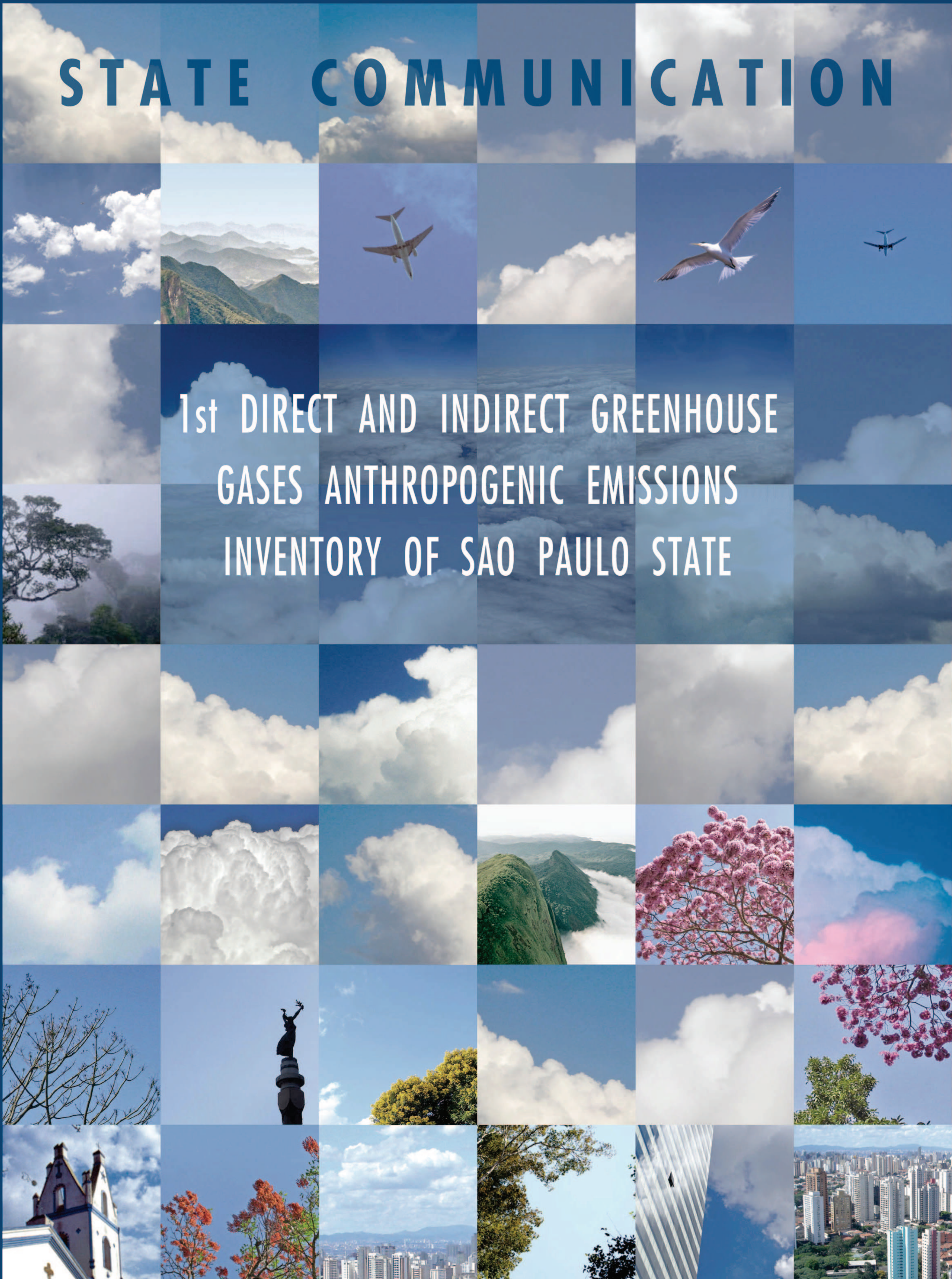
STATE COMMUNICATION



1st DIRECT AND INDIRECT GREENHOUSE GASES ANTHROPOGENIC EMISSIONS INVENTORY OF SAO PAULO STATE

SAO PAULO STATE GOVERNMENT - ENVIRONMENT SECRETARIAT
CETESB - SAO PAULO STATE ENVIRONMENT AGENCY

SAO PAULO STATE ENVIRONMENT AGENCY
– CETESB –

1st Direct and Indirect Greenhouse Gases Anthropogenic Emissions Inventory of Sao Paulo State

Sao Paulo State Government
Environment Secretariat
CETESB – Sao Paulo State Environment Agency
Sao Paulo, 2011

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Support:

British Embassy in Brazil

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X-Ray of the Emissions

Sao Paulo State is so strongly committed to the environmental policies that it created the State Policy on Climate Change (PEMC), instituted by the State Law n. 13,789 of 2009. The law establishes the State's commitment towards challenges of global climate change and defines the 20% reduction in the greenhouse gases emissions.

The 1st Direct and Indirect Greenhouse Gases (GHG) Anthropogenic Emissions Inventory of Sao Paulo State – From 1990 to 2008 – provides us with a wide view of those emissions, and that will facilitate its correct identification and increase the possibility to outline a more efficient reduction and compensation strategy. It will probably provide other environmental gains, such as reduction in consumption of raw materials and energy efficiency, for example.

The inventory is an important part of the State Communication and a tool for the GHG emissions management, and as such, it must be used within a mitigation strategy of the climate changes effects and sustainability. The document will be updated periodically to generate comparable information, both nationally and internationally, and to allow the quantification of State emissions in the global context.

Contain the emissions is an indispensable task, thus imposing the necessity of creating and implementing mitigation and adaptation measures. It is a fundamental part of the commitment made by Sao Paulo State to actively participate in efforts for the protection of the global climate system and promote the transition for a low-carbon economy in the State.

Bruno Covas

Environment Secretary

Presentation

This Direct and Indirect Greenhouse Gases Anthropogenic Emissions Inventory of Sao Paulo State is an important instrument for the implementation of the State Policy on Climate Change (PEMC). Instituted by the State Law 13,798/2009 and regulated by Decree 55,947/2010, this policy defines the preparation, the periodical update and the publication of anthropogenic emissions inventories, discriminated according to their sources, in addition to the removals through sinks of the greenhouse gases not-controlled by the Montreal Protocol.

From the analysis of the results of estimatives and the evaluated sectors, the inventory allows us to get to know the profile of the emission sources and identify the State priorities for the implantation of mitigation programs which may promote reduction initiatives of the GHG emissions in Sao Paulo State. This document is also highly relevant in providing the government, the public opinion, the industries and other productive areas with the importance of the topic and the need for measures to be taken.

The inventory was coordinated by the State Program on Climate Change (PROCLIMA), created in 1995 by CETESB/SMA. Being motivated by the learning opportunity acquired in the participation on the elaboration of the GHG Emissions National Inventory from the Waste Sector with the Ministry of Science and Technology (MCT), CETESB aimed at developing a state inventory with levels of accuracy and credibility compatible with the relevance of Sao Paulo State in the national context. The document was made in compliance with the methods approved by the Intergovernmental Panel on Climate Changes (IPCC) and in the likeness of the federal publication, also aiming for coherence and comparability of national results.

The successful conclusion of this project was only possible with the trust and support of the British Embassy in Brazil, as well as the participation of universities, research institutes, employers, associations, private and public capital companies, governmental organizations, innumerable researchers and volunteers, who, in different ways, contributed to the attainment of emissions estimations from sectors of State economy.

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The accomplishment of this work was only possible with the support of the British Embassy in Brazil.

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ABIA – Brazilian Food Industry Association (*Associação Brasileira das Indústrias da Alimentação*)

ABIEC – Association of Brazilian Beef Exporters (*Associação Brasileira das Indústrias Exportadoras de Carne*)

ABIPECS – Brazilian Pork Industry and Exporter Association Association (*Associação Brasileira da Indústria Produtora e Exportadora de Carne Suína*)

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ABTCP – Brazilian Pulp and Paper Technical Association *(Associação Brasileira Técnica de Celulose e Papel)*

AEA – Brazilian Automotive Engineering Association *(Associação Brasileira de Engenharia Automotiva)*

AEA Technology

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ANAC – National Civil Aviation Agency (*Agência Nacional de Aviação Civil*)

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ANP – National Agency of Petroleum, Natural Gas and Biofuels *(Agência Nacional do Petróleo, Gás Natural e Biocombustíveis)*

ANTT – National Ground Transport Agency *(Agência Nacional de Transportes Terrestres)*

APTA – Sao Paulo Agency for Agribusiness Technology *(Agência Paulista de Tecnologia dos Agronegócios)*

BASF – The Chemical Company

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CBFT – *Companhia Brasileira de Florestas Tropicais*

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CEA – Environmental Education Coordination – Sao Paulo State Secretariat for Environment *(Coordenadoria de Educação Ambiental – Secretaria do Meio Ambiente do Estado de São Paulo)*

CERPCH – Reference Center on Small Hydroelectric Plants *(Centro Nacional de Referência em Pequenas Centrais Hidrelétricas)*

CESP – *Companhia Energética de São Paulo*

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CNPC – Brazilian National Beef Cattle Council (*Conselho Nacional de Pecuária de Corte*)

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CRHI – Water Sources Coordination – Sao Paulo State Secretariat for Environment *(Coordenadoria de Recursos Hídricos – Secretaria do Meio Ambiente do Estado de São Paulo)*

CTC – Center of Sugarcane Technology *(Centro de Tecnologia Canavieira)*

DAESP – *Departamento Aeroviário do Estado de São Paulo*

DEDINI – *Indústrias de Base*

e&e – Economy and Energy

Eccaplan

Econergy

ECOPLAN Engenharia

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EMBRAPA – Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária*)

Enviroconsult

EQAO

ERM – Environmental Resources Management

FAS – Amazonas Sustainable Foundation *(Fundação Amazonas Sustentável)*

FEB – Fabrica Ethica Brasil

FGV – *Fundação Getúlio Vargas*

Fibria

FIESP – *Federação das Indústrias do Estado de São Paulo*

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ICLEI – Local Governments for Sustainability

ICONE – Institute for International Trade Negotiations *(Instituto de Estudos do Comércio e Negociações Internacionais)*

IEA – Institute for Advanced Studies of the University of Sao Paulo *(Instituto de Estudos Avançados da Universidade de São Paulo)*

IEMA – *Instituto de Energia e Meio Ambiente*

IF – *Instituto Florestal*

IMT – *Instituto Mauá de Tecnologia*

INFRAERO – *Empresa Brasileira de Infraestrutura Aeroportuária*

SEMA – INMET – *Instituto Nacional de Meteorologia*

INPE – National Institute on Space Research (*Instituto Nacional de Pesquisas Espaciais*)

IPT – Institute for Technological Research *(Instituto de Pesquisas Tecnológicas)*

ISA – Socio-Environmental Institute *(Instituto Socioambiental)*

IVG – Vale das Garças Institute *(Instituto Vale das Garças)*

Luftech

MCT – Science and Technology Ministry *(Ministério da Ciência e Tecnologia)*

METRÔ – *Companhia do Metropolitano de São Paulo*

MMA – Environment Ministry *(Ministério do Meio Ambiente)*

PETROBRAS – Brazilian Petroleum S.A. (*Petróleo Brasileiro S.A.*)

Pinheiro Pedro Advogados

Prefeitura Municipal de Nova Odessa

Purcom

Rhodia

SABESP – *Companhia de Saneamento Básico do Estado de São Paulo*

São João Energia Ambiental

SDECT – Sao Paulo State Secretariat of Economic Development, Science and Technology *(Secretaria de Desenvolvimento Econômico, Ciência e Tecnologia do Estado de São Paulo)*

Sao Paulo State Secretariat of Energy *(Secretaria de Energia do Estado de São Paulo)*

Sao Paulo State Secretariat of Logistics and Transportation *(Secretaria de Logística e Transportes do Estado de São Paulo)*

Parana State Secretariat for Environment and Water Sources *(Secretaria do Meio Ambiente e Recursos Hídricos do Estado do Paraná)*

SINDICAL – Union of the Industries of Limestone and Derivates for Agricultural Usage of Sao Paulo State (*Sindicato das Indústrias de Calcário e Derivados para Uso Agrícola no Estado de São Paulo*)

SINDRATAR – *Sindicato da Indústria de Refrigeração, Aquecimento e Tratamento de Ar no Estado de São Paulo*

SMA – Sao Paulo State Secretariat for Environment (*Secretaria do Meio Ambiente do Estado de São Paulo*)

SMACNA Brasil – Sheet Metal and Air Conditioning Contractors' National Association

SNIC – National Cement Industry Union (*Sindicato Nacional da Indústria do Cimento*)

SNIS – National System on Sanitation Information *(Sistema Nacional de Informações sobre Saneamento)*

STM – Sao Paulo State Secretariat of Metropolitan Transportation

SVMA – Sao Paulo Municipal Secretariat for Green Areas and Environment *(Secretaria Municipal do Verde e do Meio Ambiente do Município de São Paulo)*

Swiss Energy Corporation

UBABEF – Brazilian Poultry Union (*União Brasileira de Avicultura*)

UFABC – *Universidade Federal do ABC*

UFES – *Universidade Federal do Espírito Santo*

UFSCar – *Universidade Federal de São Carlos*

UNDP – United Nations Development Programme (*PNUD*)

UNESP – *Universidade Estadual Paulista "Júlio de Mesquita Filho"*

UNICA – *União da Indústria de Cana-de-Açúcar*

UNIFEI – *Universidade Federal de Itajubá*

UNINOVE – *Universidade Nove de Julho*

Usiminas

USP – University of Sao Paulo (*Universidade de São Paulo*)

Votorantim Metais

List of Reference Reports by Sector and its Responsible Entities that Contributed with General Information, Data and Results about Each Activity in Sao Paulo State at 1st Direct and Indirect GHG Anthropogenic Emissions Inventory of Sao Paulo State[1]

INDUSTRIAL PROCESSES

– CHEMICAL INDUSTRY – ABIQUIM
– FOOD AND BEVERAGE INDUSTRY – CETESB
– LIME PRODUCTION – CETESB
– PULP AND PAPER INDUSTRY – CETESB
– GLASS INDUSTRY – CETESB
– METALLURGICAL INDUSTRY – CETESB, IABr, IMT
– CEMENT PRODUCTION – CETESB, SNIC, ABCP
– SOLVENT AND OTHER PRODUCT USE – IMT

ENERGY

– FUEL COMBUSTION EMISSIONS: REFERENCE APPROACH (TOP-DOWN) – CICLO AMBIENTAL
– FUEL COMBUSTION EMISSIONS: SECTORAL APPROACH (BOTTOM-UP) – CICLO AMBIENTAL
– WATER TRANSPORT – CETESB
– RAIL TRANSPORT – CETESB
– AIR TRANSPORT – IMT
– ROAD TRANSPORT – IMT
– REFINING OF OIL AND DERIVATIVES – PETROBRAS

AGRICULTURE

– LIMING SOIL – CETESB
– AGRICULTURAL SOILS AND MANURE MANAGEMENT – EMBRAPA
– LIVESTOCK: ENTERIC FERMENTATION AND MANURE – EMBRAPA
– BURNING OF AGRICULTURAL RESIDUES – EMBRAPA
– RICE CULTIVATION – EMBRAPA

LAND USE, LAND-USE CHANGE, AND FORESTRY

– LAND USE, LAND-USE CHANGE, AND FORESTRY – FUNCATE

WASTE

– SOLID WASTE DISPOSAL AND WASTEWATER HANDLING – CETESB

[1] EDITOR'S NOTE: Cited reports are referenced in this document, and are in press.

Executive Summary and Additional Remarks

The State Policy on Climate Change

Due to the increase in the atmospheric concentrations of Greenhouse Gases (GHG) and the consequent global climate changes, not only the national governments members of the United Nations Framework Convention on Climate Change (UNFCCC) (BRASIL, 1992), but also the state and municipal governments, have made all and every effort in estimating the emissions of those gases aiming for helping society identify the local priorities and the adoption of more adequate measures in order to reduce such emissions.

In that sense, the Government of Sao Paulo State, on November 9th, 2009, published the Act no. 13,798 (SÃO PAULO, 2009a), institutes the State Policy on Climate Change (PEMC), regulated by Decree 55,947/2010, of 24 June 2010 (SÃO PAULO, 2010).

In the Article 6 of that Law (13,798/2009) are defined the guidelines for the elaboration, the updating on regular basis and the publication of anthropogenic emissions inventories, described by sources and removals, by means of sinks, of the GHG not controlled by the Montreal Protocol, by using methods comparable both national and internationally. Mainly in the GHG Emissions Inventory of Sao Paulo State, by widening the legal framework, the emissions of the gases controlled by the Montreal Protocol were included, once they also contribute to the greenhouse effect increase. In the Article 7 of the same Law, is the definition of the State Communication, which includes the Emissions Inventory in its structure (SÃO PAULO, 2009a).

This document deals with the 1st Direct and Indirect Greenhouse Gases Anthropogenic Emissions Inventory of Sao Paulo State, including the gases controlled by the Montreal Protocol for the period from 1990 to 2008. It is the result of the consolidation of 26 reference sector reports developed by excellence institutions and experts. Those reports were available to Public Reading in the website of CETESB for around ten month.

Sao Paulo State in the National Context

The GHG National Inventory, in a country with the size and diversity of Brazil, is an organizational challenge that demands statistic data that sometimes simply either do not exist or lack the quality needed for the estimations on the topic. In that sense, the National Communication[2] plays its role in a clear and transparent way with all the other methodological principles settled by the Intergovernmental Panel on Climate Change[3] according to the national reality of GHG emissions. Nevertheless, even with the high quality of this document, we should consider that, even because it is not one of the objectives of its elaborators, the National Communication does not provide the

[2] BRASIL. MCT. **Segunda Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima**. Brasilia: MCT, 2010. 520 p.
[3] IPCC. **Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories**. IPCC National Greenhouse Gas Inventories Programme. Hayama, Japan: IGES, 2000.
______. **Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventory**. Reporting Instructions [Houghton, J.T; Meira Filho, L.G; Lim, B.; Tréanton, K.; Mamaty, I; Bonduki, Y.; Griggs, D.J.; Callander, B.A (eds.)]. Bracknell: IPCC, OECD, IEA, 1997.
EDITOR'S NOTE: The State Communication uses the year of 1996 as reference. Nevertheless, it was only published in 1997.

government and the society of Sao Paulo State with the necessary information for the development of a proper Climate Change Policy for the local reality.

On the other hand, aiming for comparing the results of the Inventory of Sao Paulo State with those of Brazil, other information are presented next: according to the Brazilian Institute for Geography and Statistics (IBGE)[4], in 2008, the national GDP was R$3.0 trillion, while the Sao Paulo State GDP was R$1.0 trillion, what means the economy of the State produces 33% of the national wealth. The same publication points out the national *per capita* income in that year were R$16,000, while the *per capita* income in the Sao Paulo State was R$24,500.

According to the World Bank[5], the GDP of Brazil in 2009 was the eighth largest in the world, corresponding to US$1.6 trillion. By keeping the ratio of 2008, between the GDP of Sao Paulo and the national one, the GDP of Sao Paulo could have been estimated, in the World Bank list, at US$0.51 trillion in 2009. Comparing that data to the GDP, out of the 193 countries surveyed by the World Bank, Sao Paulo State would be the 19th in the rank, being overcome, in the Americas, by the economies of the USA (1st – US$14.1 trillion, Brazil (8th – US$1.6 trillion, Canada (10th – US$1.3 trillion) and Mexico (14th – US$0.87 trillion).

1st Direct and Indirect Greenhouse Gases Anthropogenic Emissions Inventory of Sao Paulo State

Sao Paulo State emitted in 2005, 88,844 Gg_{CO2} and, including the other GHG, 139,811 Gg_{CO2eq}.

Estimations for the Period from 1990 to 2008

This Inventory considered the GHG listed in Annex A of the Kyoto Protocol (KYOTO PROTOCOL, 1997): carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbon (HFC), perfluorocarbons (PFC) and hexafluoride (SF_6). The emissions of the Indirect GHG were also considered (IPCC, 1996[6], 2000a): nitrogen oxide (NOx), carbon monoxide (CO) and the volatile organic compounds (VOC). Besides that, the emissions of the chlorinefluorocarbons (CFC) and the hydrofluorocarbons (HCFC) were also estimated, substances that, besides contributing to the global warming, destroy the ozone layer and, for that, are controlled by the Montreal Protocol. The GHG were estimated by sectors, as determined by IPCC (1996, 2000a and 2006): Energy, Industrial Processes, Agriculture, Land Use, Land-use Change, and Forestry, and Waste.

The method used for the elaboration of the Inventory, in order to generate an estimation comparable to the national one and other international and subnational ones, was IPCC's Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories – Guidelines 1996, published in 1997; the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories – Good Practice Guidance 2000, published in 2000; the Good Practice Guidance for Land Use, Land-use Change and Forestry – Good Practice Guidance

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[4] IBGE. **Produto Interno Bruto a preços correntes e Produto Interno Bruto *per capita*, segundo as Grandes Regiões, as Unidades da Federação e os Municípios: 2004-2008**. Rio de Janeiro, 2010.
[5] WORLD BANK. **Gross Domestic Product 2009**. World Development Indicators Database. World Bank, December, 15, 2010.
[6] EDITOR'S NOTE: The State Communication uses the year of 1996 as reference. Nevertheless, it was only published in 1997.

2003, published in 2003; and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Guidelines 2006.

Reference Year

The State Law (13,789/2009) defines the year 2005 as reference, for a target to be reached in 2020. That's why the reference year for the Inventory is 2005. Aiming for generating a historic series, the emissions of 1990 and 2008 were also estimated.

GHG and CO_{2eq} Emissions

The emissions presented in the carbon dioxide equivalent unit (CO_{2eq}) refer to the GHG emissions using as equivalence metrics the Global Warming Potential (GWP) within 100 years. Considering that for different verification sources it is possible to identify differences in the GWP, the factors applied in this estimation were obtained in IPCC (1996).

The Inventory Elaboration Coordination

The elaboration of the Inventory involved a total of 320 researchers and 120 institutions, both governmental and private. 08 meetings of the inventory network were held in the auditorium of the Sao Paulo State Environment Agency (CETESB), with the attendance of a total of 400 participants to the set of meetings. The elaboration project of the inventory, supported by the British Government, started on May 2008 and was finished on March 2011, fulfilling the schedule agreed between CETESB and the British Government.

Results of the Emissions Estimation in Sao Paulo State

Next, in Table 1, we have the results of the Inventory of the GHG emissions and removals in Sao Paulo State for the years 1990, 1994, 2000, 2005 and 2008[7].

Comparison of the Results in Sao Paulo State to the Results of Brazil

Aiming for comparing the emissions in Sao Paulo State to those of Brazil, in Table 2 are presented the results of the GHG estimations in Brazil for the years 1990, 1994, 2000 and 2005, and in Table 3, the comparison of the results of Sao Paulo to those of Brazil. The same way, such comparison for the year 2005 is presented for the different sectors of the economy in Table 4.

[7]Due to the large amount of information from 1990 to 2008, we decided to present, in this summary, the results of only some years. These were the same selected from the Executive Summary of the National Communication, except the year 2008 (BRASIL, 2010a).

Table 1. GHG Emissions and Removals in Sao Paulo State in 1990, 1994, 2000, 2005 and 2008

Sector	Year	unit	CO_2	CH_4	N_2O	HFC-134a	SF_6	CFC-11	CFC-12	CFC-113	HCFC-22	HCFC-141b	CO	NOx	VOC
Energy	1990	Gg	56,395	16	1								571	369	219
	1994		64,795	19	2								637	427	284
	2000		80,161	22	2								802	541	372
	2005		78,584	30	3								804	514	345
	2008		85,335	35	3								867	549	353
	Var. 90/00	%	42	40	70								40	46	70
	Var. 90/05		39	88	130								41	39	57
	Var. 90/08		51	124	182								52	48	61
Industrial Processes	1990	Gg	3,396	1.1	10.5	NE	0.001	0.7	0.1	0.26	0.7	NE	4	1	59
	1994		3,268	1.0	16.2	NE	0.001	1.2	0.2	0.09	0.9	NE	9	2	84
	2000		4,577	1.5	19.8	0.3	0.002	1.4	0.2	0.02	1.8	NE	11	3	146
	2005		4,577	1.5	19.8	0.3	0.002	1.4	0.2	0.02	1.8	NE	11	3	146
	2008		12,218	NE	NE	0.9	0.002	0.0	0.2	-	3.0	1.1	20	5	214
	Var. 90/00	%	35	36	88	NA	23	109	130	-94	170	NA	221	220	146
	Var. 90/05		274	36	116	NA	54	NA	71	NA	215	NA	383	382	212
	Var. 90/08		260	NA	NA	NA	69	NA	68	NA	349	NA	471	469	260
Agriculture	1990	Gg	931	734	31								1.29	0.11	
	1994		2,009	770	34								1.63	0.14	
	2000		1,462	782	35								1.07	0.09	
	2005		1,476	792	38								1.48	0.13	
	2008		1,462	678	38								1.58	0.13	
	Var. 90/00	%	57	7	13								-17	-17	
	Var. 90/05		58	8	23								15	15	
	Var. 90/08		57	-8	23								23	21	
Land Use, Land-use Change, and Forestry	1990	Gg	NE												
	1994		NE												
	2000		-1,333												
	2005		-3,918												
	2008		-3,282												
	Var. 90/00	%	NA												
	Var. 90/05		NA												
	Var. 90/08		NA												
Waste	1990	Gg	0.01	278	-										
	1994		12.70	301	0.001										
	2000		19.04	365	0.001										
	2005		16.92	445	0.001										
	2008		19.69	438	0.001										
	Var. 90/00	%	NA	31	NA										
	Var. 90/05		NA	60	NA										
	Var. 90/08		NA	58	NA										
Net Total	1990	Gg	60,722	1,028	42	NE	0.001	0.7	0.1	0.26	0.7	NE	576	371	278
	1994		70,085	1,091	51	NE	0.001	1.2	0.2	0.09	0.9	NE	648	429	368
	2000		84,886	1,171	56	0.3	0.002	1.4	0.2	0.02	1.8	NE	814	544	518
	2005		88,844	1,268	63	0.6	0.002	0.03	0.2	NE	2.1	0.8	823	519	530
	2008		95,752	1,152	41	0.9	0.002	0.04	0.2	NE	3.0	1.1	889	554	567
	Var. 90/00	%	40	14	33	NA	23	109	130	-94	170	NA	41	47	86
	Var. 90/05		46	23	49	NA	54	NA	71	NA	215	NA	43	40	90
	Var. 90/08		58	12	-3	NA	69	NA	68	NA	349	NA	54	50	104
Greenhouse gases emissions only for means of information, not included in the inventory															
Biomass Fuels	1990	Gg	33,786												
	1994		37,528												
	2000		36,094												
	2005		53,195												
	2008		76,505												
	Var. 90/00	%	7												
	Var. 90/05		57												
	Var. 90/08		126												

Note: NE: Not estimated; NA: Not applicable; –: Value zero.
Blank: Emissions not provided by the IPCC methods.

Table 2. GHG Emissions and Removals in Brazil in 1990, 1994, 2000 and 2005

Sector	Year	unit	CO_2	CH_4	N_2O	HFC-23	HFC-125	HFC-134a	HFC-143a	HFC-152a	CF_4	$C2F_6$	SF_6	CO	NOx	VOC
Energy	1990	Gg	179,948	427	8.5									14,919	1,781	1,022
	1994		206,250	382	9.0									14,438	1,996	974
	2000		289,958	388	9.6									11,415	2,334	860
	2005		313,695	541	12.1									11,282	2,388	958
	Var. 90/00	%	61	-9	14									-23	31	-16
	Var. 90/05		74	27	43									-24	34	-6
Industrial Processes	1990	Gg	45,265	5.1	10.7	0,12	—	0.0004	—	—	0.302	0.026	0.01	365	8	322
	1994		48,703	6.5	16.3	0,157	—	0.0685	—	—	0.323	0.028	0.014	510	11	382
	2000		63,220	8.9	19.9	—	0.0071	0.4713	0.0075	0.0001	0.147	0.012	0.015	542	14	474
	2005		65,474	9.2	22.8	—	0.1249	2.2819	0.0929	0.1748	0.124	0.01	0.025	626	18	599
	Var. 90/00	%	40	73	87	-100	NA	108,876	NA	NA	-52	-56	54	48	69	47
	Var. 90/05		45	79	114	-100	NA	527,498	NA	NA	-59	-61	153	71	128	86
Solvent and Other Product Use	1990	Gg														350
	1994															435
	2000															473
	2005															595
	Var. 90/00	%														35
	Var. 90/05															70
Agriculture	1990	Gg		9,539	334									2,543	219	NE
	1994			10,237	369									2,741	233	NE
	2000			10,772	393									2,131	181	NE
	2005			12,768	476									2,791	237	NE
	Var. 90/00	%		12.9	17.6									-16,201	-17	
	Var. 90/05			33.9	42.7									9,7523	8	
Land Use, Land-use Change, and Forestry	1990	Gg	766,493	1,996	14									17,468	496	NE
	1994		830,910	2,238	15.4									19,584	556	NE
	2000		1,258,345	3,026	20.8									26,476	752	NE
	2005		1,258,626	3,045	20.9									26,641	757	NE
	Var. 90/00	%	64	52	52									52	52	
	Var. 90/05		64	53	53									53	53	
Waste	1990	Gg	24	1,227	9											
	1994		63	1,369	10,8											
	2000		92	1,658	12,4											
	2005		110	1,743	14											
	Var. 90/00	%	276	35	37											
	Var. 90/05		349	42	54											
Total	1990	Gg	991,731	13,195	376	0.12	—	0.0004	—	—	0	0.026	0.01	35,296	2,504	1,693
	1994		1,085,925	14,233	421	0.157	—	0.0680	—	—	0.323	0.028	0.014	37,273	2,797	1,791
	2000		1,611,615	15,852	455	—	0	0.4710	0.007	0.0001	0.147	0.012	0.015	40,563	3,280	1,807
	2005		1,637,905	18,107	546	—	0.125	2.2820	0.093	0.175	0.124	0.01	0.025	41,339	3,399	2,152
	Var. 90/00	%	63	20	21	-100	NA	108,876	NA	NA	-52	-56	54	15	31	7
	Var. 90/05		65	37	45	-100	NA	527,498	NA	NA	-59	-61	153	17	36	27
Bunker Fuels	1990	Gg	5,231	0.01	0.15									23	NE	NE
	1994		4,339	0.01	0.12									19	NE	NE
	2000		14,627	0.60	0.23									201	118	24
	2005		15,759	0.66	0.24									221	132	26
	Var. 90/00	%	NA	NA	NA									NA	NA	NA
	Var. 90/05		NA	NA	NA									NA	NA	NA
Biomass Fuels	1990	Gg	187,962													
	1994		190,896													
	2000		180,471													
	2005		243,606													
	Var. 90/00	%	-4													
	Var. 90/05		30													

Note: NE: Not estimated; NA: Not applicable; – : Value zero; 0: Value lower than 1.
Blank – Emissions not provided by the IPCC Methods. Source: Brazil (2010a).

