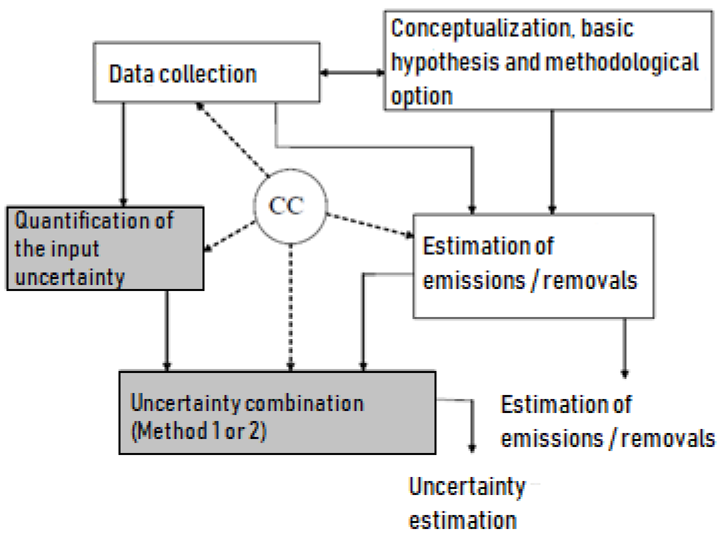


Figure 11. General structure of a generic uncertainty analysis. (IPCC, 2006)
From: Figure 3.1 of Vol. 1 Chapter E of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

There are two methods for the uncertainty analysis:

Method 1: estimation of uncertainties by category with Equations 2 and 3, by simple combination of uncertainties by category, to estimate the general uncertainty for a year and the uncertainty of the trend.

Method 2: estimation of uncertainties by category with the Monte Carlo analysis, after the use of Monte Carlo techniques to estimate the general uncertainty for a year and the uncertainty of the trend.

$$U_{total} = \sqrt{U_1^2 + U_2^2 + \cdots + U_n^2}$$

Equation 2. Uncertainty combination – Method 1 – Multiplication

$$U_{total} = \frac{\sqrt{(U_1 * x_1)^2 + (U_2 * x_2)^2 + \cdots + (U_n * x_n)^2}}{|x_1 + x_2 + \cdots + x_n|}$$

Equation 3. Uncertainty combination – Method 1 – Add and subtract

For the present work, method one was used to estimate the uncertainty. Trend uncertainty was not calculated since there is no information from previous years.

7. Results

The results of the inventory of GHG emissions are presented in Chart 4 for all categories for the State of Colima, by municipality and at the state level for the year 2015. CO_2e emissions amount to 18,137 gig grams (Gg) per year.

The emissions are distributed by GHG in 14,749.21 Gg of CO_2, 28.19 Gg of CH_4, 1.10 Gg of N_2O, 0.22 Gg of HFC y 2.39 Gg of black carbon.

Chart 4. Inventory of GHG Emissions by category for the year 2015, for the State of Colima.

Category / Subcategory		CO_2	CH_4	N_2O	Black carbon	HFC	CO_2e
Energy	Energy industries	7,034	0.45	0.02	0.09	-	7,137
	Manufacturing and construction industries	1,860	2	0.05	0.03	-	1,950
	Transportation	3,727	0.47	0.15	2	-	5,731
	Commercial / Institutional	14	0.00	0.00	0.00		14
	Residential	134	0.23	0.00	0.05		189
	Agriculture/Silviculture	33	0.00	0.00	0.02		50
IPPU	Mineral industry	430	-	-	-	-	430
	Metal industry	137	-	-	-	-	137
	Manufacturing and use of other products	-	-	-	-	0.22	157
AFOLU	Livestock	-	9	0.11	-	-	273
	Land	1,501	-	-	-	-	1,501
	Removals	-219	-	-	-	-	-219
	Aggregate sources and non-CO_2 emission sources of land	97	1	1	0.02	-	324
Waste	Disposal of solid waste	-	3	-	-	-	73
	Incineration and open incineration of waste	1	0.00	0.00	0.01	-	11
	Treatment and disposal of wastewater	-	13	0.03	-	-	380
State	**Gross emissions**	**14,968**	**28**	**1**	**2**	**0.22**	**18,357**
	Net emissions	**14,749**	**28**	**1**	**2**	**0.22**	**18,137**

The sector that contributed the most to CO_2e emissions in the state of Colima is Energy with 83%, followed by AFOLU with 10%, IPPU with 4% and waste with 3% (Figure 12).

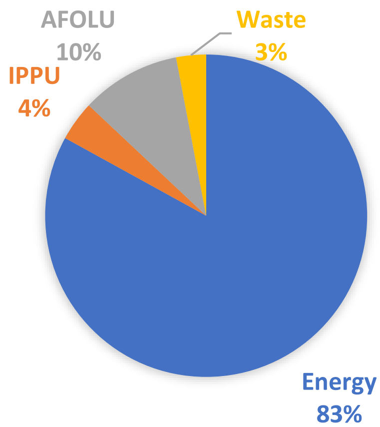


Figure 12. Percentage contribution by sector of CO2e in the State of Colima.

At municipal level, the emissions by category of IPCC are shown in Chart 5, where the municipalities that generates the highest GHG emissions per municipality are Manzanillo, Tecomán, Colima and Minatitlán.

Chart 5. Inventory of GHG Emissions by category and municipality for the year 2015.

Municipality	Energy (CO_2e)	IPPU (CO_2e)	AFOLU (CO_2e)	Waste (CO_2e)	Total (CO_2e)
Armería	173		89	13	274
Colima	841		251	32	1,124
Comala	33		197	21	251
Coquimatlán	228		213	10	450
Cuauhtémoc	570	103	268	57	998
Ixtlahuacán	108	21	79	9	216
Manzanillo	9,809	90	296	130	10,325
Minatitlán	918		105	48	1,071
Tecomán	1,688	510	255	62	2,515
Villa de Álvarez	703		127	81	911
State	**15,070**	**724**	**1,879**	**464**	**18,137**

7.1. ENERGY

The Energy category, which is the most important in most inventories of Greenhouse Gases (GHG), is subdivided into fossil fuel consumption and fugitive emissions from the manufacture of fuels and transport and storage of CO_2.

For the calculations of the inventory of GHG emissions of the energy sector of the State of Colima, the energy consumption for the base year 2015 was obtained. According to the IPCC 2006 methodology, the estimation of the inventories can be in three levels depending of the detail of the information obtained. In this case, the majority of the methodology used was Level 2 and 3, which means that most of the fuel burning information comes from fuel consumption in the entity reported by the Energy Regulatory Commission (CRE) and the consumption reported in the annual operation certificates (COA) delivered to the Ministry of Environment and Natural Resources (SEMARNAT) and IMADES; In addition, the emission factors used were the specific ones for Mexico of CO_2 generation by fuel type and the IPCC default for CH_4 and N_2O.

The estimated emissions within this category consider the emissions of CO_2, CH_4, N_2O and black carbon, calculated from the consumption of fossil fuels, as well as that obtained from renewable energy sources such as biomass, used in the residential and industrial subcategory.

In the case of mobile sources, the level of the inventory obtained was Tier 3, since it was done using a model to obtain the emission factors with MOVES Mexico. Following the guidance of the IPCC 2006, the following subcategories that include the generation and use of energy were considered (Figure 13).

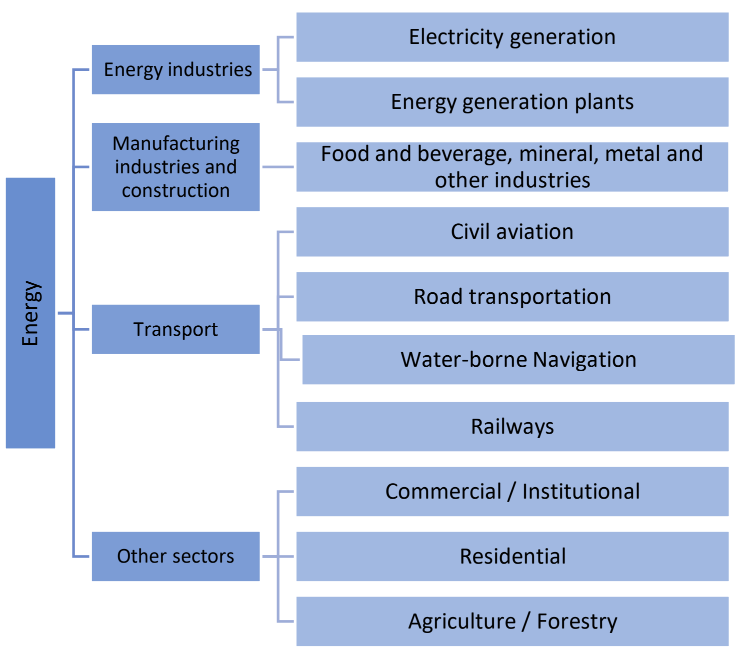


Figure 13. Subcategories of the Energy sector.

Activity data

The information on fuel consumption in this sector for the state of Colima in 2015 was obtained, through the request via office to various institutions such as the Energy Regulatory Commission (CRE), the Federal Electricity Commission (CFE), as well as making estimates on energy consumption from the data reported by the Secretary of Energy (SENER) in the National Energy Balance 2015, the Energy Information System (SIE), LP Gas Prospects 2016-2030, Prospects for Natural Gas 2016-2030, Prospects for Crude Oil and Petroleum 2016-2030 and the State and Federal Annual Operating Schedules (COA) for industrial activity in the State of 2015 and 2015-2016, respectively.

Based on the consumption of each fuel reported in the documents mentioned above, for the state of Colima, it was disaggregated according to the type of subcategory (residential, commercial, transport, industry, etc.); combining INEGI information (such as number of inhabitants, number of employees, number of homes, among others) for its disaggregation at the municipal level (for more details see the corresponding databases).

The total fuel consumed in the state of Colima and at the municipal level was derived from the summation of the information by fuel type and subcategories; Chart 6 shows the fuel consumption by type.

Chart 6. State of Colima energetic consumption by type of fuel.

Fuel	Tj/year	Percentage
Formulated fuel	1,081	0.55%
Heavy fuel	2,015	1.02%
Petroleum coke	196	0.10%
Carbon coke	1,375	0.70%
Diesel	33,901	17.17%
Gasoline	34,762	17.61%
LP Gas	1,798	0.91%
Natural Gas	99,540	50.43%
Fuel oil	16,951	8.59%
Biomass	4,761	2.41%
Biogas	14	0.01%
Kerosene	16	0.01%
Firewood	763	0.39%
Turbosine	225	0.11%
Total	197,400	100.00%

FROM: SENER, 2016c,d,e; SEMARNAT, 2018; IMADES, 2018; CFE, 2018; CRE, 2018.

Chart 7 shows the energy consumption by sector in the State, where the greatest consumption is in electricity generation with 58%, followed by land transport or motor transport with 32%, in third place, the subcategory of the manufacturing industry with 7.13%, the residential subcategory uses 0.82% of state consumption.

Chart 7. Energetic consumption by subsector.

Subsector	Consumption (TJ)	Percentage
Electricity generation	115,415	58.54%
Energy generations plants	14	0.01%
Manufacturing industries and construction	14,166	7.19%
Railways	459	0.23%
Civil Aviation	225	0.11%
Water-borne Navigation	919	0.47%
Road transportation	63,913	32.42%
Residential	1,610	0.82%
Commercial	210	0.11%
Agriculture/Forestry/Fishing	210	0.11%
State	**197,142**	**100.00%**

From: SENER, 2016; SEMARNAT, 2018; IMADES, 2018; CFE, 2018; CRE, 2018.

Energy industries

In this section, GHG emissions from the energy industry were estimated, which includes the generation of electricity, as well as power generation plants.

Electricity generation

Colima has a CFE combined cycle thermoelectric power plant called Termoeléctrica Gral. Manuel Álvarez Moreno, located in the municipality of Manzanillo, with two power generation plants, which delivered a total of 13,984 Gigawatts per hour (GWh) of energy. electricity in 2015 (SENER, 2016). This plant uses natural gas, fuel oil and diesel as part of its generation process, using 98,435, 28 and 16,951 TJ, respectively.

Energy generation plants

In the state of Colima, there are biodigesters that generate energy through the consumption of biogas, in different municipalities of the state. (Chart 8)

Chart 8. Energetic consumption for energy generation using biogas.

Municipality	Energetic consumption (TJ)
Colima	0.20
Comala	1.95
Coquimatlán	0.22
Tecomán	10.96
Villa de Álvarez	1.16
State	14.49

From: FIRCO, 2018

Manufacturing industries and construction

The manufacturing industry in the State has a considerable contribution, making the consumption of fuels by this subcategory important. The main industries are the cement and lime industry, food and beverages, metalworking, metallurgy, non-metallic minerals, among others. (Chart 9).

The industry established in the state of Colima uses fuels such as natural gas, LP gas, fuel oil, diesel, petroleum coke, coal coke, among others. This data on fuel consumption was obtained from the annual operation certificates reported by the industrial to the state government for the year of activity 2015 and to the federation of the year 2015 and 2016. The consumption by subsector is shown in Chart 9.

Chart 9. Energetic consumption by the industrial manufacturing sector.

Subsector	TJ
Cement and lime	2,636.35
Food and beverage industries	5,897.71
Metal-mechanic industry	0.02
Metallurgical (includes the steel company)	1,882.64
Non-metallic minerals	286.39
Other industries	3,462.44
Petroleum and petrochemical	0.08
Chemical	0.51

Fuente: SEMARNAT, 2018; IMADES 2018

Transport (Combustion mobile sources)

Civil aviation

The state of Colima has two airports, the Playa de Oro International Airport or the Manzanillo International Airport located in the municipality of Manzanillo and the Colima National Airport, located in the municipality of Cuauhtémoc.

The international airport of Manzanillo has an area in the terminal building of 4,700 square meters that can accommodate 470 passengers per hour with 17 documentation desks for different airlines and has a last waiting room.

The Licenciado Miguel de la Madrid Airport or Colima National Airport had 114,457 total passengers in 2014.

The activity data was obtained directly from the airport, as well as they reviewed data from the Statistical Yearbook 2015 (SCT, 2016). The fuel used by this subcategory was turbosine or kerosene, obtained from the National Energy Balance 2015 (SENER, 2016).

The number of operations carried out in 2015 amounted to 6,115 and 113,583 passengers for the national airport; for the international airport they totaled 6,403 operations and 194,400 passengers. The international airport has Superjet or Airbus 320 aircraft, Embraer 145, Airbus 319 and Boeing 737 and the national one with Boeing 737 and Airbus A320. Having a total consumption of kerosene (turbosine) of 225Tj in 2015.

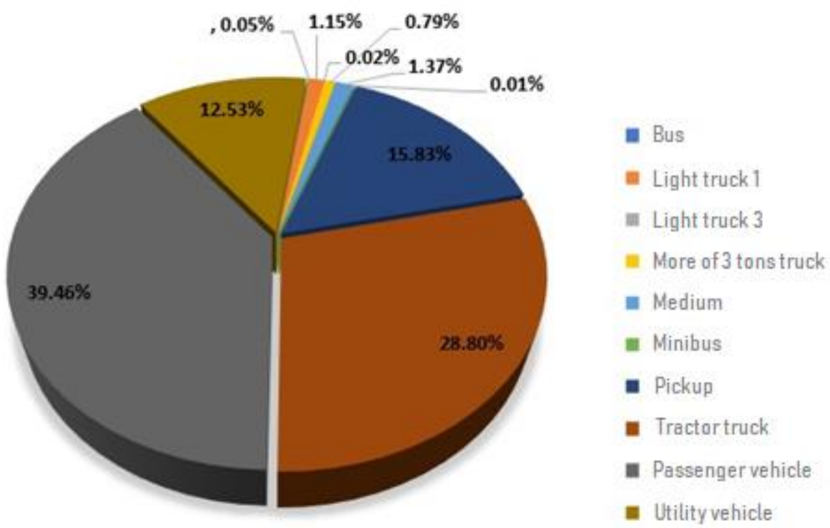
Road transportation

It refers to all emissions from burning and evaporation that emanate from the use of fuels in land vehicles, which circulate on paved roads. According to the IPCC 2006 methodology, for the calculation of motor transport emissions, the following information must be considered:

1. Number and type of vehicles that circulate.
2. Quantity of fuel consumed by type of vehicle.
3. VKT (Vehicles Total Kilometers) by type of Vehicle.
4. Proportion of trips that are made partially within the area.

The number and type of vehicles circulating in each of the municipalities and at the state level was provided by the Institute for Environment and Sustainable Development of the State of Colima (IMADES), which in turn was provided by the Mobility Secretary of the State of Colima (SEMOV).

Figure 14 shows the distribution by type of vehicle in the State of Colima:



According to the previous figure, passenger vehicles have the highest contribution (40%), followed

Figure 14. Distribution in percentage by vehicle category in the State of Colima for year 2015.

by tractor trucks (29%) and pickup trucks (16%).

Figure 15 shows the distribution of the vehicle fleet by model year, for 2015 the model year average of the fleet throughout the state is 2000.