Table 3. Ratio Estimates of GHG Emissions in Sao Paulo State and Brazil

Sector	Year	Unit	CO_2	CH_4	N_2O	HFC-134a	SF_6	CO	NOx	VOC
Energy	1990	%	31	4	13			4	21	21
	1994		31	5	17			4	21	29
	2000		28	6	20			7	23	43
	2005		25	5	22			7	22	36
Industrial Processes	1990	%	8	22	98	NA	13	1	12	18
	1994		7	16	99	NA	9	2	22	22
	2000		7	17	99	54	11	2	22	31
	2005		7	17	87	11	6	2	17	24
Agriculture	1990	%	NA	8	9			0.1	0.050	
	1994		NA	8	9			0.7	0.005	
	2000		NA	7	9			0.6	0.004	
	2005		NA	6	8			0.6	0.005	
Land Use, Land-use Change, and Forestry	1990	%	0							
	1994		0							
	2000		-0,1							
	2005		-0,3							
Waste	1990	%	1	23	1					
	1994		20	22	1					
	2000		21	22	1					
	2005		15	26	1					
Net Total	1990	%	6	8	11	NA	13	2	15	16
	1994		6	8	12	NA	9	2	15	21
	2000		5	7	12	55	11	2	17	29
	2005		5	7	12	27	8	2	15	25

Note: NA: Not applicable.

Table 4. GHG Emissions in Sao Paulo State and Brazil in 2005

Sector	Sao Paulo		Brazil		SP/BR
	Emission (Gg_{CO2eq})	Share (%)	Emission (Gg_{CO2eq})	Share (%)	(%)
Energy	80,017	57.2	328,808	15.0	24.3
Industrial Processes	20,610	14.7	77,939	3.6	26.4
Agriculture	29,818	21.3	415,754	19.0	7.2
Waste	9,366	6.7	41,048	1.9	22.8
LULUCF	0.0	0.0	1,329,053	60.6	0.0
Total	**139,811**	**100**	**2,192,602**	**100.0**	**6.4**

Figure 1 show the GHG emissions in Sao Paulo State and Brazil in the year 2005. Figure 2 shows the distribution of the GHG emissions in Sao Paulo State and Brazil, where one is able to notice the most relevant economic areas in both local and national levels.

Finally, in Table 5, comparing the GHG emissions and the GDP of the Sao Paulo State and Brazil, we conclude that the economy of the Sao Paulo State is responsible for 33% of the national GDP and 6.5% of the total of GHG of the country. In other words, for each thousand Real earned in the country, 0.72 t_{CO2eq} are emitted, while in Sao Paulo State, the same earnings correspond to 0.14 t_{CO2eq}, which is equal to 20% of the national index.

Figure 1. GHG Emissions in Sao Paulo State and Brazil in 2005 (Gg_{CO2eq})

Figure 2. GHG Emissions in Sao Paulo State and Brazil in 2005 (%)

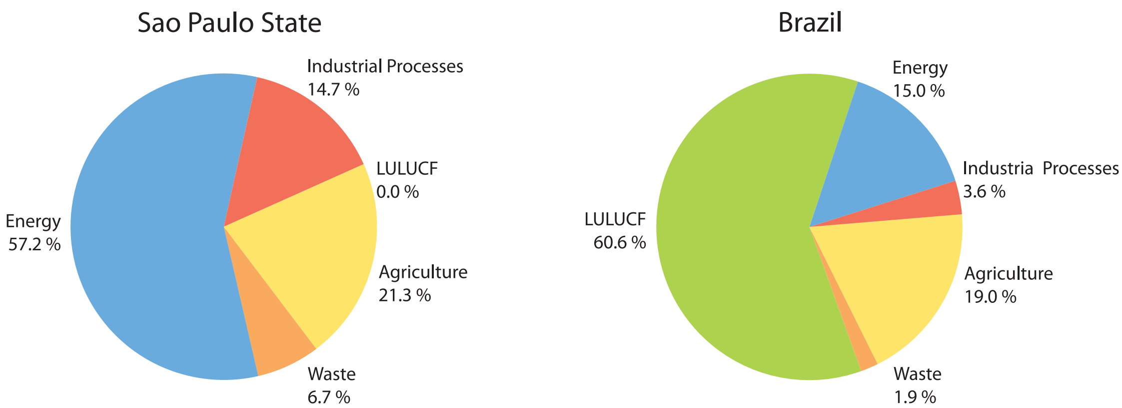

Table 5. GHG Emissions (2005) and GDP in Brazil and Sao Paulo State

	GHG Emissions	GDP	Emission Intensity
	$10^9 t_{CO2eq}$	10^9(1000 R$)	t_{CO2eq} (1000 R$)$^{-1}$
Brazil	2.19	3.03	0.72
Sao Paulo	0.14	1.00	0.14

The Inventory Elaboration Coordination

The first contacts with the British Embassy happened in 2007 for the preliminary partnership agreements. The project was effectively initiated in March 2008 with the first planning and methodological structuring works of the State Inventory and the signature of partnership agreements with the copartner entities. The IPCC method was defined as premise to be followed, as recommended by UNFCCC, and also used in the national inventory in order to generate comparable information both national and internationally, thus allowing the quantification of the emissions in the global context.

For project execution, PROCLIMA/CETESB, in charge of its coordination, articulated the establishment of a wide network of partners to survey the data and estimations of the emissions. It sought for gathering experts, entities and excellence organizations in each one of the sectors to be inventoried, thus providing conditions for the production of high quality information, which included the institutions and entities interested in joining the work. The elaboration of the inventory comprised a network that involved a total of 320 researchers and 120 institutions, such as governmental entities, universities, private companies and NGOs.

The concern about the development of a work process with such characteristics and proportions resulted in the decision to hold regular technical coordination meetings, in which the copartner institutions gave their account on the progress of their researches, shared data, solved doubts and clarified methodological aspects of their work[8]. As a complement, those meetings also included new entities and researchers who joined the work process and supported the survey of information[9].

Eight meeting on the inventory network were held in the auditorium of CETESB[10] with the total attendance of 400 participants to the set of meetings, representing an expressive share of the main partners of the project. Innumerable meeting were also held with specific entities aiming for exchanging information and performing vital technical reviews to avoid double counting of emissions, thus providing the presented results with more consistency.

Besides the network coordination, a work team was created as a technical support structure, which performed the estimations on the main sectors of the inventory, which includes Ciclo Ambiental, EMBRAPA, FUNCATE (with the support of INPE), The Maua Institute of Technology and PETROBRAS, among others. CETESB, besides coordinating the project, also calculated the emission estimations of the Waste Sector, using the expertise acquired during the accomplishment of the GHG emissions inventory of the Waste Sector

[8] The records on those meetings, as well as its taping, are available in the website of the project (GEESP): <http://www.cetesb.sp.gov.br/inventario-gee-sp/rede-de-inventario/34-rede-estadual-de-inventario-de-gee-do-estado-de-sao-paulo>.

[9] This participation is registered on the list of experts and author, revising and co-working entities of the Inventory publication.

[10] The 8 meetings of the inventory network held between 2009 and 2010 were documented and the related files are available in the website of the project.

of both National Communications from Brazil to UNFCCC and in several researches for international organizations, such as the World Bank and IPCC[11].

This partnership with the climate change team of the Ministry of Science and Technology (MCT) was fundamental for it made the access to part of the information on the National Inventory of the Land Use, Land Use-change, and Forestry, mainly for the period from 1995 to 2000. The team of PROCLIMA also made the estimations on the Subsectors of Food and Beverage, Pulp and Paper, Lime, and Glass Production, Liming Soil, Rail and Water Transport, and also joined the elaboration of the estimations on the Subsectors of Cement and Metallurgy, holding several thematic meetings with the involved sectors.

After the elaboration of the 26 Reference Reports that comprise the set of the Inventory, the documents were made available for download in the website of CETESB for public consultation from October 2010 to April 2011, thus fulfilling the determination of Article 16, paragraph 1 of the State Decree 55,947/10, which regulates the State Policy on Climate Change.

The inventory received many questions and technical contributions during the public consultation, some of which motivated a review of the 2005 GHG Inventory, formally presented on November 2010. The pertinent contributions were incorporated to the final results of this document and the proponents are on the list of co-workers, revisers and authors. We must highlight that, with this wide work process, the set of information got consistency and legitimacy.

[11] It is also meant to highlight in that set the National Network of GHG Inventory of the Wastes and Effluents Sector and the participation in the Global Methane Initiative (GMI), under the coordination of US-EPA.

List of Abbreviations and Acronyms

A – Rivers and lake (Unmaged Wetlands)

ABAL – Brazilian Aluminum Association (*Associação Brasileira do Alumínio*)

ABCP – Brazilian Association of Portland Cement (*Associação Brasileira de Cimento Portland*)

ABIA – Brazilian Food Industry Association (*Associação Brasileira das Indústrias da Alimentação*)

ABIEC – Association of Brazilian Beef Exporters (*Associação Brasileira das Indústrias Exportadoras de Carne*)

ABIPECS – Brazilian Pork Industry and Exporter Association (*Associação Brasileira da Indústria Produtora e Exportadora de Carne Suína*)

ABIQUIM – Brazilian Chemical Industry Association (*Associação Brasileira da Indústria Química*)

ABIVIDRO – Brazilian Technical Association of the Automatic Glass Industry (*Associação Técnica Brasileira das Indústrias Automáticas de Vidro*)

ABNT – Brazilian Association of Technical Standards (*Associação Brasileira de Normas Técnicas*)

ABPC – Brazilian Lime Producers Association (*Associação Brasileira dos Produtores de Cal*)

ABRAF – Brazilian Association of Planted Forests Producers (*Associação Brasileira de Produtores de Florestas Plantadas*)

Ac –Cropland Area

ALL – *América Latina Logística*

ANAC – National Civil Aviation Agency (*Agência Nacional de Aviação Civil*)

ANEEL – National Electrical Energy Agency (*Agência Nacional de Energia Elétrica*)

ANVISA – Sanitary Surveillance National Agency (*Agência Nacional de Vigilância Sanitária*)

Ap – Plated pasture

AvAgr – Cropland area

AvRef – Reforestation Area

AVGAS – Aviation Gasoline

AVK – Aviation Kerosene

BEESP – Sao Paulo State Energy Balance (*Balanço Energético do Estado de São Paulo*)

BRACELPA – Brazilian Association of Pulp and Paper (*Associação Brasileira de Celulose e Papel*)

CATI – Integral Technical Assistance Coordination (*Coordenadoria de Assistência Técnica Integral*)

CDM – Clean Development Mechanism

CETESB – Sao Paulo State Environment Agency (*Companhia Ambiental do Estado de São Paulo*)

CKD – Cement Kiln Dust

Cm – Montane Deciduous Seasonal Forest

Cs – Submontane Deciduous Seasonal Forest

CNPC – Brazilian National Beef Cattle Council (*Conselho Nacional de Pecuária de Corte*)

CONAMA – National Environmental Council (*Conselho Nacional do Meio Ambiente*)

COSIPA – *Companhia Siderúrgica Paulista*

CPTM – Sao Paulo Metropolitan Train Company (*Companhia Paulista de Trens Metropolitanos*)

CSI – Cement Sustainability Initiative

CTEEP –Sao Paulo Power Transmission Company (*Companhia de Transmissão de Energia Elétrica Paulista*)

Da – Alluvial Dense Humid Forest

Db – Lowland Dense Humid Forest

DBO –Biochemical Oxygen Demand

DI – High Montane Dense Humid Forest

Dm – Montana Dense Humid Forest

Ds – Submontane Dense Humid Forest

EMBRAPA – Brazilian Agricultural Research Corporation (*Empresa Brasileira de Pesquisa Agropecuária*)

ETE – Wastewater Treatment Plant (*Estação de Tratamento de Esgoto*)

Fa – Alluvial Semi Deciduous Seasonal Forest

fc – Soil Carbon Change Factor

FCA – *Ferrovia Centro-Atlântica*

FCC – Fluid Catalytic Cracking

fI – Carbon Change Factor from Additions of Organic Matter

fLU – Carbon Change Factor for Land Use

Fm – Montane Semi Deciduous Seasonal Forest

FM – Managed Forest

fMG – Carbon Change Factor for Management Regime

FNM – Unmanaged Forest

Fs – Sub Montane Semi Deciduous Seasonal Forest

FSec – Secondary Forest

FUNARBE – Arthur Bernardes Foundation (*Fundação Arthur Bernardes)*

FUNCATE – Foundation for Space Science, Technology and Applications (*Fundação de Ciência, Aplicações e Tecnologia Espaciais*)

GDP – Gross Domestic Product

GHG – Greenhouse Gases

GMI – Global Methane Initiative

GM – Managed Grassland

GNM – Unmanaged Grassland

GSec – Grassland with Secondary Vegetation

GTP – Global Temperature Potential

GWP – Global Warming Potential

IABr – Brazilian Steel Institute (*Instituto Aço Brasil*)

IBAMA – Brazilian Institute for the Environment and Renewable Nature Resources (*Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis*)

IBGE – Brazilian Institute for Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística*)

IEA – Institute of Agricultural Economics (*Instituto de Economia Agrícola*)

IEA – International Energy Agency

IGES – Institute for Global Environmental Strategies

IMT – *Instituto Mauá de Tecnologia*

IncrAgr – Average Annual Carbon Gains in Agricultural Areas Still in Development

IncrRef – Average Annual Carbon Gains in Reforestation Areas Still in Development

INPE – National Institute on Space Research (*Instituto Nacional de Pesquisas Espaciais*)

IPCC – Intergovernmental Panel on Climate Change

LPG – Liquefied Petroleum Gas

LSPA – Systematic Survey of Agricultural Production (*Levantamento Sistemático da Produção Agrícola*)

LTO – Landing-Takeoff Cycles

LULUCF – Land Use, Land-use Change, and Forestry

MCT – Ministry of Science and Technology (*Ministério da Ciência e Tecnologia*)

MDI – Metered-Dose Inhaler

MI – Montane Mixed High Humid Forest

Mm – Montane Mixed Humid Forest

MMA – Ministry of Environment (*Ministério do Meio Ambiente*)

MME – Ministry of Mines and Energy (*Ministério de Minas e Energia*)

MRS – *MRS Logística S.A.*

NGO – Non-governmental Organization

NGV – Natural Gas Vehicle

NO – Not Observed

O – Other Uses

OC – Organic Carbon

ODS – Ozone-depleting Substances

OECD – Organization for Economic Co-operation and Development (OCDE)

Pa – Fluvial and/or Lacustrine Influenced Vegetation

PEMC – State Policy on Climate Change (*Política Estadual de Mudanças Climáticas*)

PETROBRAS – Brazilian Petroleum S.A. (*Petróleo Brasileiro S.A.*)

Pf – Pioneer Formation Fluviomarine Influenced (Mangroves)

Pm – Pioneer Formation Marine Influenced (Sand Banks)

PNSB – National Survey of Basic Sanitation Study (*Pesquisa Nacional de Saneamento Básico*)

PPM – Municipal Livestock Production (*Produção Pecuária Municipal*)

PROCLIMA – Sao Paulo State Program on Climate Change (*Programa de Mudanças Climáticas do Estado de São Paulo*)

Ref – Reforestation

Res – Reservoirs (Managed Wetlands)

RMSP – Sao Paulo Metropolitan Region (*Região Metropolitana de São Paulo*)

Rl – High Montane Vegetation Refuge

Rm – Montane Refuge

Remf – Native Vegetation with Forest Physiognomy in Managed Land

Remg – Native Vegetation with Non-forest Physiognomy in Managed Land

S – Urban Area

Sa – Wooded Savanna

Sd – Forested Savanna

Sg – Woody-grass Savanna

SIGEA® – Computerized System for Air Emissions Management (*Sistema Informatizado de Gestão de Emissões Atmosféricas da Petrobras*)

SIN – National Integrated System

SINDICAL – Union of the Industries of Limestone and Derivatives for Agricultural Usage of Sao Paulo State (*Sindicato das Indústrias de Calcário e Derivados para Uso Agrícola no Estado de São Paulo*)

SINDSOLV – Solvent Petroleum Commercial Wholesaler National Union (*Sindicato Nacional do Comércio Atacadista de Solventes de Petróleo*)

SMA – Sao Paulo State Secretariat for Environment (*Secretaria do Meio Ambiente do Estado de São Paulo*)

SNIC – National Cement Industry Union (*Sindicato Nacional da Indústria do Cimento*)

SNUC – National System of Protected Areas (*Sistema Nacional de Unidades de Conservação da Natureza*)

Sp – Park Savanna

SRU – Sulfur Recovery Units

SSE – Sao Paulo State Secretariat of Sanitation and Energy (*Secretaria de Saneamento e Energia do Estado de São Paulo*)

ST – Sao Paulo State Secretariat of Transportation (*Secretaria de Transportes do Estado de São Paulo*)

TGW – Total Gross Weight

UBABEF – Brazilian Poultry Union (*União Brasileira de Avicultura*)

UNDP – United Nations Development Programme

UNEP – United Nations Environment Programme

UNFCCC – United Nations Framework Convention on Climate Change

UNICAMP – University of Campinas (*Universidade Estadual de Campinas*)

USP – University of Sao Paulo (*Universidade de São Paulo*)

WSA – World Steel Association

List of Symbols

Al – Aluminum

C – Carbon

$C_6H_{10}O_4$ – Adipic Acid

Ca – Calcium

$CaCO_3$ – Calcium Carbonate

CaMg $(CO_3)_2$ – Dolomite

CaO – Calcium Oxide

CF_4 – Tetrafluoromethane

$C2F_6$ – Hexafluoroethane

$C2H_4$ – Ethylene

$C2H_4Cl_2$ – Dichloroethane

C_2H_4O – Ethylene Oxide

CFC – Chlorofluorocarbons (CFC-11, CFC-12, CFC-113)

CH_4 – Methane

CH_2CHCl – Vinyl Chloride

CH_3Cl – Methyl Chloride

CH_3OCH_3 – Dimethyl Ether

C_4H_{10} – Isobuthane

Cl – Chlorine

CO – Carbon Monoxide

CO_2 – Carbon Dioxide

CO_{2eq} –Carbon Dioxide Equivalent

CTC – Carbon Tetrachloride

Gg – Gigagram

GJ – Gigajoule

Ha – Hectare

H_2 – Hydrogen

HC – Hydrocarbons (HC-600a)

HCFC – Hydrochlorofluorocarbons (HCFC-22, HCFC-141b)

H_3PO_4 – Phosphoric Acid

HFC – Hydrofluorocarbon (HFC-134a)

hL – Hectoliter

HNO_3 – Nitric Acid

M – Molar Mass

Mcal – Megacalory

MCF – Methyl Chloroform

Mg – Magnesium

MgO – Magnesium Oxide

MP – Particulate Material

N – Nitrogen

N_2 – Molecular Nitrogen

N_2O – Nitrous Oxide

Na_2CO_3 – Sodium Carbonate

NH_3 – Ammonia

NMHC – Non-Methane Hydrocarbons

NMVOC – Non-Metallic Volatile Organic Compounds

NO_2 – Nitric Oxide (Nitrogen Dioxide)

NOx – Nitrogen Oxides

O_3 – Ozone

P – Phosphorus

PFC – Perfluorocarbons

R – Refrigeration Fluids (R-502, R-600a-R404a)

SF_6 – Sulfur Hexafluoride

SO_2 – Sulfur Dioxide

SOx – Sulfur Oxides

t – Ton

tOE – Ton of Oil Equivalent

VOC – Volatile Organic Compounds

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Part I

State Caracteristics

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1

Sao Paulo State Profile

1 Sao Paulo State Profile

1.1 Characterization of the Territory

Sao Paulo State is one of the 27 Federative Units of Brazil, and is located in the Southeast Region of the country. Cross cut by the Tropic of Capricorn and bathed by the Atlantic Ocean along its 700 km of coastline, Sao Paulo shares boundaries with the states of Rio de Janeiro at East, Minas Gerais at North and Northeast, Mato Grosso do Sul at Northwest and Parana at Southwest.

Figure I.1. Political Map of Brazil – Sao Paulo State

Its territory presents a relief inserted into a medium frame of altitudes, with 74.6% of its area located between hypsometric curves of 300 to 900m, including the important compartments of the Atlantic Plateau, besides the totality of the Peripheral Depression and the tablelands ("*chapadões*") of West of the State. The remaining is scattered in curves below 300m, corresponding to fluviomarine coastal flatlands and the foothills of the Serra do Mar and coastal hills; and curves above 900m, comprising the high plateau blocks raised from Serra da Bocaina and Campos do Jordao, the scarps of Serra da Mantiqueira, the highest promontories of Upper Paraiba, Upper Tiete and Upper Ribeira, some parts of Serra do Mar and Serra da Paranapiacaba, the top of the rejuvenated mountains of the Sao Roque series and the high massifs of Sao Sebastiao Island and Serra dos Itatins (AB'SÁBER, 2004).

Except by the great gaps of the scarpments and the spurs of Serra do Mar and Serra da Mantiqueira, the mamelonar promontories and "seas of hills" of Paraiba do Sul River Basin and the rejuvenated mountains of the Sao Roque series, the predominant relief of the Sao Paulo State are the gentle shapes of the old massifs, the tabular hills and tablelands, only interrupted by the irregular alignment of the basaltic cuestas, the only features of the Southern Plateau of Sao Paulo State (AB'SÁBER, 2004). In the Sao Paulo State, the highest mountains are located at Serra da Mantiqueira, on the border with the states of Minas Gerais and Rio de Janeiro, specially the Pedra da Mina, with 2,770m, and Pico dos Tres Estados, with 2,665m.

Occupying an area of 248 thousand km^2, the State is the 12th largest state of Brazil, comprehending 3% of the Country surface. It is divided into 645 municipalities, grouped in fifteen Administrative Regions[12], including three Metropolitan Regions (Sao Paulo, Campinas e Baixada Santista). Among these, especially the Metropolitan Region of Sao Paulo (RMSP), comprised by the Municipality of Sao Paulo, the capital of the State, and other 38 municipalities, occupying an area of 8,051 km^2. Known as Greater Sao Paulo, the RMSP forms a continuous urban area which houses over 20 million people. It is the largest urban center of Brazil and South America, and the sixth largest urban area in the world.

According to Brazilian Institute for Geography and Statistics (IBGE), the State's population reached 41.2 million people in 2010, placing it as the third most populated administrative unit in South America, overcome only by Brazil (with 190.7 million people) and by Colombia (44.3 million people) and with a population superior to 178 countries. This number represents 21% of the Brazilian population and 11% of all South American population. The population density of the State is 166.2 inhabitants/km^2 and its annual growth rate between 2000 and 2010 was 1.08% (11.39% within the period), a number inferior to the national average, 1.17% a year, totalizing a growth of 12.33% within the same period (IBGE, 2011).

The capital of the State is the main financial, corporative and trade center in Latin America and the largest city in Brazil, in the America and in the Southern Hemisphere, with a population of around 11 million people. As the sixth largest city in the planet, Sao Paulo is the tenth richest and the 14th more globalized, and it represents, without considering the other cities of the RMSP, 12.26% of all the GDP of Brazil, it concentrates 36% of all the production of goods and services of the State and houses 63% of the multinational companies incorporated in Brazil.

[12]The State is divided into the Administrative Regions of Araçatuba, Central, Barretos, Bauru, Franca, Marília, Presidente Prudente, Registro, Ribeirao Preto, Sao Jose do Rio Preto, Sao Jose dos Campos, Sorocaba, besides the Metropolitan Areas of Baixada Santista, Campinas and Sao Paulo.

Besides the capital, Sao Paulo State has other eight municipalities whose population exceeds 500 thousand people, four of which are in the Metropolitan Area of Sao Paulo (Guarulhos, Sao Bernardo do Campo, Osasco and Santo Andre). The Administrative Regions of Campinas and Baixada Santista are also considered as metropolitan areas, and cities such as Sao José dos Campos, Sorocaba and Jundiaí are under the metropolization process. All those metropolitan areas together form the Expanded Metropolitan Complex, housing over 29 million people, 75% of the population of the State and 12% of the Brazilian population.

The transport infrastructure, the paved road network of Sao Paulo comprises 35 thousand kilometers, 22 thousand state ones, 1.050 federal ones and 12 thousand kilometers of paved vicinal roads, which are carried by 93% of all the cargo handled in the State (SÃO PAULO, 2011e). The railway system is more than 5 thousand kilometers, and carries both passengers and cargo. The State has 45 airports, three large-sized ones (Congonhas, Guarulhos and Viracopos), the last two international. There are two ports: Santos, the largest one in Latin America and the 39th in the world rank on the operation of cargo in containers, and the one of Sao Sebastiao, on the North coast of the State.

In 2009, Sao Paulo State had a total energy supply of 90,024 tOE (tons of Oil Equivalent), most of which came from oil and derivatives (45.9%) and sugarcane and derivatives (29.0%).The hydroelectricity supply responded for 7.9% of that amount, followed by the supply of natural gas (4.5%), charcoal (1.5%) and other sources (11.2%). The energy supplied was demanded specially by the industrial sector (30.1%) and transportation (21.2%), followed by the export/transformation sector (22.5%), non-energetic use (9.6%) and home use (5.1%). The other sectors used 8.2% of the supplied energy and the loss percentage was 3.3% (SÃO PAULO, 2010b).

The political system of the State follows the federal one, divided into executive, legislative and judicial powers, respectively represented by the Governor, the State Assembly and the Court of Justice. The State Assembly is formed by 94 members, elected by over 25.6 million voters every four years, as determined by the Federal Constitution. In the Federal level, the State is represented by three senators and 70 congressmen. The number of congressmen is not proportional to the population of the State in relation to the country's, due to a constitutional arrangement that limits the number of seats to be taken per state in the Lower House to 70 representatives.

1.1.1 Vegetation and Botanical Resources

Sao Paulo State is inserted into the Atlantic Forest and Cerrado biomes (Figure I.2), both included in the hotspots list as areas considered as priority to be preserved due to being rich in biodiversity, endemism and for being seriously threatened (MYERS et al., 2000). The forest physiognomies of those biomes, which used to cover about 85% of the State area at the beginning of the colonization, now comprehend 17.5% of the territory (IF, 2010).

Most of the remaining forest existing in the State is Atlantic Forest, located in Serra do Mar, forming a continuous forest from the Parana to the Rio de Janeiro crossing the entire State of Sao Paulo (FigureI.3). This biome presents, in the State, the following physiognomies (IBGE, 2004; IF, 2005):

– Dense Humid Forest (*Floresta Ombrófila Densa*): vegetation typical from tropical regions with high temperatures (average 25°C) and rains scattered along the year (0 - 60 dry days), with no biologically dry seasons;

– Mixed Humid Forest (*Floresta Ombrófila Mista or Mata de Araucária)*: forests with the predominance of Araucaria forests, found on the *Serra do Mar* and *Serra da Mantiqueira*. This formation in Sao Paulo State is associated to altitude;

– Seasonal Semi Deciduous Forest (*Floresta Estacional Semidecidual*): forest formation in which part of the trees lose their leaves (20% to 50% of the forest) due to the tropical climate seasonality, with summer rain periods followed by severe droughts, or the subtropical seasonality, with no dry period, but with a physiologic draught caused by the winter, with average temperatures inferior to 15°C.

Figure I.2. Biomes of the Sao Paulo State

Source: FUNCATE (2011).

The biodiversity of the Cerrado is even more endangered due to the high fragmentation of its remaining, with only 7,683 fragments of Cerrado, totalizing 218,007 ha, (IF, 2010). The following physiognomies are found in the State (IBGE, 2004; IF, 2005):

– Cerradao (*Cerradão*): formation of forest physiognomy with continuous canopy characterized by the presence of species of the Cerrado and forest species, composed of three stages: a creeping species or small, a woody species with up to 5 to 6 meters high, and a higher trees with species up to 10 to 12 meters;

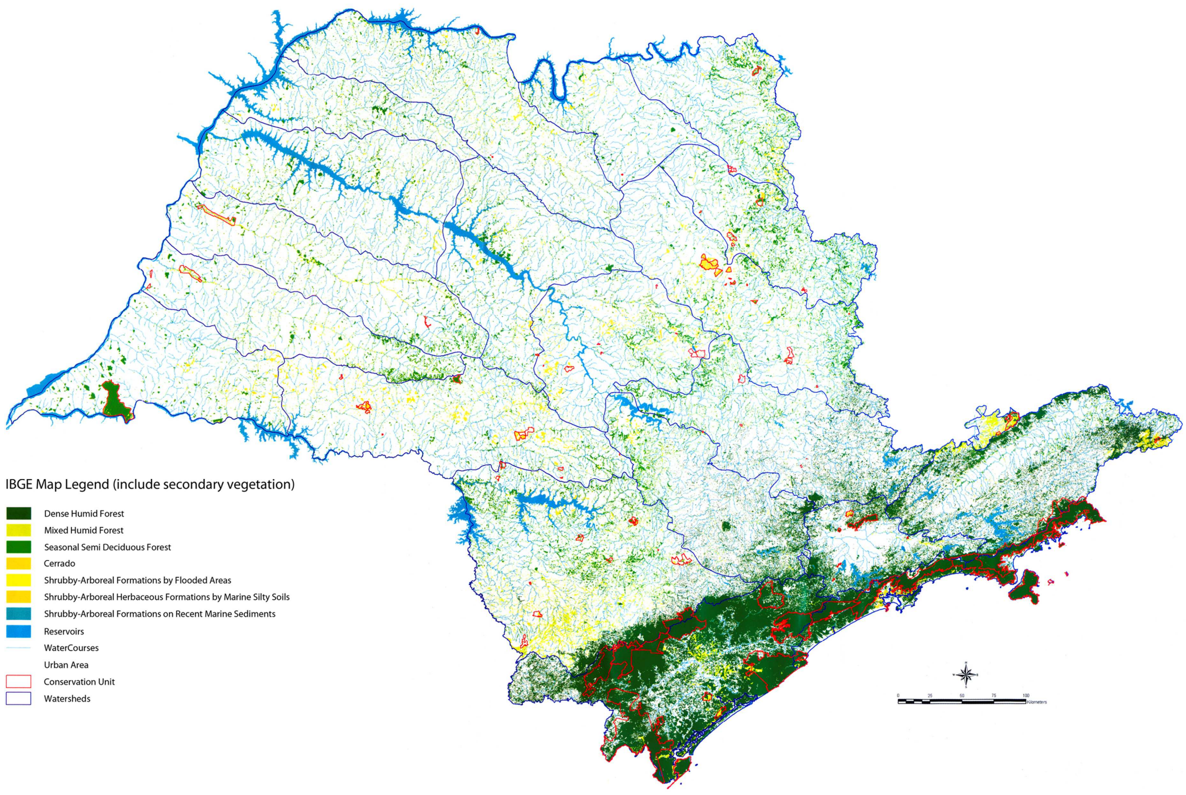
– Cerrado *Stricto Sensu*: presents peculiar physiognomy, characterized by twisted trees and shrubs with glossy thick leaves, by the presence of woody and herbaceous strata well defined, with a large number of species of shrubs, subshrubs and herbs;

– Cerrado Grassland (*Campo Cerrado*): characterized by ill-defined tree layer, with the predominance of low vegetation, with many species of subshrubs and herbs and a few trees and bushes spaced;

– Grassland with trees (*Campo Sujo*): characterized by the tree layer absent, with the predominance of low vegetation, with few continuous and herbaceous shrubs spaced;

– Grassland without trees (*Campo Limpo*): characterized by non-existent tree layer, with the predominance of low vegetation composed of grasses and herbs.

Figure I.3. Vegetal Coverage Map of the Sao Paulo State 2008-2009



Source: IF (2010).

Sao Paulo State also has the pioneer formations, vegetation that colonize soils in constant modification, either by marine or fluvial deposition, subdivided into (IBGE, 2004; IF, 2005):

– Shrubby and arboreal formations of sludge sea lands or Mangrove: occurs in salty environments of rivers confluence with sea. They have a flora adapted to such environment and serves as a nursery for many marine species;

– Shrubby-arboreal formations on recent marine sediments or Restinga: typical vegetation from areas with marine and fluviomarine influence, such as the coastal lines and dunes along the whole coast, with herbs and arboreal physiognomy;

– Shrubby-arboreal herbaceous formations by flooded areas or Riparian Forest (*Mata Palustre*): vegetation formations on the banks of water bodies forming alluvial land subject to periodic flooding or not with shrubby and arboreal physiognomy.

1.1.2 Fauna

The Brazilian fauna is very rich in species, but, on the other side it is very fragile, since it involves a relatively small number of individuals, many of them endemic. Given the preponderant influence of the vegetation over the fauna, it is scattered along the zoo-geographic provinces, according to the phytophysiognomy and the dominant botanical composition in the respective territories. So, there are types of fauna in Brazil adapted to different forms of vegetation cover that correspond to the most varied rainfall, temperature and relief conditions, as well as other morphologic factors (BRASIL, 2004).

Nevertheless, many factors, such as the destruction of the habitats by eliminating native vegetation, environmental degradation and anthropic occupation have highly contributed to the gradual increase of in the number of endangered species, some of which are already considered as extinct in the Country. Sao Paulo State has calculated those numbers since the publication of Decree n. 42,838/98 (SÃO PAULO, 1998a), which defines the State's list of the endangered or almost endangered species of the wild fauna, and the collapsed fish species, over exploited and threatened of over exploitation.

Table I.1. Endangered Vertebrates of the Sao Paulo State in 2008

Group	Total ofspecies/ sub-species	Locallyextinct	Endangered						Almostendangered		Insufficient data	
	sp	sp	sp	%	CR[1]	EN[2]	VU[3]	CO4	sp	%	sp	%
Birds	789	1	171	22	69	33	69		47	6	33	4
Fish (Sea)	650	7	16	2,5				16	-		-	
Fish (river)	350	1	65	16	16	15	34		8	2	17	5
Mammals	240	-	38	16	9	6	23		22	9	58	24
Amphibians	226	1	11	5	4	2	5		7	3	45	20
Reptiles	216	-	33	15	3	9	21		2	1	8	4

[1] CR: critically endangered [3] VU: vulnerable
[2] EN: endangered [4] CO: collapsed
Source: FPZSP (2009).

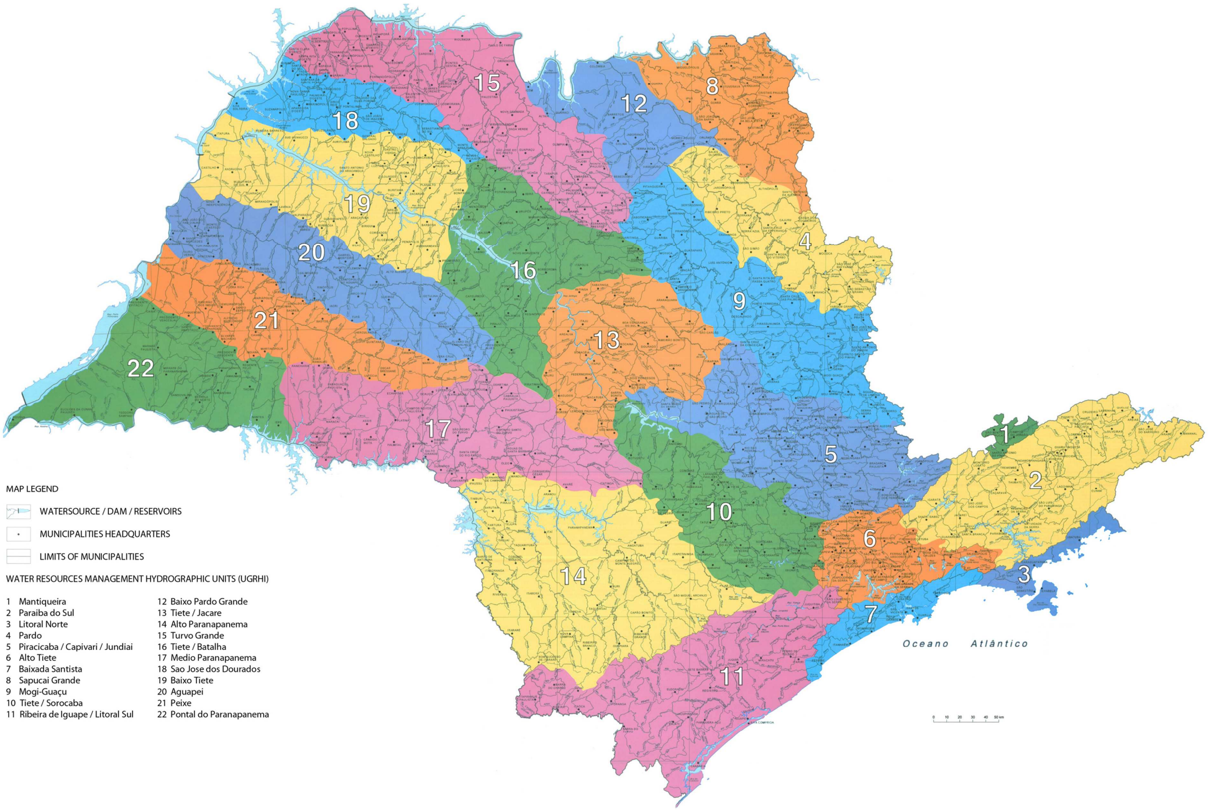
Since then, with the update of the endangered fauna list of the State (SÃO PAULO, 2008), as well as the institution of programs such as those to protect the wild fauna, Sao Paulo State has proposed complementary actions to fulfill and integrate the services for the regulation, supervisions and management of the wild fauna, aiming for the conservation of the diversity of its gene pool and the protection of its integrity. Table I.1 shows a summary of this list of the endangered vertebrates.

1.1.3 Water Resources

Brazil is divided into 12 hydrographic regions. The rivers of Sao Paulo belong to those two regions: the main one is the Parana Hydrographic Region, responsible for the hydropower potential of the State, while the rivers of the Coastal Lowland and part of the Cristalino Plateau integrate the Southeast Atlantic Hydrographic Region.

Aiming for improving the control over its superficial and ground waters, the State Government instituted the State Water Resources Policy in 1991, through Law n. 7,663, (SÃO PAULO, 1991). This law sets out rules on the decentralized and participative management of the water resources through the Water Resources Management Units (UGRHI), administratively defined according to the 22 watersheds of the State, as seen in Figure I.4 (DAEE, 1991).

Figure I.4. Map of the Water Resources Management Hydrographic Units (UGRHI)



Source: TALAMONI; JAHNEL (1998).

This law also sets out rules on the creation of an Integrated Water Resources Management System (SIGRH), as well as the regular elaboration of a State Water Resources Plan, made for the first time in 1990 and, later, in 1994, 1996 and 2003.

The water supply in the State is 2,880m^3/s, equals to 1.6% of the Brazilian supply. Today, the demand in Sao Paulo is 453m^3/s, 137m^3/s for urban activities, 138m^3/s for industrial purposes and 178m^3/s for irrigation (SÃO PAULO, 2010a).

There are around 200 rivers in the State. Among them we may highlight: Tiete, Parana, Paranapanema, Ribeira, Grande, Turvo, Peixe, Paraiba do Sul, Piracicaba, Pardo, Mogi-Guaçu, Sorocaba, Jacare-Pepira and Jacare-Guaçu.

Sao Paulo State also has a meaningful reserve of ground water: 16% of the total area of the Guarani Aquifer, one of the main groundwater reservoirs in Brazil, is located in its territory. This aquifer, with 1,200,000km^2, is extended along the territories of Brazil, Uruguay, Argentina and Paraguay. Besides the Guarani Aquifer, Sao Paulo also houses the aquifers of Pre-Cambrian, Taubate, Tubarao, Serra Geral, Bauru and Litoraneo (DAEE, 2005).

The underground water in the State is used, totally or in part, for public supply by around 80% of the municipalities, besides being used in irrigation and industrial processes. It is the main supply source for the west area of the State (SÃO PAULO, 2010a).

1.2 Climate of the State

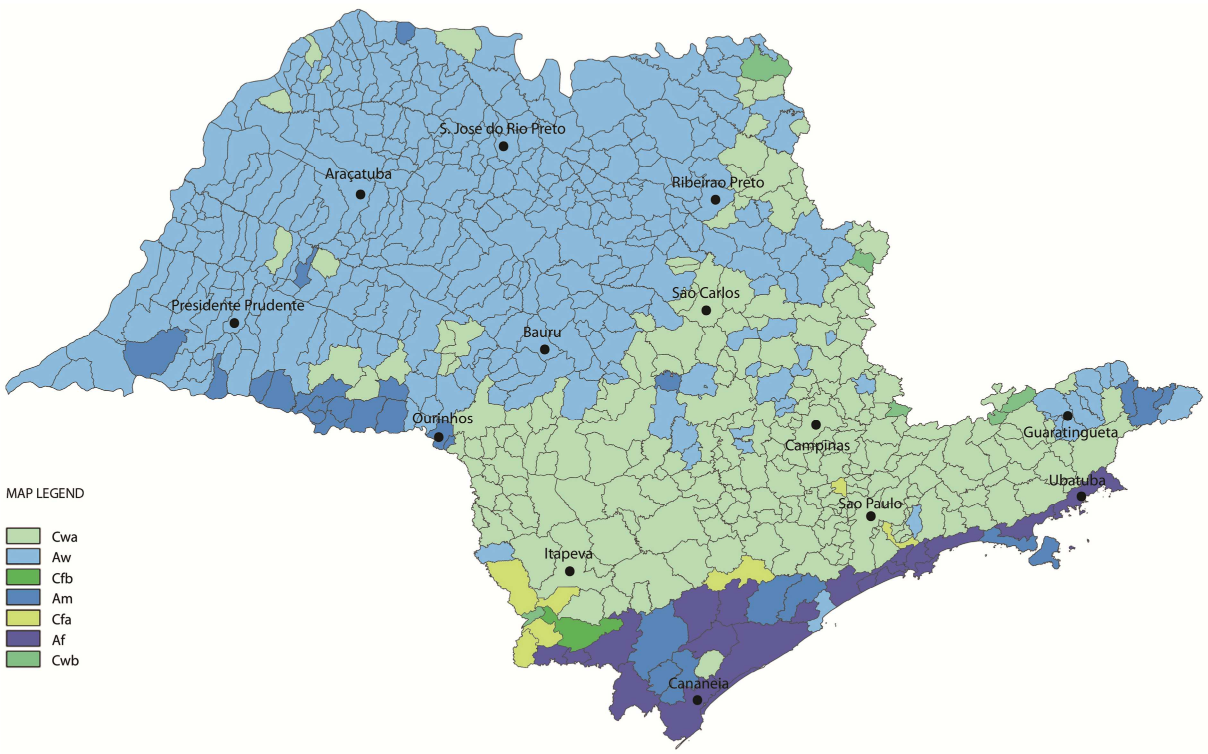
The Climate Classification of Koëppen-Geiger is a system that considers the seasonality and the monthly and annual average numbers of temperature and rainfall. Each great climate type is represented by a code formed by higher-case and lower-case letters. By using monthly temperature and rainfall data of the municipalities of Sao Paulo, MIRANDA et al (2011) classified the climate of the State as seen in Figure I.5.

The type climate prevails in most of the State is the *Cwa*, high altitude tropical with rains in summer and drought in winter, when the warmest month average temperature is above 22°C. In some mountain regions occurs the *Cwb*, with a dry season in winter and warm summer, with average temperature of warmest month below 22°C and at least four months with the average temperature exceeding 10°C.

The Northwest region is warmer, and climate is characterized by *Aw*, equatorial savanna with dry winter, with average temperatures in all months of the year above 18°C, with the rainy season occurring in the season of autumn and the driest month with precipitation less than 60mm. In some isolated points in the State *Am* is the climate, Tropical wet climate (monsoon), with dry winter (dry season months with rainfall less than 60mm), but compensated by high rainfall in the rest of the year. The climate of coastal region is *Af*, humid tropical without dry season, average rainfall in the rainy months less than 60mm.

In the Southern State dominated by the *Cfa*, humid subtropical characterized by hot summer with no dry season and winter and by its characteristic mesothermal, with an average temperature of the coldest month between -3°C and 18°C. In some areas of Serra do Mar the climate is *Cfb*, Maritime Temperate climates, rainy all year round with Warm Summer, which is the warmest month average temperature below 22°C.

Figure I.5. Climate Classification of Koëppen-Geiger for the Sao Paulo State



Source: MIRANDA et al. (2011).

1.3 Social and Economic Profile

Sao Paulo State has a privileged position in the Brazilian context due to its economic, social and political importance. Being the most populated unit of federation, Sao Paulo has a different profile in several economic and social indicators, such as the highest Gross Domestic Product (GDP) of the country, second largest *per capita* GDP (IBGE, 2009a), the third best Human Development Index (HDI)[13] and the largest industrial production of the country.

According to IBGE (2011), its population reached 41.2 million people in 2010, the largest among the other states, followed by Minas Gerais (19.5 million), Rio de Janeiro (15.9 million) and Bahia (14 million). Since the 1980s, there has been noticed a deceleration trend in the population growth in the State, with a drop in the fertility levels and the reduction of the migration rates towards Sao Paulo, besides the increase in life expectancy.

The period of greatest population growth in the State took occurred in the 1950s, reaching 3.6% a year, while the national average was 3.2%. Since then the growth pace has decreased gradually, reaching 1.08% in the first decade of the 21st Century. His age pyramid indicates a society in transition, with a predominance of the groups between 20 and 29 years of age, and a lower relative participation of the other groups, specially the

[13] Comparative evaluation system of the human development and well-being that considers indicators of health-care, education and income, evaluating them through an index whose grade varies between 0 and 1.

youngest ones (SEADE, 2006). According to the census by IBGE (2009b), the ethnic background of Sao Paulo comprises 64.4% white, 28.4% mulatto, 5.4% black, and 1.6% Asian or indigenous. The population is descended mainly from European immigrants, Asians and Africans, in addition to the native Indians. During the XX Century, mainly in the 1960s, 1970s and 1980s, the State also received migration from other states, mainly from the Northeast Region.

Sao Paulo has 96 men for each 100 women, similar to the national average. The total fertility rate is 1.57, lower than the national average of 1.89, a value similar to those observed in developed countries, particularly the European ones, and lower than the rate of natural replenishment of the population. The life expectancy in Sao Paulo is 74.5 years of age, above the national average of 73 years of age (IBGE, 2009c). Sao Paulo State is meaningfully more urbanized than the rest of Brazil. In 2010, the urbanization rate of the State was around 95.8%, above the national one of 84.3%, and lower only than those of Rio de Janeiro and the Federal District. On the labor market, highlight the services sector, accounting for 52.3% of formal employment in the State. Concentrates approximately 69% of all its GDP and contributes about 44% of revenues generated by this sector in the Country. The demographic, social and industrial dynamics of the State favors both the supply and the demand for services the most varied sectors, for companies and final consumers, besides the public services in education, health-care and infrastructure.

In 2008, the sectors which most contributed to the generation of income in the services sector were information and communication; transportation, auxiliary transportation services and post (which includes all types of transportation); and professional, administrative and supplementary services. Table I.2 shows the gross revenue in rendered services and the share of Sao Paulo of the total of Brazil, per activity (SÃO PAULO, 2011c).

Sao Paulo counts on one of the best facilities and technological infrastructures of the country. In 2008, it had over 41% of the Value of Industrial Transformation (VIT) of Brazil, around US$ 145 billion, mainly in the transformation industry. In absolute numbers, the manufacturing of vehicles, towage and trucks, focused mainly in the Metropolitan Areas of Sao Paulo, Campinas and in Vale do Paraiba exceeded US$ 19 billion, followed by the sector of coke, oil derivatives and biofuels, food, chemicals and machinery and equipment. Table I.3 shows the VIT according to the divisions of the transformation industry of the State in 2008.

Table I.2. Gross Revenue of Rendered Services and the Share of Sao Paulo in the Total of Brazil, per Activity – 2008

Activities	Gross Revenue (in US$ million)	State of Sao Paulo/Brazil (%)
TOTAL	181,441	44.2
Services rendered for families	12,612	37.5
Informationand communication services	61,656	46.9
Professional, administrative and supplementary services	45,337	47.1
Transportation, auxiliary transportation services and post	46,980	39.9
Real estate	3,047	42.2
Maintenanceandrepairservices	2,212	43.7
Otherserviceactivities	9,597	49.4

Source: IBGE (2008) apud SÃO PAULO (2011c).

In addition to the industrial sector, the second largest employer in the State with 26.3% of the total, are also worth highlighting the aerospace, pharm chemical, pharmaceutical, and information technology sectors (mainly in the region of Campinas), with a high technologic added value. In Sao Paulo, those sectors have benefitted from researches aiming for development and innovation. In 2008, over US$ 11.9 billion were invested in innovation in the State, what is equal to 50% of the total investment made by the Brazilian industry. 54% of the amount invested in internal research and development activities in Brazil took place in Sao Paulo, with amounts close to US$ 2.3 billion coming from State public funds from institutions such as FAPESP (Sao Paulo Research Foundation), *Nossa Caixa Desenvolvimento*, and FUNCET (State Fund for Scientific and Technological Development) (SÃO PAULO, 2011c).

Table I.3. Value of Industrial Transformation According to the Divisions of the Transformation Industry in the Sao Paulo State – 2008

Divisions	Value (in US$ million)	State of Sao Paulo/Brazil (%)
TOTAL	145,574	41.4
Food	15,782	33.1
Beverages	2,831	25.5
Tobacco	30	1.1
Textile	2,778	42.5
Clothes and Accessories	2,085	32.1
Leather artifacts, travel goods and shoes	1,064	17.6
Wood	755	17.2
Paper and cellulose	6,079	49.1
Printing and reproduction of recordings	1,599	45.5
Coke, oil derivatives and biofuels	18,387	39.6
Chemicals	13,472	47.3
Pharmaceuticals and Pharm-Chemicals	6,792	73.1
Rubber and plastic	6,624	53.2
Non-metallic minerals	4,217	34.5
Metallurgy	8,176	26.2
Metal products, except machines and equipment	7,833	50.4
Informatics, electronic and optical products	3,977	38.3
Electric machines, devices and materials	5,572	55.4
Machines and equipment	11,096	58.9
Vehicles, towage and trucks	19,701	51.4
Other transportation equipment, except vehicles	2,948	45.0
Furniture	1,010	26.1
Miscellaneous	1,655	47.6
Maintenance, repairing and installation of machines and equipment	1,111	28.1

Source: IBGE (2008) apud SÃO PAULO (2011d).

In 2009, the agriculture sector generated an income of US$22 billion, and agricultural production responded for 68.4% of that amount, followed by the animal products (23.0%) and forestry (8.6%). In the agriculture sector we may highlight the production of sugarcane, that generated US$9.23 billion, thus responding for 42% of the total agriculture production of the State, followed by the orange industry (US$977 million, 4.4% of the total production of the State) and the corn production (US$664 million, 3% of the production of the sector). Among the animal products, the beef responded for 10.9% of the sector, with a production of US$2.39 billion and the chicken, at 5.4% reaching the number of US$ 1.19 billion, followed by the eggs production (2.7%) and milk production (3.1% of the production, adding up the types C and B of milk) (SÃO PAULO, 2011a).

The exports of the Sao Paulo State in 2009 totalized US$43 billion, equal to 28% of the Brazilian exports. Of those, 90% were industrialized products, including high added value ones, such as airplanes and air vehicles, cellular phone terminals and automobiles, and 10% of primary products or of low added value, such as derivatives of sugarcane (sugar and alcohol), beef and orange juice. The destination of the exports of Sao Paulo was mainly the European Union, responsible for 18% of the imports, followed by MERCOSUR[14] (16%), ALADI[15] (15%), Asia, exclusively the Middle East (13%) and the United States (12%).

Table I.4. Gross Domestic Product at the Total Market Price and *per capita* and the Population Living in Sao Paulo State – 1995-2008

Years (1)	Total GDP				Per Capita GDP		
	Current Price (In millions of Reais)	Price of 2002 (In millions of Reais)	Annual Real Variation (%)	ResidentPopulation (2)	CurrentPrice (In Reais)	Priceof 2002 (In Reais)	Annual Real Variation (%)
1995	263.298	473.513	-	34.470.230	7.638	13.736	-
1996	307.924	479.538	1,3	34.997.455	8.798	13.702	(0,3)
1997	344.891	495.756	3,4	35.522.975	9.709	13.955	1,9
1998	353.085	489.831	(1,2)	36.058.173	9.792	13.584	(2,7)
1999	383.250	483.274	(1,3)	36.785.780	10.418	13.137	(3,3)
2000	424.161	503.875	4,3	37.384.512	11.345	13.478	2,6
2001	463.478	505.810	0,4	37.986.966	12.201	13.315	(1,2)
2002	511.736	511.736	1,2	38.595.825	13.258	13.258	(0,4)
2003	579.847	509.909	(0,4)	39.210.662	14.788	13.004	(1,9)
2004	643.487	540.891	6,1	39.825.226	16.157	13.581	4,4
2005	726.984	560.053	3,5	40.442.795	17.975	13.848	2,0
2006	802.655	582.239	4,0	41.055.734	19.550	14.181	2,4
2007	902.784	625.362	7,4	39.827.690	22.667	15.701	10,7
2008	1.003.016	662.204	5,9	41.011.635	24.457	16.147	2,8

Source: SEADE (2011a).

(1) Up to 1994, the IBGE used a different methodology to calculate the GDP, what made the comparison between the current and latter numbers at this date difficult, reason why the table above shows only the data from 1995 on.

(2) Population on 1st July each year, estimated by IBGE. For 2007, the population estimate taken into account was the one sent to the Federal Court of Auditors by IBGE and published in the Federal Official Journal *(Diário Oficial da União)* on 08/05/2009.

In 2009, the numbers of the imports of the State was superior to US$50 billion, resulting in a negative statement of the trade balance at eight billion dollars (BRASIL, 2011).Such trend became evident after the international financial crises of 2008, whose effects caused the depreciation of the price of the agriculture and mineral commodities. From 2002 to 2007, the State balance was a surplus, benefiting from the good moment the international was going through and by the Brazilian exports.

The manufactured imports made by the State responded for 42% of the national total. As for the imports of basic products, Sao Paulo responds for 26% of the national total. The main products imported by Sao Paulo are crude oil, diesel, parts for airplanes and helicopters, auto parts and automobiles (SÃO PAULO, 2011b).

[14] MERCOSUR – Common Southern Market (*Mercado Comum do Sul*).

[15] ALADI – Latin American Integration Association (*Associação Latino-Americana de Integração*).

In 2008, the GDP of the Sao Paulo State[16] reached R$1.003 trillion, the largest Gross Domestic Product among the states of Brazil, responding in that year for 33.1% of the total of the country, around R$3.031 trillion (Table I.4). However, there is a gradual decrease in the share of Sao Paulo in the national GDP, mainly due to the development of other regions of Brazil out of Rio-Sao Paulo axis, notably in the Midwest Region. Table I.5 shows the evolution of the share of Sao Paulo in the Gross Value Added (GVA)[17] of Brazil, by economic sector, from 1995 to 2007. Table I.6 shows the share of the economic activities in the GVA at basic price in the State at the same period.

Table I.5. Share of Sao Paulo State in the Gross Value Added of Brazil at Basic Price, per Economic Sector – 1995-2008 (%)

Economic Sectors and Sub-sectors	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Agriculture	10,4	8,6	10,3	11,7	10	8,6	13,3	13,5	11,2	10,2	10,7	13,1	11,8	7,9
Industry	44,4	42,9	42,9	42,4	40,9	39,9	39	37,6	37,7	36,3	36	34,8	35,4	33,9
Services	35,6	34,9	35	34,2	34,8	35,3	35,2	34,1	33,8	32,8	34	34,1	34,1	33,4
Gross Value Added at Basic Price	36,6	35,6	35,8	35,1	35	35,1	34,9	33,7	33,3	32,3	33,2	33,2	33,2	32
Taxes on Net Products from * Subsidies	-	-	-	-	-	-	-	40,4	39,6	38,4	37,7	38,2	38,2	39,1
Gross Domestic product at Market Price*	-	-	-	-	-	-	-	34,6	34,1	33,1	33,9	33,9	33,9	33,1

Source: SEADE (2009b).

Table I.6. Share of the Economic Activities in the Gross Value Added at Basic Price in the Sao Paulo State – 1995-2008

Activities	Share in the gross value added at basic price (%)													
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Agriculture	1,6	1,3	1,6	1,8	,6	1,4	2,3	2,7	2,5	2,2	1,8	2,2	2,0	1,4
Industry	33,5	31,4	31,3	31,0	30,3	31,5	30,1	30,2	31,6	33,8	31,7	30,1	29,6	29,5
Extractionindustry	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Transformationindustry	24,8	22,1	21,9	20,9	20,6	22,1	22,0	21,8	23,9	25,4	24,0	22,7	22,7	22,7
Production and distribution of electricity and gas, water and sewer and urban sanitation	3,2	3,3	3,4	3,9	3,9	3,9	2,9	3,2	3,3	3,8	3,7	3,4	2,9	2,5
Construction	5,4	5,8	5,9	6,1	5,6	5,4	5,1	5,1	4,3	4,5	4,0	4,0	3,9	4,2
Services	64,9	67,3	67,1	67,1	68,1	67,1	67,6	67,1	65,9	64,0	66,5	67,7	68,4	69,0
Trade	12,7	12,1	11,3	10,9	10,9	11,1	10,8	10,2	10,0	10,7	11,2	11,4	12,1	12,2
Financial intermediation, insurance and supplementary social security and related services	12,5	11,3	10,7	10,6	10,0	8,3	10,3	10,6	10,8	8,8	10,8	10,9	11,9	10,9
Administration, health care and public education and social security	8,8	9,0	8,4	8,0	8,0	8,2	8,5	8,9	8,8	8,5	8,5	8,5	8,9	9,3
Otherservices	30,9	34,9	36,7	37,6	39,1	39,5	38,0	37,4	36,4	36,0	36,0	36,8	35,6	36,6

Source: IBGE (2009b).

[16] Amounts on the GDP at market price.
[17] According to IBGE, Gross Value Added is the "the share in the gross domestic product of the several economic activities, obtained by the difference between the production cost and the intermediary consumption absorbed by those activities".

Between 2003 and 2008, the *per capita* GDP of the State had its growth lower than the national one, although its absolute value is still 52% above the national average. In national level, such indicator changed from R$9,497.69 to R$15,989.75 (positive variation of 68.3%), while in Sao Paulo that growth was 65.3%, jumping from R$14,787.99 to R$24,457.00, overcome only by the Federal District.

Sao Paulo is also above the national average in the indicators of human development. The Brazilian HDI reached in 2005, for the first time, the number of 0.800, what includes it among the countries with a high human development rate. The HDI of Sao Paulo followed the national growth trend and remained above the national average, at 0.833, only behind the Federal District and State of Santa Catarina and followed by the states of Rio de Janeiro and Rio Grande do Sul. The State kept the third position in relation to the rank of 2000, although the average HDI measured in that year may have been 0.821, indicating an improvement in the human development level in absolute terms. In the analysis out of the components of the 2005 DHI, Sao Paulo is in the fifth national position in longevity (0.812), sixth in education (0.921) and second in income (0.768).