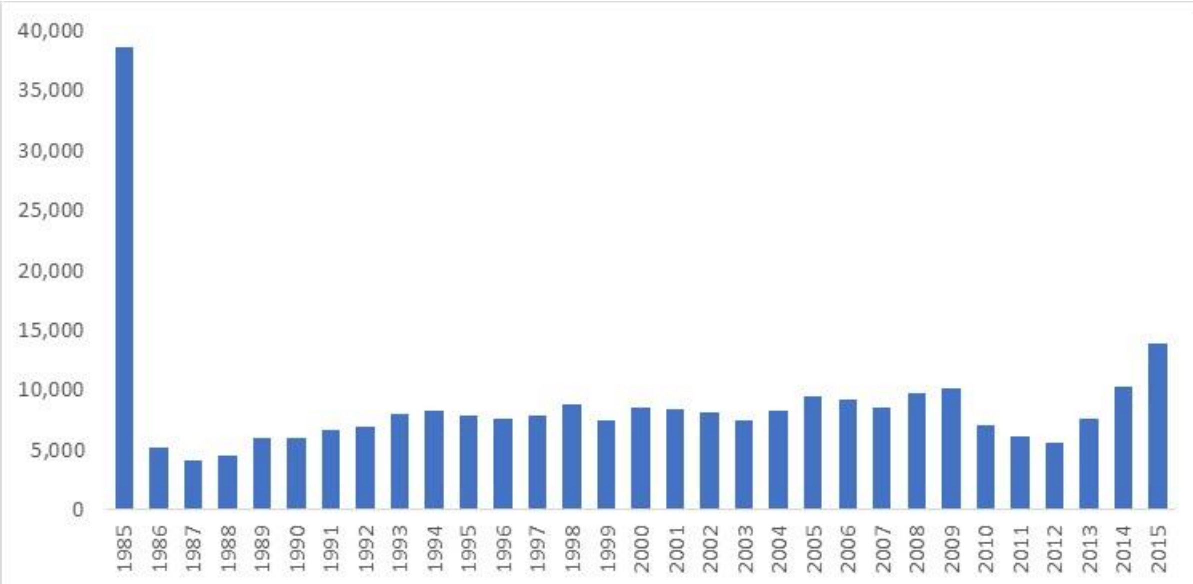


Figure 15. Distribution of the vehicle fleet by model year in the State of Colima for year 2015.

Figure 16 shows the distribution of the vehicle fleet by fuel type, in the state of Colima, 96.38% use gasoline as fuel, 3.55% diesel vehicles and 0.07% use gas or are electric.

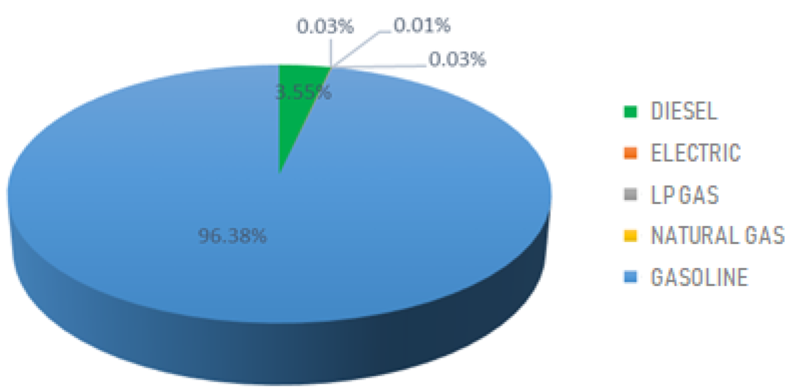


Figure 16. Distribution of the vehicle fleet by type of fuel for the year 2015 in the State of Colima.

Railways

According to SENER in the state of Colima, during 2015, the railway sector consumed 11,606 m^3 of diesel. SCT reports that in the State there are 250 km of railways distributed in six municipalities. The data of this activity was taken from the Statistical and Geographic Yearbook of Colima 2015 (INEGI, 2015), assuming that the percentage of kilometers traveled with the fuel consumption of the State is proportional, the results of Chart 10 are obtained.

Chart 10. Energetic consumption by municipality by railway sector in the State of Colima for year 2015.

Municipality	Length of municipal roads	Energetic consumption (TJ)
Armería	39.91	73.06
Colima	25.72	47.09
Comala		
Coquimatlán	41.23	75.48
Cuauhtémoc	48.99	89.68
Ixtlahuacán		
Manzanillo	49.37	90.37
Minatitlán		
Tecomán	45.77	83.79
Villa de Álvarez	0.00	0.00
State	**251.00**	**459.46**

Fuente: INEGI, 2015a; SENER, 2016e.

Water-borne Navigation

The State has the Port of Manzanillo, located in the Municipality of the same name; this sector consumed 23,212 m^3 of diesel in 2015.

Other combustion sectors

Commercial

In the commercial, institutional or service subcategory, the fuels used in the State were liquefied petroleum gas, natural gas and diesel. The activity data was determined from the information obtained from the prospects for the liquefied petroleum gas, natural gas and petroleum gas market published by SENER (SENER, 2016), as well as information provided by the CRE. In addition, it was considered for its disaggregation the data of the DENUE for 2015 of the INEGI, where the number of commercial establishments was obtained, determining the energy consumption per capita of said fuels by municipality; resulting in the data of Chart 11.

Chart 11. Energetic consumption of commercial subsector per municipality in the State of Colima, year 2015.

Municipality	Business establishments DENUE (INEGI, 2015)	Gas LP (Tj)
Armería	269	8.13
Colima	2,213	66.86
Comala	190	5.74
Coquimatlán	180	5.44
Cuauhtémoc	224	6.77
Ixtlahuacán	55	1.66
Manzanillo	1,646	49.73
Minatitlán	74	2.24
Tecomán	876	26.47

Municipality	Business establishments DENUE (INEGI, 2015)	Gas LP (Tj)
Villa de Álvarez	1,236	37.35
State	**6,963**	**210.38**

Fuente: INEGI, 2015b; SENER, 2016c

Residential

The residential subcategory demands the use of L.P. gas, kerosene and firewood as fuels. The activity data for 2015 was obtained from the information provided by CRE via trade, from the prospects for the liquefied petroleum gas, natural gas and petroleum products market published by SENER (SENER, 2016), taking into account the sales in the State of Colima, as well as the National Balance of Energy 2015 (SENER, 2016); besides the number of inhabitants and dwellings by municipality obtained from the Intercensus Survey 2015 (INEGI, 2015). The percentage of inhabitants using firewood or charcoal for cooking food was obtained from INEGI (2015). The per capita fuel consumption was obtained for each of these variables of the different fuels used, giving as a result the energy consumption by municipality presented in Chart 12.

Chart 12. Energetic consumption of the residential subsector per municipality in the State of Colima in year 2015.

Municipality	Total population	Housing inhabited	Housing using firewood	Housing using LPG	Kerosene (Tj)	LP Gas (Tj)	Firewood (Tj)
Armería	29,599	8,144	1,975	5,908	0.65	27.17	86.80
Colima	150,673	45,769	1,952	42,291	3.65	194.45	85.78
Comala	21,544	5,899	1,554	4,186	0.47	19.25	68.30
Coquimatlán	20,198	5,674	996	4,514	0.45	20.75	43.78
Cuauhtémoc	30,198	8,486	467	7,879	0.68	36.23	20.53
Ixtlahuacán	5,527	1,610	643	926	0.13	4.26	28.26
Manzanillo	184,541	52,759	3,039	47,682	4.21	219.23	133.57
Minatitlán	8,985	2,497	736	1,616	0.20	7.43	32.36
Tecomán	123,191	32,183	4,899	26,163	2.57	120.29	215.30
Villa de Álvarez	136,779	42,222	1,103	39,404	3.37	181.17	48.47
State	**711,235**	**205,243**	**17,363**	**180,569**	**16.36**	**830.22**	**763.14**

Fuente: INEGI, 2016; SENER, 2016

Agriculture, forestry and fishing

The fuel consumption and therefore the energy use of this subcategory was reported through information provided by the CRE via trade and the National Energy Balance 2015 (SENER, 2016), indicating consumption of diesel and LP gas; the activity data was obtained considering the number of production units with agricultural or forestry activity with tractor use by municipality of the Agricultural Census (INEGI, 2007) (Chart 13).

Chart 13. Energetic consumption of the agriculture, forestry and fishing subsector per municipality in the State of Colima in year 2015.

Municipality	LP Gas (TJ)	Diesel (Tj)
Armería	55.9	22.9
Colima	31.7	13.0
Comala	14.7	6.0
Coquimatlán	32.9	13.5
Cuauhtémoc	35.7	14.6
Ixtlahuacán	14.7	6.0
Manzanillo	52.0	21.3
Minatitlán	13.8	5.7
Tecomán	71.6	29.3
Villa de Álvarez	9.5	3.9
State	**332.5**	**136.3**

From: INEGI, 2007; SENER, 2016c

Methodology

As previously mentioned, the estimation of CO_2, CH_4, N_2O and black carbon emissions was made according to the decision tree for the energy category, obtaining a Tier 2 and 3 methodological level.

To calculate the estimated emissions of CO_2, CH_4, N_2O and black carbon, this was done according to the equation 4, where a result is obtained in mega grams per year.

Equation 4 $$GHG\ emissions = \left(\sum Fuel\ consumption\right) \times FE_{GHG}$$

Where:

GHG emissions = GHG emissions (CO_2, CH_4, N_2O, black carbon) per type of fuel (Mg GHG)
Fuel consumption = Amount of fuel burned (TJ)
FE_{GHG} = GHG Emission Factor (CO_2, CH_4, N_2O) according to the type of fuel (Mg C/TJ)

The emission factors used for the estimation of greenhouse gases were for carbon dioxide (CO_2) generated for Mexico (INECC-IMP, 2014) of the different fuels; in the case of CH_4 and N_2O, they were the defects of the Intergovernmental Panel on Climate Change (IPCC, 2006) (Chart 14). In the case of land transport (motor transport), the emission factors used were by type of vehicle and model year generated through modeling with MOVES Mexico for the present inventory and the EDMS model for aviation.

The following shows the calorific value used in the present inventory, obtained from the 2015 National Energy Balance Reported by SENER (Chart 15). The units in which fuel consumption was reported were converted to Terajoules (Tj) for the application of the emission factors.

Chart 14. Emission factors used in the inventory calculation (Kg/Tj).

Subcategory	CO_2	CH_4	N_2O
Energy industries, Manufacturing industries and construction			
Fuel oil	79,450	3	0.6
Diesel	72,881	3	0.6
LP Gas	65,083	1	0.1
Natural Gas	57,756	1	0.1
Kerosene	71,900	10	0.6
Biogas	54,600	1	0.1
Petroleum coke	78,991	3	0.6
Residential, commercial and agriculture/forestry/fishing			
Kerosene	71,900	10	0.6
LP Gas	65,083	5	0.1
Natural Gas	57,756	5	0.1
Firewood	103,237	300	4
Diesel	72,881	10	0.6
Railways			
Diesel	72,881	4.15	28.6
Water-borne Navigation			
Diesel	72,881	7	2
Road transportation			
Gasoline, diesel, natural gas, LP gas	Emission factors generated by the MOVES Mexico model by type of vehicle and model year (See Annex)		
Civil Aviation			
Turbocharger, gas plane	EDMS Model		

Fuente: INECC-IMP, 2014; IPCC, 2006.

Chart 15. Calorific power of the used fuels.

Fuel	Calorific value	Unities
LP Gas	4,124	MJ/bl
Natural Gas	38,268	KJ/m^3
Kerosene o turbosine	5,881	MJ/bl
Gasoline	5,176	MJ/bl
Fuel oil	6,531	MJ/bl
Diesel	6,294	MJ/bl
Petroleum coke	32,658	MJ/ton
Firewood	14,486	MJ/ton
Biogas	19.93	MJ/m^3

From: SENER, 2016a

To determine the equivalent carbon dioxide (CO_2e) emissions, the global warming potentials mentioned in Chart 2 were used.

Results

For the State of Colima, an emission of 15,023 gig grams of CO_2 equivalent derived from the sources of combustion was estimated for 2015. Chart 16 shows the GHG and CO_2e emissions by subcategory of the energy sector; where it is observed that electricity generation and transport (motor transport) are the most important in CO_2e emissions to the atmosphere with 47% and 37% respectively (Figure 17).

Chart 16. GHG emissions of the energy category in Gg/year per category, for the State of Colima in year 2015.

Subcategory	CO_2	CH_4	N_2O	Black carbon	CO_2e
Electricity generation	7,034	0.15	0.02	0.09	7,128
Energy generation plants	0	0.30	0.00	0.00	9
Manufacturing and construction plants	1,860	1.90	0.05	0.03	1,950
Railways and trawling	33	0.00	0.01	0.00	42
Civil Aviation	17	0.00	0.00	0.00	17
Water-borne Navigation	67	0.01	0.00	0.03	95
Road transportation	3,610	0.46	0.14	2.13	5,578
Residential	134	0.23	0.00	0.00	189
Commercial	14	0.00	0.00	0.00	14
Agriculture, forestry and fishing	33	0.00	0.00	0.02	50
State	**12,803**	**3.06**	**0.23**	**2.30**	**15,070**

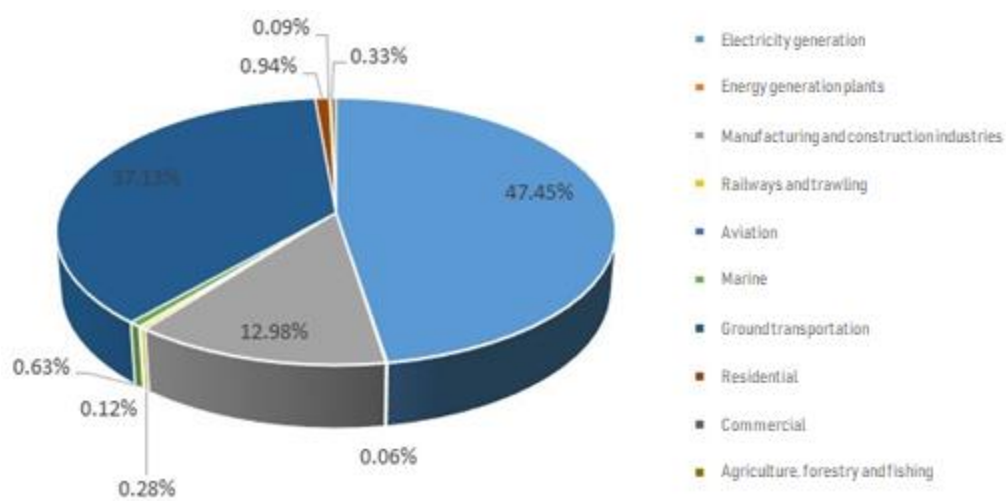


Figure 17. GHG emissions of the energy category in Gg/year per category, for the State of Colima in year 2015.

Chart 17 and Figure 18 show the GHG emissions by Municipality for the energy category of the State of Colima. Where the Municipalities with the highest CO_2e emissions are Manzanillo (65% of CO_2e emissions), in this Municipality there is an electric power plant, an airport and the port of the State, followed by Tecomán (11% of CO_2e emissions) and Minatitlán (6% of CO_2e emissions).

Chart 17. GHG emissions in Gg/year in the State of Colima in 2015, per municipality.

Municipality	CO_2	CH_4	N_2O	Black carbon	CO_2e
Armería	155	0.03	0.00	0.01	167
Colima	779	1.69	0.03	0.00	835
Comala	27	0.02	0.00	0.00	29
Coquimatlán	216	0.05	0.01	0.01	225
Cuauhtémoc	550	0.05	0.01	0.02	569
Ixtlahuacán	102	0.01	0.00	0.00	106
Manzanillo	7,765	0.46	0.05	2.23	9,801
Minatitlán	893	0.10	0.05	0.01	916
Tecomán	1,631	0.56	0.03	0.02	1,675
Villa de Álvarez	685	0.07	0.05	0.00	700
State	**12,803**	**3.06**	**0.23**	**2.30**	**15,070**

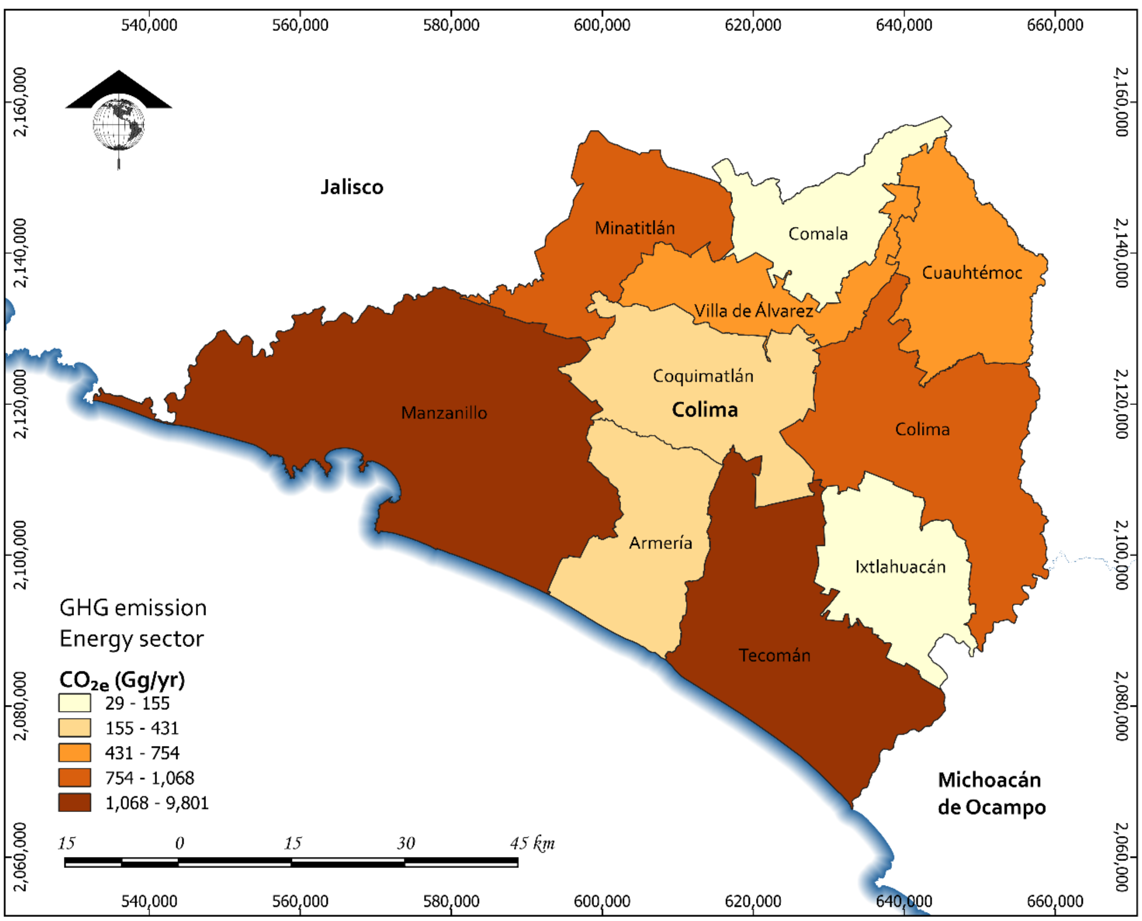


Figure 18. GHG emissions in Gg/year in the State of Colima in 2015, per municipality.