1.4 Summary of the State Characteristics

Overall, despite the progress in economic and social indicators, in recent years, Sao Paulo follows the national indicators, a typical developing country, as a State with growing population, where most of the population's basic needs have yet to be met, infrastructure is still incipient and substantial improvements are required.

Table I.7. Summary of the State Characteristics

Criteria	2005	2010
Population (millions of inhabitants)	37*(1)	41,2(2)
Population Density (inhabitants/km^2)	148,96(1)	166,2(2)
GDP (trillions of R$)	0,726(3)	1,003**(3)
Share in the GDP of Brazil (%)	33,9(3)	33,1**(3)
Per capita GDP(R$)	17975(3)	24457**(3)
Share of the industry sector in the state GDP (%)	31,7(3)	29,5(3)
Share of the service sector in the state GDP (%)	66,5(3)	69(3)
Share of the agriculture sector in the state GDP (%)	1,8(3)	1,4(3)
Urbanization Rate (%)	94(2)	95, 8(1)
Percentage of primary vegetal coverage (%)	13,9(4)	17,5(5)
Life expectancy at birth (years of age)	73,9(6)	74,5(7)
Total of endangered vertebrates	n.d.	436(8)
HDI	0,833(9)	n.d.

(1) IBGE (2000); (2) IBGE (2011); (3) SEADE (2011b); (4) IF (2005); (5) IF (2010); (6) IBGE (2007); (7) IBGE (2009c); (8) FPZSP (2009); (9) CEPAL; PNUD; OIT (2008); n.d.: Not available data.

* Population counted by IBGE in the Survey of 2000 2000 Census. Once the census is immediately prior to 2010, we used this number and not from another more recent counting produced by another source. That guarantees the adoption of a same methodology for both counting, so that it may be possible to compare both surveys.

** The data refer to the year of 2008.

2

Special Circumstances

2 Special Circumstances

This section aims to analyze the special circumstances of Sao Paulo State, for which there are specific needs and concerns arising from the negative effects of climate change and its expected impacts, either because they have greater vulnerability, is the difficulty of implementing measures appropriate response or the need for more specific studies.

2.1 Metropolitan Areas

Metropolitan areas are complex organizations, characterized by human agglomerations, high urban concentrations and by the conurbation of adjacent urban areas, due to several factors such as: natural increase of the population, changes in demographic standards, political, and economic and/or environmental issues. A large part of the Brazilian economy and population are concentrated in those areas, due to the economic dynamism provided by the availability of infrastructure, transportation, access to goods and services and labor supply.

The high demographic density allied to the intensive use of the automobiles and the high consumption of energy cause environmental impacts, such as the emissions of GHG, persistent atmospheric pollutants and Ozone-Depleting Gases, excessive paving of the soil, over exploitation and contamination of the water resources, illegal settlements in risky areas, disposal of wastes and untreated effluents, among others (HOGAN et al, 2001).

The metropolitan areas are considered especially vulnerable to the impacts of climate change in the patterns of development and transformation of space, such as high population density, the expansion of irregular settlements on the periphery, the occupation of fragile areas and risk as floodplains and unstable soils, paving of the soil and removal of primary vegetal coverage.

The most alarming events in the Metropolitan Areas of Sao Paulo, Baixada Santista and Campinas are related to the high precipitation. Preliminary studies suggest that, between 2070 and 2100, an average increase in the temperature of the region by 2ºC to 3ºC may double the number of days with pouring rains (above 10 mm) in the capital, thus causing the accumulation of superficial waters, with a high destructive and dragging power (NOBRE et al, 2010). Trends also indicate the increase in the number of hot days and the intensification of the heat islands, besides the increase in the number of casualties in landslides, drowning and car accidents and cases of leptospirosis and hepatitis cause by the contact and ingestion of contaminated water.

2.2 Human Occupation on the Coast

The coast of Sao Paulo is divided into sixteen municipalities, a linear extension of about 700km of coastline, most of this being located in the South of the Tropic of Capricorn. This climate is hot and humid tropical Atlantic, where the temperature averages and annual rainfall are high (SÃO PAULO, 1998b).

The social and economic and physical and geographic scenario of the coastal zone of Sao Paulo is complex due to factors such as difficulty in coastal management, mal-distribution of income in the municipalities, the overexploitation of real estate and touristic is some regions, the high population density and the social and environmental problems related to the port, oil-chemical and iron and steel complex of Baixada Santista, among others.

The IPCC (2007), based on different scenarios of GHG emissions requires the combination of thermal expansion of water by the melting of glaciers located on the continents may result in an increase in global mean sea level between 18 and 59 cm up to 2100.

The impacts forecasted for the coastal zone of Sao Paulo as a consequence of the global climate change, excluding those that would be common to continental areas (such as agriculture and climate, for instance), may be the following (NEVES; MUEHE, 2008):

– Coastal erosion;

– Damage to coastal protection constructions;

– Effects of the salt spray in concrete structures, such as buildings and sea facilities, and in historical monuments;

– Structural or operational damages to ports and terminals;

– Damages to urban constructions in coastal cities;

– Structural damages or operational harm to sanitation constructions;

– Exposure of dug pipes or structural damage to exposed pipes;

– Land sliding;

– Saline intrusion in estuaries and aquifers, what may affect the water harvesting;

– Changes in the mangroves, impacting avifauna including migratory ones, as well as over the local ichthyofauna;

– Damage to ecosystems due to the lack of freshwater, caused by the effects related to the saline instability;

– Damage to coral reefs.

2.3 Ports and Terminals

The ports have a significant role in domestic and international trade and are the main outlet and entry of cargo in the world, especially for long distance transportation. The two most important sea ports of the country are in the State of Sao Paulo: Santos and Sao Sebastiao.

The Port of Santos, located in the municipality of Santos in the center of the coast of the State, is the main Brazilian port and the largest one in the Southern Hemisphere, with a total operational area of 7.8 million square meters. Its facilities are located on the banks of the estuary, between the islands of Sao Vicente and Santo Amaro and the cities of Santos, Sao Vicente, Guaruja and Cubatao. In operation since 1892, it is the busiest containers port in Latin America, with a great diversity of cargo terminals (SÃO PAULO, 2009). The port is less than 100 km away from the industrial park of RMSP and it is connected to the producing centers of the countryside by Anchieta and Imigrantes highways and by two railways, Ferroban and MRS. Its geographic position is crucial to the development of the intermodal transport, ensuring a quick and low cost for material handling of the Southern Cone Countries (GOLEMBIOUSKI, [s.d.]).

The Port of Sao Sebastiao was built by the State with federal authorization for the construction and exploitation for 60 years, from 1934 to 1994, now postponed until 2007. Located in the North coast of the State, in the municipality of Sao Sebastiao, the Port of Sao Sebastiao was opened in 1955 and, since 1969 it has had facilities of PETROBRAS for the loading and unloading of oil and derivatives. From 1989 on, an agreement was signed between the State Secretariat of Transportation and Dersa (*Desenvolvimento Rodoviário S/A*) to administrate it. In 2007, the agreement was renewed for another 25 years, and created the *Companhia Docas de Sao Sebastião* to manage the port, a company linked to the State Secretariat of Logistics and Transport.

The ports may be directly affected by changes in the sea level, thus resulting consequences for their structures and operations (BRASIL, 2004). The vulnerability of the ports to the increase in the sea level may be evaluated by comparing the elevation record of the high tide with the height of the pier. The importance of the impacts may be measured by the type and quantity of cargo.

Other characteristics must be taken into account, such as the increase in the height of the waves that have reached the coast with a higher intensity, changing the construction and maintenance concept of the breakwater. Besides that, one must be attentive to the changes in the standard of sediments transportation and deposition, which may alter the sedimentation rates and places due to changes in the sea level (BRASIL, 2004).

2.4 Coastal Ecosystems

Sao Paulo State coast is characterized by ecosystems of great biological importance and beauty, housing a rich diversity of species scattered in sea, coast and insular areas, directly influenced by ocean, atmospheric and continental agents. These ecosystems are considered particularly sensitive to climate changes, once they are located in vulnerable areas and subject to the increase in sea level, to the exposure to extreme events, to the superficial temperature increase of the sea and to the acidification of the oceans.

Among the forecasted consequences of the climate changes in coastal ecosystems, special emphasis has been given to the increase in sea level, due to the direct impacts, with the inundation of lowlands, the erosion of the coast line, the most severe inundations by storm waves, the intrusion of sea water in estuaries and aquifers, the change in the amplitude of the tide in rivers, estuaries and bays and the changes in the standards of sediments and the consequent reduction of light for the benthonic organisms.

2.4.1 Sea Islands

Habitat for a great variety of sea species, the insular environments are highlighted for their ecologic relevance, low biodiversity[18] and high levels of endemism[19] – with a higher incidence of invertebrates, amphibians and reptiles, some of which are endangered. They are places for the rest and nesting for sea and migratory birds and the habitat for innumerous species of sea animals such as fish, mammals and turtles.

Priority area for the conservation of the sea and coast biodiversity in Brazil, the coast of Sao Paulo has 106 islands, 23 islets and 20 flagstones (SÃO PAULO, 1989) of different sizes. The insular set of Sao Paulo may be grouped in two distinct sectors: one in the North, where the islands are predominantly rocky, small in length, with few beaches or none. The other one, in the Center South of the State, has sedimentary islands, with wide plateaus of sea deposition and long and linear beaches.

The islands of Sao Paulo are used in different ways, as per their particularities, historical and geographic aspects and the distance from the mainland. If in some cases the process of occupation reaches intense urbanization levels, with many problems associated with anthropogenic actions, in others, the occupation does not exist or is by traditional inhabitants (*caiçaras*) living in semi-isolation.

In Brazil, the study of islands is still little diffused, with limited information about their biota, geology and geomorphology. The potential sea level rise caused by the climate changes makes the environment islands particularly vulnerable, mainly those with urban centers considered as special and of high risk. These are the islands of Cananeia and Comprida (Cananeia and Ilha Comprida) on the South Coast, Sao Vicente and Santo Amaro (Sao Vicente, Santos and Guaruja) in Baixada Santista, and Sao Sebastiao (Ilhabela) in the North Coast, are needed more detailed studies that lead to possible measures of prevention and mitigation.

2.4.2 Mangroves

Widely found in Brazilian coastal areas, the mangroves are one of the most typical tropical ecosystems restricted to the saline environments, of a relevant ecologic and geologic importance for the estuarine regions. It is an ecosystem that takes place in the transition between the sea and the land and its dynamic, just like the beaches, follows the daily move of the tides. They are places hard to penetrate and occupy, with a soft and silty soil,

[18] Number of species per area.
[19] Genetic differentiation of local species due to geographic isolation and reproductive.

constant flood and twisted vegetation, which, nevertheless, does not impede the exploratory use for the extraction of food and wood.

Besides its flora presenting singularities to the special environmental adaptations, it may be considered as poor in terms of diversity if compared to other coastal ecosystems. Nevertheless, its fauna is rich, especially in birds and invertebrates, turning the biome into an example of high biological productivity, considered as a genetic data base and a vivarium for hundreds of sea specimens, fish and birds (CARDOSO, 2000).

Mangroves near urban centers have problems associated with two different processes of urbanization, an official occupation by the resorts, where the original structure is destroyed and then urbanized, and other illegal, the slumming, as an invasive process, in the midst of the waters (stilts), without sanitation infrastructure and the consequent pollution of the environment.

Sensitive to any anthropogenic intervention, the mangroves of the State have undergone transformations by different processes. In the North coast and Baixada Santista, the mangroves are retracting due to the urban expansion and ports structures and by the occupation of second-home allotments (CUNHA-LIGNON et al., 2009).

Because it is an ecosystem of transition between the fluvial and marine systems, the mangrove is vulnerable to any rise in sea level, whose impacts may vary from the loss of the existing biome area, up to the compromising of some of its ecological features, either in the fauna of fish, crustaceans and birds, or in the flora, with the death of the vegetation by saline stress (ARASKI; ALFREDINI; AMARAL, 2008).

Being located at the transition between marine and river system, the mangrove ecosystem is an extremely vulnerable to any rise in sea level, with impacts ranging from loss of extension of the existing area of the biome, to the commitment of some of its ecological functions, is in the fauna of fish, crustaceans and birds, both in flora, with the death of vegetation by salt stress.

2.4.3 Restinga

Restinga are vegetal formations that cover almost all coastal areas flatlands, between the ocean and the crystalline mountains of the hills, rocky shoals and mountains. These vegetal communities have distinct physiognomies, under the marine and fluviomarine influence, ecologically classified as costal ecosystems of recent sedimentary origin (Quaternary) and that easily adapt to sandy and saline soils, poor in nutrients and with a very high water table (MACEDO,1993). The vegetation varies from shrubby to dense-ligneous, scattered in a mosaic in areas of great ecological diversity, considered edaphic communities due to depending much more on the soil nature than the climate (CONAMA, 1996).

Seen on beaches, sandy banks, dunes and depressions, these formations have the herbaceous, shrubby and arborous strata, in a physiognomic and floristic gradient with the Atlantic Lowland Forest forming an extensive ecotone (SÃO PAULO, 1996). It is the place of the richest sea sandy vegetation of the coast, not having its own fauna, varying very much according to the formation of the local landscape and the neighboring ecosystems (CARDOSO, 2000).

Restinga are scattered along the whole Brazilian coast, with a special highlight to the formations of the states of Bahia, Espirito Santo, Rio de Janeiro and Sao Paulo, in a great environmental and biological diversity, besides its important role in containing and stabilizing the dunes, serving as shield against its migration (SOUZA et al, 2008). Due to existing in the most flat areas of the coast, the restingas have been exploited in extreme levels, mainly by the non-sustainable extraction and the human settlement.

There are no more specific studies on the impacts of the climate changes in the areas of restingas, still little studied and protected. Nevertheless, it is known they are unstable and complex ecosystems, and thus vulnerable and fragile, where the excessive consumption of its resources, allied to the climate changes impact, leads to an unbalanced situation.

The impacts caused by the climate changes may include the sea level rise over the coast line, implying in the immediate alteration of the physical and biotic environments of all low coastal areas. Another preoccupying factor are the possible changes in the precipitation standards, with the occurrence of more storms (extra-tropical cyclones), causing inundations, coastal erosions, land sliding and silting of water bodies, with negative effects mainly over the biodiversity of the coastal biomes.

2.4.4 Beaches and Rocky Shores

Beaches are variable strips along the coast line, formed by unconsolidated mineral material, commonly sand, that has its shape defined by the action of the currents (marine and fluvial) and the winds, and whose morphology is directly associated to the dynamics of the movement of the waters (waves and tides). They are extremely important environments, either by their biological wealth, or by the role they play in relation to the other coastal biomes, providing several communities of fish, birds and turtles with food resources (LAMPARELLI; MOURA, 1999).

Its wealth and biological composition are variable, depending on its typology and geographic location. They also play an important role for society as a physical space, resisting well to intensive anthropogenic actions, being excellent locations for leisure and fun. Nevertheless, some anthropogenic actions have caused severe alterations, meaningfully impacting its ecological structure, such as the eradication of the restinga forest and jundu, urbanization close to the shore, lowering and contamination of the water table, pollution of the coastal waters, and alteration of the dynamics of the sea cycles.

The rocky shores are basic environments for the coastal biodiversity. They comprehend the rocky surfaces located along the coast line (MACEDO, 1993). A complex biological community develops in those surfaces, comprising from invertebrates that live fixed to rocks to several fish species that use its support for food and shelter.

Due to their restricted and sometimes dangerous aspect, these formations are not a landscape as beautiful as the beaches. In general, they are almost untouched, for not being directly affected by predatory human actions, mainly by the difficult condition of occupation and urbanization. Even though, many urban settlements were consolidated, in most of the cases aimed to a high income people, thus impacting the environment mainly due to the continuous burying of biologically meaningful areas (because of landfills and land sliding), or even due to the pollution by discharge of effluents and waste.

Studies on the impact of the climate changes in the coast line, especially those on the beaches and rocky shores, indicate the high vulnerability of those ecosystems, which may be affected by any changes in the sea level. Besides the morphologic impacts, the changes in the dynamics of the movement and the physical-chemical property of the waters may cause social and economic losses to the coast area due to its high dependence on the sea economic activities.

2.5 Mountain Areas

The relief of the Sao Paulo State comprises a medium frame of altitudes, except by the great gaps of the scarpments and the spurs of Serra do Mar and Serra da Mantiqueira, the mamelonar promontories and "seas of hills" of Paraiba do Sul River Basin and the rejuvenated mountains of the Sao Roque series. Its highest mountains are located in Serra da Mantiqueira, on the border with the states of Minas Gerais and Rio de Janeiro.

Presenting both landscape and cultural importance, the mountains hold a high biodiversity of fauna and flora, serving as a recharge area for aquifers and source of energy and resources, mainly for the stock of potable water. They are assets of national interest, considered as Permanent Preservation Areas (CONAMA, 2002), with the role of preserving the water resources, the landscape, the geological stability, the biodiversity and the gene flow of fauna and flora, protect the soil and ensure the well-being of human populations. Its degradation is usually associated to the direct human pressure, to the deforestation and/or clearance for agricultural and urban purposes, and indirectly by the erosion, many times caused by the bad use of the soil or bad weather.

Some attention has been paid in the last few years to the preservation and conservation of these environments in the country, mainly Serra do Mar, a large mountains system extended from Espirito Santo to the South of Santa Catarina, and whose scarps are believed to be arisen from vertical tectonic movements (epyrogenic) initiated about 80 million years ago, still in the Cretaceous era, thus resulting in the lifting of the edge of the continent in the whole Southeast Brazil.

Housing the main remains of Atlantic Forest of the State (83.6% of the total of the remaining biome), Serra do Mar is classified as the largest continuous preserved area of Atlantic Forest in Brazil, thus having almost the total of its area protected by the environmental legislation (including the Federal Constitution) and by Conservation Units, such as parks and state and national reserves and/or heritage listed (BRASIL, 1988).

There are no further studies on the effects of the global warming over the hills and mountains and/or remaining of Atlantic Forest in the State. Some experts advocate the hypothesis that increasing the temperature added to humidity rise, would be benefic for tropical forests, making them probably bigger. According to scientist Aziz Ab'Sáber, if the climate dynamics does not change much, mainly on the association of heat and humidity, nothing more drastic may happen, and the heat should then help keep the forest (JANSEN, 2007).

3

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Part II

1st Direct an Indirect GHG Anthropogenic Emissions Inventory of Sao Paulo State

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1

Introduction

1 Introduction

Due to the increase in the concentrations of Greenhouse Gases (GHG) in the atmosphere and the consequences of the climate change, in many parts of the world the governments have adopted measures in order to estimate the anthropogenic emissions of these gases. In that sense, Sao Paulo State, on November 9th, 2009, established the State Policy on Climate Change[20] (PEMC), law that, in its Article 2, defines the commitment of the State in face of the climate changes challenge and the objective to contribute towards reducing or stabilizing the concentration of the GHG in the atmosphere (SÃO PAULO, 2009a). This inventory is the result of cooperation between CETESB and the British Government. It estimates the emissions of direct and Indirect GHG according to the respective sectors of economy.

1.1 Important Information

According to Section V (Guidelines), Article 6, Item I of the PEMC, the Government's guideline is to prepare, update periodically and place at the disposal of the public in general, inventories of anthropogenic emissions, discriminated according to their sources, in addition to the removals through sinks, of the greenhouse gases not- controlled by the Montreal Protocol, making use of methodologies comparable both nationally and internationally.

This inventory is part of the State Communication, also defined by the PEMC. According to Article 28 of Law 13,798/2009, was assigned to the Executive Power through CETESB, organize and coordinate the anthropogenic emissions inventory (SÃO PAULO, 2010).

1.2 Guidelines

The GHG Emissions Inventory of Sao Paulo State was developed with references on the guidelines of the National Inventory elaborated by the Ministry of Science and Technology (MCT), described as follows:

1.2.1 Comparability

The method used for the elaboration of the Inventory, in order to generate an estimation comparable to the national one and other international and subnational ones, was IPCC's Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories – Guidelines 1996, published in 1997; the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories – Good Practice Guidance 2000, published in 2000; the Good Practice Guidance for Land Use, Land-use Change and Forestry – Good Practice Guidance 2003, published in 2003. Some of the estimations already take into account information

[20] The PEMC is defined by State Law n. 13,798 of November 2009 and regulated by the State Decree n. 55,947 of June 2010.

such as, for instance, emission factors published in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Guidelines 2006.

In the same way, the sequence of the presentation of the data and results of this document follow the Second National Communications of Brazil to the United Nations Framework Convention on Climate Change (BRASIL, 2010a).

From the whole inventory, only the information on the CFC and HCFC emissions has no similarities with the Second National Communication of Brazil. Estimate the emissions of those gases was a decision by the coordination of the GHG Inventory of Sao Paulo State, for besides destroying the ozone layer, they also contribute to the increase in the concentration of GHG.

1.2.2 Consistency

Having as premise that the data of emission activities and factors are the most adequate to the estimation method, the consistency of the results may be verified along time. The observation of the abnormal variation of the results (for instance: 50% more or less in a year period) indicates the need to check the data consistency, emission or processing factors.

The period whose emissions were estimated is from 1990 to 2008. In the meantime, the variation of the emissions estimations allows us to comprehend the facts associated to the sectors. The emissions variations take place due to the level of economic activity and the emission factors that may point out changes in the production technology.

In that respect, the historical series from 1990 to 2008 was properly represented in the Energy, Agriculture and Waste Sectors. The results of the estimations in the Land Use, Land-use Change, and Forestry Sector, are from 1995 to 2008. The preceding years were not estimated for technical reasons, among which are the lacks of data access. The results of the estimation of the Industrial Processes Sector were influenced by the results of the Metallurgy and Chemical Production Subsectors. The Chemical Industry Subsector has shown results from 1990 to 2005. The Metallurgical Industry Subsector has shown results from 2005 to 2008. Besides that, the use of substances in Refrigerators, Air Conditioners, Solvents and Aerosols does not extend along the whole considered period. From 1990 to 2008, we could notice a large variation in the use of substances at different moments. That way, these last inventories, especially those from the Industrial Sector, must be completed in the future.

1.2.3 Completeness

The Inventory of Sao Paulo State, elaborated according to the Second National Communication of Brazil, adopted the economic activity data of Sao Paulo State.

Additionally, it used emission factors more adequate to the local reality. In that sense, the emissions from charcoal mining, for instance, were not estimated, for such activity does not take place in Sao Paulo State. On the other hand, the estimations on the emissions of CFC and HCFC were included. So, in the State inventory, the emissions of the main direct and indirect gases, as well as part of those controlled by the Protocol of Montreal, emitted by the most relevant sector of economy were also estimated.

1.2.4 Transparency and Quality Control

Both the transparency and the quality control of this document were built along three years of development of the project. Eight open technical coordination meetings were held, with memories and records of attendants available in the website of CETESB. These technical meetings and the Reference Reports, at the end of the process, counted on the participation of 320 co-workers and 120 entities, such as universities, governmental organizations, non-governmental organizations (NGOs) and companies in general.

As for the transparency, this document summarizes the set of Reference Reports of all economic activities considered by IPCC, developed according to the already mentioned methods. The interpretation of the methods, which includes the decisions tree[21], the emissions factors and the equations, was registered in the said Reports that can be found in the website of CETESB[22]. The data on the State statistics base were used, national and international; all mentioned according to NBR 10520/2002 and NBR 6023/2002. The data on the emission activities and factors obtained from non-published sources were duly identified, thus allowing its verification.

As for the quality control, the Reference Reports were under Public Hearing for a period of four month, and some documents were disclosed in the website of CETESB for over ten months, receiving all sorts of contributions.

1.2.5 Accuracy

This inventory aimed for obtaining the most accurate results possible on the estimations of emissions and GHG sinks, aiming for avoiding the reduction of uncertainties. This inventory aims for representing the reality of the emissions as accurately as possible.

[21] The decision trees are methodological resources used to define, according to IPCC method, the strictness level to be used in the estimation.

[22] <www.cetesb.sp.gov.br/geesp>.

2

Greenhouse Gases

2 Greenhouse Gases

As determined by the United Nations Framework Convention on Climate Change (UNFCCC), the national inventory must include the anthropogenic emissions and removals of GHG. That way, just like the National Inventory, the Inventory of Sao Paulo State estimates the emissions of the following GHG: CO_2, CH_4, N_2O, HFC, PFC and SF_6. Other gases, such as CO, NOx and VOC, even not being Direct GHG, hold influence over the chemical reactions taking place in the atmosphere, and because of that, information on the anthropogenic emissions of those gases were also included. By adding data in relation to the National Inventory, this document includes the emissions of CFC and HCFC[23], which at the same time destroy the ozone layer and have a high Global Warming Potential (GWP), thus contributing to the aggravation of the climate change.

The GWP, or Global Warming Potential, is the measure of the radioactive effect during a certain time frame, caused by the emission of a GHG mass compared to the emission of a CO_2equivalent mass. This equivalent mass is written down as [Gg_{CO2eq}]. The GWP may be calculated for different time frames. The factors used in this document consider a time frame of 100 years. According to IPCC, some GWP averages are uncertain, especially for some gases whose detailed laboratory data are not available yet (IPCC, 2001).

The GTP, or Global Temperature Potential, is as alternative to GWP that measures average temperature variation of the global surface within a certain time frame, caused by the emission of a GHG mass compared to the emission of a CO_2equivalent mass (IPCC, 2007). Just like the GWP, this equivalent mass is written down as [Gg_{CO2eq}].

According to IPCC (2007), the GTP metrics would have an advantage over the GWP, because the first one is more directly related to the change in surface temperature change. Nevertheless, the IPCC does not invalidate the GWP concept nor provides guidance so it may be replaced by GTP.

This study adopts the GWP measure because it matches the IPCC reference. All measures whose unit is given in Gg_{CO2eq}, has the GWP as reference. Nevertheless, the GTP measure was also presented in order to allow the comparison and evaluation of possible differences in the results of the GHG estimations.

For the Indirect GHG, the result of the radioactive force effect was also estimated by IPCC for some gases, including CO. Nevertheless, in this report, the use of the GWP was only for the GHG. They are presented in Table II.1 and Figure II.1 according to the gases evaluated in this Inventory.

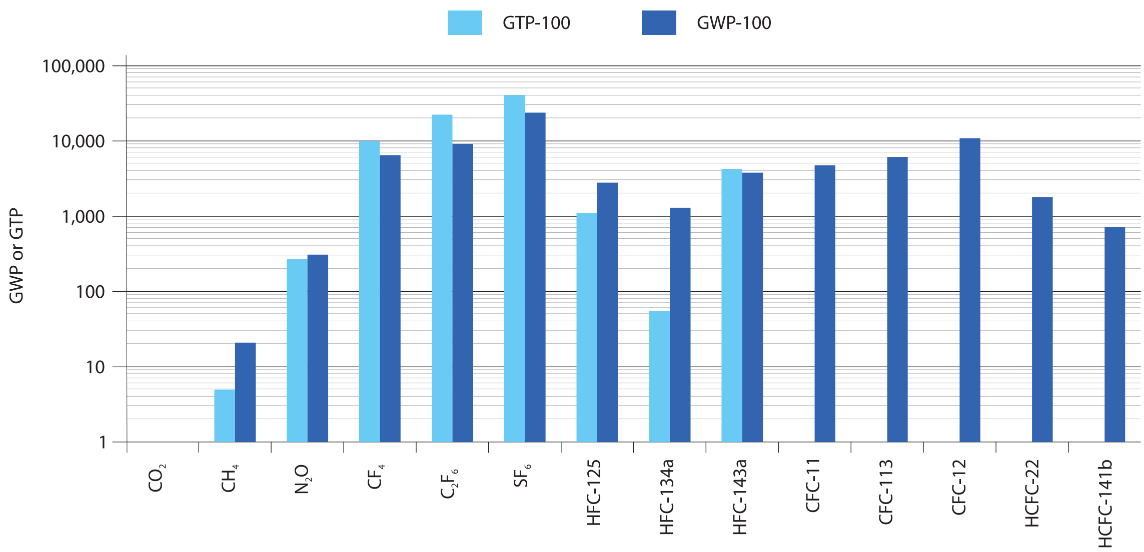
[23] Controlled by the Montreal Protocol.

Table II.1. GTP-100 and GWP-100

Gas	GTP-100	GWP-100
CO_2	1	1
CH_4	5	21
N_2O	270	310
CF_4	10,052	6,500
C_2F_6	22,468	9,200
SF_6	40,935	23,900
HFC-125	1,113	2,800
HFC-134a	55	1,300
HFC-143a	4,288	3,800
CFC-11		4,750
CFC-113		6,130
CFC-12		10,900
HCFC-22		1,810
HCFC-141b		725

Note: GWP and GTP are presented for a horizon of 100 years.
Source: IPCC (2000b, 2007).

Figure II.1. GTP-100 and GWP-100 Factors



Note: GWP and GTP are presented for a horizon of 100 years.

3

Inventoried Sectors

3 Inventoried Sectors[24]

According to the structure presented by IPCC, the Inventory is divided into the following Sectors: Energy, Industrial Processes, Agriculture, Land Use, Land-use Change, and Forestry and Waste. Those will be presented in further details in Chapter 3 of this document, as well as the obtained results.

3.1 Energy[25]

This Sector estimates all anthropogenic emissions from production, transformation and consumption of energy. That includes both the emissions from fuel combustion as the fugitive emissions from production, transformation, distribution and consumption of energy (BRAZIL, 2010a)

3.1.1 Fuel Combustion Emissions: Reference Approach (Top-down) and Sectoral Approach (Bottom-up)

This Sector includes the emissions of CO_2 by the oxidation of the carbon contained in different fuels during burning for the generation of other forms of energy, such as electricity, heat or mechanic energy. The emissions of other GHG are also registered during the combustion process, such as CH_4 and N_2O, as well as CO, NOx and VOC.

The CO_2 emissions of the biomass fuels such as firewood, charcoal, alcohol and sugarcane bagasse were not included in this estimation. According to IPCC (1996, 2000a), the emissions of the renewable fuels do not generate liquid emissions and the emissions from the non-renewable fuels are included in the Land Use, Land-use Change, and Forestry Sector. The other GHG emissions of the biomass fuels are considered as recommended by IPCC.

The top-down approach considers only the energy supply in the country, without details on how that energy is consumed to estimate the emissions of CO_2. The bottom-up approach identifies where and how the emissions take place (BRASIL, 2010a). The same considerations were made in this State Inventory, using for that purpose the data of the Sao Paulo State Energy Balance (BEESP), (SÃO PAULO, 2009c).

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[24] According the Article 7 of Law 13,798/2009, the Emissions Inventory is discriminated according to their emissions sources in addition to the removals through sinks of the GHG, according to the Legal frame. That way, the Inventoried Sectors were (1) Energy, (2) Industrial Processes, including the Solvents and Other Products Use, (3) Agriculture and (4) Waste. Besides those set up by Law, the methods of IPCC (1996, 2000a and 2006) consider the Land Use, Land-use Change, and Forestry Sector, which was included to the document. Such changes aim for the adaptation of the document to the IPCC method adopted both national and internationally.

[25] According the Article 7 of Law 13,798/2009, the Emissions Inventory of the Energy Sector comprises the Subsectors included in the legal text, added by others, which complement the set of information, the following way: Fuel Combustion: Reference (Top-down) and Sectoral (Bottom-up) Approaches; Refining and Transportation of Oil and Derivatives; Air Transport; Rail Transport; Water Transport; and Road Transport. Such changes aim for the adaptation of the document to the IPCC method adopted both national and internationally.

3.1.2 Refining and Transportation of Oil and Derivatives

In this Subsector are included the GHG emissions during the transportation and treatment process of oil, natural gas and charcoal.

The emissions associated to oil and natural gas includes the fugitive emissions of CH_4 during the transportation and distribution in ducts and ships and during the treatment in refineries. The emissions of CO_2 from flaring are also considered in the refinery facilities (PETROBRAS, 2011).

3.1.3 Transportation

In the Transportation Subsector were inventoried the modes of transport include air, rail, water, and road in the State.

3.1.3.1 Air Transport

In this inventory are addressed GHG emissions and pollutants on civil aviation in Sao Paulo State, including all with the purpose of commercial use as transport of passengers or cargo; they are considered the international travel, interstate and domestic, including regular and charter flights, including the air taxi and general aviation aircraft (agricultural, private aircraft and helicopters) (IMT, 2011a). The gases emitted from aircraft engines are composed of approximately 70% of CO_2, a little less than 30% of water vapor and less than 1% of NOx, CO, SOx, MP[26] and traces of other compounds. Modern turbines emit little or no amount of N_2O (IPCC, 2006 apud IMT 2011a).

3.1.3.2 Rail Transport

Currently, the railway system of Sao Paulo State has a train network of approximately 5,000Km, connecting regions from the interior and from other states to the Sao Paulo Metropolitan Region (RMSP) and to the Port of Santos.

This inventory did not estimate GHG emissions of metropolitan rail transportation, since this Subsector consumes only electricity of the National Interconnected System (SIN), whose emissions are presented in the inventory of the Energy Sector. The railway for the transport of cargo was privatized, but under federal control and the government of Sao Paulo State has very limited action over this sector. This made it difficult to obtain the best data of activity and emission factors (SÃO PAULO, 2009b). The estimates of GHG emissions (CO_2, CH_4, N_2O) were based on fuel consumption of diesel and fuel oil, presented in BEESP.

[26] Particulate Matter (PM), Sulfur Oxide (SOx).

These estimates did not consider the source and destination travel data and consequently, details of the definition of the allocation of emissions in Sao Paulo State. The emissions of CH_4 and N_2O from the burning of fuel oil were not considered because there are no emission factors specific to the country or state, and not even default emission factors of IPCC (CETESB, 2011h).

3.1.3.3 Water Transport

In the Water Transport Subsector the main environmental impacts are related to port enterprises and ships. Sao Paulo State presents Water Transport by inland waterway (waterways and terminals), lake and river, and crossing navigation, and cabotage (SÃO PAULO, 2007 apud CETESB, 2011g). This Inventory has estimated the emissions of CO_2, CH_4 and N_2O, resulting from the consumption of fossil fuels in the Water Transportation (CETESB, 2011g).

3.1.3.4 Road Transport

The Subsector of Road Transport includes all types of vehicles equipped with combustion engine, subject to licensing for public roads: cars, motorcycles, trucks and buses. The machines and equipment for construction, agricultural and special use are not part of the scope (IMT, 2011b). The GHG registered in this Subsector are CO_2 CH_4 and N_2O, and the indirect GHG as well as CO, NOx and VOC.

3.2 Industrial Processes[27]

The following Subsectors of Industrial Processes are taken into consideration: Cement Production, Lime Production, Chemical Industry, Metallurgical Industry, Food and Beverage Industry, Glass Industry, Pulp and Paper Industry, and Solvent and other Product Use, which includes the Fugitive Emissions from the Electricity Distribution, manufacture and Use of Foam, Use of Aerosols, Use of Solvents and Cleaning Agents, Refrigeration and Air Conditioning. In Industrial Processes are estimated the anthropogenic emissions as result from the productive processes of the industry, which are not the result of burning fuel, these last ones reported in the Energy Sector (BRASIL, 2010a).

[27] According the Article 7 of Law 13,798/2009, the Emission Inventories of the Industrial Processes Sector and the Solvents and Other Products Use were gathered in the Industrial Processes Sector. It is composed of the Subsectors predicted in legal text, added of other, which complement the set of information. Such changes aim for the adaptation of the document to the IPCC method adopted both national and internationally.

3.2.1 Cement Production

The emission of CO_2 from Cement Production occurs, for the most part (90%), during the production of cement clinker (intermediate material of cement), whether in the calcination/from decarbonation of raw material, either by burning fuel in the interior of the furnace.

The remaining emissions result from the transportation of raw materials from electricity consumption in the factories (CETESB; SNIC; ABCP, 2011). Were estimated the emissions of the process from decarbonation of limestone, which occur in calcination furnace for manufacture of clinker. Emissions from the combustion of fuel in the interior of the furnace are dealt in the reports of the Energy Sector, according to the method of the IPCC (SNIC; ABCP, 2010).

3.2.2 Lime Production

In This Subsector are included the emissions that occur in the calcination of limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), as well as the emissions from the production and consumption of sodium carbonate (Na_2CO_3) or kali. In the glass industry, steel industry and in the magnesium production (Mg) also occur CO_2 emissions by calcination of limestone and dolomite (BRASIL, 2010a). In the production of Na_2CO_3, may occur emissions of CO_2 depending on the production process, it is not the case in Brazil. But during the consumption of Na_2CO_3 in other industries, such as glass, occurs the emission of CO_2 (BRASIL, 2010a).

3.2.3 Chemical Industry

In this Subsector, the most significant emissions are: the CO_2, resulting from the production of ammonia (NH_3), the N_2O and NOx emissions during the production of nitric acid (HNO_3) and N_2O, CO and NOx emissions resulting from the production of adipic acid ($C_6H_{10}O_4$) are the most important. VOC emissions may also occur in the petrochemical industry, during the production of other chemicals (BRASIL, 2010a).

3.2.4 Metallurgical Industry

This Subsector includes the steel and iron alloys, where CO_2 emissions during the process of reduction of iron ore, and the aluminum industry, where emissions of perfluoroethane (CF_4), perfluoroethane (C_2F_6), CO_2, CO and NOx. Other emissions for the steel industry are reported in the Energy Sector (electricity production) and in the production of lime (production of lime, use of limestone and dolomite) (BRASIL, 2010a).

There is CO_2 emissions in the aluminum industry during the process of electrolysis. Emissions of other GHG (CF_4 and C_2F_6) can occur if there is a rapid increase in voltage difference, generated by the reduction of aluminum oxide in electrolytic cell. Depending on the technology used emissions of CO and NOx may also occur (BRASIL, 2010a).

The emissions of steel production, estimated by the Brazil Steel Institute (IABr apud CETESB; IABr; IMT, 2011), observes the method of the World Steel Association (WSA) and include the GHG emissions for the Scope 1[28], and all the stages listed below: sintering, coke ovens, calcination, blast furnace, steel mill and thermal power plant. Other metallurgical processes were not included in the inventory of this Subsector in Sao Paulo State.

3.2.5 Food and Beverage Industry

According to IPCC (1996, 2000a), the Subsector of Food and Beverage Industry , VOC emissions occur during the processes of transformation of primary products, such as, for example, the production of sugar, animal feed and beer (BRASIL, 2010a). Only these emissions were estimated.

3.2.6 Glass Industry

According to IPCC (1996, 2000a), the main raw materials used as the source of carbonate in Glass Industry that emit CO_2 during the merger process are the limestone ($CaCO_3$), dolomite ($CaMg(CO_3)_2$) and sodium carbonate (Na_2CO_3). The emissions of VOC are also considered indirect GHG that increase these emissions directly related to the increase in the production of glass.

3.2.7 Pulp and Paper Industry

The Subsector of Pulp and Paper Industry generates emissions during the treatment to which it is submitted to the pulp of wood. However, the emissions depend on the type of raw material used and the quality of the product that you want to obtain. In Brazil, the eucalyptus tree is mainly used as a source of cellulose and the emissions that occur are CO, NOx and VOC (BRASIL, 2010a).

[28] Identifies the scope of the Inventory.

3.2.8 Solvent and Other Product Use

The use of solvents and other products imply the emission of several greenhouse gases. The activities which correspond to these emissions are: fugitive of the Sector of Distribution of Electricity, foams, aerosols, solvents and cleaning agents, and refrigeration and air conditioning.

3.2.8.1 Fugitive Emissions from Electricity Transmission and Distribution

The SF_6 replaces the oil in the electrical isolation of the circuit breakers of the processors. It is a non-toxic gas and condenser, non-flammable, which allowed for the development of electrical equipment from high capacity and performance, more compact and safe.

The SF_6 is not produced in Brazil. Thus, the emissions informed in the Inventory are only due to leaks in the equipment installed in the country (BRASIL, 2010a).

3.2.8.2 Foams

The manufacture of foams consists of four Subsectors: rigid foams, flexible, molded and polystyrene. The main estimated gases were: the CFC-11, HCFC-141b and the HFC-134a (IMT, 2011c).

Due to the great variety of application, several industry segments use Foams as part of their products. According to the United Nations Development Program (UNDP, 2007 apud IMT, 2011c), they are: the automobile, furniture, civil construction, refrigeration and packaging. The estimate developed in this Inventory considers, as recommended by the IPCC (2006), emissions due to manufacture and use.

3.2.8.3 Aerosols

According to IMT (2011c), since the beginning of the production of aerosols, various propellants were used, such as CO_2, methyl chloride (CH_3Cl), dimethyl ether (CH_3OCH_3), butane (C_4H_{10}) and vinyl chloride (C_2H_3Cl). With the advancement of the chemical industry, the use of synthetic propellants, replacing the previous, was one of the essential factors to the mass production of Aerosols and the consolidation of its application in cosmetics and medicinal products. This Inventory estimates the emissions of CFC-11, CFC-12 by the use of aerosols.

3.2.8.4 Solvents

Most of the solvents used in Brazil are derived from the refining of petroleum or the processing of naphtha. These, in turn, are the raw material for the adhesives industries, rubber artifacts, cosmetics, pesticides, detergents, explosives, packaging, specialty chemicals, synthetic fibers, pigments, dyes, plastics, resins, hygiene and cleaning products, basic chemicals, paints and varnishes (IMT, 2011c).

3.2.8.5 Refrigeration and Air Conditioning

The applications of refrigeration and air conditioning represent the Subsector which is the largest consumer of chemicals halogenated used as refrigerants (CFCS, HCFCS and HFCS) (IMT, 2011c).

The CFC and HCFC, in addition to being substances that deplete the ozone layer, are also potent GHG (IMT, 2011c). For this reason, the refrigeration industry has sought substitutes. In the past 15 years, the most commonly used refrigerants evolved from four substances CFC-11, CFC-12, HCFC-22 and R-502[29], for nearly fifty fluids including HFC, NH_3, CO_2 and Hydrocarbons (HC). The HFC do not contain chlorine (Cl), so they do not destroy the ozone layer, but contribute to the process of global warming.

3.3 Agriculture[30]

Due to the extent of arable land and available for grazing, agriculture and livestock are important economic activities in the Sao Paulo State. Several practices result in GHG emissions.

3.3.1 Livestock: Enteric Fermentation and Manure

One of the largest sources of CH_4 emission is the enteric fermentation, which corresponds to a stage in the digestion of ruminants herbivores. The intensity of this process depends on various aspects such as: the type of animal, its food, the intensity of their physical activity and the various practices of breeding.

The various management alternatives in manure of animals can generate different emissions of CH_4 and N_2O. The anaerobic decomposition produces CH_4, but the greater is the anaerobic treatment process, the greater is the proportion of CH_4 for the same quantity of manure.

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[29] Refrigerant gas.

[30] According the Article 7 of Law 13,798/2009, the Emissions Inventory of the Agriculture Sector comprises the Subsectors included in the legal text, added by others, which complement the set of information, the following way: Livestock: Enteric Fermentation and Manure; Irrigated Rice Cultivation; Burning of Agricultural Residues; Agricultural Soils and Manure Management; and Liming Soil. Such changes aim for the adaptation of the document to the IPCC method adopted both national and internationally.

3.3.2 Irrigated Rice Cultivation

Another important source of CH_4 is the cultivation of rice in flooded fields or in areas of lowland. This is due to the anaerobic decomposition of organic matter present in water. In the State, as well as in the rest of the country, most of the rice is produced in non-flooded areas, reducing the importance of the Subsector in the emissions of CH_4.

3.3.3 Burning of Agricultural Residues

The incomplete burning of agricultural residues produces emissions of CH_4, N_2O, NOx, CO and VOC. The practice of Burning of Agricultural residues occurs mainly in the culture of sugarcane. The CO_2 emitted is not considered as liquid emission, because through photosynthesis, the same quantity of CO_2 is necessarily absorbed during the growth of the plants (BRASIL, 2010a).

3.3.4 Agricultural Soils and Manure Management

In this Subsector, fit in the cultivation of organic soils which emit N_2O through the increase of the mineralization of organic matter, the plant residues left on the field and through the use of nitrogen fertilizers, both synthetic and animal, in agricultural soils, and the deposition of manure of animals on pasture.

3.3.5 Liming Soil

The Liming, or application of limestone, is an agricultural practice that corrects the acidity of the soil, provides calcium (Ca) and Magnesium (Mg), improves the efficiency of fertilizers, among other effects. This Inventory shows that consumption of limestone in the agriculture of Sao Paulo State and the estimates of CO_2 emissions (CETESB, 2011a).

3.4 Land Use, Land-use Change, and Forestry[31]

In This Sector, changes are estimated in carbon stocks and emissions and removals of GHG. These estimates are based on the sum of the areas that have remained with the same use (in cases where there was change in carbon stocks) and those that were converted to other uses. Changes are estimated in carbon stock of the forest above the ground, from the carbon of the roots and from the soil (FUNCATE, 2011).

[31] According the Article 7 of Law 13,798/2009, The State Inventory does not provide estimates of emissions from the Land Use, Land-use Change, and Forestry. However, the Sector has been included in this document aiming for its adaptation to the IPCC method adopted both national and internationally.

Were estimated the changes in liquid stock that occurred in the State in the periods from 1994 to 2002, 2002 to 2005 and 2005 to 2008 (FUNCATE, 2011). These data were annualized, converted into arithmetic averages quantities of the periods considered.

3.5 Waste[32]

The emission of CH_4 occurs with the disposal of solid waste in landfills. In These places, anaerobic condition may occur with the consequent generation of CH_4. The better are the operational conditions of the landfill and greater is the depth, the greater is the potential for emission of CH_4.

The incineration of municipal waste is an activity of little relevance in Brazil. The same can be said for Sao Paulo State. The organic load of domestic and commercial sewage, and industrial effluents, can generate CH_4 is subjected to anaerobic treatment. Emissions of N_2O also occur by domestic sewage, due to the content of Nitrogen (N) in human nutrition (BRASIL, 2010a).

[32] According the Article 7 of Law 13,798/2009, Emissions Inventory of Waste Sector is as was predicted in the legal text.

4

Anthropogenic Emissions by Sources and Removals through Sinks of the GHG by Gas

4 Anthropogenic Emissions by Sources and Removals through Sinks of the GHG by Gas

In 2005, the liquid anthropogenic emissions of GHG were estimated at 88.844 Gg_{CO2}; 1.268 Gg_{CH4}; 63 Gg_{N2O}; 0.002 Gg_{SF6} and 0.8 $Gg_{HCFC\text{-}141b}$. In 2008, emissions were estimated at 95,762 Gg_{CO2}; 1,152 Gg_{CH4}; 41 Gg_{N2O}; 0.002 Gg_{SF6} and 1.1 $Gg_{HCFC\text{-}141b}$.

Between 1990 and 2008, in Sao Paulo State the total emissions of CO_2, CH_4 and N_2O varied in 63%, 12% and -3%, respectively. The indirect GHG, in 2008, were estimated at 554 Gg_{NOx}; 889 Gg_{CO}; and 567 Gg_{VOC}. Between 2005 and 2008, the total emissions of Sao Paulo State of CO_2, CH_4 and N_2O varied in 10%, -9.1% and -34.9%, respectively.

4.1 Emissions and Removals of Carbon Dioxide

The emissions and removals of CO_2 are divided in the following Sectors: Energy, Industrial Processes, Agriculture, LULUCF and Waste. In Sao Paulo State, the largest share of estimated liquid emissions of CO_2 is derived from the Energy Sector which accounted for 84.7% of GHG emissions in 2005, followed by The Industrial Processes Sector with 13.7% of emissions. The Agricultural Sector contributed 1.6% of CO_2 emissions.

Table II.2 shows the CO_2 emissions according to the involved sectors between the years of 1990 to 2008 The Figure II.2 and Figure II.3 show the evolution of CO_2 emissions by Sector in the respective years in Gg and in percentage. Table II.3 shows the removals of CO_2 in the Sector of LULUCF, which, in 2005, were 3,918 Gg_{CO2}.

Table II.2. CO_2 Emissions According to the Involved Sectors in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[$Gg_{CO2}.year^{-1}$]									
Energy	56,395	58,043	58,629	59,725	64,795	67,095	74,634	79,800	80,748	81,278
Industrial Processes	3,396	3,540	3,046	3,011	3,268	3,724	4,300	4,738	4,744	4,495
Agriculture	931	968	1,509	1,589	2,009	1,479	1,512	1,639	1,583	1,410
Waste	0.01	0.31	20.36	8.21	12.70	12.70	12.70	13.31	13.22	16.58
LULUCF	NE	NE	NE	NE	NE	0	0	0	0	0
Total	**60,722**	**62,552**	**63,205**	**64,333**	**70,085**	**72,311**	**80,460**	**86,189**	**87,088**	**87,200**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[$Gg_{CO2}.year^{-1}$]									
Energy	80,161	78,298	75,852	76,636	77,996	78,584	79,375	83,221	85,335	
Industrial Processes	4,577	3,978	3,864	3,394	3,418	12,685	12,281	12,968	12,218	
Agriculture	1,462	1,380	1,408	1,691	1,327	1,476	1,805	1,865	1,462	
Waste	19.04	16.92	16.92	16.92	16.92	16.92	17.98	18.84	19.69	
LULUCF	0	0	0	0	0	0	0	0	0	
Total	**86,219**	**83,672**	**81,140**	**81,738**	**82,758**	**92,762**	**93,478**	**98,074**	**99,034**	

Note: NE – Not estimated.

Table II.3. CO_2 Removals in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[$Gg_{CO2}.year^{-1}$]									
LULUCF	NE	NE	NE	NE	NE	1,333	1,333	1,333	1,333	1,333

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[$Gg_{CO2}.year^{-1}$]									
LULUCF	1,333	1,333	1,333	3,918	3,918	3,918	3,282	3,282	3,282	

Note: NE: Not estimated.

Figure II.2. CO_2 Emissions in Sao Paulo State (Gg)[33]

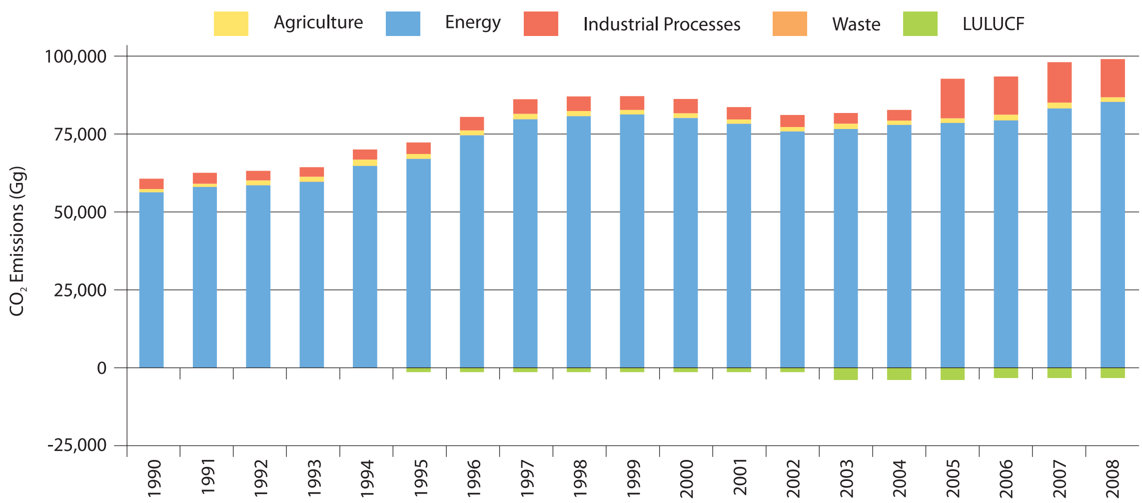
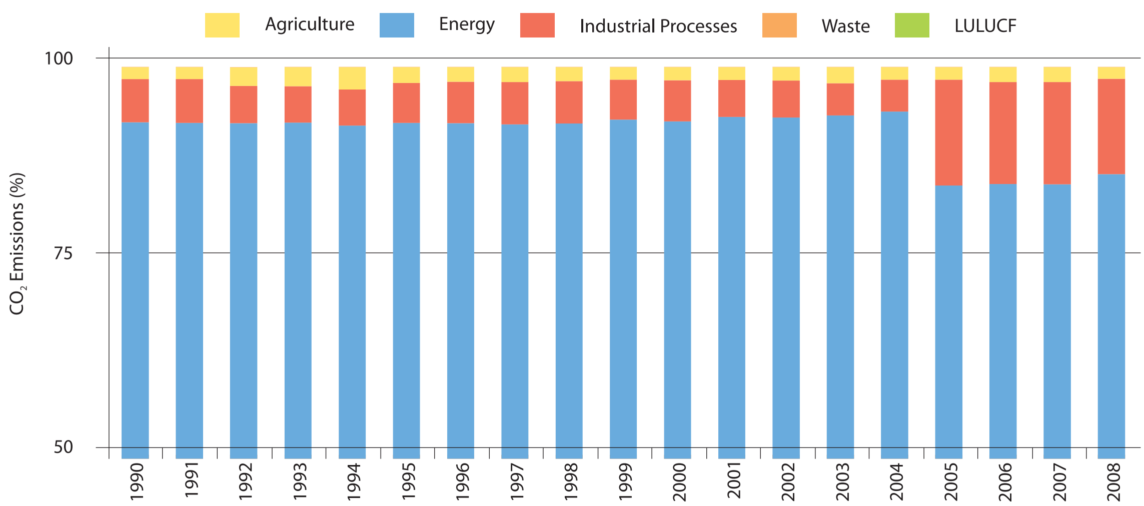


Figure II.3. CO_2 Emissions in Sao Paulo State (%)



[33] CO_2 emissions from LULUCF Sector are estimated only from 1994. CO_2 emissions of the Industrial Sector are estimated for the whole period. However, there are variations in inventory periods - the Chemical Industry estimates range from 1990 to 2005 (no results for the years 2005 to 2008), and Metal Industry, estimates range from 2005 to 2008 (there are no results for the year 1990 to 2004).

Figure II.4 and Figure II.5 show the CO_2 emissions in 1995 and 2005 by involved sectors.

Figure II.4. CO_2 Emissions by Sector, in 2005, in Sao Paulo State (92,762 Gg)

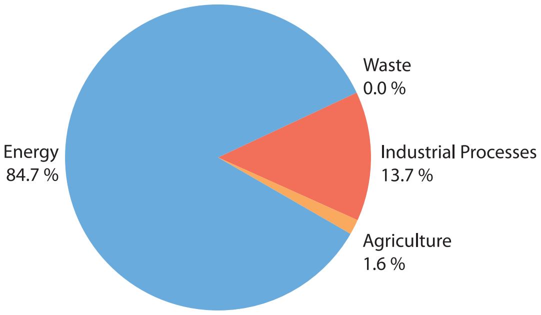
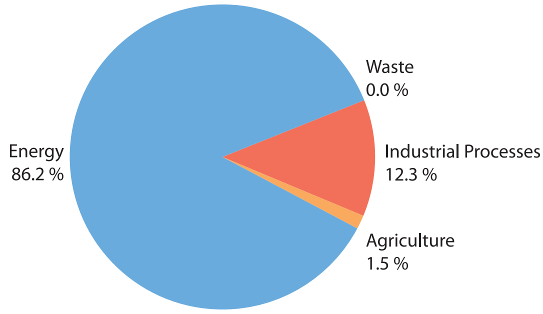


Figure II.5. CO_2 Emissions by Sector, in 2008, in Sao Paulo State (99,034 Gg)



4.2 Methane Emissions

The emissions of CH_4 in Sao Paulo State is the result of numerous activities, such as, for example, landfills, sewage treatment, processing and transportation of oil and natural gas, agricultural activities, burning of fossil fuels and biomass, and some industrial processes. The Agricultural Sector is the most responsible for the emissions of CH_4 (62.4% in 2005), and the main source is the enteric fermentation.

In the Energy Sector, the emission of CH_4 occurs due to the incomplete burning of fuels and the fugitives of CH_4 during the processes of production and transportation of oil and natural gas. Its responded for 2.3% of the total emissions of CH_4 in 2005. In Industrial Processes, the CH_4 emissions occur during the production of petrochemicals. The Waste Sector is the second largest emitter of CH_4, with 35% of total emissions in 2005.

Table II.4. CH_4 Emissions by Sector in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[$Gg_{CH4}.year^{-1}$]									
Energy	16	17	17	18	19	20	21	22	24	25
Industrial Processes	1	1	1	1	1	1	1	1	1	2
Agriculture	734	733	743	759	770	781	765	764	763	779
Waste	278	281	294	292	301	309	323	324	340	345
LULUCF	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total	**1,028**	**1,032**	**1,055**	**1,069**	**1,091**	**1,111**	**1,111**	**1,111**	**1,127**	**1,151**

	2000	2001	2002	2003	2004	2005	2006	2007	2008
	[$Gg_{CH4}.year^{-1}$]								
Energy	22	24	25	25	27	30	34	34	35
Industrial Processes	2	1	1	1	2	2	NE	NE	NE
Agriculture	782	791	800	825	810	792	763	710	678
Waste	365	382	407	426	422	445	446	420	438
LULUCF	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total	**1,171**	**1,198**	**1,233**	**1,278**	**1,261**	**1,268**	**1,244**	**1,164**	**1,152**

Note: NE: Not estimated.

Table II.4 shows the CH_4 emissions in accordance with the sectors involved between the years 1990 to 2008. Similarly, the Figure II.6 and Figure II.7 show the evolution of CH_4 emissions over the years in Gg and in percentage.

Figure II.6. CH_4 Emissions in Sao Paulo State (Gg)

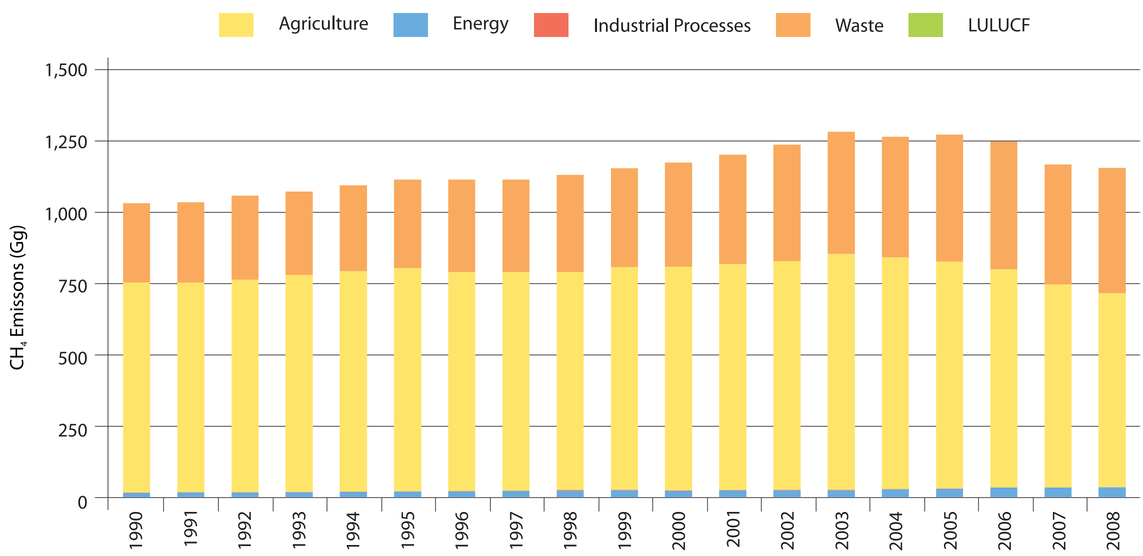


Figure II.7. CH_4 Emissions in Sao Paulo State (%)

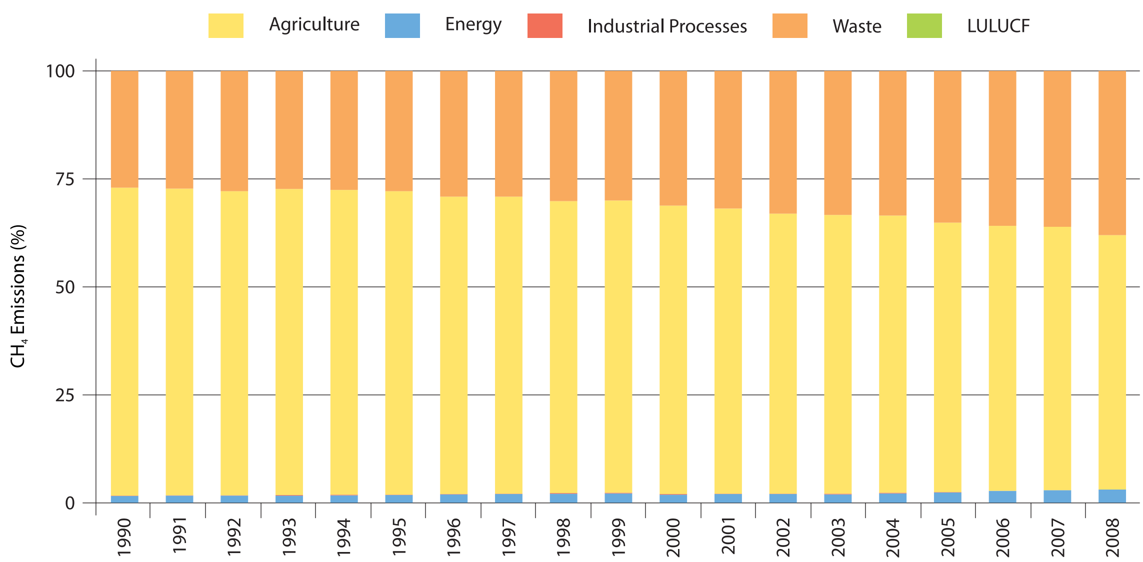


Figure II.8 and Figure II.9 show the CH_4 emissions in 2005 and 2008. Table II.5 and Figure II.10 shows the CH_4 emissions in CO_{2eq}, according to the GWP indicated in the session corresponding to this document.