Energy industries

The generation of electricity in the State has a significant contribution to CO_2e emissions, amounting to 7,136 Gg. The municipality of Manzanillo is the one that generates the most emissions for this subcategory due to the presence of the thermoelectric plant.

Chart 18. CO_2e emissions per municipality and gas in Ton/year in 2015 in the State of Colima.

Municipality	CO_2	CH_4	N_2O	Black carbon	CO_2e
Armería	0.00	0.00	0.00	0.00	0.00
Colima	0.00	0.01	0.00	0.00	0.20
Comala	0.11	0.00	0.00	0.00	0.11
Coquimatlán	0.00	0.01	0.00	0.00	0.22
Cuauhtémoc	0.00	0.00	0.00	0.00	0.00
Ixtlahuacán	0.00	0.00	0.00	0.00	0.00
Manzanillo	7,034.06	0.15	0.02	0.09	7,128.01
Minatitlán	0.00	0.00	0.00	0.00	0.00
Tecomán	0.16	0.29	0.00	0.00	8.17
Villa de Álvarez	0.06	0.00	0.00	0.00	0.06
State	**7,034.39**	**0.45**	**0.02**	**0.09**	**7,136.78**

Manufacturing and construction industry

The manufacturing and construction industry generated in the entity 1,949 Gg CO_2e, desegregated as shown in Chart 19; the non-metallic mineral industry contributes 35% of these emissions and other industries with 22%.

Chart 19. GHG emissions per fuel consumption in the manufacturing and construction industry subsectors in the State of Colima in 2015 (Gg/year).

Subsector	CO_2	CH_4	N_2O	Black carbon	CO_2e
Cement and lime	231.755	0.008	0.002	0.013	244.345
Food and beverage industry	267.084	0.026	0.001	0.012	279.109
Metal-mechanic industry	0.000	0.000	0.000	0.000	0.000
Metallurgical (includes the steel company)	270.012	0.009	0.018	0.000	275.265
Non-metallic minerals	659.992	1.434	0.020	0.000	705.638
Other industries	423.795	0.231	0.003	0.000	431.273
Petroleum and petrochemical	7.352	0.191	0.004	0.000	13.726
Chemical	0.120	0.000	0.000	0.000	0.120
Treatment of hazardous waste	0.137	0.000	0.000	0.000	0.137
Total	**1,860.248**	**1.899**	**0.048**	**0.026**	**1,949.612**

Figure 19 shows the percentage contributions of the manufacturing industries in the entity.

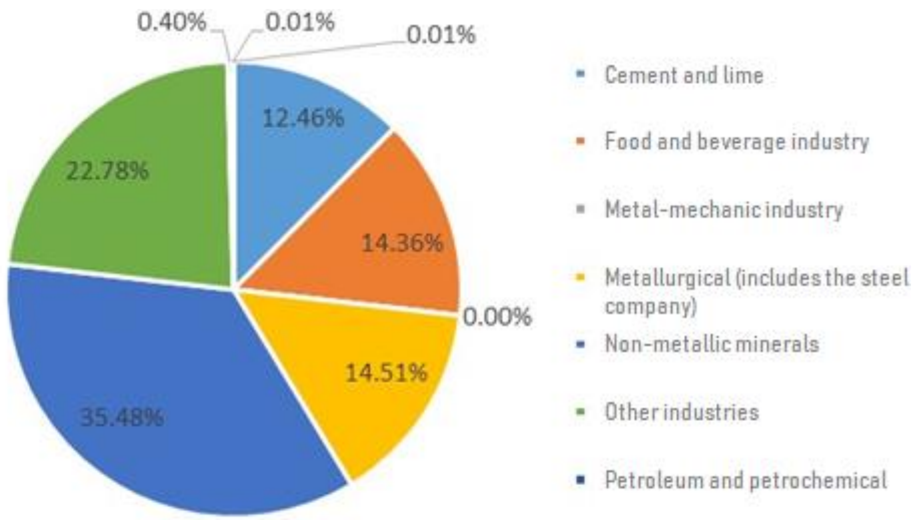


Figure 19. Contribution in percentage of the CO_2e emissions by the manufacturing and construction industry in 2015.

Colima (39%), Manzanillo (22%) and Cuauhtémoc (15%) are the main municipalities that generate emissions from fuel consumption in the manufacturing industry in the state (Figure 20).

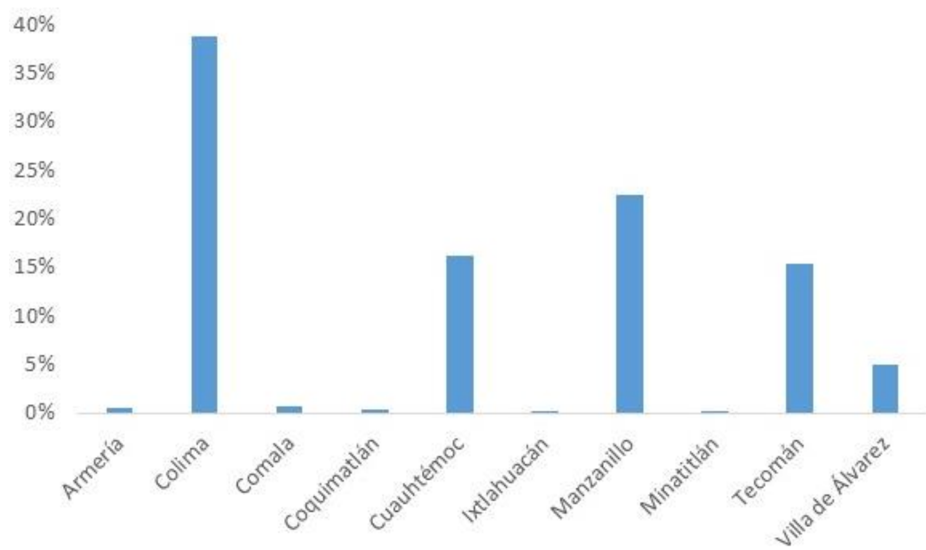


Figure 20. Contribution in percentage of the CO_2e emissions per manufacturing and construction industry subsector in 2015 in the State of Colima

Transportation (Combustion mobile sources)

Amongst the diverse means of transport, the auto transport or land transport is the one that emits the highest GHG emissions to the atmosphere in all the municipalities (Chart 20); being the municipalities of Manzanillo and Tecomán those that generate the largest emissions of the Entity.

Chart 20. GHG emissions per fuel consumption on each municipality of the transportation sector in 2015 (Gg/year).

Municipality	CO_2	CH_4	N_2O	Black carbon	CO_2e
Armería	127.864	0.007	0.003	0.009	136.505
Colima	45.752	0.004	0.004	0.001	47.752
Comala	2.043	0.000	0.000	0.000	2.119
Coquimatlán	198.239	0.032	0.006	0.004	204.609
Cuauhtémoc	234.151	0.038	0.008	0.004	241.272
Ixtlahuacán	93.366	0.004	0.000	0.003	96.517
Manzanillo	266.486	0.038	0.024	2.134	2,194.877
Minatitlán	883.761	0.093	0.051	0.007	906.036
Tecomán	1,308.688	0.200	0.016	0.003	1,321.044
Villa de Álvarez	566.874	0.055	0.044	0.001	580.842
State	**3,727.224**	**0.472**	**0.157**	**2.166**	**5,731.573**

Chart 21 presents a summary of GHG emissions by subcategory of transportation in the State of Colima. The motor transport contributes by 99% of the emissions of this subcategory. In the case of aviation, there are two airports that are located in the municipalities of Manzanillo and Cuauhtémoc.

Chart 21. GHG emissions per transportation subsector in Gg/year in 2015.

Subsector	CO_2	CH_4	N_2O	Black carbon	CO_2e
Civil Aviation	16.60	0.00	0.00	0.00	17.38
Railways	33.49	0.00	0.01	0.00	41.51
Water-borne Navigation	66.97	0.01	0.00	0.03	94.74
Road transportation	3,610.17	0.46	0.14	2.13	5,577.93
Total	**3,727.22**	**0.47**	**0.16**	**2.17**	**5,731.57**

In terms of vehicle fleet, it is observed that the average model year is 2000, which indicates that there is a 15-year-old vehicle fleet, which allows knowing where the efforts to reduce emissions to the atmosphere should be generated. Passenger vehicles in the State represent 40% of the total, tractor trucks 29% and pick up 16%. 98% of the fleet is gasoline and 2% diesel.

In terms of emissions, it is observed that emissions are generated where there is greater urban development, in the Metropolitan Area of Colima-Villa de Álvarez and in the municipality of Manzanillo, with more than 71% of the emission of the four pollutants evaluated.

Chart 22 and Figure 21 show the GHG emissions by vehicle type; where private vehicles, followed by trucks and pickup trucks are what mostly contribute to GHG emissions in this subcategory.

Chart 22. GHG emissions (Gg/year) per vehicular category in the State of Colima in year 2015.

Vehicular category	CO_2	CH_4	N_2O	Black carbon	CO_2e
Bus	122.54	0.01	0.00	0.01	130.20
Light truck 1	42.32	0.00	0.00	-	43.23
Light truck 3	2.04	-	-	-	2.04
More of 3 tons truck	192.74	0.03	0.00	0.00	197.39
Medium	220.01	0.04	0.01	0.00	225.10
Minibus	93.37	0.00	-	0.00	96.18
Pickup	183.94	0.03	0.02	2.10	2,082.80
Tractor truck	883.76	0.09	0.05	0.01	906.18
Passenger vehicle	1,302.58	0.20	0.01	0.00	1,313.69
Utility vehicle	566.87	0.06	0.04	0.00	580.97
Total	**3,610.17**	**0.46**	**0.14**	**2.13**	**5,577.76**

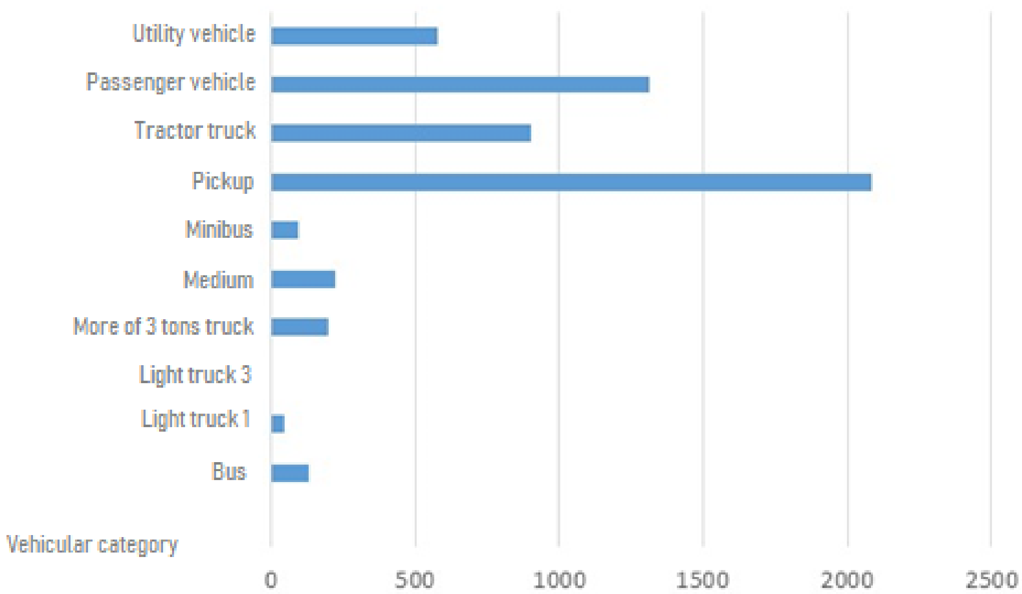


Figure 21. GHG emissions per vehicular category in the State of Colima in year 2015.

Other combustion sectors

In the area of other sources of combustion, within energy category, the one that generates the highest GHG emissions and the global CO2 equivalent is the residential subsector due to the consumption of fuel in homes, with Tecomán and Manzanillo as the municipalities with the highest emissions by these sources in the State (Figure 22).

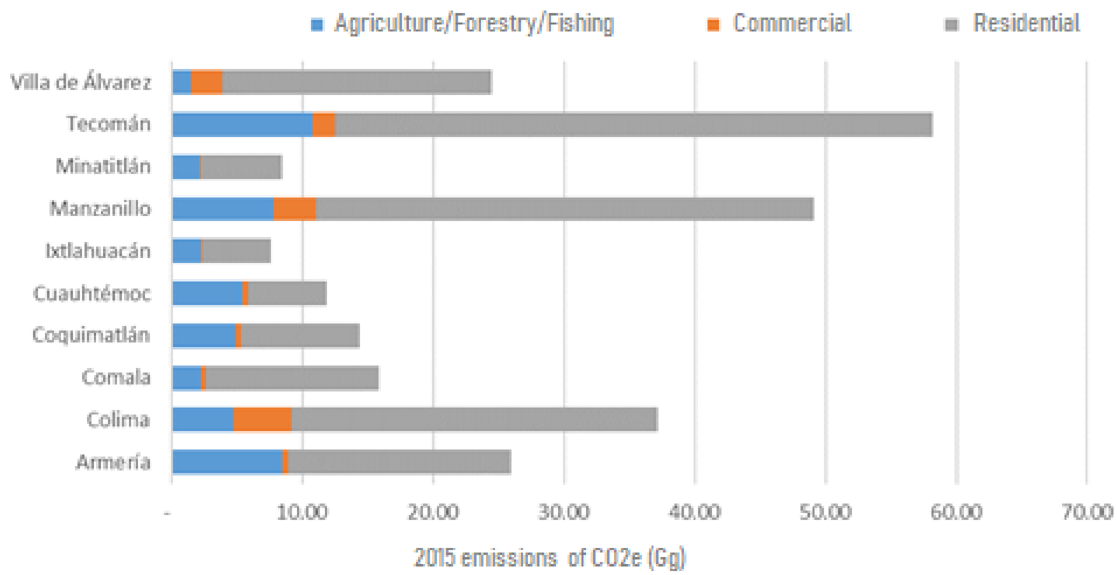


Figure 22. CO2e emissions (Gg/year) per municipality and other combustion sectors subsector in 2015.

In the commercial sector in the State of Colima, LP gas and diesel were consumed. The municipalities with the highest amount in this sector are Colima (31.8%) and Manzanillo (23.6%), directly linked to commercial activity. Finally, in the agriculture/forestry category those ejidos and communities with infrastructure such as tractors were evaluated, where the use of fuels such as LP gas and diesel is reported; the municipalities of Tecomán (17.8%), Armería (16.8%) and Manzanillo (15.6%) are the ones that contribute most to emissions from this activity.

Chart 23 presents a summary of the energy consumption in each subcategory of other combustion sources of the State of Colima, as well as the emissions associated with its combustion.

Chart 23. Other combustion sources GHG emissions in Gg for the year 2015 in the State of Colima.

Subcategory	CO_2	CH_4	N_2O	Black carbon	CO_2e
Agriculture/Forestry	33.10	0.00	0.00	0.02	49.88
Commercial	13.69	0.00	0.00	0.00	13.78
Residential	133.99	0.23	0.00	0.05	189.05
State	**180.79**	**0.24**	**0.00**	**0.07**	**252.72**

From the previous chart it is highlighted that the main GHG emissions are generated by the use of firewood in the residential subcategory, followed by the use of LP gas in the same subcategory. To a lesser extent, the consumption of LP Gas in the commercial subcategory and the use of diesel in the agriculture/forestry subcategory.

7.2. INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)

The sector of industrial processes and use of products (IPPU), includes the emissions of greenhouse gases generated by industrial processes, using greenhouse gases in products and by the non-energy uses of the carbon contained in fossil fuels according to the guidelines of the Intergovernmental Panel on Climate Change (IPCC, 2006) and the information available from the State of Colima (IMADES, 2018, SEMARNAT, 2018).

Information on the industrial sector was collected through the State and Federal Annual Operation Cards (COA) base year 2015 provided by the State government; as well as information from the INEGI through the DENUE (National Statistical Directory of Economic Units) and the web pages of the companies.

In the State of Colima, there are only some of the industrial transfers that according to the guidance of the IPCC 2006 are possibly being evaluated with respect to their GHG contribution due to the characteristics of their processes and / or availability of the data of activity; so the following subcategories were considered (Figure 23).

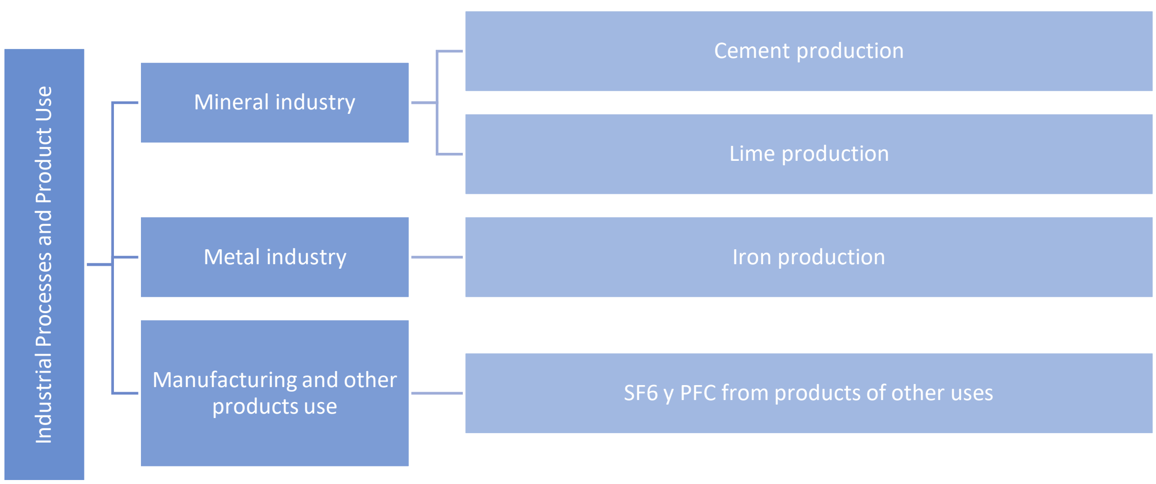


Figure 23. Subcategories of the Industrial Processes and Product Use category.

Industrial processes

The methodology applied was recommended by IPCC 2006; starting from the use of decision trees, which serve as support to define the method, emission factors and activity data.

Cement production

In the manufacture of cement, CO_2 is generated during the production of clinker, since the limestone is heated or calcined, composed essentially of calcium carbonate ($CaCO_3$), producing lime (CaO) and CO_2 as by-products.

Activity data

The information on cement production at the State of Colima was obtained from the annual operation document submitted to SEMARNAT for the year of activity 2015, as well as information from the National Cement Chamber (CANACEM). In Colima there is a cement production plant (Cementos Apasco) located in the Municipality of Tecomán, which produced 911,668 tons of cement.

For the calculation of CO2 emissions, there is data on the quantity of clinker and cement produced in the cement plant. So we chose the Level 1 Method: Estimation of clinker production through cement production data, according to the equation 5.

Equation 5 $$CO_2emissions = \sum_i[(M_{ci} \times C_{cli}) - Im + Ex] \times EF_{clc}$$

Where:

CO_2 emissions = CO_2 emissions coming from cement production, tons
M_{ci} = weight (mass) of cement produced type i, tons
C_{cli} = Clinker fraction of type I cement, fraction
Im = imports for clinker consumption, tons
Ex = clinker exports, tons
EF_{clc} = factor of emission of clinker in cement in particular, tons of CO_2 / tons of clinker. The default emission factor of clinker (EF_{clc}) is corrected for the CKD (Cement Kiln Dust).

The cement clinker fraction (C_{cli}) was determined by dividing the amount of clinker reported by the industrial company by the amount of cement produced, resulting in 0.86.

Emission factor

For the choice of the emission factor, the default was taken for the clinker (IPCC, 2006. Volume 3, chapter 2, page 2.13). The final calculation is shown in Equation 6.

Equation 6

$$EF_{clc} = 0.51 \times 1.02\ (CKD\ correction) = 0.52\ tons\ of\ CO_2/clinker\ tons$$

Lime production

Calcium oxide (CaO) or lime is obtained by heating the limestone for decomposition of the carbonates; This process is carried out in rotary kilns at high temperature and the process releases CO_2 depending on the product requirements (eg metallurgy, paper, construction materials, effluent treatment, water softening, pH control, and soil stabilization). Limestone is used mainly with a high proportion of calcium (calcite), according to the following reaction in equation 7:

Equation 7

$$CaCO_3\ (limestone\ of\ great\ purity) + heat\ \rightarrow CaO\ (quicklime) +\ CO_2$$

The production of lime is carried out in a series of stages, including extraction of raw materials, crushing and sizing, calcination of raw materials to produce lime and (if required) hydration of lime to obtain hydroxide calcium, at whose stage of the process we find the generation of CO_2.

Activity data

The information on lime production at the State of Colima was not reported in the annual operation document submitted to SEMARNAT for the 2015 activity year. However, it is known that in Colima there is a lime production plant (Calidra del Occidente) located in the Municipality of Ixtlahuacán, for which the 2005 activity data was considered, which produced 27,363 tons of lime.

The amount of lime produced is counted, which is why the estimation method of level 1 was used, according to the equation 8:

Equation 8 $$CO_2 emissions = \sum_i (EF_{cal,i}\ \times\ M_{l,i}\ \times CF_{lkd,i}\ \times\ C_{h,i})$$

Where:

CO_2 emissions = CO_2 emissions coming from the production of lime, tons
$EF_{cal,i}$ = emission factor for type i lime, tons of CO_2/ tons of lime
$M_{l,i}$ = Type i lime production, tons
$CF_{lkd,i}$ = correction factor for the LKD (for Lime Kiln Dust) for type i lime, without dimension. This correction can be justified in a similar way as for the CKD (from Cement Kiln Dust)
$C_{h,i}$ = correction factor for hydrated lime type i, without dimension
i = each of the specific limes

Emission Factor

For the election of the emission factor, the default was taken for the production of lime (IPCC, 2006. Volume 3, chapter 2, page 2.25). The final calculation is shown in equation 9.

Equation 9 $$EF_{cal} = 0.85\ \times\ EF_{lime\ with\ strong\ calcium\ content} + 0.15\ \times\ EF_{dolomite\ lime}$$

= 0.85 X 0.75 + 0.15 X 0.77

=0.6375 + 0.1155

= 0.75 tons of CO_2 / tons of produced lime

Iron production

In the State of Colima, the production of iron occurs in pellets; pellets are formed from raw materials that contain iron (that is, fine ore and additives), in a process at very high temperatures that reduces them to spheres of 9-16 mm of diameter. The process includes grinding, drying, granulation and thermal treatment of raw materials. Pelletizing plants are located mainly in iron mines or boarding ports but can be part of the facilities of an integrated iron and steel plant. In pelletizing plants, natural gas or coal can be used as fuel; in plants located within an integrated iron and steel facility, coke oven gas can be used. The energy consumption for the process, as well as the associated CO_2 emissions, depends, in part, on the quality of the iron and the other raw materials used in the process. CO_2 emissions also depend on the carbon content and the caloric value of the fuels used in the process.

Activity data

The information on iron production in the State of Colima was obtained from the annual operation document submitted to SEMARNAT for the year of activity 2015. In Colima, there are two iron production plants (Consorcio Minero Benito Juárez, Peña Colorada and Las Encinas, a pelleting plant) located in the Municipality of Manzanillo and Cuauhtémoc, respectively; generating a production in the State of 4,552,339 tons of pellets (Chart 24).

Chart 24. Iron production in the State of Colima in 2015.

Plant	Municipality	Production of pellets (ton), 2015
Consorcio Minero Benito Juárez, Peña Colorada	Manzanillo	2,981,665
Las Encinas, pelleting plant	Cuauhtémoc	1,570,674

For the estimation of CO_2 emissions for this subcategory, the Tier 1 method was used since only data on pellet production is available for each company, so default emission factors were used as in equation 10.

Equation 10 $$E_{CO_{2,no-energia}} = P \times EF_P$$

Where:

$E_{CO2,\ no\text{-}energy}$ = CO_2 emissions, tons
P = amount of pellets produced, tons
EF_P= emission factor, tons of CO_2/tons of P produced

Emission factor

For the estimation of CO_2, the default emission factor of pellets (tons of CO_2 per tonne of pellets produced) was used according to Table 4.1 of Chapter 4: Emissions from the metals industry of the IPCC guidelines, 2006 (Vol. 3, page 4.27). The result obtained is 0.03.

Use of products

Use of products

There are GHG emissions from the use of products in industries in the State of Colima.

Activity data and emission factors

The emissions reported by the industrialist in the COA 2015 were considered, due to the use of substances (inputs) in the process and by product for the State of Colima.

Results

For the State of Colima, an emission of 723.6 Gg of CO_2 equivalent derived from the sources of industrial processes and use of products in 2015 was estimated.

Chart 25. Emissions for use of products per municipality in the State of Colima, 2015.

Municipality	CO_2e (ton/year)	CO_2e (Gg/year)
Armería	-	-
Colima	-	-
Cómala	-	-
Coquimatlán	-	-
Cuauhtémoc	102,807	102.8
Ixtlahuacán	21,070	21.1
Manzanillo	90,175	90.2
Minatitlán	-	-
Tecomán	509,563	509.6
Villa de Álvarez	-	-
State	**723,615**	**723.6**

As can be seen in the Chart 26, the municipality with the highest CO_2e emissions was Tecomán, due to the presence of the cement industry, followed by the municipality of Cuauhtémoc for the production of iron and the use of products, and by Manzanillo for the production of iron as well. Finally, Ixtlahuacán for the production of lime.

Cement production is the subcategory that contributes the most to CO_2e emissions (56.5%) by the sector of industrial processes and use of products, followed by the use of products with 21.7%, in addition to 18.9% for the production of iron and the production of lime with 2.9% (Chart 26).

Chart 26. Emissions by subsector in the IPPU category, per pollutant type in Gg in 2015.

Subcategory	CO_2	HCFC-22	CO_2e
Cement production	408.8		408.8
Lime production	21.1		21.1
Iron production	136.6		136.6
Use of products		0.217	157.2
State			**723.6**

In the State of Colima, cement production is the industrial process that generates the largest CO_2e emissions, followed by the use of products, the production of iron and lime (Figure 24).

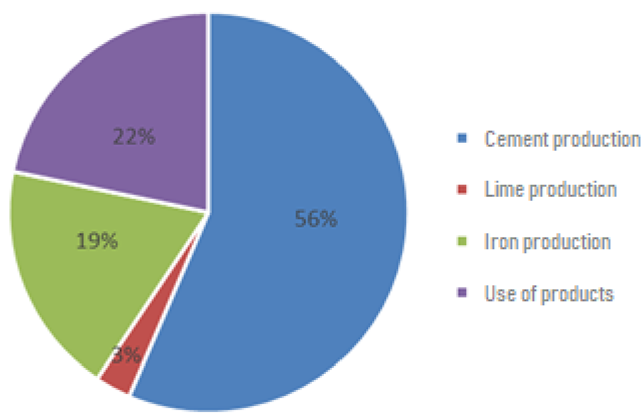


Figure 24. CO_2e emissions per subsector of the IPPU category.

Figure 25 shows the distribution of emissions of the IPPU sector at the municipal level in the entity.

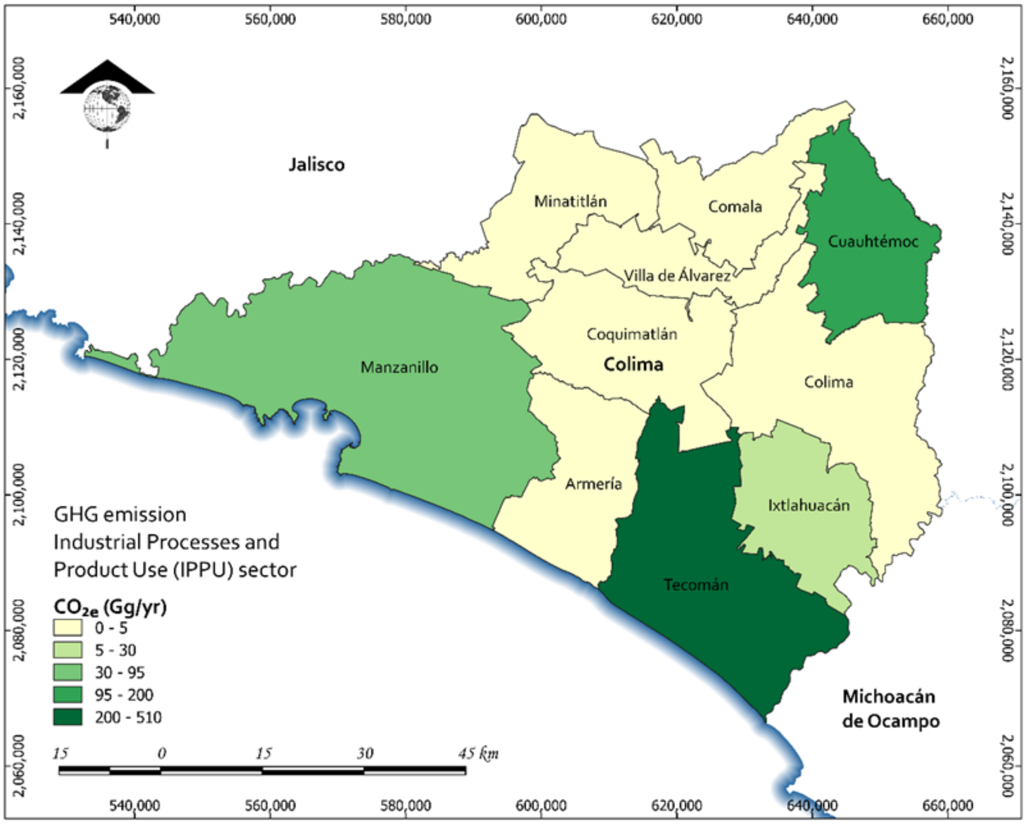


Figure 25. Distribution of the CO_2e emissions at municipality level for the IPPU category for the State of Colima in 2015.

7.3. AGRICULTURE, FORESTRY AND OTHER LAND USES (AFOLU)

This section includes the estimation of greenhouse gas emissions from anthropogenic activities related to the primary agricultural production sector and changes in land use, also called AFOLU. In accordance with the IPCC 2006 methodology, the types of activities that should be evaluated within the study area are identified. Figure 26 shows the activities for which emissions disaggregated by their subcategories were estimated.

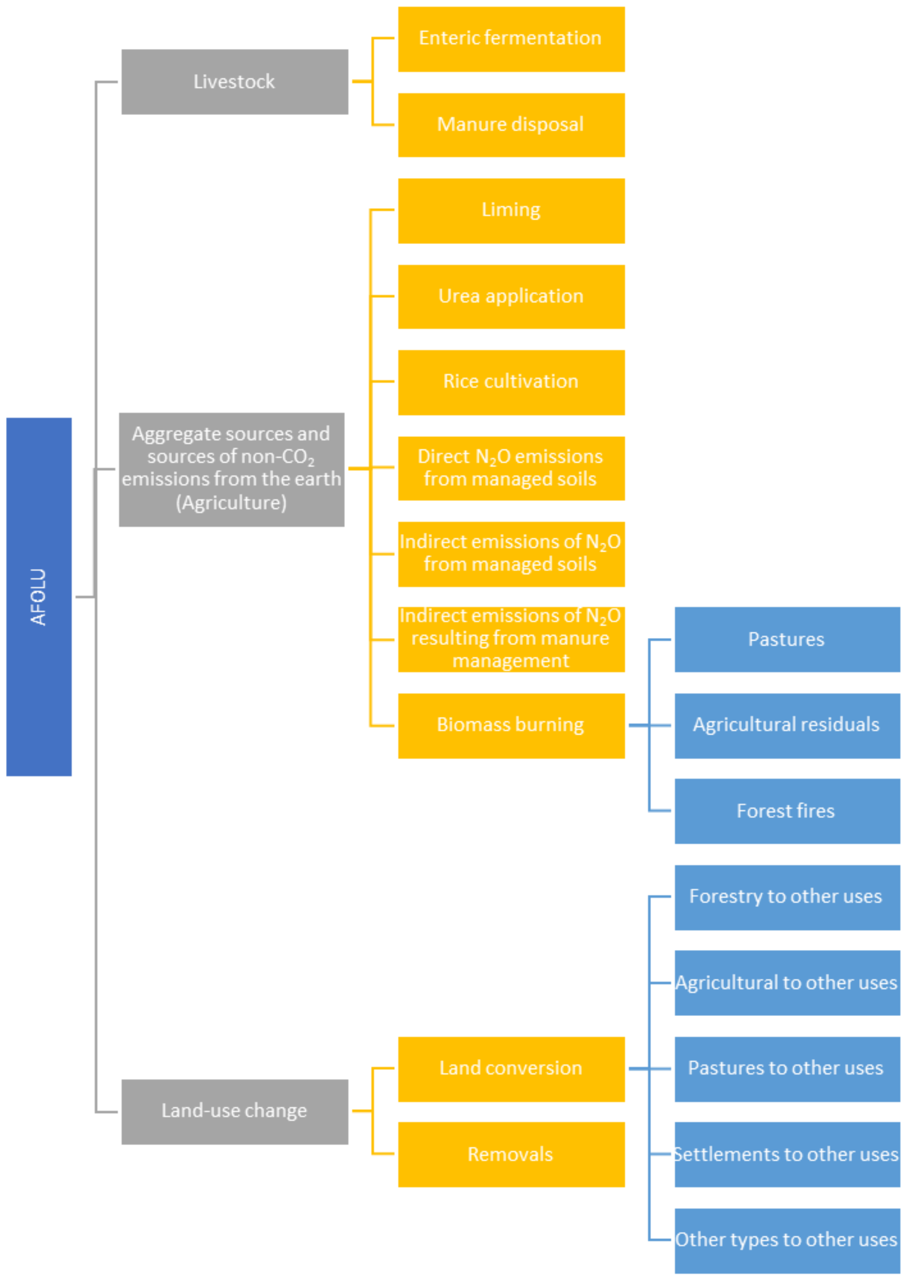


Figure 26. Subcategories of the Agriculture, Forestry and Other Land Uses subcategories.