Figure II.8. CH_4 Emissions by Sector, in 2005, in Sao Paulo State (1,268 Gg)

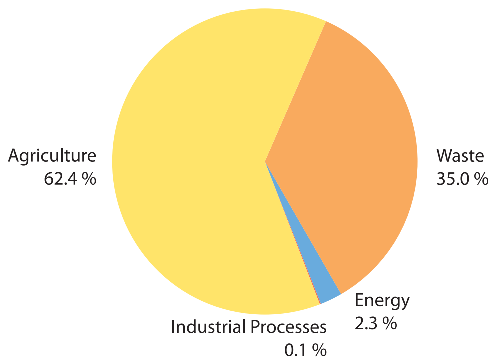


Figure II.9. CH_4 Emissions by Sector, in 2008, in Sao Paulo State (1,152 Gg)

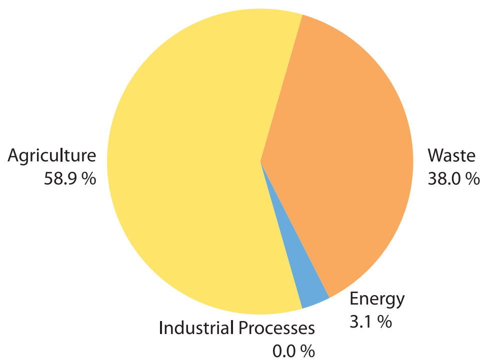


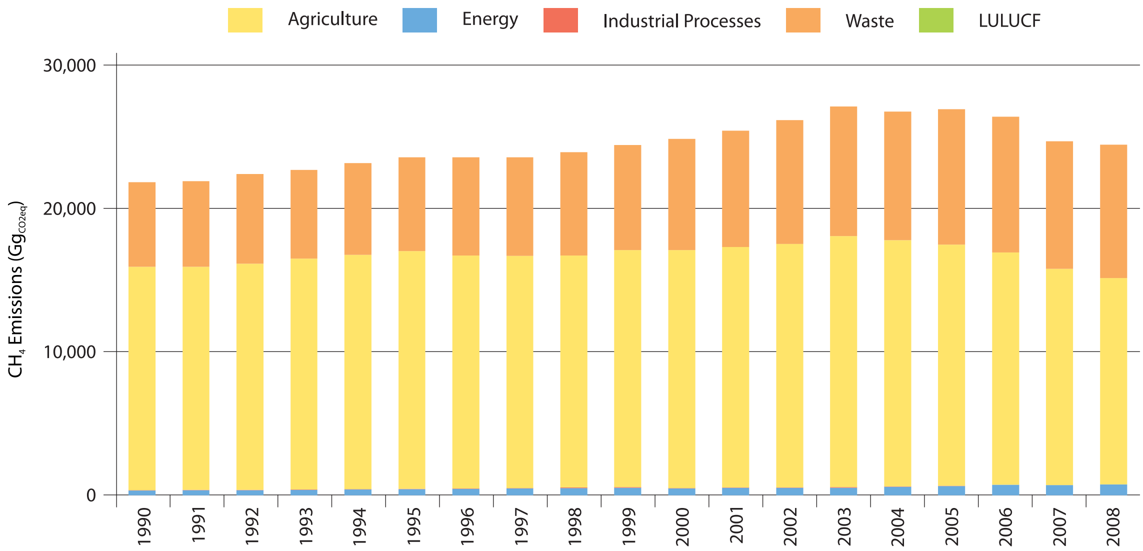
Table II.5. CH_4 Emissions by Sector in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{CO2eq} \cdot year^{-1}]$									
Energy	332	353	357	372	398	417	446	462	495	516
Industrial Processes	23	18	19	21	22	21	25	30	31	32
Agriculture	15,405	15,386	15,607	15,932	16,179	16,399	16,061	16,035	16,016	16,357
Waste	5,838	5,905	6,175	6,128	6,315	6,492	6,790	6,799	7,136	7,255
LULUCF	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total	**21,598**	**21,663**	**22,157**	**22,454**	**22,914**	**23,329**	**23,321**	**23,327**	**23,677**	**24,161**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{CO2eq} \cdot year^{-1}]$									
Energy	466	500	515	519	572	624	712	708	742	
Industrial Processes	32	31	28	31	33	32	NE	NE	NE	
Agriculture	16,425	16,605	16,802	17,331	17,001	16,627	16,032	14,910	14,242	
Waste	7,658	8,023	8,552	8,950	8,868	9,349	9,75	8,818	9,199	
LULUCF	NE	NE	NE	NE	NE	NE	NE	NE	NE	
Total	**24,581**	**25,159**	**25,897**	**26,832**	**26,474**	**26,632**	**26,119**	**24,436**	**24,183**	

Note: NE: Not estimated.

Figure II.10. CH_4 Emissions by Sector in Sao Paulo State (Gg_{CO2eq})



4.3 Nitrous Oxide Emissions

The emissions of N_2O are result of various activities such as agricultural practices, industrial processes, burning of fossil fuels and biomass (BRASIL, 2010a).

In Sao Paulo State, N_2O emissions occur predominantly in the Agriculture Sector, by enteric fermentation (approximately 59.8% in 2005).

In the Energy Sector, the emission of N_2O is the result of the incomplete burning of fuels. This Sector represented 4.1% of total emissions in 2005

Table II.6. N_2O Emissions in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{N2O}.year^{-1}]									
Energy	1	1	1	1	2	2	2	2	2	2
Industrial Processes	11	13	12	16	16	17	13	12	19	19
Agriculture	31	31	32	33	34	34	34	34	34	34
Waste	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
LULUCF	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total	**42**	**46**	**46**	**50**	**51**	**53**	**49**	**48**	**55**	**56**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{N2O}.year^{-1}]									
Energy	2	2	2	2	3	3	3	3	3	
Industrial Processes	20	16	20	18	22	23	NE	NE	NE	
Agriculture	35	35	36	37	37	38	38	38	38	
Waste	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
LULUCF	NE	NE	NE	NE	NE	NE	NE	NE	NE	
Total	**56**	**54**	**58**	**57**	**61**	**63**	**40**	**41**	**41**	

Note: NE: Not estimated.

In the Industrial Processes Sector, N_2O emissions occur during the production of nitric acid (HNO_3) and adipic acid ($C_6H_{10}O_4$) and it represents 36% of total emissions in 2005 in Sao Paulo State.

In the Waste Sector, emissions of N_2O occur due to the presence of molecular nitrogen (N2) in the protein of human consumption, which are released in the soil or in water bodies. Another part comes from the incineration of residues, but these quantities are insignificant in the context of the State. N_2O emissions in the Sao Paulo State are presented in Table II.6, Figure II.11, Figure II.12 and Figure II.13.

Figure II.11. N_2O Emissions in Sao Paulo State (Gg)

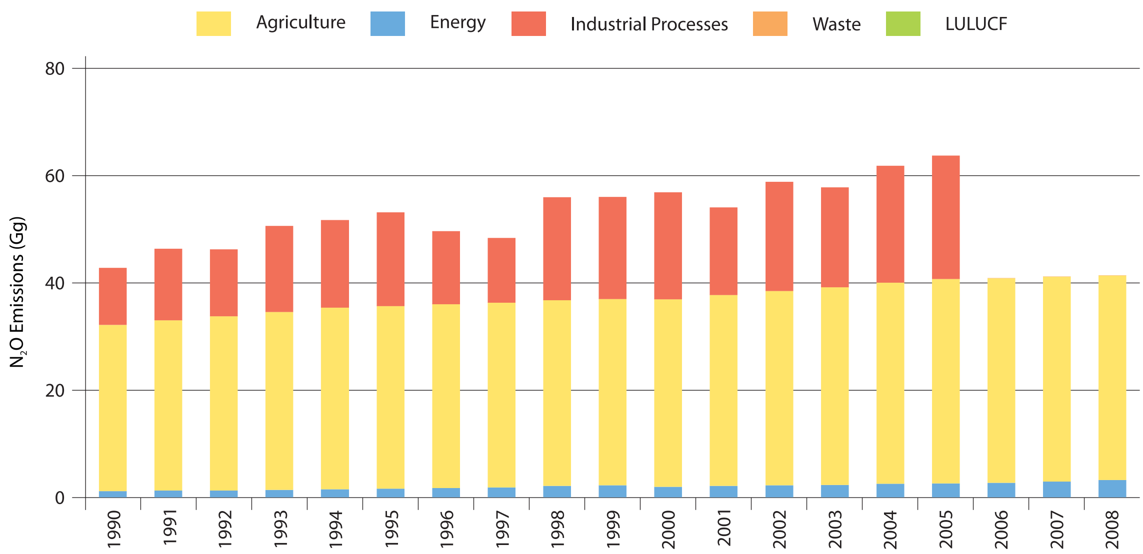


Figure II.12. N_2O Emissions in Sao Paulo State (%)

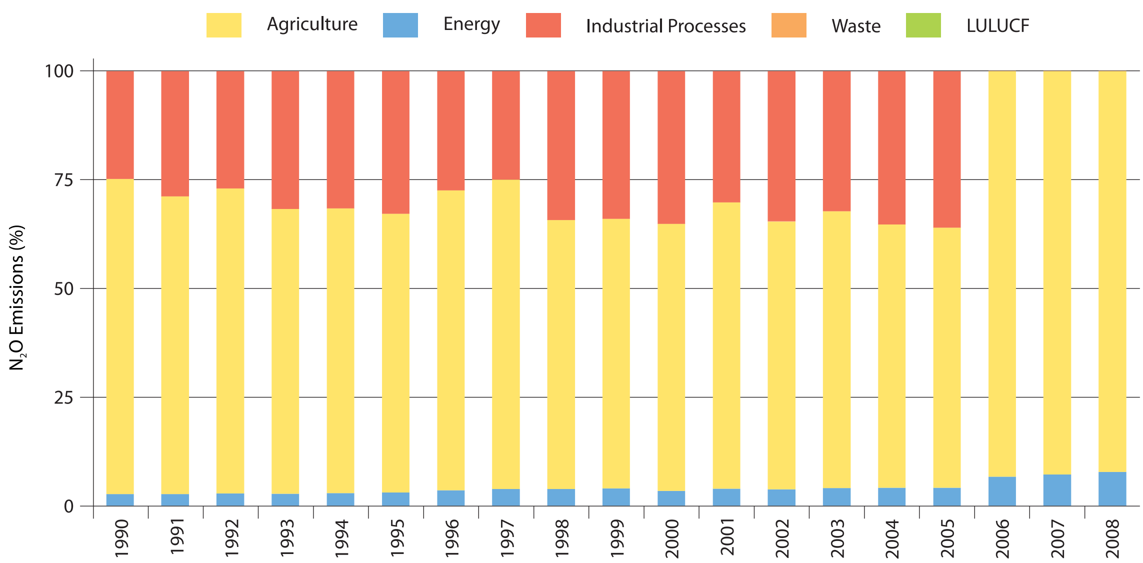
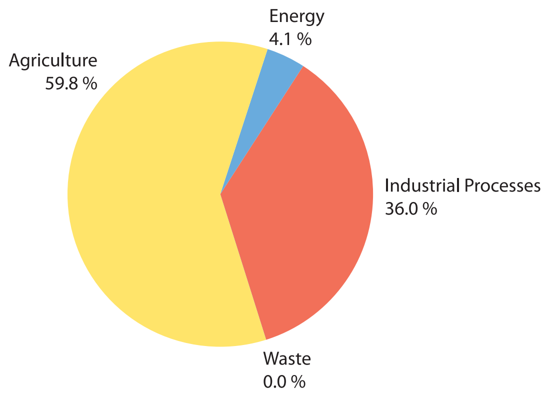


Figure II.13 show the estimated emission of N_2O for the year 2005.

Figure II.13. N_2O Emissions by Sector in Sao Paulo State (63 Gg)



The same way, Table II.7 and Figure II.14 shows the N_2O emissions in Gg_{CO2eq}, in the same years and involved sectors.

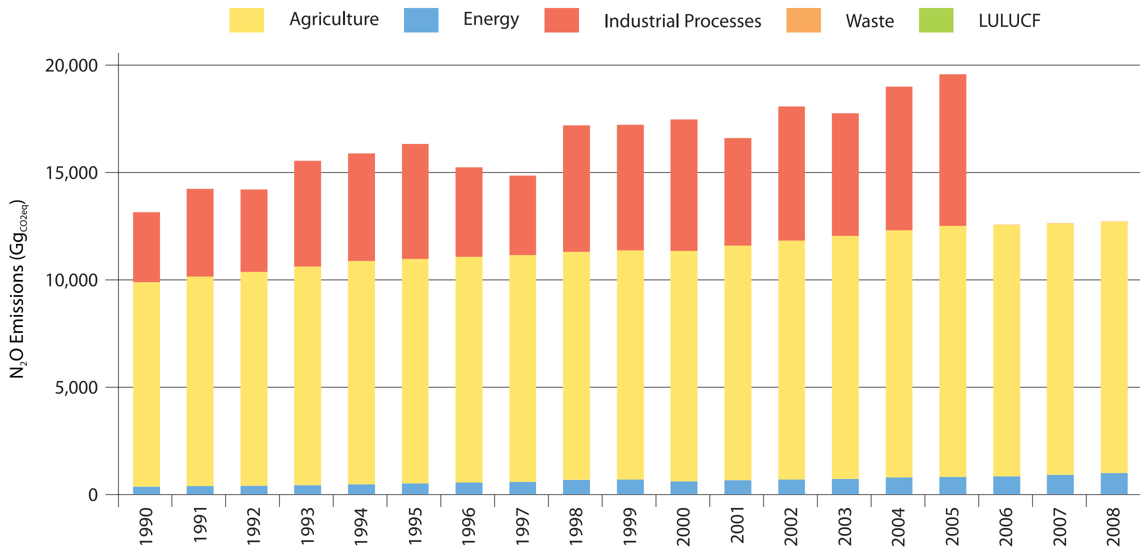
Table II.7. N_2O Emissions in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.$year^{-1}$]									
Energy	351	388	401	429	468	503	544	573	668	686
Industrial Processes	3,261	4,103	3,833	4,933	5,015	5,361	4,182	3,713	5,893	5,848
Agriculture	9,535	9,754	9,973	10,192	10,412	10,467	10,523	10,579	10,634	10,690
Waste	0.01	0.01	0.38	0.16	0.24	0.24	0.24	0.25	0.25	0.32
LULUCF	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total	**13,147**	**14,246**	**14,208**	**15,554**	**15,894**	**16,331**	**15,249**	**14,865**	**17,195**	**17,224**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.$year^{-1}$]									
Energy	598	657	690	720	785	809	837	914	989	
Industrial Processes	6,137	5,015	6,252	5,720	6,701	7,057	NE	NE	NE	
Agriculture	10,746	10,940	11,134	11,328	11,522	11,716	11,717	11,719	11,720	
Waste	0.37	0.33	0.33	0.33	0.33	0.33	0.35	0.37	0.39	
LULUCF	NE	NE	NE	NE	NE	NE	NE	NE	NE	
Total	**17,481**	**16,613**	**18,076**	**17,768**	**19,008**	**19,581**	**12,555**	**12,633**	**12,710**	

Note: NE: Not estimated.

Figure II.14. N_2O Emissions by Sector in Sao Paulo State (Gg_{CO2eq})



4.4 Emissions of Hydrofluorocarbons and Sulfur Hexafluoride

The gases HFCS, PFCS and SF_6 are produced only by human activities, and have no origin in the nature (BRASIL, 2010a).

In Brazil, there is no production of HFC. The emission of HFC-134a were estimated by Tier[34] 2b, which considers the sales of this gas and its use in various products identified as being made in Brazil: domestic refrigeration, troughs, commercial refrigeration, refrigerated transport done by refrigerated trucks, air conditioning and industrial refrigeration, vehicular air conditioning and the Subsector of Foams.

The SF_6 is used as an insulator in electrical equipment of large size. The emissions occur due to loss in the equipment. Table II.8 and Table II.9 show the emissions of SF_6 and HFC-134a in Sao Paulo State in the Subsector of the Distribution of Electricity.

Table II.8. HFC and SF_6 Emissions in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
HFC-134a	NE	NE	NE	NE	NE	NE	0.0416	0.0958	0.1385	0.1887
SF_6	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0015	0.0016

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
HFC-134a	0.2568	0.3343	0.3978	0.4605	0.5302	0.6068	0.7011	0.8183	0.9471	
SF_6	0.0016	0.0016	0.0017	0.0018	0.0019	0.0020	0.0020	0.0021	0.0022	

Note: NE: Not estimated.
The HFC-134a emissions were estimated from 1996, for that was when this gas started being used as an alternative to replace CFC and HCFC.

[34] Tier: In the method of the IPCC, is the level of accuracy of estimates of GHG emissions. The higher the Tier, the higher the level of rigor.

Table II.9. HFC and SF_6 Emissions in Sao Paulo State (Gg_{CO2eq})

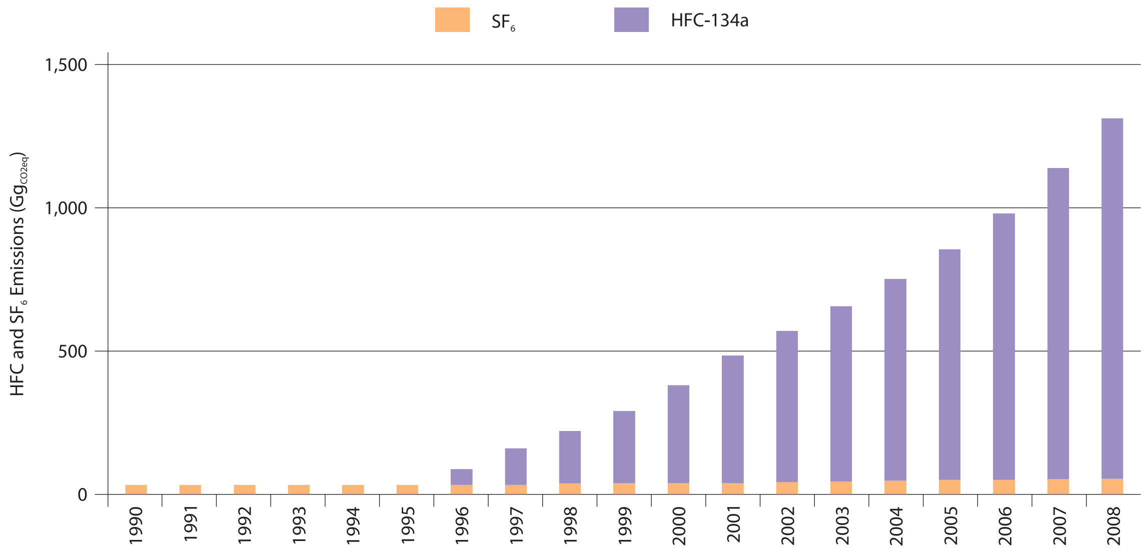
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{CO2eq}.year^{-1}]$									
HFC-134a	NE	NE	NE	NE	NE	NE	54	125	180	245
SF_6	31	31	31	31	31	31	31	31	36	38

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{CO2eq}.year^{-1}]$									
HFC-134a	334	435	517	599	689	789	911	1.064	1.231	
SF_6	38	38	41	43	45	48	48	50	53	

Note - NE: Not estimated.
The HFC-134a emissions were estimated from 1996, for that was when this gas started being used as an alternative to replace CFC and HCFC.

Figure II.15 shows the SF_6 and HFC emissions in CO_{2eq}, according to the PAG indicated in the session corresponding to this document.

Figure II.15. HFC and SF_6 Emissions in Sao Paulo State (Gg_{CO2eq})



4.5 Emissions of CFC and HCFC

The emissions of CFCS and HCFCS in Sao Paulo State are caused by the Solvents and Other Products Use Subsector, including the solvents (CFC-113), aerosols (CFC-11 and CFC-12), foam (CFC-11 and HCFC-141b), and in refrigeration and air conditioning (CFC-12 and HCFC-22). Table II.10 and Table II.11 show the GHG emissions controlled by the Montreal Protocol in Gg and Gg_{CO2eq}. Figure II.16 also show the Gg_{CO2eq} emission.

Until the year 2001, the biggest emission corresponded to the CFC-11, when it could not be used anymore in the manufacture of new products, due to the Montreal Protocol. From that year, the largest share of emissions became of HCFC-141b, which showed an increase of 94% between the years 2002 and 2008.

Table II.10. Emissions of GHG Controlled by the Montreal Protocol in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CFC-11	0.67	0.61	1.23	1.23	1.24	1.23	1.08	1.10	1.14	1.14
CFC-12	0.11	0.12	0.14	0.16	0.21	0.25	0.24	0.23	0.22	0.24
CFC-113	0.26	0.23	0.17	0.11	0.09	0.07	0.04	0.02	0.02	0.02
HCFC-22	0.66	0.72	0.78	0.84	0.92	0.99	0.99	1.07	1.17	1.55
HCFC-141b	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CFC-11	1.39	1.39	0.34	0.03	0.03	0.03	0.04	0.04	0.04	
CFC-12	0.24	0.20	0.21	0.19	0.19	0.18	0.20	0.20	0.18	
CFC-113	0.02	NE	NE	NE	NE	NE	NE	NE	NE	
HCFC-22	1.79	1.61	1.93	1.91	2.05	2.09	2.35	2.37	2.97	
HCFC-141b	NE	NE	0.56	0.66	0.82	0.82	0.80	1.10	1.09	

Note: NE: Not estimated.

The CFC-113 emissions were estimated for the period from 1990 to 2000, the HCFC-141b emissions were estimated from 2002.

Table II.11. Emissions of GHG Controlled by the Montreal Protocol in Sao Paulo State (Gg_{CO2eq})

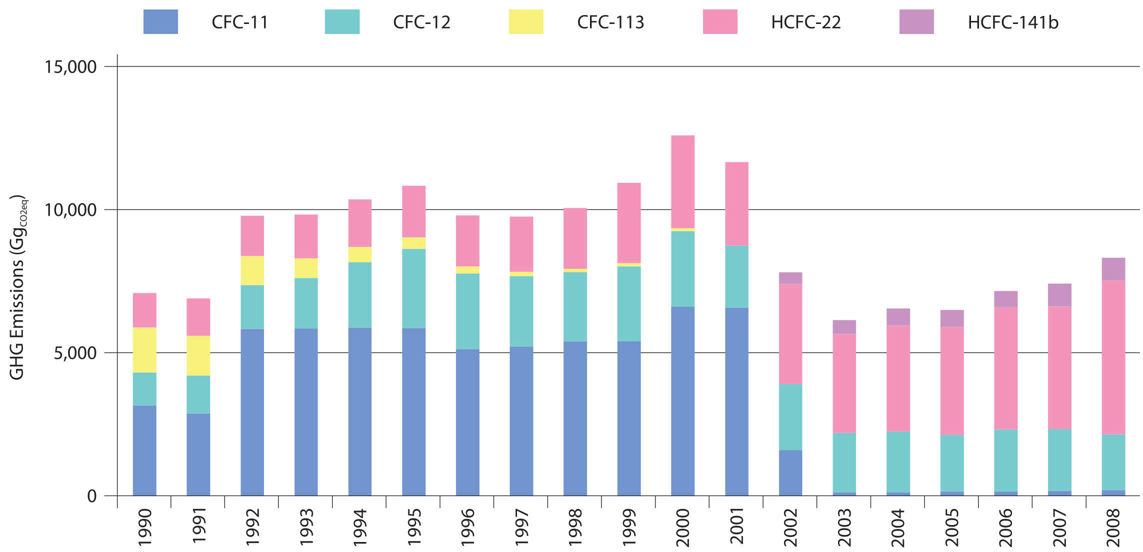
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.year^{-1}]									
CFC-11	3,164	2,888	5,833	5,857	5,890	5,864	5,134	5,224	5,401	5,414
CFC-12	1,153	1,322	1,532	1,761	2,278	2,763	2,635	2,460	2,421	2,604
CFC-113	1,571	1,390	1,017	685	533	410	248	148	111	113
HCFC-22	1,198	1,298	1,408	1,528	1,656	1,796	1,783	1,928	2,125	2,807
HCFC-141b	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total	7,086	6,898	9,791	9,831	10,357	10,833	9,800	9,760	10,058	10,938

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.year^{-1}]									
CFC-11	6,609	6,585	1,606	120	135	151	167	187	209	
CFC-12	2,648	2,161	2,302	2,083	2,117	1,976	2,158	2,147	1,942	
CFC-113	100	NE	NE	NE	NE	NE	NE	NE	NE	
HCFC-22	3,233	2,916	3,497	3,463	3,709	3,779	4,261	4,292	5,381	
HCFC-141b	NE	NE	406	477	592	592	579	798	787	
Total	12,589	11,662	7,811	6,142	6,552	6,499	7,165	7,424	8,319	

Note: NE: Not estimated.

The CFC-113 emissions were estimated from 1990 to 2000, the HCFC-141b emissions were estimated from 2002.

Figure II.16. Emissions of GHG Controlled by the Montreal Protocol in Sao Paulo State (Gg_{CO2eq})



4.6 Indirect Greenhouse Gases

The Indirect GHG, for the most part resulting from human activities, generates influence on chemical reactions that occur in the troposphere and exert indirect role in the increase in radioactive effect. They are: CO, NOx and VOC.

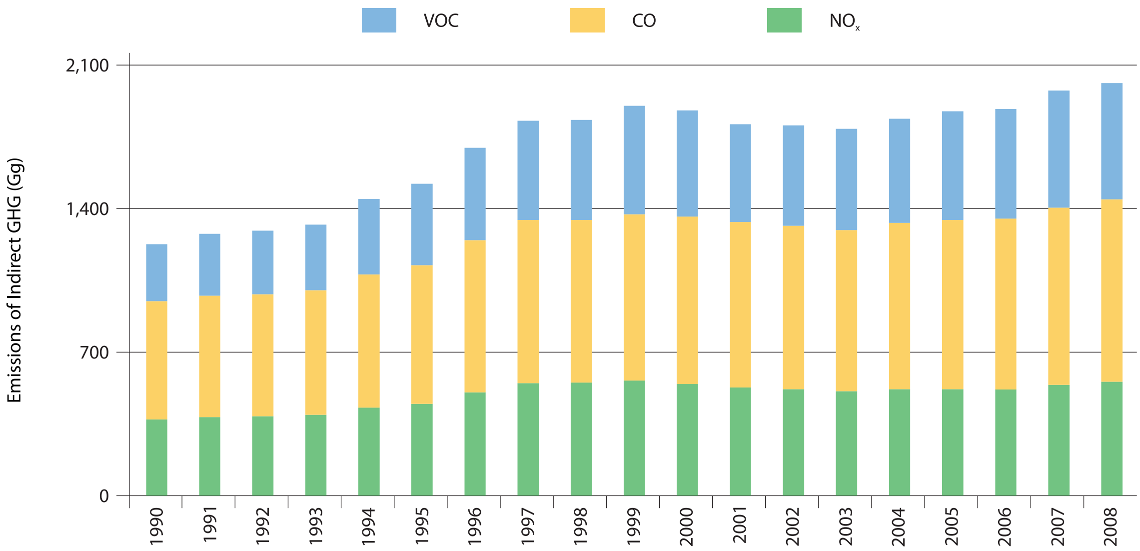
The emissions of these indirect GHG may result from incomplete burning of fuels, as well as in Industrial Processes, in the Subsector of Food and Beverage, Glass, and Pulp and Paper. Table II.12 and Figure II.17 show the estimates of the Indirect GHG emissions in Sao Paulo State.

Table II.12. Total Emissions of Indirect GHG in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
NOx	371	382	387	393	429	446	503	547	550	560
CO	576	591	593	607	648	676	741	795	793	811
VOC	278	302	310	320	368	397	450	484	487	527

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
NOx	544	527	518	508	518	519	517	540	554	
CO	814	805	796	785	810	823	833	863	889	
VOC	518	477	488	494	507	530	534	571	567	

Figure II.17. Total Emissions of Indirect GHG in Sao Paulo State (Gg)



4.7 Greenhouse Gas Emissions in CO_{2eq}

4.7.1 Emissions of GHG Not Controlled by the Montreal Protocol

In Table II.13, Figure II.18 and Figure II.19 show the estimates of GHG emissions in CO_{2eq}. For this reason, two different factors of equivalence were used: the GWP and the GTP, both for the horizon of 100 years.