Agriculture and Livestock

In Mexico, at the federal level, the Secretary of Agriculture, Livestock and Rural Development, Fisheries and Food (SAGARPA) has the legal authority to monitor and promote public policies that promote the development of the agricultural sector throughout the national territory. At the same time, the federated entities in collaboration with SAGARPA and the municipalities carry out actions to promote the development of the sector through different financing, training and technology schemes. As a result, there are entities or agencies in the three levels of government that carry out tasks to monitor the productive activities of the sector, this is very important as there are different sources of information for each of the items. For the purposes of this report, the Agroalimentary and Fishing Information System (SIAP) dependent on SAGARPA was considered as the primary source of information and as complementary sources:

- National Institute of Statistics, Geography and Information Technology (INEGI)
- State Information Office for Sustainable Rural Development (OEIDRUS)

Emissions estimations

The calculation of the emission is made using the equation 11:

Equation 11 $$Emission = Activity\ data \times Emission\ factor$$

Where the activity data refers to the information that allows characterizing the behavior of the emission source and can refer to production, number of animals, etc. And the emission factor is the mathematical relationship that expresses an amount of emission of certain GHG associated with the activity data.

In all cases information was used as an activity data at the municipal level of 2015, the emission factors used correspond to those used by the INECC to prepare the INEGEI-2009. In some cases, they are the factors given by default in the Guidelines and in others they are calculated specifically for Mexico.

Livestock activity data

During the digestive process, herbivores (ruminants) produce methane by the action of the fermentation of cellulose, from the food consumed. The decomposition originates in the rumen, organ of the digestive system that is part of the stomach, the gases produced in this process are expelled while belching. Ruminants are considered cattle (milk, meat and dual purpose producers), buffaloes, goats and sheep, all of them a significant source of methane and in a smaller proportion are other herbivores (horses, mules and donkeys) and monogastric (pigs). The amount of methane produced depends mainly on the number of animals, the type of digestive system, and the type and amount of food consumed. Cattle manure is composed mainly of organic matter that when decomposed under anaerobic conditions produces CH_4 as well as N_2O as a product of the nitrification and bacterial denitrification of organic matter.

At municipal level, the intensity of the activity varies depending on the type of livestock. The municipalities of Colima, Coquimatlán and Manzanillo presented the largest populations of livestock for 2005. The Chart 27 shows the detailed characterization of the population at municipal level obtained from the Agrifood and Fishing Information System of SAGARPA.

Chart 27. Distribution of livestock population of the State of Colima per municipality in 2015

Municipalities	Bovine Meat	Bovine Milk	Pig	Goat	Sheep	Horse	Donkey	Mule	Fowl Meat	Fowl Egg	Turkey	Rabbit
Armería	4,876	123	204	619	574	195	16	46	55		-	3
Colima	51,883	2,474	5,515	1,675	1,609	1,066	165	181	48,329	2,600	143	17
Cómala	7,651	462	7,162	1,027	2,204	1,220	333	115	48,199	2,500	62	397
Coquimatlán	9,216	423	2,027	800	904	572	124	150	25,527	13,020	60	28
Cuauhtémoc	26,428	1,183	291	450	324	634	81	44	6,290	8,100	114	62
Ixtlahuacán	2,392	798	278	682	438	72	14	45	59	2,410	-	1
Manzanillo	18,952	636	926	2,004	616	648	222	191	249	12,540	176	16
Minatitlán	5,865	262	678	786	85	304	219	107	96	2,415	49	3
Tecomán	25,120	796	6,632	2,333	2,591	236	28	56	67	2,200	63	18
Villa de Álvarez	4,846	213	1,617	509	1,388	502	121	60	23,095	1,860	45	6
State	**157,228**	**7,370**	**25,330**	**10,886**	**10,732**	**5,449**	**1,323**	**995**	**151,967**	**47,645**	**713**	**552**

Fuente: SAGARPA-SIAP, 2018; INEGI 2007.

Activity data of Aggregate sources and no CO_2 sources of emissions (Agriculture)

Within this category, the following emission sources are identified:

1. Whitewashed
2. Application of fertilizers
    - Urea
    - Synthetics
    - Manure
3. Rice cultivation

4. Biomass burning
    - Pastures
    - Agricultural residuals
    - Forest fires

The estimation of emissions was made as follows:

Whitewashed

Soil pH influences the availability of nutrients for plants, to improve the yield of agricultural productive soils. It is a commonly applied technique to maintain soil pH between 6.5 and 7, in acidic soils lime is often applied as a soil improver; which favors an environment conducive to the normal development of crops, mainly the root.

The database of production costs developed by the SIAP was verified, according to which the State of Colima has records of the application of lime in the cultivation of sugarcane and corn for the year 2015, considering a consumption of 2,000 kg / ha of CO_3Ca (Chart 28).

Chart 28. Lime applied per municipality in 2015.

Municipality	Area planted with corn (Ha)	Quantity of lime applied (tons)
Armería	191	382
Colima	4,024	8,048
Comala	3,276	6,552
Coquimatlán	1,694	3,388
Cuauhtémoc	8,150	16,300
Ixtlahuacán	263	525
Manzanillo	1,813	3,626
Minatitlán	1,735	3,470
Tecomán	2,909	5,817
Villa de Álvarez	1,314	2,628
State	**25,368**	**50,736**

Using an emission factor of 0.12 ton of carbon (C) per ton of lime applied.

Application of fertilizers

There are different sources of nitrogen applied to the soil, synthetic, organic fertilizers and / or manure in different ways, which generate emissions indirectly, the main processes are:

- Nitrogen volatilization, resulting in atmospheric depositions of ammonia (NH_3) and nitrogen oxides (NOx)
- Loss of nitrogen (N) through leaching and runoff
- Disposition of N content in wastewater.

The basic variables for estimating N use the amount of nitrogen (kg N / year) incorporated into the soil, either as a fertilizer or as manure. In order to estimate the amount of nitrogen that is volatilized or leaching, different factors are used by default of IPCC, as well as data of the agricultural production cost base of SAGARPA.

The emissions of three types of fertilization were quantified:

- Urea
- Manure
- Application of fertilizers

In the case of Urea, the information on the use of Urea in the entity by type of crop in the Agricultural Technical Agenda of Colima was considered. (INIFAP, 2017) (Chart 29).

Chart 29. Urea apply data per type of crop in 2015.

Crop type	Urea applied (kg/ha)
Sugarcane	300
Fodder corn	392
Corn grain	300
Mango	1000
Pastures and grasslands	130
Zacate	216
Sorghum	324
Tamarind	200

Fuente: INIFAP, 2017

The amount of synthetic fertilizers used in Colima was estimated from the national apparent consumption. The data was taken from Faostat in the category of total nutrients as nitrogen "N total nutrients" that for 2015 was 1,361,598 tons. From apparent consumption, the N content per kilogram of fertilizer is adjusted to 34.5% of N, which is the national average of N in nitrogen fertilizers and is broken down by fertilized area according to SAGARPA by municipality (Chart 30).

Chart 30. Quantity of fertilizer applied by municipality of the State of Colima in 2015.

Municipality	Amount of synthetic fertilizer applied in ton / year
Armería	385,282
Colima	276,104
Cómala	170,070
Coquimatlán	190,972
Cuauhtémoc	289,360
Ixtlahuacán	138,482
Manzanillo	810,332
Minatitlán	230,398
Tecomán	789,490
Villa de Álvarez	92,325

Fuente: INIFAP, 2017.

Emissions by application of manure as fertilizer. For this category, the activity data is the same as for emissions from manure management.

Rice cultivation

The anaerobic decomposition of organic material in the flooded rice fields produces methane emissions. The area destined to the cultivation of rice fields in Colima, disaggregated by municipality, is presented in Chart 31. The data was taken from the SIAP for the agricultural year 2015.

Chart 31. Quantity of sown surface of rice per municipality in 2015.

Municipality	Sown surface (ha)	Modality
Colima	512	Irrigation
Colima	75	Temporary
Coquimatlán	537	Irrigation
Cuauhtémoc	1,496	Temporary
Tecomán	505	Irrigation

Fuente: SAGARPA-SIAP, 2018

Biomass burning

The burning of biomass is an important source of GHG, mainly of CH_4, CO_2 and black carbon; however, it could present considerable variability, especially in regard to forest fires, while for agricultural issues, the importance depends of the waste disposal techniques in the field after harvest. For purposes of the Inventory, the IPCC methodology considers CO_2 emissions for burning agricultural waste neutral and includes N_2O emissions in the accounting.

In the case of agricultural waste, only the burned residues were counted in the field, since the possible ones used as an energy source were accounted for in the energy sector for which information was available, mainly for the bagasse derived from sugarcane. The sugar cane, rice, corn and sorghum crops reported by SAGARPA were considered (Chart 32); Annual data was obtained by municipality from the SIAP.

Chart 32. Harvested area and production of different crops in the State of Colima in 2015.

Municipality	Harvested area (ha)				Production (Ton)			
	Sugarcane	Rice	Corn	Sorghum	Sugarcane	Rice	Corn	Sorghum
Armería	137		54	20	10,914		331	179
Colima	1,941	587	1,783	491	203,130	3,372	7,622	5,758
Comala	810		2,416	204	72,264		10,198	1,308
Coquimatlán	375	537	1,319	373	41,681	3,759	6,597	5,645
Cuauhtémoc	6,535	1,488	1,615	203	550,535	8,586	6,948	1,261
Ixtlahuacán	144		86	38	11,460		1,119	390
Manzanillo			164	79			2,395	2,112
Minatitlán	35		1,700	42	1,295		12,315	877
Tecomán	2,672	504	199	292	213,252	2,505	3,317	2,106
Villa de Álvarez	358		956	233	29,780		3,969	1,413

Fuente: SAGARPA-SIAP, 2018

For the grasslands and fires the annual information was obtained from the National Forestry Commission (CONAFOR) for the State of Colima. In the case of pastures, the fires were not reported in 2015 in the entity. The information of fires in Forest Areas is presented in Chart 33.

Chart 33. Pastures and forest fires in 2015 per municipality.

Municipality	Type of Vegetation	Shrubby	Herbaceous	Leaf litter	Total (ha)
Coquimatlán	Encino Forest - BQ	30.45	0	20.3	50.75
Manzanillo	Encino Forest - BQ	6	0	8.04	14.04
Manzanillo	Deciduous forest - SBC	0	0	5.2	5.2
Minatitlán	Encino Forest - BQ	0	1.34	1	2.34
Minatitlán	Encino Forest - BQ	1	0	2	3
Minatitlán	Encino Forest - BQ	0	0	0.35	0.35
Minatitlán	Encino Forest - BQ	0	0	0.68	0.68
Minatitlán	Encino Forest - BQ	0.68	0	0	0.68
Minatitlán	Encino Forest - BQ	10	0	18.96	28.96
Tecomán	Deciduous forest - SBC	0	1	4.36	5.36
Villa de Álvarez	Deciduous forest - SBC	4.15	0	0	4.15

Fuente: CONAFOR, 2018

Land-use change

The estimation of the emission or absorption of greenhouse gases, for the agriculture, forestry and other land use sectors, in the period of 2010-2012, was carried out as established in the Guidelines of the Intergovernmental Panel on Climate Change (IPCC) of 2006 for national inventories of greenhouse gases. The 2006 IPCC Guidelines consider estimation methods for three levels of detail, based on their accuracy and precision, as well as the information required for their evaluation. Level 1 is the one of greatest uncertainty and considers the use of default data and simple equations; level 2 uses country-specific data, and level 3 uses data and models that adapt to local conditions. The estimation of the greenhouse gas content and its associated uncertainty then depends on the available information (forest inventories, information on land use and vegetation, satellite images, estimation models, etc.) for the evaluation at different times. In order to obtain the least uncertainty, the most recent information available for Mexico and for the State of Colima was used.

This annex describes the method for obtaining the surface by type of vegetation or land use in two periods, to subsequently evaluate the changes, by municipality and by type of vegetation or land use. This information is what is known as activity data and is an input to estimate the emission of greenhouse gases.

Emissions estimation

The general procedure for approaching this section is shown in Figure 27:

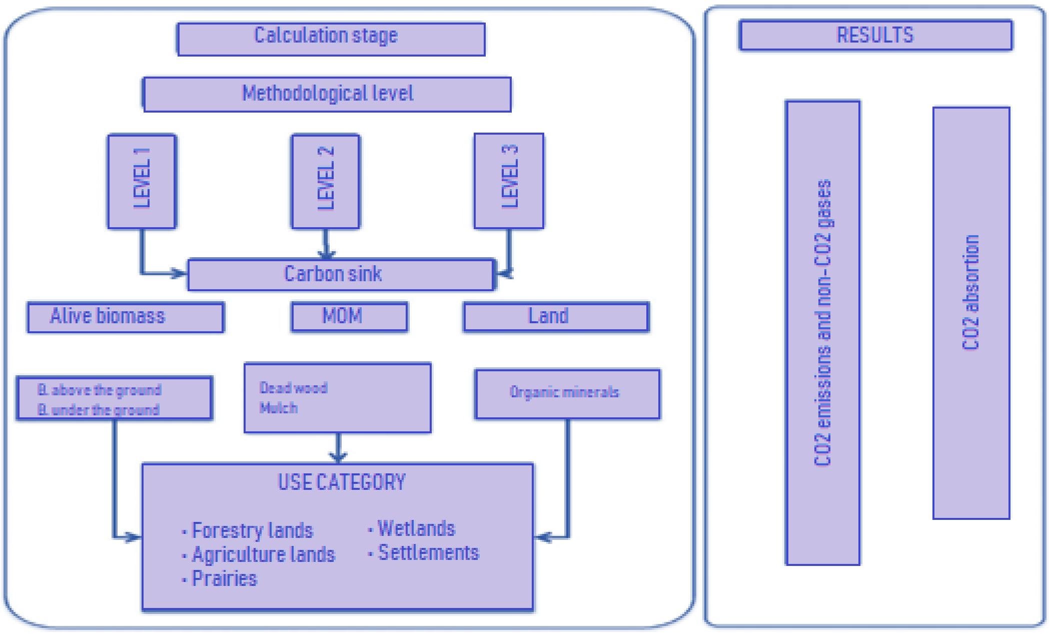


Figure 27. Emissions estimation general process.

Results

Livestock results

Livestock is one of the main sources of GHG emissions both for the product of enteric fermentation of ruminants and for the management of manure and its application as fertilizer. The results by municipality per greenhouse gas are shown in Chart 34:

Chart 34. Livestock subsector results in Tons/year for 2015, per municipality.

Municipality	Enteric fermentation, CH_4 (Gg/year)	Manure management, CH_4 (Gg/year)	Manure management, N_2O(Gg/year)	CO_2e (Gg/year)
Armería	0.25	0.01	0.00	8.11
Colima	2.76	0.06	0.04	88.68
Comala	0.46	0.02	0.01	15.65
Coquimatlán	0.50	0.01	0.01	16.33
Cuauhtémoc	1.39	0.03	0.02	44.40
Ixtlahuacán	0.20	0.00	0.00	6.48
Manzanillo	0.99	0.02	0.01	31.77
Minatitlán	0.32	0.01	0.00	10.24
Tecomán	1.31	0.03	0.02	42.57
Villa de Álvarez	0.27	0.01	0.00	8.92
State	**8.48**	**0.21**	**0.11**	**273.16**

Livestock is one of the main sources of GHG emissions. In terms of CO_2e, the main source of emission is the enteric fermentation with a state total for this category of 237.38 Gg of CO_2, equivalent to 87% of the emissions for this subsector at the State; and the manure management corresponds to 35.78 Gg of CO_2e. The municipalities of Colima, Cuauhtémoc and Tecomán have the highest contribution in this category in the entity with 32, 16 and 15%, respectively (Figure 28).

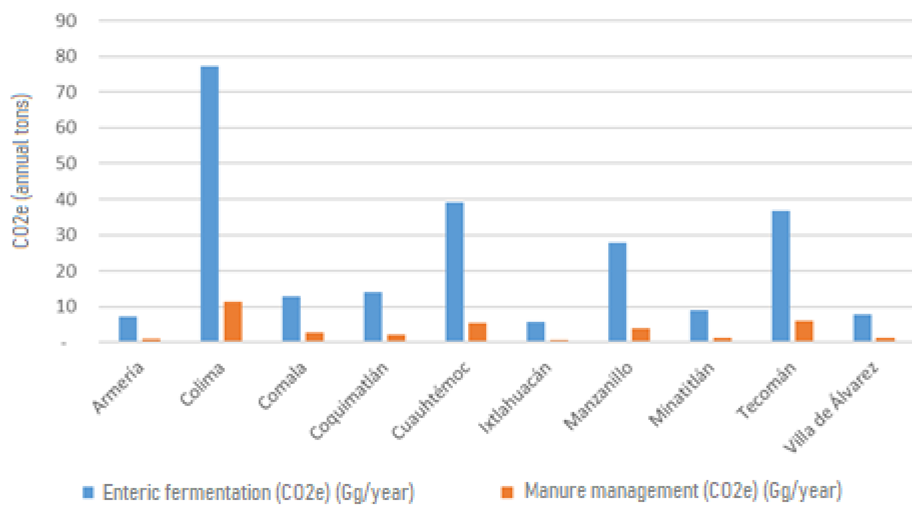


Figure 28. CO_2e emissions by livestock per subsectors in 2015.

Results Aggregate sources and sources of emissions No CO_2 (Agriculture)

In the case of emissions by the agricultural sector, they are shown in Chart 35 by municipality.

Chart 35. CO_2e emissions per municipality in the Agriculture subsector for Colima in 2015 (Gg/year).

Municipality	Whitewashed	Urea apply	Rice cultivation	Synthetic fertilizers	Biomass burning	Direct N_2O emissions from managed soils	Indirect emissions from manure management	Indirect N_2O emissions from managed soils
Armería	0.17	0.97	-	1.15	0.53	0.03	0.02	0.03
Colima	3.54	1.67	3.04	0.82	12.42	0.02	0.01	0.02
Comala	2.88	1.04	-	0.51	10.64	0.01	0.01	0.01
Coquimatlán	1.49	0.98	3.01	0.57	11.19	0.01	0.01	0.02
Cuauhtémoc	7.17	2.12	3.35	0.86	22.84	0.02	0.01	0.03
Ixtlahuacán	0.23	0.59	-	0.41	0.69	0.01	0.01	0.01
Manzanillo	1.60	4.67	-	2.42	2.07	0.06	0.04	0.07
Minatitlán	1.53	1.21	-	0.69	8.83	0.02	0.01	0.02
Tecomán	2.56	2.08	2.83	2.35	8.16	0.06	0.04	0.07
Villa de Álvarez	1.16	0.57	-	0.28	4.76	0.01	0.00	0.01
State	**22.32**	**15.91**	**12.22**	**10.06**	**82.11**	**0.25**	**0.17**	**0.30**

The municipalities that contribute the most emissions for this subcategory are Manzanillo, Villa de Álvarez and Tecomán (Figure 29).

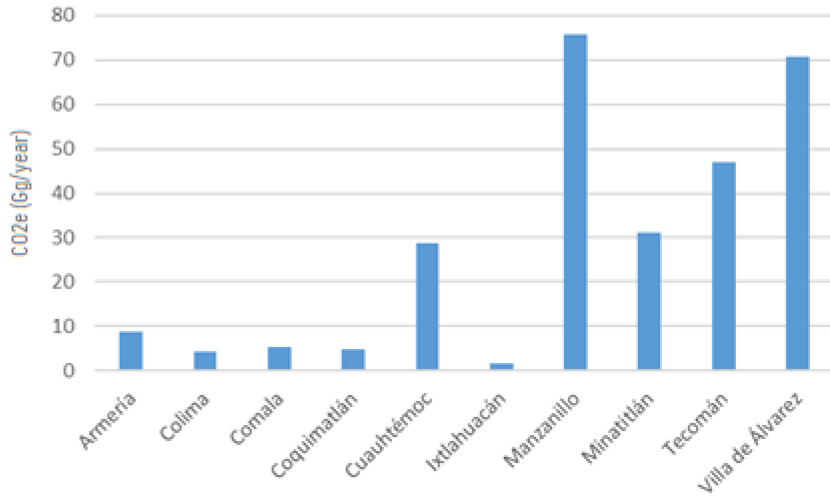


Figure 29. Agriculture subsector in the State of Colima for year 2015.

Results of the change of land use

The evaluation of the change of land use indicates, among other results, that there is a degradation of 10% and deforestation of 9% of the total state surface. In terms of emissions by this category, they amounted to 1,761 Gg, desegregated as in Chart 36. The emissions and removals (permanence) of the following types of land uses are reported: forest lands; pastures, agricultural lands, settlements and other lands.

Chart 36. Total CO_2 emissions per municipality for Change of Land Use Subcategory in 2015 (Gg/year).

Municipality	Lands converted to grasslands	Lands converted to settlements	Lands converted to other lands	Land converted to agricultural land	Degraded forest lands	Removals	
						Forest lands that remain as forest lands	Pastures that remain as grasslands
Armería	3.51	0.20		66.25	3.62	14.39	1.85
Colima	32.97	2.78	0.01	93.32	16.99	13.76	6.21
Comala	51.91	0.67	0.34	103.72	18.50	4.93	13.45
Coquimatlán	26.53	0.66	0.15	134.15	25.38	17.62	0.33
Cuauhtémoc	25.80	1.26		145.39	5.66	2.75	3.51
Ixtlahuacán	22.27	0.44		39.45	17.31	10.61	5.93
Manzanillo	114.13	12.14	1.16	120.86	38.62	44.82	32.29
Minatitlán	65.44	1.06	2.25	14.33	12.49	14.38	11.16
Tecomán	1.15	0.99	0.13	146.20	13.78	9.76	0.43
Villa de Álvarez	19.34	1.93	0.09	87.13	8.13	7.63	2.96
Total	**363.06**	**22.14**	**4.12**	**950.80**	**160.48**	**-140.65**	**-78.13**

In 2015, the Change of Land Use sector in the State of Colima had a sink effect, due to the absorption of CO_2, mainly by permanence (forest lands and pastures). The contribution of CO_2 emissions by this category corresponds to 1,386.94 Gg of CO_2 (Figure 30).

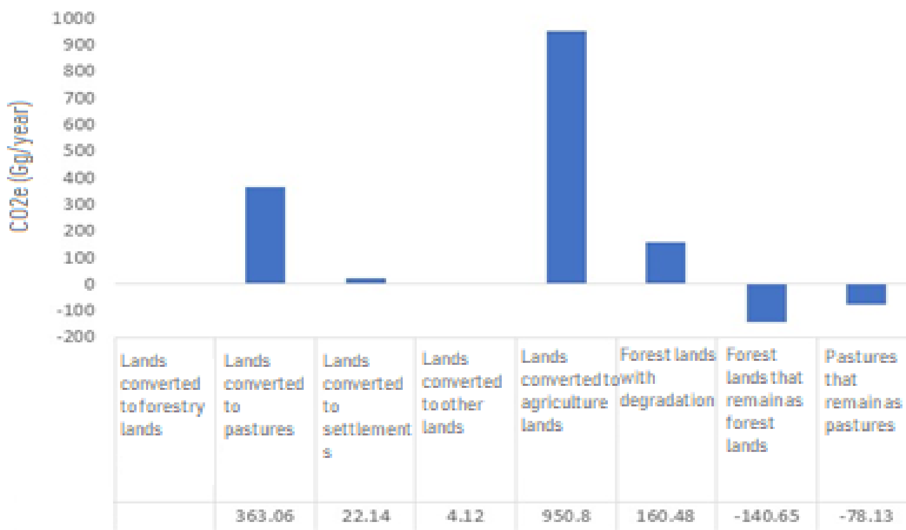


Figure 30. GHG emissions and absorptions for the Change of Lands Use subcategory in 2015.

Figure 31 shows the total emissions of CO_2e by municipality in the AFOLU sector, where the main municipalities of these emissions are Manzanillo and Cuauhtémoc, for the various activities carried out in them, especially agricultural activities.

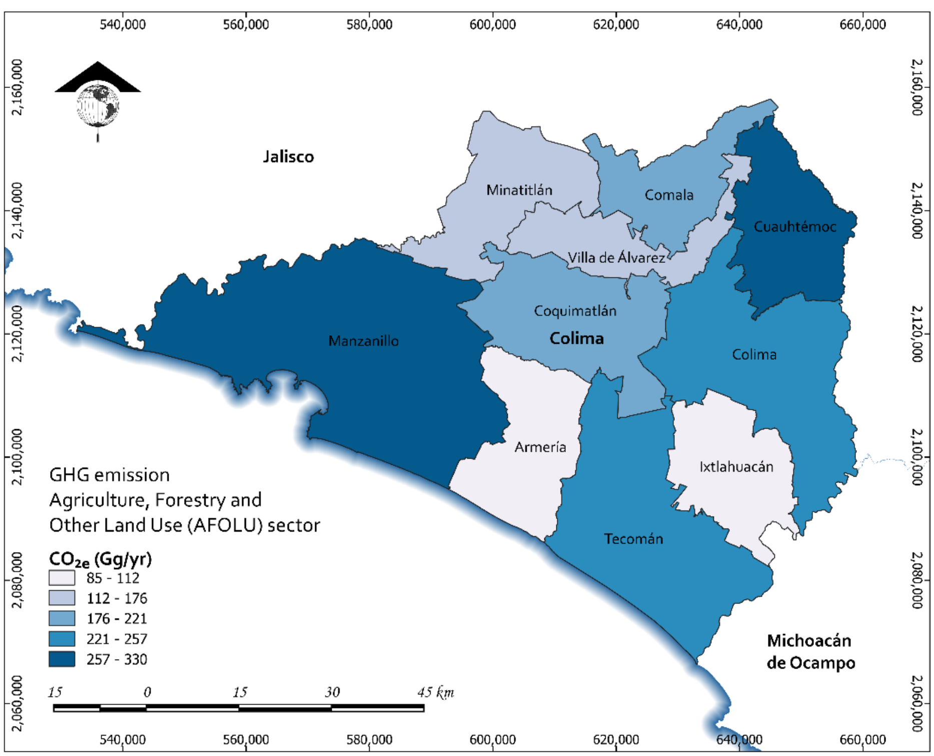


Figure 31. Distribution of CO_{2}e emissions at municipality level in the AFOLU category for the State of Colima in 2015.

7.4. WASTE

This category includes the emission sources of CO_2, CH_4, N_2O and black carbon, from solid waste and wastewater; where the CH_4 emissions come from the anaerobic decomposition of the organic matter that is part of the solid waste, whether its disposal is controlled or not, as well as the emissions generated during the wastewater treatment and disposal processes, both municipal and industrial (Figure 32).

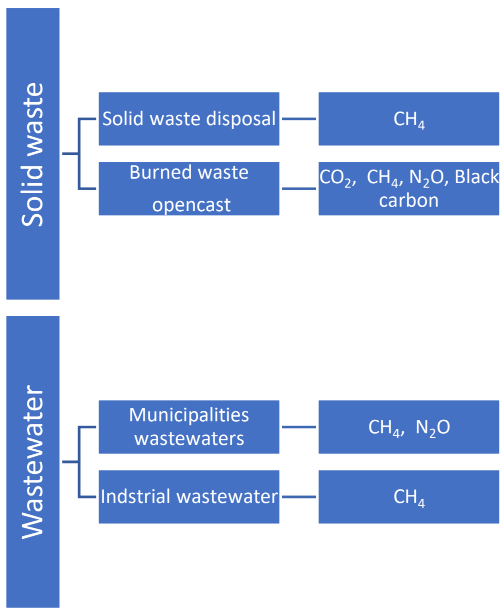


Figure 32. Subcategories included in Waste category.

Solid urban waste disposal data activity

For this section, information on the number of inhabitants by municipality was compiled for 2015, from the Intercensus Survey 2015 (INEGI).

Information was obtained from IMADES on the final disposal sites of solid urban waste (MSW) that exist in the entity, the amount of waste disposed in them and the operating conditions in them. Based on the above, the Mexican Biogas model was used to calculate the CH_4 emissions generated by each site.

In the case of the burning in open sky of MSW, the information from the Intercensus Survey 2015 (INEGI) was obtained, which indicates that 2.06% of the population in the entity burn their waste. Therefore, considering that in the State each person has a waste generation of 1.08 kg / day (IMADES, 2011), 5,978.96 tons of MSW were burned in 2015. This information is shown in Chart 37.

Chart 37. Solid urban waste final disposal for 2015 in the State of Colima.

Entity	% Solid waste generated that is taken to a final disposal site	% Solid waste that burns in the open	Urban solid waste generated in 2015 (tons)
Colima	96.63	2.06	768,133.80

Fuente: INEGI, 2015a.

Wastewater treatment activity data

According to data from the National Water Commission (CONAGUA), in 2015, 3.740 lps of water was supplied to the Entity, covering 98% of the population. Of the total population in the State, 98.9% has sewerage service (CONAGUA, 2016).

Information was obtained via trade from CONAGUA, from the municipal wastewater treatment plants in operation at the State of Colima in 2015. In addition, this information was supplemented for the case of untreated wastewater generated in the entity with public data from CONAGUA in its statistical yearbooks for 2015 (CONAGUA, 2016).

In the case of industrial wastewater, information was obtained via INFOMEX directly from the CONAGUA, complementing with public information in the document "Situation of the Sub-sector Potable Water, Drainage and Sanitation, 2016 edition" (CONAGUA, 2016.).

The Chart 38 shows the quantity of treatment plants and its flows for the State of Colima in year 2015.

Chart 38. Quantity of treatment plants and its flows for the State of Colima in year 2015.

Wastewater	Number of treatment plants	Treated flow (lps)	Treatment coverage (%)
Municipal	67	1614	63
Industrial	13	292	nr

nr= no reported.
Fuente: CONAGUA, 2016

Results

The GHG emissions in the entity by the waste sector amounted to 464 Gg of CO_2e in 2015, where most are due to the generation of methane with 16.32 Gg per year, 1.25 Gg of CO_2, 0.03 Gg of N_2O and 0.01 Gg of black carbon (Chart 39).

Chart 39. Total CO_2e emissions of the Waste category for the State of Colima in 2015 (Gg/year).

Municipality	Final disposition of MSW	Burning waste opencast	Municipal untreated	Municipal treated	Industrial
Armería		2.22	6.43	3.86	-
Colima		0.81	2.15	28.92	0.50
Comala		0.19	4.74	16.46	-
Coquimatlán		0.54	4.17	5.44	-
Cuauhtémoc		0.05	4.97	29.52	22.92
Ixtlahuacán		0.52	1.02	7.27	-
Manzanillo	33.65	3.09	31.29	55.49	6.05
Minatitlán		0.14	1.53	17.69	29.02
Tecomán	8.61	3.76	22.10	15.54	12.01
Villa de Álvarez	30.43	0.14	39.83	10.84	0.12
State	**72.70**	**11.45**	**118.23**	**191.01**	**70.61**

In terms of CO_2e it is observed that treated municipal wastewater is the one that contributes the largest emissions in this category with 41%, followed by those not treated (26%) and the final disposal of waste with 16% of the emission in the entity (Figure 33).

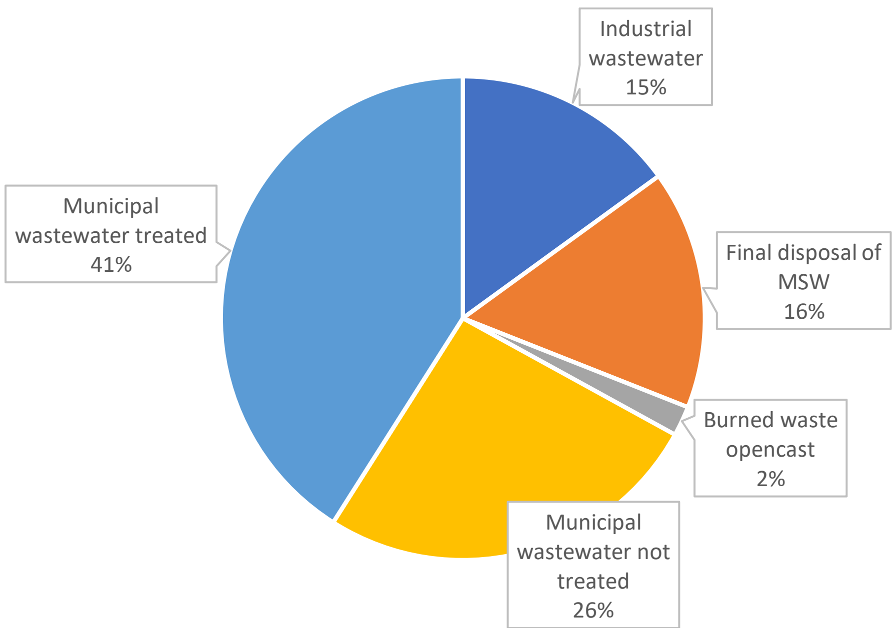


Figure 33. Contribution in percentage of the Waste subcategories to the total CO_2e emissions in 2015.

Figure 34 shows the distribution of emissions at the municipal level of CO_2e in the Waste sector. The municipalities with the highest population index and those with the largest urban areas in the state have higher emissions; The municipalities of Manzanillo, Villa de Álvarez, Tecomán and Minatitlán stand out, due to the magnitude of the population present in them, which generate waste and have sanitary landfills, as well as large wastewater treatment plants.