Table II.13. Emissions of GHG Not Controlled by the Montreal Protocol in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{CO2eq}.year^{-1}]$									
Energy	57,078	58,785	59,386	60,526	65,661	68,014	75,624	80,835	81,911	82,480
Industrial Processes	6,711	7,693	6,929	7,996	8,335	9,137	8,592	8,637	10,884	10,659
Agriculture	25,872	26,108	27,089	27,713	28,600	28,345	28,097	28,253	28,232	28,457
Waste	5,838	5,906	6,196	6,137	6,328	6,504	6,803	6,813	7,149	7,272
LULUCF	0	0	0	0	0	0	0	0	0	0
Total	**95,499**	**98,492**	**99,601**	**102,372**	**108,925**	**112,002**	**119,115**	**124,537**	**128,176**	**128,868**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{CO2eq}.year^{-1}]$									
Energy	81,225	79,455	77,058	77,876	79,352	80,017	80,924	84,844	87,066	
Industrial Processes	11,118	9,497	10,702	9,787	10,887	20,610	13,240	14,082	13,502	
Agriculture	28,633	28,924	29,343	30,349	29,850	29,818	29,554	28,493	27,423	
Waste	7,678	8,040	8,569	8,967	8,885	9,366	9,394	8,837	9,219	
LULUCF	0	0	0	0	0	0	0	0	0	
Total	**128,654**	**125,917**	**125,671**	**126,979**	**128,974**	**139,811**	**133,111**	**136,256**	**137,210**	

Figure II.18. GHG Emissions in Sao Paulo State (Gg_{CO2eq})

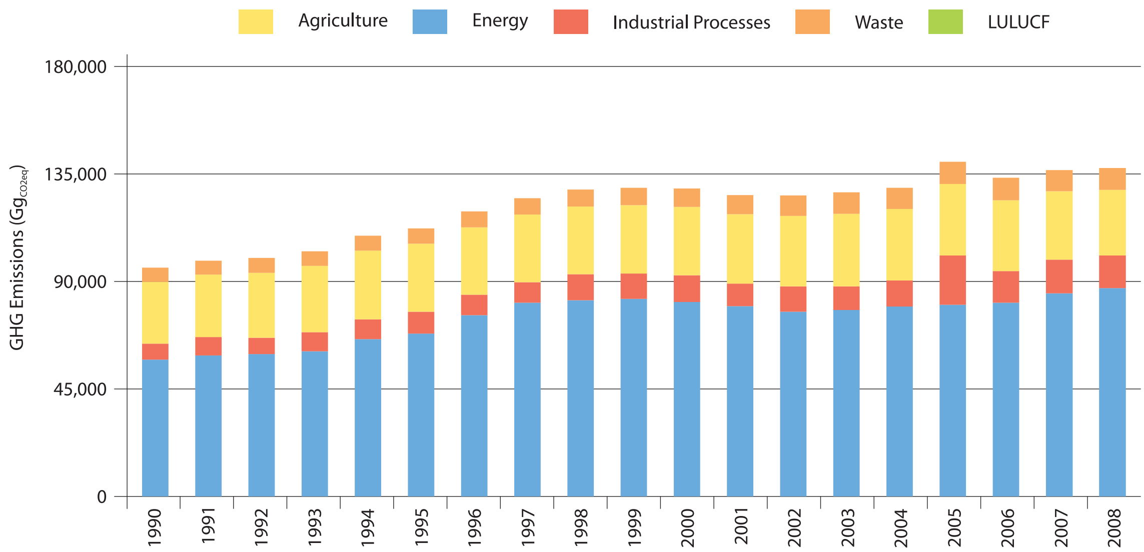


Figure II.19. GHG Emissions in Sao Paulo State (%)

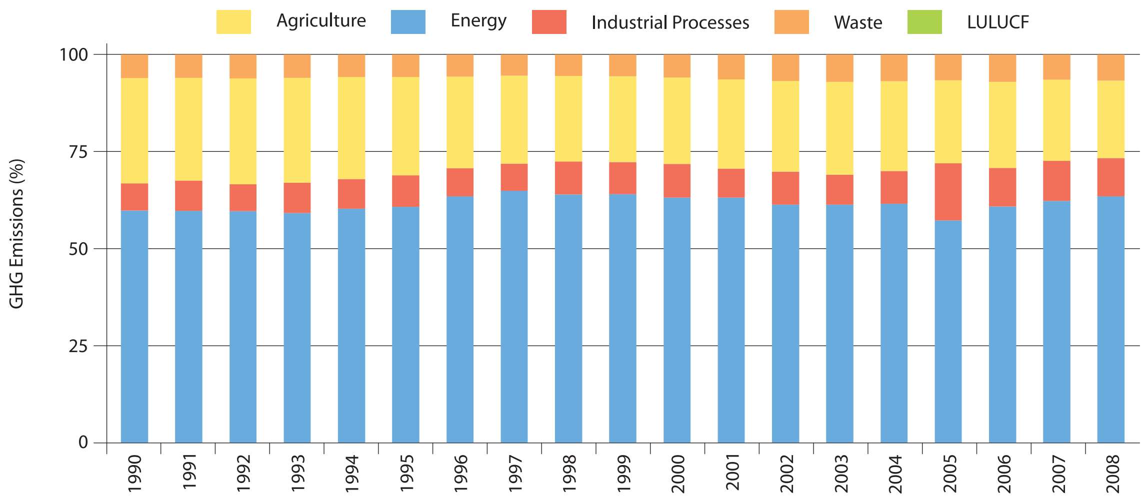


Table II.14. GHG Emissions by Sources, Converted by GTP and GWP Metrics, in 2005, by Sector, in Sao Paulo State (Gg_{CO2eq})

Sector	GTP		GWP	
	2005	Share 2005	2005	Share 2005
	(Gg_{CO2eq})	(%)	(Gg_{CO2eq})	(%)
Energy	79,437	68.3	80,017	57.2
Industrial Processes	18,953	16.3	20,610	14.7
Agriculture	15,638	13.4	29,818	21.3
Waste	2,243	1.9	9,366	6.7
LULUCF	0	0.0	0	0.0
Total	**116,272**	**100.0**	**139,811**	**100.0**

In Table II.14, Figure II.20 and Figure II.21 we can observe that the Agricultural Sector and the Waste Sector are the ones presenting higher difference according to the metric used. In GTP, Agriculture participates with 13% in 2005 while residues are equivalent to 1.9%. In GWP, these sectors are representing 21.3% and 6.7%, respectively.

Figure II.20. GHG Emissions by Sector in 2005, in Sao Paulo State (GTP)

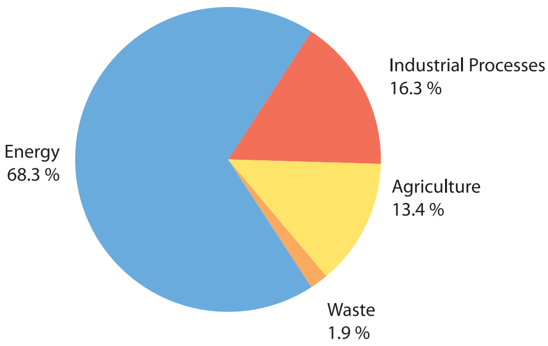
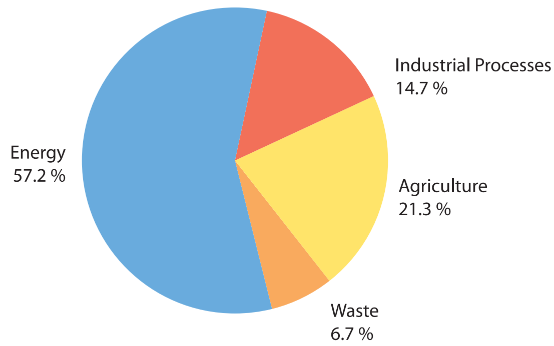


Figure II.21. GHG Emissions by Sector in 2005, in Sao Paulo State (GWP)



4.7.2 GHG Emissions Including the Controlled by the Montreal Protocol

Figure II.22 are presented the estimates of emissions of GHG not including the Montreal Protocol gases. Figure II.23 are presented the estimates of emissions of GHG not controlled by the Montreal Protocol combined with the Montreal Protocol gases. This inclusion represents an increase of 3% in the Industrial Sector in the year of 2005.

Figure II.22. GHG Emissions not Including the Montreal Protocol Gases, by Sector, in 2005, in Sao Paulo State

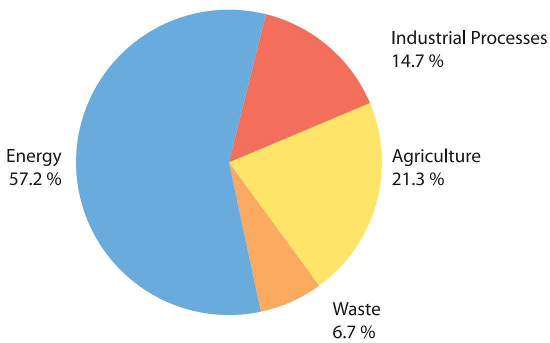
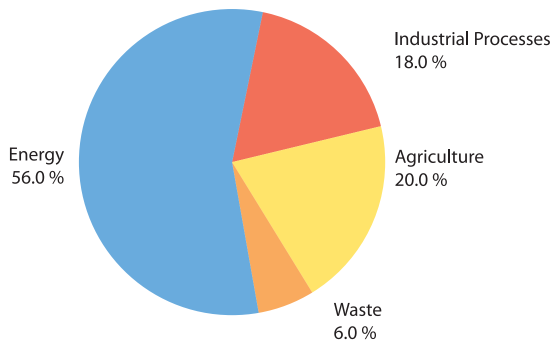


Figure II.23. GHG Emissions Including the Montreal Protocol Gases, by Sector, in 2005, in Sao Paulo State



5

Anthropogenic Emissions by Sources and Removals through Sinks of the GHG by Sector

5 Anthropogenic Emissions by Sources and Removals through Sinks of the GHG by Sector

5.1 Energy

5.1.1 Characteristics of Energy Matrix of Sao Paulo State

Gross domestic offerings of the three main energy sources (oil and derivatives, sugarcane and hydraulic products) maintained their prominent positions between the years of 1990 and 2008 in the energy matrix of Sao Paulo State, as seen in Table II.15.

Table II.15. Domestic Gross Power Supply (tOE)

Source	Year													
	1990		1991		1992		1993		1994		1995		1996	
	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%
Non renewable energy	20,608	53.3	21,479	53.5	21,550	53,2	22.429	53.1	24,324	54.9	25,471	56.0	28,305	57.9
Oil and derivatives (2)	18,596	48.1	19,240	47.9	19,819	47.8	20,140	47.7	21,664	48.9	22,738	50.0	25,533	52.2
Natural gas	207	0.5	242	0.6	320	0.8	408	1.0	577	1.3	768	1.7	899	1.8
Coal and derivatives (3)	1,805	4.7	1,997	5.0	1,861	4.6	1,881	4.5	2,083	4.7	1,965	4.3	1,873	3.8
Renewable energy	18,083	46.7	18,692	46.5	18,943	46.8	19,802	46.9	19,994	45.1	20,038	44.0	20,604	42.1
Hydraulic and electricity	6,773	17.5	7,058	17.6	7,146	17.6	7,522	17.8	7,819	17.6	8,201	18.0	8,458	17.3
Charcoal and firewood	1,464	3.8	1,393	3.5	1,308	3.2	1,284	3.0	1,206	2.7	1,167	2.6	1,170	2.4
Sugarcane production	9,319	24.1	9,657	24.0	9,864	24.1	10,274	24.3	10,130	22.9	9,727	21.4	9,922	20.3
Lixivium	332	0.9	360	0.9	380	0.9	459	1.1	506	1.1	551	1.2	576	1.2
Other renewable primary sources (4)	195	0.5	224	0.6	245	0.6	263	0.6	333	0.8	392	0.9	478	1.0
Total	38,691	100	40,171	100	40,493	100	42,231	100	44,318	100	45,509	100	48,909	100

Source	Year													
	1997		1998		1999		2000		20001		2002		2003	
	10^3tOE	%	10^3tOE	%	10^3tOE	%	10^3tOE	%	10^3tOE	%	10^3tOE	%	10^3tOE	%
Non renewable energy	28,226	55.0	28,517	54.9	27,242	53.4	29,438	58.2	28,671	57.1	27,903	55.6	28.155	54.8
Oil and derivatives (2)	25,394	49.5	25,734	49.6	24,625	48.3	26,548	52.4	25,115	50.0	23,823	47.5	23,394	45.5
Natural gas	1,010	2.0	985	1.9	1,115	2.2	1,367	2.7	1,849	3.7	2,458	4.9	2,852	5.6
Coal and derivatives (3)	1,822	3.6	1,798	3.5	1,502	2.9	1,523	3.0	1,707	3.4	1,622	3.2	1,909	3.7
Renewable energy	23,082	45.0	23,415	45.1	23,731	46.6	21,179	41.8	21,534	42.9	22,290	44.4	23,225	45.2
Hydraulic and electricity	8,967	17.5	9,088	17.5	9,247	18.1	9,684	19.1	8,576	17.1	9,050	18.0	9,596	18.7
Charcoal and firewood	1,153	2.2	1,132	2.2	1,097	2.2	1,120	2.2	1,103	2.2	1,078	2.1	1,051	2.0
Sugarcane production	11,872	23.1	12,126	23.3	12,240	24.0	9,114	18.0	10,654	21.2	10,911	21.7	11,244	21.9
Lixivium	605	1.2	559	1.1	622	1.2	713	1.4	709	1.4	748	1.5	818	1.6
Other renewable primary sources (4)	485	0.9	510	1.0	525	1.0	548	1.1	492	1.0	503	1.0	516	1.0
Total	51,308	100	51,932	100	50,973	100	50,617	100	50,205	100	50,193	100	51,380	100

To be continued

Continuation

Source	Year									
	2004		2005		2006		2007		2008	
	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%
Non renewable energy	30,533	54.0	30,662	52.9	29,832	50.5	30,902	48.6	30,893	45.5
Oil and derivatives (2)	25,168	44.5	25,077	43.3	23,755	40.2	24,562	38.6	24,410	35.9
Natural gas	3,328	5.9	3,865	6.7	4,321	7.3	4,618	7.3	4,899	7.2
Coal and derivatives (3)	2,037	3.6	1,720	3.0	1,756	3.0	1,722	2.7	1,584	2.3
Renewable energy	26,037	46.0	27,281	47.1	29,205	49.5	32,729	51.4	37,018	54.5
Hydraulic and electricity	10,047	17.8	10,392	17.9	11,121	18.8	11,763	18.5	12,137	17.9
Charcoal and firewood	1,063	1.9	1,084	1.9	1,080	1.8	1,113	1.7	1,129	1.7
Sugarcane production	13,517	23.9	14,343	24.8	15,460	26.2	18,247	28.7	22,094	32.5
Lixivium	861	1.5	906	1.6	956	1.6	994	1.6	1,039	1.5
Other renewable primary sources (4)	549	1.0	556	1.0	588	1.0	612	1.0	619	0.9
Total	56,570	100	57,943	100	59,037	100	63,631	100	67,911	100

Source: SÃO PAULO (2009b) apud Ciclo Ambiental (2011a).
Notes:
(1) tOE = 10.000 Mcal = 41,9GJ.
(2) The following sources are included in this category: oil, diesel, fuel oil, gas, LOG (liquefied oil gas), naphtha, kerosene, other energetics from oil and non-energetic products.
(3) The following sources are included in this category: steam coal, metallurgy coal and coking coal.
(4) The following sources are included in this category: sugarcane juice, sugar-cane syrup, crushed sugar-cane, anhydrous alcohol and hydrated alcohol.

Highlight the participation of renewable energy sources in the energy matrix of Sao Paulo State, as occurs in the national matrix. In the period 1990 to 2008, the share of these sources varied little (40 to 55% of the energy produced), mainly due to the use of sugarcane derivatives.

About the final energy consumption (Table II.16), predominates the hydroelectricity throughout the analyzed period. It stands out, also, the consumption of diesel oil (mostly in the Transportation Sector, Modal Road) and sugarcane bagasse, mainly used in the Industrial Sector.

Regarding the sectoral consumption, stands out the Industrial Sector, which uses electricity, sugarcane bagasse and natural gas, followed by the Sector of Transportation, where the consumption of diesel dominates.

Table II.16. Final Power Consumption by Source and by Sector[35] in the Sao Paulo State

Source	Year													
	1990		1991		1992		1993		1994		1995		1996	
	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%
Primary energy	6,971	20.1	7,598	21.0	7,477	20.7	7,858	20.7	7,951	19.9	8,189	19.8	9,094	20.3
Natural gas	195	0.6	227	0.6	303	0.8	387	1.0	557	1.4	745	1.8	890	2.0
Steam coal	155	0.4	256	0.7	132	0.4	99	0.3	80	0.2	103	0.2	108	0.2
Firewood	1,047	3.0	988	2.7	945	2.6	916	2.4	841	2.1	824	2.0	826	1.8
Sugarcane bagasse	5,216	15.1	5,740	15.9	5,690	15.7	5,989	15.8	5,964	15.0	5,962	14.4	6,680	14.9
Lixivium	283	0.8	306	0.8	319	0.9	382	1.0	420	1.1	456	1.1	473	1.1
Other primary ones	75	0.2	81	0.2	88	0.2	85	0.2	89	0.2	99	0.2	117	0.3
Secondary energy	27,650	79.9	28,546	79.0	28,728	79.3	30,015	79.3	31,915	80.1	33,210	80.2	35,721	79.7
Oil derivatives	17,263	49.9	17,746	49.1	17,900	49.4	18,697	49.4	20,026	50.2	20,996	50.7	23,209	51.8
Diesel	5,221	15.1	5,461	15.1	5,543	15.3	5,567	14.7	5,798	14.5	6,051	14.6	6,646	14.8
Fuel oil	4,100	11.8	3,896	10.8	4,000	11.0	4,058	10.7	4,217	10.6	4,145	10.0	4,519	10.1
Gasoline	2,522	7.3	2,804	7.8	2,830	7.8	2,873	7.6	3,472	8.7	3,796	9.2	4,444	9.9
LPG	1,489	4.3	1,522	4.2	1,548	4.3	1,636	4.3	1,667	4.2	1,699	4.1	1,955	4.4
Naphtha	1,369	4.0	1,360	3.8	1,091	3.0	1,467	3.9	1,426	3.6	1,487	3.6	1,508	3.4
Kerosene	596	1.7	709	2.0	750	2.1	911	2.4	1,039	2.6	1,317	3.2	1,551	3.5
Piped gas	124	0.4	118	0.3	100	0.3	93	0.2	64	0.2	32	0.1	11	0.0
Refinery gas	424	1.2	482	1.3	559	1.5	702	1.9	835	2.1	839	2.0	842	1.9
Other energy oil products	404	1.2	424	1.2	457	1.3	407	1.1	449	1.1	462	1.1	455	1.0
Non energetic products	1,014	2.9	970	2.7	1,022	2.8	983	2.6	1,059	2.7	1,168	2.8	1,278	2.9
Gas coke	284	0.8	285	0.8	288	0.8	299	0.8	290	0.7	303	0.7	321	0.7
Coke coal	1,204	3.5	1,290	3.6	1,279	3.5	1,244	3.3	1,411	3.5	1,303	3.1	1,292	2.9
Electricity	6,389	18.5	6,594	18.2	6,634	18.3	7,061	18.6	7,310	18.3	7,667	18.5	7,868	17.6
Charcoal	184	0.5	177	0.5	171	0.5	163	0.4	159	0.4	152	0.4	147	0.3
Sugarcane derivatives	2,326	6.7	2,454	6.8	2,456	6.8	2,551	6.7	2,719	6.8	2,789	6.7	2,884	6.4
Anhydrous alcohol	248	0.7	335	0.9	382	1.1	542	1.4	598	1.5	697	1.7	794	1.8
Hydrated alcohol	2,078	6.0	2,119	5.9	2,074	5.7	2,009	5.3	2,121	5.3	2,092	5.1	2,090	4.7
Total	34,621	100	36,144	100	36,205	100	37,873	100	39,866	100	41,399	100	44,815	100

Source	Year													
	1997		1998		1999		2000		2001		2002		2003	
	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 t OE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%
Primary energy	9611	20.1	10,246	21.2	10,163	20.9	8,665	18.7	10,361	22.4	11,131	24.1	12,237	25.7
Natural gas	998	2.1	975	2.0	1,045	2.1	1,253	2.7	1,567	3.4	2,057	4.5	2,639	5.5
Steam coal	50	0.1	42	0.1	40	0.1	36	0.1	34	0.1	34	0.1	30	0.1
Firewood	827	1.7	828	1.7	837	1.7	868	1.9	872	1.9	858	1.9	835	1.8
Sugarcane bagasse	7,115	14.9	7,822	16.2	7,614	15.7	5,812	12.5	7,203	15.5	7,472	16.2	7,970	16.7
Lixivium	497	1.0	457	0.9	510	1.0	583	1.3	580	1.3	611	1.3	669	1.4
Other primary ones	124	0.3	122	0.3	117	0.2	113	0.2	105	0.2	99	0.2	94	0.2
Secondary energy	38,145	79.9	38,185	78.8	38,482	79.1	37,751	81.3	35,990	77.6	35,013	75.9	35,392	74.3
Oil derivatives	25,319	53.0	25,724	53.1	25,873	53.2	25,399	54.7	24,759	53.4	23,428	50.8	23,084	48.5
Diesel	7,327	15.3	7,421	15.3	7,588	15.6	7,666	16.5	7,906	17.1	8,045	17.4	7,748	16.3
Fuel oil	4,863	10.2	4,820	10.0	4,382	9.0	3,825	8.2	3,226	7.0	2,741	5.9	2,251	4.7
Gasoline	4,739	9.9	4,821	10.0	4,944	10.2	4,577	9.9	4,495	9.7	4,212	9.1	3,994	8.4
LPG	2,024	4.2	2,037	4.2	2,203	4.5	2,197	4.7	2,151	4.6	2,023	4.4	1,994	4.2
Naphtha	1,992	4.2	2,006	4.1	2,109	4.3	2,184	4.7	2,574	5.6	1,871	4.1	1,969	4.1
Kerosene	1,649	3.5	1,912	3.9	1,771	3.6	1,585	3.4	1,333	2.9	1,407	3.0	1,588	3.3
Piped gas	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Refinery gas	809	1.7	744	1.5	822	1.7	962	2.1	966	2.1	1,068	2.3	1,059	2.2
Other energy oil products	486	1.0	529	1.1	677	1.4	1,057	2.3	835	1.8	864	1.9	978	2.1
Non energetic products	1,430	3.0	1,434	3.0	1,377	2.8	1,346	2.9	1,273	2.7	1,197	2.6	1,503	3.2
Gas coke	320	0.7	296	0.6	240	0.5	243	0.5	242	0.5	226	0.5	205	0.4
Coke coal	1,308	2.7	1,324	2.7	1,152	2.4	1,063	2.3	998	2.2	1,003	2.2	1,295	2.7
Electricity	8,392	17.6	8,578	17.7	8,765	18.0	9,219	19.9	8,412	18.1	8,599	18.6	9,203	19.3
Charcoal	143	0.3	138	0.3	132	0.3	128	0.3	126	0.3	122	0.3	119	0.2
Sugarcane Derivatives	2,663	5.6	2,125	4.4	2,320	4.8	1,699	3.7	1,453	3.1	1,635	3.5	1,486	3.1
Anhydrous alcohol	819	1.7	773	1.6	964	2.0	779	1.7	812	1.8	853	1.8	808	1.7
Hydrated alcohol	1,844	3.9	1,352	2.8	1,356	2.8	920	2.0	641	1.4	782	1.7	678	1.4
Total	47,756	100	48,431	100	48,645	100	46,416	100	46,351	100	46,144	100	47,629	100

To be continued

[35] The data on fuel consumption and sectoral consumption were obtained from the BEESP 2009 (Base year 2008), except for the Cement Industrial Subsector have been replaced by data provided by SNIC and the ABCP. Thus, the final consumption data presented in this paper will not be compatible with the data presented in the final consumption from the BEESP 2009. This also applies to all tables, of CO_2 and non-CO_2 emissions, of Sectoral Approach.

Continuation

Source	Year									
	2004		2005		2006		2007		2008	
	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%	10^3 tOE	%
Primary energy	14,053	27.6	15,002	29.2	16,224	30.2	17,814	30.8	20,067	32.6
Natural gas	3,161	6.2	3,561	6.9	4,079	7.6	4,373	7.6	4,356	7.1
Steam coal	32	0.1	33	0.1	24	0.0	22	0,0	22	0.0
Firewood	839	1.6	854	1.7	870	1.6	879	1.5	895	1.5
Sugarcane bagasse	9,211	18.1	9,713	18.9	10,363	19.3	11,616	20.1	13,833	22.5
Lixivium	704	1.4	741	1.4	782	1.5	812	1.4	849	1.4
Other primary ones	106	0.2	100	0.2	106	0.2	112	0.2	112	0.2
Secondary energy	36,868	72.4	36,339	70.8	37,511	69.8	40,092	69.2	41,401	67.4
Oil derivatives	23,712	46.6	22,636	44.1	22,690	42.2	23,616	40.8	23,896	38.9
Diesel	8,047	15.8	8,045	15.7	7,974	14.8	8,481	14.6	9,148	14.9
Fuel oil	1,921	3.8	1,543	3.0	1,253	2.3	1,192	2.1	1,029	1.7
Gasoline	4,010	7.9	4,165	8.1	4,183	7.8	4,244	7.3	4,165	6.8
LPG	2,000	3.9	1,948	3.8	1,959	3.6	1,965	3.4	2,035	3.3
Naphtha	2,355	4.6	1,727	3.4	1,950	3.6	2,037	3.5	1,648	2.7
Kerosene	1,639	3.2	1,720	3.4	1,637	3.0	1,750	3.0	1,891	3.1
Piped gas	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Refinery gas	1,051	2.1	929	1.8	994	1.8	993	1.7	978	1.6
Other energy oil products	1,026	2.0	1,147	2.2	1,402	2.6	1,467	2.5	1,532	2.5
Non energetic products	1,663	3.3	1,412	2.8	1,338	2.5	1,487	2.6	1,470	2.4
Gas Coke	228	0.4	259	0.5	248	0.5	256	0.4	264	0.4
Coke coal	1,184	2.3	1,110	2.2	1,106	2.1	1,171	2.0	1,036	1.7
Electricity	9,776	19.2	10,226	19.9	10,701	19.9	11,315	19.5	11,645	18.9
Charcoal	123	0.2	125	0.2	125	0.2	127	0.2	125	0.2
Sugarcane derivatives	1,845	3.6	1,983	3.9	2,641	4.9	3,607	6.2	4,435	7.2
Anhydrous alcohol	811	1.6	842	1.6	855	1.6	869	1.5	853	1.4
Hydrated alcohol	1,034	2.0	1,141	2.2	1,786	3.3	2,738	4.7	3,582	5.8
Total	**50,921**	**100**	**51,341**	**100**	**53,735**	**100**	**57,906**	**100**	**61,468**	**100**

5.1.2 CO_2 Emissions from Fossil Fuel Combustion

The CO_2 emissions inventory from Fuel Combustion in Sao Paulo State was conducted in accordance with contract signed between CETESB and Ciclo Ambiental[36]. CO_2 emissions from combustion sources present this compound during the process of oxidation (burning) of fuels containing carbon. During this process, most part of the carbon is emitted directly as CO_2. However, some of the carbon, usually a small part, is released as CO, CH_4 and VOC. All these gases oxidize and turn into CO_2 in the atmosphere (IPCC, 1996). As a secondary effect, there is also the generation of N_2O and NOx.

The CO_2 emissions in Sao Paulo State from fuel combustion were estimated by using two methods of IPCC (1996, 2000a): the Reference Approach (Top-down), which uses data on apparent consumption to estimate CO_2 emissions, and the Sectoral Approach (Bottom-up) which uses data of final consumption by sector to estimate these emissions. These methods include only the emissions from fossil fuel combustion because the emissions of CO_2 from burning of renewable biomass are considered null. The data used for the estimates of emissions of CO_2 were from the energy supply and final consumption by sector, obtained in BEESP (SÃO PAULO, 2009c). The factors of emissions adopted in the two approaches were factors default (Tier 1) from the IPCC (1996).

[36] The contract was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for CETESB´s Project to improve State Policy on Climate Change.

5.1.2.1 Reference Approach (Top-down)

The Reference, or Top-down approach uses as input data for the calculation of CO_2 emissions the apparent consumption of fossil fuels, which takes into account the production, importation, exportation, international bunkers and variation in the stocks of each fuel. The CO_2 emissions were calculated based on the consumed amount of these fuels and carbon content from each one.

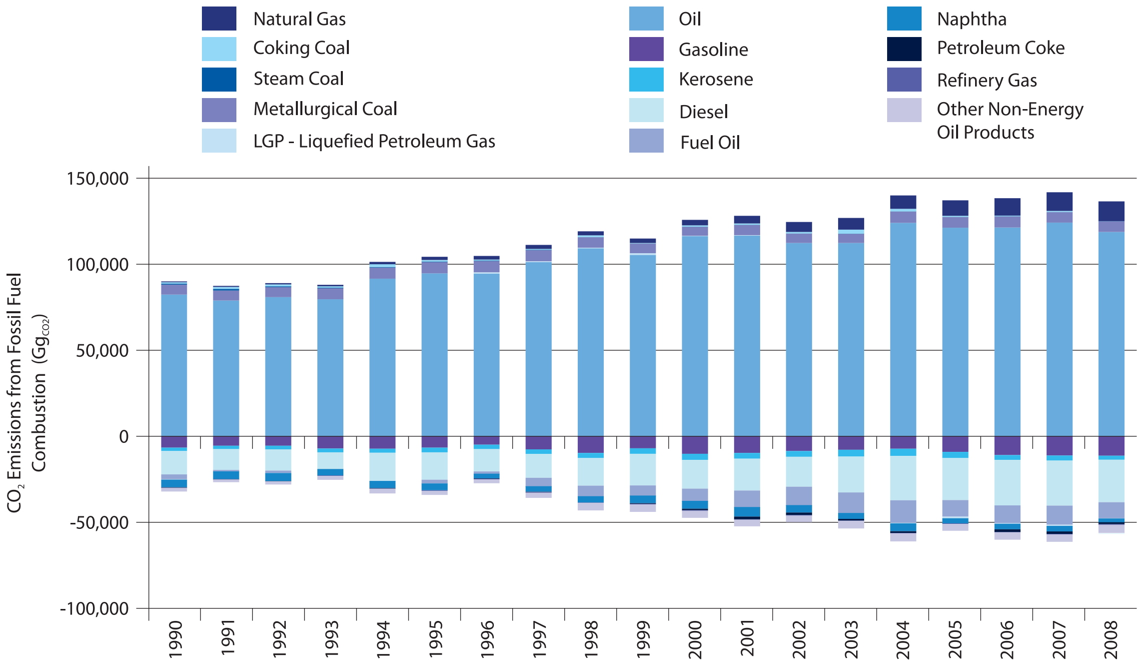
Table II.17 and Figure II.24 show the result of the CO_2 emissions estimated by Reference Approach for the period 1990 to 2008.