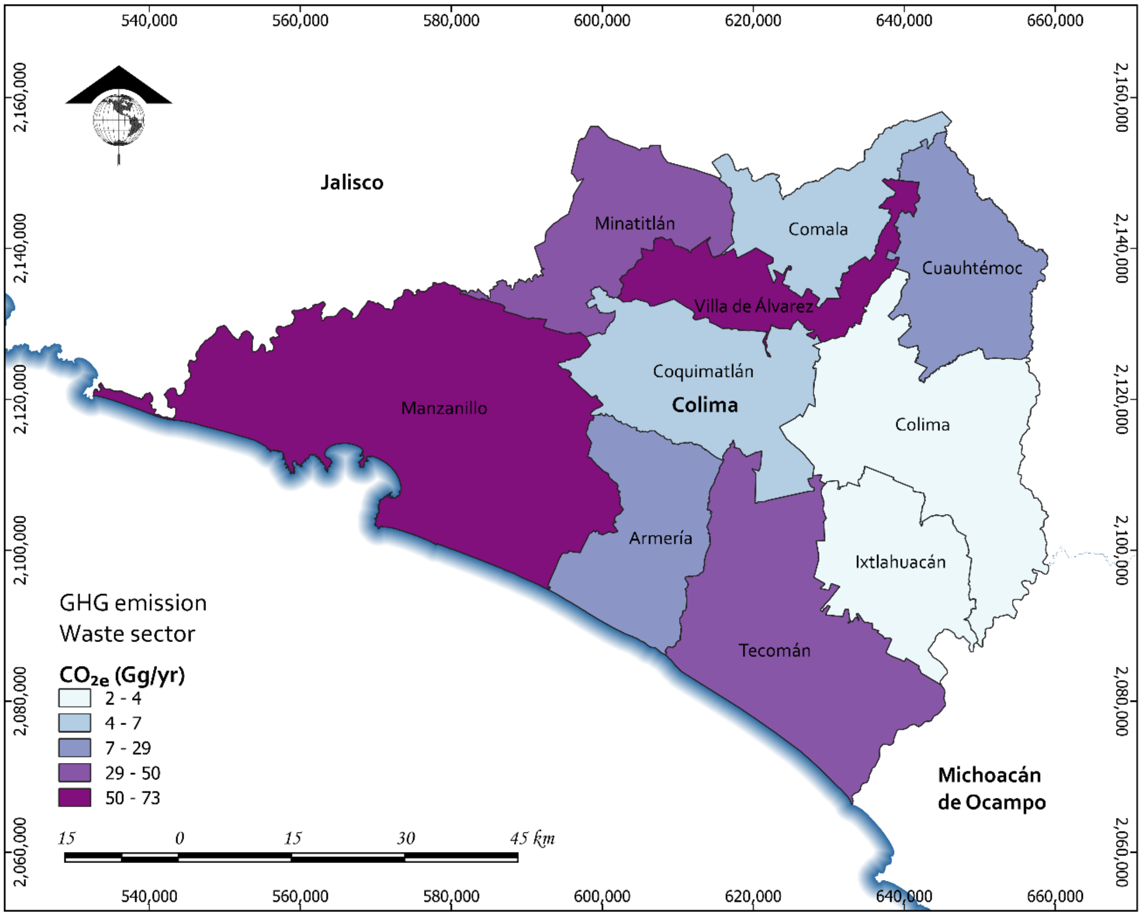


Figure 34. CO_2e emissions distribution at municipal level in the Waste category for the State of Colima in 2015.

7.5. UNCERTAINTY ESTIMATION

In the present inventory, the uncertainties are associated both with the emission factors chosen for each source and with the activity data used in the estimates. As suggested by the IPCC Good Practice Guides (GBP), the uncertainties associated with the Global Warming Potential values are not considered.

For this inventory, the methodology of level 1 "Estimation of uncertainties by source category with simplified assumptions" is used, recommended in chapter 6 of the IPCC GBP, for all the subcategories of the inventory, except for the motor transport in which method 2 was used (Monte Carlo model), for the evaluation of uncertainty of the MOVES-Mexico model (see uncertainty annex).

The uncertainty values presented in Chart 40 contemplate the subcategories and sectors for which it was possible to individually estimate a value of the uncertainty for the year 2015, either for the activity data and / or for the emission factor. The total of the emissions considered for the calculation of the uncertainty values represent 100% of the total emissions of the inventory.

According to this approach, it is estimated that the inventory has an overall combined uncertainty of 8.9% due to the uncertainty introduced in the contribution of the emissions.

Chart 40. Uncertainty estimation per category and combined uncertainty.

Category	Category-subcategory code/ name	Source	Uncertainty FE (%)	Uncertainty DA (%)	Combined uncertainty %	Gas	Emission Gg 2015	Emissions CO_2 eqv	Contribution to variance
Energy	1A1 Energy industries	1A1ai Electricity generation	8.67	1	8.72	CO_2	7,034.06	7034.059	11.6465
		1A1aiii Energy generation plants	4.84	2	5.23	CO_2	0.33	0.334	0.0000
	1A2 Manufacturing and construction industries	1A2a Iron and steel	3.33	1	3.47	CO_2	270.01	270.012	0.0027
		1A2c Chemistry substances	4.56	1	4.67	CO_2	0.12	0.120	0.0000
		1A2e Food, beverage and tobacco industries	2.67	1	2.85	CO_2	267.08	267.084	0.0018
		1A2f non-metallic minerals	24.97	1	24.99	CO_2	891.75	891.747	1.5360
		1A2m non-specified industries	3.63	1	3.76	CO_2	431.28	431.284	0.0081
	1A3 Transport	1A3a Civil aviation	5.00	5	7.07	CO_2	16.60	16.601	0.0000
		1A3b Road transportation			22.00	CO_2	3,610.00	3610.000	19.5120
		1A3c Railways	1.18	5	5.14	CO_2	33.49	33.486	0.0001
		1A3d Navigation	1.48	5	5.22	CO_2	66.97	66.972	0.0004
	1A4 Other sectors	1A4a Commercial / Institutional	0.44	12	12.01	CO_2	13.69	13.692	0.0001
		1Ab Residential	25.62	12	28.29	CO_2	133.99	133.995	0.0445
		1A4c Agriculture/Silviculture	0.89	12	12.03	CO_2	33.10	33.099	0.0005
Industrial Processes and Product Use (IPPU)	2A Mineral industry	2A1 Cement production	2.00	7	7.28	CO_2	408.81	408.813	0.0274
		2A2 Lime production	2.00	2	2.83	CO_2	21.07	21.070	0.0000
	2C Metal industry	2C1 Production of iron and steel	25.00	10	26.93	CO_2	136.57	136.570	0.0418
	2G Manufacturing and use of other products	2G2c Others	5.00	5	7.07	CO_2			0.0000
Agriculture, Forestry and Other Land Uses (AFOLU)	3A Livestock	3A1 Enteric fermentation				CO_2			0.0000
		3A2 Manure management				CO_2			0.0000
	3B Land	Land converted to forest land	18.09	0.5	18.10	CO_2			0.0000
		Lands converted to Grasslands	18.09	0.5	18.10	CO_2	363.06	363.059	0.1335
		Lands converted to Settlements	18.09	0.5	18.10	CO_2	22.14	22.140	0.0005
		Land converted to Agricultural land	18.09	0.5	18.10	CO_2	950.80	950.796	0.9157
		Lands converted to other lands	18.09	0.5	18.10	CO_2	4.12	4.120	0.0000
		Degraded forest lands	18.09	0.5	18.10	CO_2	160.48	160.475	0.0261
	Removals	Forest lands that remain as forest lands	18.09	0.5	18.10	CO_2	-140.65	-140.653	0.0200
		Pastures that remain as grasslands	18.09	0.5	18.10	CO_2	-78.12837192	-78.128	0.0062
		Agricultural Lands that remain as Agricultural land	18.09	0.5	18.10	CO_2			0.0000
	3C Aggregate sources and non-CO2 emission sources of land	3C1 Biomass burn	5.00	40	40.31	CO_2	58.97	58.970	0.0175
		3C2 Whitewashing	50.00	50	70.71	CO_2	22.32	22.324	0.0077
		3C3 Application of urea	50.00	50	70.71	CO_2	15.91	15.910	0.0039
		3C4 Direct N2O emissions from managed soils				CO_2			0.0000
		3C5 Indirect N2O emissions from managed soils				CO_2			0.0000
		3C6 Indirect emissions of N2O resulting from manure management				CO_2			0.0000
Waste	4A Solid waste disposal	Municipal solid waste disposal				CO_2			0.0000
	4C Incineration and open incineration of waste	Burning waste opencast				CO_2			0.0000
	4D Wastewater treatment and disposal	Municipal Wastewater (treated)	30.00	15	33.54	CO_2	1.25	1.253	0.0000
		Municipal Wastewater (untreated)				CO_2			0.0000
		Industrial Wastewater (treated)				CO_2			0.0000
Energy	1A1 Energy industries	1A1ai Electricity generation	329.03	1	329.03	CH_4	0.149373332	4.182	0.0059
		1A1aiii Energy generation plants	0.00	2	2.00	CH_4	0.301040717	8.429	0.0000
	1A2 Manufacturing and construction industries	1A2a Iron and steel	150.00	1	150.00	CH_4	0.008842	0.248	0.0000
		1A2c Chemistry substances	137.88	1	137.88	CH_4	2.80846E-06	0.000	0.0000
		1A2e Food, beverage and tobacco industries	156.96	1	156.96	CH_4	0.025684336	0.719	0.0000
		1A2f non-metallic minerals	163.38	1	163.38	CH_4	1.442330837	40.385	0.1347
		1A2m non-specified industries	150.37	1	150.37	CH_4	0.421747434	11.809	0.0098
	1A3 Transport	1A3a Civil aviation	20.00	5	20.62	CH_4	0.000022	0.001	0.0000
		1A3b Road transportation			37.00	CH_4	0.46	12.880	0.0007
		1A3c Railways	105.18	5	105.30	CH_4	0.001906767	0.053	0.0000
		1A3d Navigation	50.00	5	50.25	CH_4	0.006432468	0.180	0.0000
	1A4 Other sectors	1A4a Commercial / Institutional	5720.00	12	5720.01	CH_4	0.001051922	0.029	0.0001
		1Ab Residential	14719.16	12	14719.17	CH_4	0.233257819	6.531	28.5888
		1A4c Agriculture/Silviculture	7349.59	12	7349.60	CH_4	0.004005988	0.112	0.0021
Industrial Processes and Product Use (IPPU)	2A Mineral industry	2A1 Cement production				CH_4		0.000	0.0000
		2A2 Lime production				CH_4		0.000	0.0000
	2C Metal industry	2C1 Production of iron and steel				CH_4		0.000	0.0000
	2G Manufacturing and use of other products	2G2c Others				CH_4		0.000	0.0000
Agriculture, Forestry and Other Land Uses (AFOLU)	3A Livestock	3A1 Enteric fermentation	30.00	30	42.43	CH_4	8.477786889	237.378	0.3138
		3A2 Manure management	30.00	30	42.43	CH_4	0.209396768	5.863	0.0002
	3B Land	Land converted to forest land				CH_4			0.0000
		Lands converted to Grasslands				CH_4			0.0000
		Lands converted to Settlements				CH_4			0.0000

Category	Category-subcategory code/ name	Source	Uncertainty FE (%)	Uncertainty DA (%)	Combined uncertainty %	Gas	Emission Gg 2015	Emissions CO_2 eqv	Contribution to variance
		Land converted to Agricultural land				CH_4			0.0000
		Lands converted to other lands				CH_4			0.0000
		Degraded forest lands				CH_4			0.0000
	Removals	Forest lands that remain as forest lands				CH_4			0.0000
		Pastures that remain as grasslands				CH_4			0.0000
		Agricultural Lands that remain as Agricultural land				CH_4			0.0000
	3C Aggregate sources and non-CO2 emission sources of land	3C1 Biomass burn	5.00	40	40.31	CH_4	0.122620362	3.433	0.0001
		3C2 Whitewashing				CH_4			0.0000
		3C3 Application of urea				CH_4			0.0000
		3C4 Direct N2O emissions from managed soils				CH_4			0.0000
		3C5 Indirect N2O emissions from managed soils				CH_4			0.0000
		3C6 Indirect emissions of N2O resulting from manure management				CH_4			0.0000
		3C7 Rice cultivations	5.00	40	40.31	CH_4	0.43648	12.221	0.0008
Waste	4A Solid waste disposal	Municipal solid waste disposal	30.00	30	42.43	CH_4	2.596253185	72.695	0.0294
	4C Incineration and open incineration of waste	Burning waste opencast	30.00	30	42.43	CH_4	3.05893E-08	0.000	0.0000
	4D Wastewater treatment and disposal	Municipal Wastewater (treated)	30.00	15	33.54	CH_4	4.6	128.800	0.0577
		Municipal Wastewater (untreated)	30.00	15	33.54	CH_4	6.171731316	172.808	0.1039
		Industrial Wastewater (treated)	30.00	15	33.54	CH_4	2.52	70.560	0.0173
Energy	1A1 Energy industries	1A1ai Electricity generation	422.94	1	422.94	N_2O	0.020031118	5.308	0.0156
		1A1aiii Energy generation plants	135.00	2	135.01	N_2O	6.11642E-07	0.000	0.0000
	1A2 Manufacturing and construction industries	1A2a Iron and steel	150.00	1	150.00	N_2O	0.017831	4.725	0.0016
		1A2c Chemistry substances	149.48	1	149.48	N_2O	4.3524E-07	0.000	0.0000
		1A2e Food, beverage and tobacco industries	194.32	1	194.32	N_2O	0.000613071	0.162	0.0000
		1A2f non-metalic minerals	153.66	1	153.66	N_2O	0.022282256	5.905	0.0025
		1A2m non-specified industries	150.61	1	150.61	N_2O	0.006908956	1.831	0.0002
	1A3 Transport	1A3a Civil aviation				N_2O			0.0000
		1A3b Road transportation			39.00	N_2O	0.14	37.100	0.0065
		1A3c Railways	125.00	5	125.10	N_2O	0.013140613	3.482	0.0006
		1A3d Navigation	40.00	5	40.31	N_2O	0.001837848	0.487	0.0000
	1A4 Other sectors	1A4a Commercial / Institutional	148.15	12	148.63	N_2O	2.10384E-05	0.006	0.0000
		1Ab Residential	84.05	12	84.90	N_2O	0.003145414	0.834	0.0000
		1A4c Agriculture/Silviculture	119.41	12	120.01	N_2O	0.000213104	0.056	0.0000
Industrial Processes and Product Use (IPPU)	2A Mineral industry	2A1 Cement production				N_2O			0.0000
		2A2 Lime production				N_2O			0.0000
	2C Metal industry	2C1 Production of iron and steel				N_2O			0.0000
	2G Manufacturing and use of other products	2G2c Others				N_2O			0.0000
Agriculture, Forestry and Other Land Uses (AFOLU)	3A Livestock	3A1 Enteric fermentation				N_2O			0.0000
		3A2 Manure management	135.00		135.00	N_2O	0.112907196	29.920	0.0505
	3B Land	Land converted to forest land			0.00	N_2O			0.0000
		Lands converted to Grasslands			0.00	N_2O			0.0000
		Lands converted to Settlements			0.00	N_2O			0.0000
		Land converted to Agricultural land			0.00	N_2O			0.0000
		Lands converted to other lands				N_2O			0.0000
		Degraded forest lands			0.00	N_2O			0.0000
	Removals	Forest lands that remain as forest lands			0.00	N_2O			0.0000
		Pastures that remain as grasslands			0.00	N_2O			0.0000
		Agricultural Lands that remain as Agricultural land			0.00	N_2O			0.0000
	3C Aggregate sources and non-CO2 emission sources of land	3C1 Biomass burn	5.00	40	40.31	N_2O	0.003325623	0.881	0.0000
		3C2 Whitewashing			0.00	N_2O			0.0000
		3C3 Application of urea			0.00	N_2O			0.0000
		3C4 Direct N2O emissions from managed soils	135.00		135.00	N_2O	0.252979772	67.040	0.2534
		3C5 Indirect N2O emissions from managed soils	112.50		112.50	N_2O	0.3	79.500	0.2474
		3C6 Indirect emissions of N2O resulting from manure management	18.75		18.75	N_2O	0.17	45.050	0.0022
		3C7 Rice cultivations				N_2O			0.0000
Waste	4A Solid waste disposal	Municipal solid waste disposal				N_2O			0.0000
	4C Incineration and open incineration of waste	Burning waste opencast	30.00	30	42.43	N_2O	7.05906E-10	0.000	0.0000
	4D Wastewater treatment and disposal	Municipal Wastewater (treated)	30.00	15	33.54	N_2O	0.03	7.950	0.0002
		Municipal Wastewater (untreated)				N_2O			0.0000
		Industrial Wastewater (treated)				N_2O			0.0000
Energy	1A1 Energy industries	1A1ai Electricity generation			3.00	Black carbon	0.093847446	84.463	0.0002
		1A1aiii Energy generation plants			3.00	Black carbon	2.50034E-06	0.002	0.0000
	1A2 Manufacturing and construction industries	1A2a Iron and steel			21.00	Black carbon	0.000310301	0.279	0.0000
		1A2c Chemistry substances			21.00	Black carbon	5.85E-08	0.000	0.0000

Category	Category-subcategory code/ name	Source	Uncertainty FE (%)	Uncertainty DA (%)	Combined uncertainty %	Gas	Emission Gg 2015	Emissions CO_2 eqv	Contribution to variance
		1A2e Food, beverage and tobacco industries			21.00	Black carbon	0.012380843	11.143	0.0002
		1A2f non-metallic minerals			21.00	Black carbon	0.013273581	11.946	0.0002
		1A2m non-specified industries			21.00	Black carbon	0.000235541	0.212	0.0000
	1A3 Transport	1A3a Civil aviation			17.00	Black carbon	0.0008673	0.781	0.0000
		1A3b Road transportation			36.58	Black carbon	2.13	1917.000	15.2115
		1A3c Railways			11.00	Black carbon	0.00499062	4.492	0.0000
		1A3d Navigation			16.00	Black carbon	0.030116094	27.104	0.0006
	1A4 Other sectors	1A4a Commercial / Institutional			10.00	Black carbon	6.25755E-05	0.056	0.0000
		1Ab Residential			10.00	Black carbon	0.052994702	47.695	0.0007
		1A4c Agriculture/Silviculture			5.00	Black carbon	0.018457421	16.612	0.0000
Industrial Processes and Product Use (IPPU)	2A Mineral industry	2A1 Cement production				Black carbon			0.0000
		2A2 Lime production				Black carbon			0.0000
	2C Metal industry	2C1 Production of iron and steel				Black carbon			0.0000
	2G Manufacturing and use of other products	2G2c Others				Black carbon			0.0000
Agriculture, Forestry and Other Land Uses (AFOLU)	3A Livestock	3A1 Enteric fermentation				Black carbon			0.0000
		3A2 Manure management				Black carbon			0.0000
	3B Land	Land converted to forest land				Black carbon			0.0000
		Lands converted to Grasslands				Black carbon			0.0000
		Lands converted to Settlements				Black carbon			0.0000
		Land converted to Agricultural land				Black carbon			0.0000
		Lands converted to other lands				Black carbon			0.0000
		Degraded forest lands				Black carbon			0.0000
	Removals	Forest lands that remain as forest lands				Black carbon			0.0000
		Pastures that remain as grasslands				Black carbon			0.0000
		Agricultural Lands that remain as Agricultural land				Black carbon			0.0000
	3C Aggregate sources and non-CO2 emission sources of land	3C1 Biomass burn			15.00	Black carbon	0.020918184	18.826	0.0002
		3C2 Whitewashing				Black carbon			0.0000
		3C3 Application of urea				Black carbon			0.0000
		3C4 Direct N2O emissions from managed soils				Black carbon			0.0000
		3C5 Indirect N2O emissions from managed soils				Black carbon			0.0000
		3C6 Indirect emissions of N2O resulting from manure management				Black carbon			0.0000
		3C7 Rice cultivations				Black carbon			0.0000
Waste	4A Solid waste disposal	Municipal solid waste disposal				Black carbon			0.0000
	4C Incineration and open incineration of waste	Burning waste opencast			19.00	Black carbon	0.011325348	10.193	0.0001
	4D Wastewater treatment and disposal	Municipal Wastewater (treated)				Black carbon			0.0000
		Municipal Wastewater (untreated)				Black carbon			0.0000
		Industrial Wastewater (treated)				Black carbon			0.0000
							Sumatory		**79.0**
							Total uncertainty of the inventory		**8.9**

Key categories and their relation to uncertainty

For the identification of main categories, method 1 and 2 were used, with the purpose of evaluating both the absolute value of emissions and their association with uncertainty. Charts 41 and 42 show the results of methods 1 and 2 of the resulting main categories for the GHG inventory of Colima 2015.

Chart 41. Resulting key categories using the method 1 for the GHG Inventory of the State of Colima, base year 2015.

Category-subcategory code/ name	Source	Gas	Percentage
1A1 Energy industries	1A1ai Electricity generation	CO_2	38.19%
1A3 Transport	1A3b Road transportation	CO_2	19.60%
1A3 Transport	1A3b Road transportation	Black carbon	10.41%
3B Land	Land converted to Agricultural land	CO_2	5.16%
1A2 Manufacturing and construction industries	1A2f non-metallic minerals	CO_2	4.84%
1A2 Manufacturing and construction industries	1A2m non-specified industries	CO_2	2.34%
2A Mineral industry	2A1 Cement production	CO_2	2.22%
3B Land	Lands converted to Grasslands	CO_2	1.97%
1A2 Manufacturing and construction industries	1A2a Iron and steel	CO_2	1.47%
1A2 Manufacturing and construction industries	1A2e Food, beverage and tobacco industries	CO_2	1.45%
3A Livestock	3A1 Enteric fermentation	CH_4	1.29%
4D Wastewater treatment and disposal	Municipal Wastewater (untreated)	CH_4	0.94%
3B Land	Degraded forest lands	CO_2	0.87%
Removals	Forest lands that remain as forest lands	CO_2	0.76%
2C Metal industry	2C1 Production of iron and steel	CO_2	0.74%
1A4 Other sectors	1Ab Residential	CO_2	0.73%
4D Wastewater treatment and disposal	Municipal Wastewater (treated)	CH_4	0.70%
1A1 Energy industries	1A1ai Electricity generation	Black carbon	0.46%
3C Aggregate sources and non-CO2 emission sources of land	3C5 Indirect N_2O emissions from managed soils	N_2O	0.43%
Removals	Pastures that remain as grasslands	CO_2	0.42%
		Total	**95.00%**

As we can see in Chart 41, the energy category reflects the largest contribution in the subcategories of electricity generation and land transport in the CO_2 and black carbon pollutants. With this method, the land use categories are reflected, particularly in lands converted to agriculture and livestock, these for CO_2.

Chart 42 shows that the energy category is the one that contributes more to the percentage when using method 2 (using uncertainty), but now the residential subcategory in the CH_4 pollutant is the first, if we notice the position and contribution of method 1 and 2 we can observe that, although this subcategory exists in both methods, its position is different. Chart 43 shows the relationship and percentages following method 1 and 2.

Chart 44 shows that there are 4 subcategories that do not appear with method 1, this is of special interest considering that uncertainty and emissions were associated in method 2 and therefore are subcategories that should be addressed and improved in future inventories; for example, in the residential subcategory the CH_4 pollutant is of special interest since in the present inventory were used national emission factors for CO_2, but it is not the case for CH_4.

Chart 42. Resulting key categories using the method 2 for the GHG Inventory of the State of Colima, base year 2015.

Category-subcategory code/ name	Source	Gas	Percentage
1A4 Other sectors	1Ab Residential	CH_4	21.36%
1A3 Transport	1A3b Road transportation	CO_2	17.64%
1A3 Transport	1A3b Road transportation	Black carbon	15.58%
1A1 Energy industries	1A1ai Electricity generation	CO_2	13.63%
1A2 Manufacturing and construction industries	1A2f non-metallic minerals	CO_2	4.95%
3B Land	Land converted to Agricultural land	CO2	3.82%
3A Livestock	3A1 Enteric fermentation	CH_4	2.24%
3C Aggregate sources and non-CO_2 emission sources of land	3C4 Direct N_2O emissions from managed soils	N_2O	2.01%
3C Aggregate sources and non-CO_2 emission sources of land	3C5 Indirect N_2O emissions from managed soils	N_2O	1.99%
1A2 Manufacturing and construction industries	1A2f non-metallic minerals	CH_4	1.47%
3B Land	Lands converted to Grasslands	CO_2	1.46%
4D Wastewater treatment and disposal	Municipal Wastewater (untreated)	CH_4	1.29%
4D Wastewater treatment and disposal	Municipal Wastewater (treated)	CH_4	0.96%
4a Livestock	3A2 Manure management	N_2O	0.90%
1A4 Other sectors	1Ab Residential	CO_2	0.84%
		Total	90.13%

Chart 43. Key categories comparison using both methods.

Category-subcategory code/ name	Source	Gas	(%) Method 1	(%) Method 2
1A1 Energy industries	1A1ai Electricity generation	CO_2	38.19%	13.63%
1A3 Transport	1A3b Road transportation	CO_2	19.60%	17.64%
1A3 Transport	1A3b Road transportation	Black carbon	10.41%	15.58%
3B Land	Land converted to Agricultural land	CO_2	5.16%	3.82%
1A2 Manufacturing and construction industries	1A2f non-metallic minerals	CO_2	4.84%	4.95%
1A2 Manufacturing and construction industries	1A2 m non-specified industries	CO_2	2.34%	
2A Mineral industry	2A1 Cement production	CO_2	2.22%	
3B Land	Lands converted to Grasslands	CO_2	1.97%	1.46%
1A2 Manufacturing and construction industries	1A2a Iron and steel	CO_2	1.47%	
1A2 Manufacturing and construction industries	1A2e Food, beverage and tobacco industries	CO_2	1.45%	
3A Livestock	3A1 Enteric fermentation	CH_4	1.29%	2.24%
4D Wastewater treatment and disposal	Municipal Wastewater (untreated)	CH_4	0.94%	1.29%
3B Land	Degraded forest lands	CO_2	0.87%	
Removals	Forest lands that remain as forest lands	CO_2	0.76%	
2C Metal industry	2C1 Production of iron and steel	CO_2	0.74%	
1A4 Other sectors	1Ab Residential	CO_2	0.73%	0.84%
4D Wastewater treatment and disposal	Municipal Wastewater (treated)	CH_4	0.70%	0.96%
1A1 Energy industries	1A1ai Electricity generation	Black carbon	0.46%	
3C Aggregate sources and non-CO2 emission sources of land	3C5 Indirect N2O emissions from managed soils	N_2O	0.43%	1.99%
Removals	Pastures that remain as grasslands	CO_2	0.42%	
1A4 Other sectors	1Ab Residential	CH_4		21.36%
4a Livestock	3A2 Manure management	N_2O		0.90%
1A2 Manufacturing and construction industries	1A2f non-metallic minerals	CH_4		1.47%
3C Aggregate sources and non-CO2 emission sources of land	3C4 Direct N2O emissions from managed soils	N_2O		2.01%

8. Conclusions

ENERGY CATEGORY

The estimation of greenhouse gas emissions (CO_2, CH_4, N_2O and black carbon) of the energy sector was made based on the consumption of directly burned fuels in the subcategories that generate energy, industry, transportation, residential, commercial and agricultural.

Being the electric power generation sector and the transport sector (mobile highway) the ones that have the greatest contribution of GHG emissions in the entity with 47% and 37%, respectively.

The fuel consumption information was obtained from specific sources as indicated below:

- Sectors generating energy and manufacturing industry, based on what is reported in the annual operating documents (COA) reported by the industrialists. Which when compared with the fuel consumption reported in official documents such as the SENER prospects, the sales of the State of SIE and that reported by the CRE via trade; there is a difference given that indicates that not all the industries report COA.
- In the case of motor transport, fuel consumption was obtained from the activity data generated by surveys and road routes in the entity, which gives greater certainty in the results obtained; However, there are also areas of opportunity with respect to the reported sales of SENER in the entity, since not all the fuel sold in the State is consumed in it.
- Respect to the fuel consumption by the residential, commercial and agricultural sector, the result of estimates derived from the information reported by the Secretary of Energy (SENER) in the prospects of the natural gas, LP gas, oil and data market of INEGI (population, housing, employees, among others); for the case of the consumption of the different fuels by subcategory so the data can vary with the actual consumption of these fuels in the State.

The emission factors generated at the national level were used for CO_2 emissions by type of fuel, which has greater certainty in the results obtained.

The following recommendations are obtained in order to have a future estimate with greater accuracy and reliability:

- Perform the energy balance of the State by updating it annually, in order to obtain a greater precision in the quantification of emissions. Contemplating the different fuels used in the Entity, since the use of unconventional fuels is reported for example in the COA.
- Bring together the efforts of national and state agencies that regulate these activities, to obtain consistent and accurate information on fuel consumption in the State.
- Have an inventory of the state and federal industry with the type of fuels used, as well as its main products.

INDUSTRIAL PROCESSES AND USE OF PRODUCTS CATEGORY

The estimation of emissions of carbon dioxide (CO_2) and hydrofluorocarbons (HCFC-22) was made; of the sector industrial processes and use of products of the subcategories lime and cement production, iron production, use of other products in the state of Colima.

The result of the CO_2e emissions from this category has a relative significance given that only some of the drafts that are evaluated according to the 2006 IPCC Guidelines are located in the State of Colima, so they were only evaluated for those that information was available; contributing to 4% of the state emissions.

The industrial turnaround that resulted with the greatest contribution to the generation of CO_2e in this category was the production of cement.

It is recommended that for future inventories, emission factors from industrial processes be developed or reliable measurements of said processes in the State be considered.

In the same way, it is very important to generate local information in order to estimate the emissions generated by the different uses of products that emit greenhouse gases into the atmosphere.

AGRICULTURE, FORESTRY AND OTHER USES OF THE EARTH CATEGORY

CO_2e emissions of the AFOLU category at the state level contribute with 13%, mainly due to the emission of the land use change subsector.

The estimation of emissions of greenhouse gases (CO_2, CH_4, N_2O and black carbon) of the sector was made from data related to the activity of the agricultural and livestock sector of the entity. Although in most of the subcategories evaluated local data was used and some national emission factors were used for livestock and land use change, in other subcategories, default emission factors were used, representing a greater degree of uncertainty. Considering the importance of emissions by this sector, it is necessary that national and / or local factors are developed that allow more accurate estimates to be made.

Another point of improvement is in the subcategories of application of synthetic fertilizers, although local data were used for the available crops, it is necessary to increase the information for a greater number of species in the entity, especially those of greater importance in terms of area of sowing.

In the case of land use change, emissions were made at the municipal level and national emission factors were used, there are areas of opportunity in terms of the most detailed calculation factors for a greater number of vegetation types, in addition to data on detailed land and vegetation use in the entity more frequently for future estimates.

WASTE CATEGORY

This sector was estimated based on specific data in the entity by site of final disposal of MSW, as well as municipal and industrial wastewater treatment plant, in cases where information was available, which results in a higher level of reliability in the obtained emissions.

This sector contributed with 1% of emissions at the state level, of which the most important is the disposal of treated wastewater, which contributes 41% of these emissions.

As for areas of opportunity in the estimate, we have the specific information requirement:

- Generate a specific and up-to-date database of the final disposal sites of urban solid waste referring to the amount of waste disposed annually, characterization of waste, capture and disposal of biogas, among others.
- Obtain information from the final disposal sites prior to the three sites that the entity currently has, since they are generating GHG emissions that could not be evaluated.
- In the case of the burning of urban solid waste opencast, update the activity data of the percentage of waste burned by municipality.
- To have more information on municipal and industrial wastewater treatment plants since there was no BOD and COD information for each plant, so general data were considered for the estimation.
- Generate specific emission factors for Mexico, or have reliable measurements of GHG generation by these subcategories, and by type of treatment.

Uncertainty and key categories

The uncertainty for this inventory could be calculated more accurately, in the case of energy, the associated uncertainty was counted for the new emission factors following method 1, especially the uncertainty of the MOVES-Mexico model evaluated for Colima was evaluated using the Monte Carlo model (Method 2), which gave us uncertainties associated with each type of vehicle and fuel.

The main categories of the inventory were identified using methods 1 and 2, this for future inventories and considering the results obtained in uncertainty and main categories, the residential sub-sector for the pollutant CH_4 should be improved in its calculation and precision since it has a percentage of contribution greater than 20%. Other subsectors that should be of special interest are generation of manure for N_2O, non-metallic minerals for CH_4 and direct emissions of N_2O for managed soils.

9. Initial progress, challenges and potential of the Inventory

The gathering of information, as initial progress of the development of the Update of the Greenhouse Gas Inventory of the State of Colima, was satisfactory because there was detailed information, as the state and federal COAs, the disaggregated per municipality vehicular census, the State forestry inventory, different emission factors per type of fuel and land uses characteristic of Mexico.

As said in methodology, some information was obtained through official request, increasing direct communication with public and private institutions that develop or process information base for the development of the Inventory. Even so, it should be noted that in many subcategories there is information missing because it isn't registered in official data bases or there are not processes or studies that allow the gathering of information. The opportunity areas, mentioned in the conclusions chapter, need to be considered as a base to make information reports that can be used in next years for new GHG inventories.

The comments made by The Climate Group staff as Secretariat of the Under2 Coalition in the interim report, helped the developers of this Inventory to maintain a good quality process. This document will be checked by The Climate Group staff, the IMADES members and SEMARNAT workers in order to improve it and correct and add whatever information that is needed in order to make it a reliable source of information.

The inventory of GHG emissions for the state of Colima was determined with base year 2015, this had as its starting point the one developed for the base year 2005 and published in 2013. The relevant aspect considered was having a higher level of calculation (tier 1, 2 and 3) in each inventory category; this implied obtaining more and more detailed information to calculate characteristic emission factors or use more precise models. The substantial improvements are:

1. Characteristic emission factors of Mexico for the AFOLU category instead of those indicated in IPCC 2006.
2. CO_2 energy sector's emission factors for Mexico.
3. Forest inventory base year for Colima 2014.
4. For the transport subsector, the model was changed to MOVES-Mexico, which was adapted to Mexican conditions.

As stated above, the Greenhouse Gas Inventory Update will be essential to recognize the sources of our state's emissions in order to develop an objective and effective mitigation strategy, which will use the results of this project to support the programs, plans and actions to be developed by the state of Colima in order to reduce the global emissions problem and keep ecosystems and citizens safe and healthy.

In terms of the updates of the GHG emissions inventory of the state, it is considered to take place every 3 or 5 years, taking into account the collection and generation of information from the public and private institutions that own it.

Because of the changes for base year 2015 to the emission factors for the AFOLU, energy and transport sectors, it will be needed to make new calculations for the GHG Inventory base year 2005, in order to make both inventories comparable with the most reliable information. These new calculations are planned to be done as part of the State Program of Actions in the face of Climate Change, an actual project of the State of Colima.

The progress and technical information in this project will be available and shared via webinar and other means facilitated by contributors with Under2 Coalition peers as an example for future projects of this nature and as open information. Also, this document and its annexes will be available online in the IMADES webpage for all the interested public.

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