Table II.17. CO_2 Emissions from Fossil Fuels Combustion in the Sao Paulo State (Gg_{CO2})

Fuels	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Liquid fuels	49,376	51,275	51,980	53,396	57,551	59,713	67,023	64,839	65,533	61,519
Oil	81,744	78,237	80,206	79,027	90,912	93,955	93,821	100,365	108,329	104,563
Gasoline	-6,549	-5,504	-5,501	-7,095	-7,253	-6,635	-4,852	-7,618	-9,671	-6,928
Kerosene	-2,012	-1,953	-2,039	-2,190	-2,329	-2,691	-2,599	-2,703	-2,881	-3,201
Diesel	-13,422	-11,955	-12,292	-9,861	-16,016	-15,807	-12,827	-13,662	-15,976	-18,325
Fuel oil	-2,880	-1,081	-1,523	-48	16	-2,161	-1,712	-5,320	-6,497	-6,189
LPG	-546	-227	-316	-173	-617	-416	735	484	403	970
Naphtha	-4,486	-4,486	-4,691	-3,676	-4,126	-3,922	-2,733	-3,143	-3,649	-4,467
Petroleum coke	-255	-21	-17	4	-213	-	-226	-247	21	-368
Refinery gas	-175	-200	-234	-292	-348	-350	-350	-336	-259	-322
Other non energy oil products	-2,043	-1,535	-1,614	-2,301	-2,474	-2,258	-2,234	-2,982	-4,286	-4,213
Solid fuels	7,097	7,896	7,367	7,388	8,292	7,741	7,328	7,128	7,098	5,853
Metallurgical coal	5,752	5,733	5,706	6,304	6,327	6,424	6,439	6,478	5,978	5,508
Steam coal	613	1,013	520	392	318	411	427	202	171	163
Coke coal	732	1,149	1,141	692	1,647	905	462	448	950	182
Gas fuels	484	566	748	954	1,348	1,795	2,101	2,360	2,302	2,606
Natural gas	484	566	748	954	1,348	1,795	2,101	2,360	2,302	2,606
Total	**56,957**	**59,736**	**60,094**	**61,738**	**67,191**	**69,249**	**76,452**	**74,327**	**74,933**	**69,978**

Fuels	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Liquid fuels	68,043	63,572	61,466	57,912	61,889	64,013	60,190	61,791	61,646	
Oil	115,323	115,706	111,390	111,487	123,010	120,314	120,357	123,147	117,779	
Gasoline	-10,122	-9,626	-8,620	-7,882	-7,164	-9,042	-10,829	-11,085	-11,223	
Kerosene	-3,607	-3,379	-3,210	-3,838	-4,220	-3,619	-2,833	-3,032	-2,347	
Diesel	-16,471	-18,322	-17,281	-20,680	-25,570	-24,235	-26,215	-25,877	-24,511	
Fuel oil	-7,510	-9,973	-11,092	-11,997	-13,029	-9,511	-10,297	-11,079	-9,351	
LPG	240	303	-	-264	-748	-1,281	-695	-1,025	-484	
Naphtha	-4,529	-5,467	-4,180	-3,498	-4,475	-2,995	-3,245	-3,200	-2,210	
Petroleum coke	-878	-1,542	-1,488	-874	-932	-25	-1,542	-1,496	-1,074	
Refinery gas	-403	-348	-381	-364	-348	-311	-331	-331	-325	
Other non energy oil products	-4,000	-3,781	-3,672	-4,179	-4,635	-3,948	-4,179	-4,231	-4,608	
Solid fuels	5,993	6,727	6,408	7,714	8,088	6,746	6,856	6,761	6,135	
Metallurgical coal	5,197	5,780	5,376	5,166	6,513	6,055	6,443	6,059	6,152	
Steam coal	147	140	140	120	132	136	93	85	89	
Coke coal	648	808	892	2,428	1,442	555	320	617	-107	
Gas fuels	3,195	4,321	5,744	6,665	7,778	9,033	10,098	10,793	11,449	
Natural gas	3,195	4,321	5,744	6,665	7,778	9,033	10,098	10,793	11,449	
Total	**77,231**	**74,621**	**73,618**	**72,291**	**77,754**	**79,792**	**77,144**	**79,345**	**79,231**	

Figure II.24. CO_2 Emissions from Fossil Fuels Combustion in Sao Paulo State (Gg_{CO2})



Note: the negative emissions indicate they took place out of Sao Paulo State. The quantities of fuel that generated those emissions refer to the exports, stock variation or international bunker.

The total emissions of CO_2 from fossil fuel combustion have increased from 56,957 Gg_{CO2} in 1990, to 79,231 Gg_{CO2} in 2008, which represents a growth of 39%, i.e., an average annual growth of 1.85%. In the year 2008, among the emissions from the Energy Sector, the petroleum-based fuels were responsible for 78% of CO_2 emissions, followed by natural gas (14%) and mineral coal and derivatives (8%). The growth of emissions from fossil fuels was lower than the increase of total gross domestic supply of energy in the same period, 75%.

Fossil fuels have a slightly declining participation in total gross domestic supply of energy, ranging from 53% in 1990 to 45.5% in 2008. This participation has presented the following distribution: oil derivatives decreased from 48% to 36% of total gross domestic supply of energy; coal and derivatives from 5% to 2%; and the natural gas was the only one that showed an increase of 0.5% to 7%.

The increase of CO_2 emissions from fossil fuels, lower than the increase of domestic supply total gross energy signals a greater use of fuels that are less carbon intensive (such as natural gas) and also the increased participation of renewable sources (biomass) in Sao Paulo energy system.

5.1.2.2 Sectoral Approach (Bottom-up)

The Sectoral or Bottom-up Approach uses the source categories defined by the IPCC for estimating emissions of CO_2 and other greenhouse gases. This sectoral detailing of CO_2 emissions is necessary to subsidize discussions related to monitoring and the reduction of these emissions. Table II.18 shows the emissions by fuel, while Table II.19 presents the same emissions by sector of activity for the period 1990 to 2008.

Table II.18. CO_2 Emissions from Fossil Fuels Combustion by Type of Fuel in Sao Paulo State (Gg_{CO2})

Fuels	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
	[Gg_{CO2}]											
Kerosene	295	244	209	203	185	203	107	110	125	119	125	101
Aviation kerosene	1,473	1,858	2,015	2,498	2,895	3,702	4,490	4,777	5,542	5,130	4,573	3,850
Diesel	16,035	16,756	17,002	17,082	17,794	18,571	20,400	22,510	22,886	23,320	23,580	24,289
Fuel oil	14,668	14,026	14,142	14,113	14,767	14,367	16,656	17,304	16,358	15,854	14,183	11,936
Gasoline	7,244	8,054	8,129	8,253	9,973	10,904	12,765	13,612	13,848	14,201	13,147	12,912
LPG	3,892	3,978	4,046	4,276	4,357	4,441	5,111	5,291	5,325	5,759	5,743	5,623
Petroleum coke	1,689	1,659	1,789	1,588	1,747	1,810	1,546	1,622	1,350	2,307	3,578	2,800
Refinery gas	1,004	1,140	1,321	1,660	1,974	1,982	1,990	1,913	1,810	1,963	2,271	2,338
Gas coke	564	566	572	594	576	602	638	635	587	477	483	481
Piped gas	290	276	234	215	150	75	26	0	0	0	0	0
Natural gas	456	531	708	902	1,297	1,741	2,078	2,330	2,279	2,477	3,101	4,251
Steam coal	58	66	66	43	16	16	8	8	8	8	8	8
Coke coal	5,867	6,151	5,974	5,885	6,537	6,156	6,142	6,253	6,302	5,530	4,807	4,443
Naphtha	832	827	663	892	867	904	917	1,211	1,219	1,282	1,328	1,565
Other non energy oil products	0	0	0	0	0	0	0	0	0	0	0	0
Alternative fuels	0	0	0	0	0	0	0	6	130	12	15	18
Total	**54,366**	**56,133**	**56,869**	**58,202**	**63,135**	**65,471**	**72,874**	**77,583**	**77,770**	**78,439**	**76,942**	**74,614**

Fuels	2001	2002	2003	2004	2005	2006	2007	2008	Part. 2008	1990/ 2008		
	Gg_{CO2}								%	%		
Kerosene	125	74	71	66	63	48	12	12	0.01	-96.0		
Aviation kerosene	3,850	4,096	4,635	4,792	5,035	4,804	5,174	5,592	7.02	279.7		
Diesel	24,289	24,719	23,821	24,742	24,738	24,539	26,101	28,140	35.31	75.5		
Fuel oil	11,936	9,316	7,818	6,924	5,885	4,268	4,025	3,652	4.58	-75.1		
Gasoline	12,912	12,099	11,473	11,518	11,964	12,015	12,191	11,964	15.01	65.1		
LPG	5,623	5,288	5,213	5,228	5,092	5,121	5,137	5,319	6.67	36.7		
Petroleum coke	2,800	2,575	2,825	2,938	3,306	4,439	4,735	4,890	6.14	189.6		
Refinery gas	2,338	2,588	2,580	2,574	2,271	2,433	2,430	2,394	3.00	138.5		
Gas coke	481	449	407	453	514	493	508	524	0.66	-7.0		
Piped gas	0	0	0	0	0	0	0	0	0.00	-100.0		
Natural gas	4,251	5,630	6,635	7,736	8,986	10,049	10,732	11,386	14.29	2,398.5		
Steam coal	8	8	8	8	8	8	8	8	0.01	-86.7		
Coke coal	4,443	4,465	5,774	5,157	4,842	4,914	5,323	4,706	5.90	-19.8		
Naphtha	1,565	1,137	1,197	1,432	1,050	1,185	1,238	1,002	1.26	20.4		
Other non energy oil products	0	0	0	0	0	0	0	0	0.00	-		
Alternative fuels	18	32	46	46	36	63	108	102	0.13	-		
Total	**74,614**	**72,476**	**72,502**	**73,613**	**73,789**	**74,378**	**77,722**	**79,690**	**100.00**	**46.6**		

CO_2 emissions from fossil fuel combustion in Sao Paulo State in 2008 were estimated at $79{,}690_{GgCO2}$. These emissions have grown by around 47% in the period 1990 to 2008, i.e. an average annual increase of almost 2.15%.

The fuel that has had the largest participation in emissions of CO_2 was the diesel (33% in 2005), showing an increase of 54% over the period 1990 to 2005. The second largest fuel contributor was gasoline (16%), with a growth rate of 65%. Natural gas was in third place in the contribution of CO_2 emissions (12%), but it was the fuel that presented the greatest growth in the period studied (1,870%). This increase was due to its massive introduction in the Brazilian energy matrix, either for use in thermal power plants for electricity generation or use as vehicular fuel, and mainly as a substitute for other fuels in the production of thermal energy, in the Residential Sector and mainly in the Industrial Sector.

The data on fuel consumption and sector consumption were obtained in BEESP in the year 2009 - base 2008, except for the Cement Industry Subsector, where data was supplied by National Union Cement Industry (SNIC) and the Brazilian Association of Portland Cement (ABCP), which is why the data of final consumption presented in this Inventory differ from the data of final consumption presented in BEESP 2009. This is also valid for all tables in the CO_2 emissions and not CO_2 of Reference Approach. Figure II.25 and Figure II.26 show the CO_2 emissions by 2005 and 2008.

Figure II.25. CO_2 Emissions from Energy Sector by Subsector, in 2005, in Sao Paulo State (71,136 Gg)

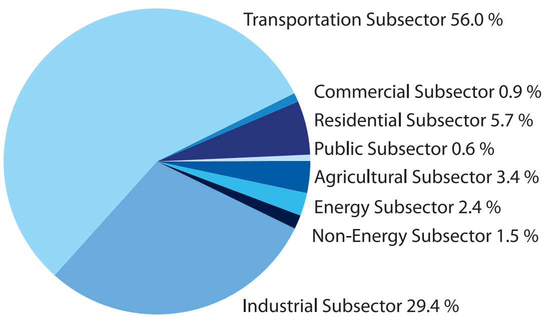
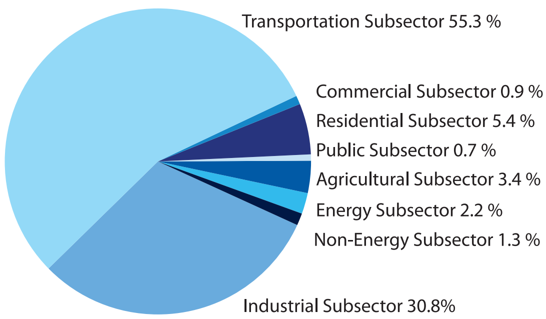


Figure II.26. CO_2 Emissions from Energy Sector by Subsector, in 2008, in Sao Paulo State (77,233 Gg)



Among the sectors that more contributed to the increase of CO_2 emissions, highlight the Transportation (56% in 2005), specially the Road Segment, responsible for 81% of total emissions in the Sector. The Industrial Sector contributed with the other 29% of these emissions. The Segment that contributed with CO_2 emissions in this Sector was the Pig Iron and Steel, with 34% due to energy consumption by industry. The emissions from Industrial Sector increased by 25% in the period 1990 to 2008.

Table II.20 shows the comparison of the estimates of CO_2 emissions obtained from the two approaches used. The Reference Approach (Top-down) uses a greater number of variables, which can contribute to the small difference that should be of 2% (BRASIL, 2010b). In Table II.20, we observed that the quantities obtained in Reference Approach are slightly higher than the Sectoral Approach. However, this last one does not account for the loss of energy in processing and distribution, which results in an estimate lower.

Table II.19. CO_2 Emissions by Sector in Sao Paulo State (Gg_{CO2})

Setor	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2}]									
Energy Sector	971	981	1,035	1,010	1,134	875	1,436	1,117	1,053	2,028
Public eletricity plants	138	151	160	109	208	77	805	375	446	1,363
Auto producer eletricity plants	833	830	875	901	926	798	631	742	607	665
Charcoal kiln	0	0	0	0	0	0	0	0	0	0
Energy consumption*	3,062	3,084	3,375	3,594	4,034	4,206	4,306	4,365	4,026	3,973
Industrial Sector	18,979	19,182	19,232	19,327	20,651	20,774	21,954	22,978	22,536	21,420
Food and beverage	1,608	1,870	1,932	1,996	2,029	1,914	2,168	2,242	2,130	2,028
Ceramic	514	570	635	719	762	841	879	989	732	968
Cement	1,511	1,437	1,129	1,066	1,166	1,384	1,841	1,840	1,852	1,876
Pig iron and steel	6,508	6,886	6,866	6,779	7,591	7,064	7,301	7,641	7,368	6,798
Iron	0	0	0	0	0	0	0	0	0	0
Mining and pelleting	82	147	147	147	150	153	145	192	235	245
Non-ferrous metals	1,850	1,810	1,935	1,749	1,900	1,958	1,618	1,699	1,409	1,511
Pulp and paper	815	880	904	1,011	1,044	1,427	1,781	1,690	1,683	1,719
Chemical	3,010	2,368	2,329	2,420	2,472	2,624	2,834	2,838	2,846	2,970
Textile	525	516	532	556	581	521	475	441	473	479
Others	2,556	2,698	2,824	2,883	2,956	2,888	2,913	3,406	3,807	2,826
Transportation Sector	23,756	25,144	25,531	26,169	29,122	31,276	35,968	39,483	40,904	41,301
Air transport	1,502	1,887	2,041	2,524	2,924	3,736	4,536	4,838	5,602	5,187
Road transport	19,256	20,435	20,845	20,899	23,165	24,688	28,190	30,773	31,389	32,023
Rail transport	329	270	243	246	258	252	264	283	224	206
Water transport	2,669	2,552	2,402	2,500	2,775	2,600	2,978	3,589	3,689	3,885
Commercial Sector	919	786	743	810	803	767	709	755	611	762
Housing Sector	3,339	3,468	3,524	3,621	3,623	3,637	4,135	4,030	4,180	4,234
Public Sector	216	277	263	249	228	217	278	328	266	304
Agriculture Sector	2,293	2,384	2,501	2,532	2,673	2,814	3,171	3,316	2.975	3.134
Non Energy Subsector	832	827	663	892	867	904	917	1,211	1,219	1,282
Total	**51,305**	**53,049**	**53,492**	**54,610**	**59,101**	**61,264**	**68,568**	**73,218**	**73,744**	**74,465**

Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2}]									
Energy Sector	2,264	2,428	1,577	1,257	1,265	1,718	854	847	1,698	
Public eletricity plants	1,521	1,586	767	522	707	1,031	259	218	911	
Auto producer eletricity plants	743	842	810	735	558	687	595	629	787	
Charcoal kiln	0	0	0	0	0	0	0	0	0	
Energy consumption*	4,332	3,760	3,785	3,250	3,102	2,653	2,620	2,627	2,459	
Industrial Sector	20,867	19,856	19,062	20,726	20,684	20.931	22,942	24,103	23,815	
Food and beverage	2,146	2,363	2,263	2,006	1,854	1,891	2,016	2,137	2,355	
Ceramic	952	946	1,150	1,141	1,138	1,374	1,431	1,541	1,642	
Cement	1,795	1,492	1,327	1,065	955	1,046	1,380	1,510	1,567	
Pig iron and steel	6,612	6,281	6,096	7,324	6,747	6,700	6,839	7,087	6,544	
Iron	0	0	0	0	0	0	0	0	0	
Mining and pelleting	236	157	169	180	173	170	170	167	198	
Non-ferrous metals	1,959	1,584	1,449	1,721	1,752	1,787	1,789	1,871	1,923	
Pulp and paper	1,057	1,116	1,234	1,297	1,342	1,415	1,508	1,620	1,491	
Chemical	2,920	2,941	2,832	2,703	2,643	2,934	2,918	3,098	3,268	
Textile	505	485	435	348	433	483	480	452	462	
Others	2,685	2,491	2,107	2,941	3,647	3,130	4,410	4,620	4,366	
Transportation Sector	40,140	39,259	38,851	38,125	38,956	39,834	39,084	41,020	42,710	
Air transport	4,630	3,913	4,133	4,658	4,821	5,073	4,844	5,200	5,618	
Road transport	31,782	32,215	32,061	30,901	31,611	32,410	32,018	33,758	35,171	
Rail transport	230	328	362	393	378	399	396	399	457	
Water transport	3,497	2,803	2,295	2,173	2,146	1,952	1,826	1,663	1,463	
Commercial Sector	736	730	717	718	720	673	698	698	710	
Housing Sector	4,138	4,119	4,138	4,228	4,214	4,056	3,972	4,009	4,160	
Public Sector	301	326	386	375	441	458	428	431	504	
Agriculture Sector	2,838	2,572	2,823	2,626	2,798	2,416	2,594	2,747	2,634	
Non Energy Subsector	1,328	1,565	1,137	1,197	1,432	1,050	1,185	1,238	1,002	
Total	**72,612**	**70,855**	**68,691**	**69,252**	**70,510**	**71,136**	**71,757**	**75,093**	**77,233**	

*Not included in the Emission of the Energy Sector and Total Emission, for those emissions are kept in the Sector of Refining and Transportation of Oil and Gas and Metallurgy Sector, specifically in the Production of Steel.

Table II.20. CO_2 Emissions from Fossil Fuels Combustion Estimated by Reference (Top-down) and Sectoral (Bottom-up) Approaches in Sao Paulo State

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Reference approach [Gg_{CO2}] (A)	56,958	59,736	60,094	61,738	67,191	69,249	76,452	74,327	74,933	69,978
Sectoral approach [Gg_{CO2}] (B)	51,305	53,049	53,492	54,610	59,101	61,264	68,568	73,218	73,744	74,465
Difference (%) ((A-B)/B)*100	11.0	12.6	12.3	13.1	13.7	13.0	11.5	1.5	1.6	-6.0

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Reference approach [Gg_{CO2}] (A)	77,231	74,621	73,618	72,291	77,754	79,792	77,144	79,345	79,231	
Sectoral approach [Gg_{CO2}] (B)	72,612	70,855	68,691	69,252	70,510	71,136	71,757	75,093	77,233	
Difference (%) ((A-B)/B)*100	6.4	5.3	7.2	4.4	10.3	12.2	7.5	5.7	2.6	

According to the National Communication, the calculation in Sectoral Approach is simpler, done directly with the data on the consumption of fuel, according to the application of the method. In the Reference Approach the apparent consumption resulting from the consideration of production, import, export, and changes in inventories (BRASIL, 2010a). The results of the estimates of sector emissions were used to estimate the total, adding these to the other sectors.

5.1.3 Non-CO_2 GHG and Indirect GHG Emissions from Fuel Combustion

In stationary sources, non CO_2 GHG emissions (CH_4 and other pollutants such as CO and VOC) are the result of incomplete combustion of fuels. The IPCC (1996) also considers the NOx and N_2O in these estimates. To estimate the emissions of other non CO_2 GHG are used the same sectors of the estimates of emissions of CO_2 and the sum of all emissions, including those caused by the fuel combustion from biomass.

Table II.21. CH_4, N_2O, NOx, CO and VOC Emissions in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[$Gg.year^{-1}$]									
CH_4*	16	17	17	18	19	20	21	22	24	24
N_2O*	1	1	1	1	1	2	2	2	2	2
NOx	369	381	385	391	427	444	500	545	547	557
CO	571	585	587	600	637	665	731	784	781	799
VOC	219	238	240	243	284	307	355	380	386	395

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[$Gg.year^{-1}$]									
CH_4*	22	23	24	25	27	28	29	32	34	
N_2O*	2	2	2	2	2	3	3	3	3	
NOx	541	524	515	504	514	514	511	534	549	
CO	802	792	784	769	792	804	812	842	867	
VOC	372	365	348	332	335	345	344	353	353	

*Emissions concerning the Energy Sector consumption were not included in the Wide Power Sector nor in the Total Emission, for such emissions are kept in the Refining Sector and Oil and Gas Transportation and Metallurgy Sector, specifically in the Production of Steel.

For this estimate was used the Tier 1, because it has not yet been found specific data from technology by Sector to define the local emission factors. In general, because it was the calculation of emissions caused by the final consumption of fuel, it was possible to perform all the steps of the IPCC method. Only for fuels derived from sugarcane were not made the calculations of emissions for gases N_2O, CO, NOx and VOC, because the default data are not for this type of biomass, particularly important in the composition of the energy matrix of Sao Paulo State and because there are no studies that will consolidate the emission factors of these gases for products of the sugarcane.

Table II.21 presents the total emissions of non CO_2 GHG from fuel combustion in Sao Paulo State during the period 1990 to 2008. In 2008, all non CO_2 gases showed an increase in emissions, and the largest growth rate for the period 1990 to 2008 was the N_2O (182%). Below is presented a more detailed analysis of the result of the emissions for non CO_2 gases.

Methane

In 2005, the fuel combustion in the Sao Paulo State was responsible for emissions to 28 Gg of CH_4. The emissions in the period 2005 to 2008 have increased by 21%. In 2005, the Industrial Sector was the largest emitter of CH_4 (55%), due to the participation of the Food and Beverage Subsector (73%), followed by the Transportation Subsector (26%).

Nitrous Oxide

In 2005, Sao Paulo State emitted 3 Gg of N_2O from fuel combustion. The emissions in the period 2005 to 2008 are increased by 23%. In 2005, the Industrial Sector was the largest emitter of N_2O (74%), due to the participation of the Food and Beverage Subsector (79%), followed by the Wide Energy Sector (7%).

Carbon Monoxide

In 2005, Sao Paulo State emitted 804 Gg of CO by fuel combustion. The emissions in the period 2005 to 2008 are increased by 8%. In 2005, the Transportation Subsector was the largest emitter of CO (57%), due to the participation of the Road Segment (90%), followed by the Industrial Sector (28%).

Nitrogen Oxide

In 2005, Sao Paulo State emitted 514 Gg of NOx by fuel combustion. The emissions in the period 2005 to 2008 are increased by 7%. In 2005, the Transportation Subsector was the largest emitter of NOx (76%), due to the participation of the Road Segment (85%), followed by the Industrial Sector (12%).

Volatile Organic Compounds

In 2005, Sao Paulo State emitted 345 Gg of VOC by fuel combustion. The emissions in the period 2005 to 2008 are increased by 2%. In 2005, the Transportation Subsector was the largest emitter of VOC (94%), due to the participation of the Road Segment (97%). Table

II.22 and Figure II.27 show the total emissions of GHG into CO_{2eq} from fuel combustion by subsector in the Sao Paulo State during the period 1990 to 2008.

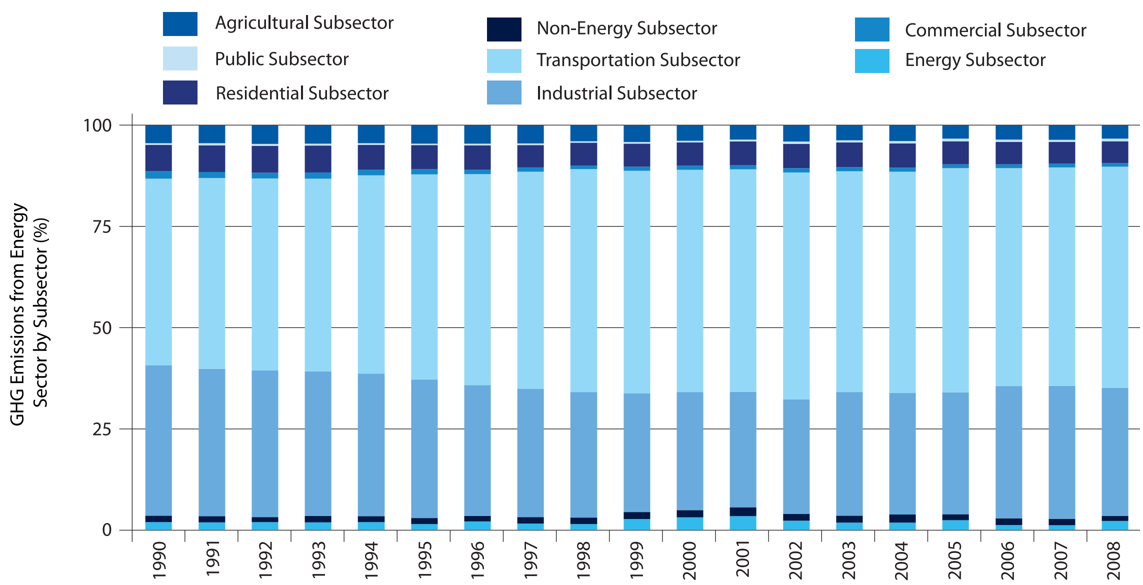
Table II.22. GHG Emissions from Fuel Combustion by Subsector, by Sectoral Approach in Sao Paulo State (GgC_{O2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{CO2eq}.year^{-1}]$									
Energy Subsector	1,018	1,032	1,089	1,065	1,197	942	1,512	1,187	1,126	2,101
Non Energy Subsector	832	827	663	892	867	904	917	1,211	1,219	1,282
Industrial Subsector	19,325	19,570	19,626	19,752	21,107	21,255	22,466	23,523	23,205	22,117
Transportation Subsector	23,925	25,326	25,719	26,364	29,340	31,514	36,238	39,770	41,191	41,597
Commercial Subsector	946	813	770	837	830	794	732	778	633	784
Residential Subsector	3,398	3,528	3,584	3,684	3,687	3,701	4,200	4,096	4,246	4,301
Public Subsector	217	278	264	250	229	218	279	329	267	305
Agricultural Subsector	2,309	2,400	2,517	2,548	2,690	2,834	3,192	3,338	2,996	3,155
Total	**51,970**	**53,773**	**54,232**	**55,393**	**59,948**	**62,163**	**69,536**	**74,230**	**74,882**	**75,642**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{CO2eq}.year^{-1}]$									
Energy Subsector	2,334	2,500	1,649	1,330	1,346	1,800	945	936	1,793	
Non Energy Subsector	1,328	1,565	1,137	1,197	1,432	1,050	1,185	1,238	1,002	
Industrial Subsector	21,445	20,537	19,788	21,508	21,543	21,829	23,890	25,146	24,956	
Transportation Subsector	40,415	39,521	39,117	38,389	39,232	40,121	39,377	41,342	43,050	
Commercial Subsector	758	752	739	740	741	694	719	719	731	
Residential Subsector	4,205	4,186	4,201	4,285	4,271	4,114	4,031	4,069	4,224	
Public Subsector	302	327	387	376	442	459	429	432	505	
Agricultural Subsector	2,859	2,589	2,843	2,643	2,818	2,432	2,611	2,768	2,651	
Total	**73,645**	**71,977**	**69,862**	**70,467**	**71,826**	**72,499**	**73,187**	**76,649**	**78,912**	

Note: This total does not include the refining and transportation emissions of oil and derivatives. The GHG emissions comprehend the addition of the CO_2, CH_4 and N_2O emissions.

Figure II.27. GHG Emissions from Energy Sector by Subsector in Sao Paulo State (%)



5.1.4 Refining and Transportation of Oil and Derivatives

The GHG emissions inventory from Refining and Transportation of Oil and Derivatives in Sao Paulo State was accomplished with a cooperation firmed in 2010 between CETESB and PETROBRAS[37].

In 2002, PETROBRAS implemented a computerized system of management for the atmospheric emissions, the SIGEA®. An inventory is obtained through this system from all units, calculated based on consumption and operation data for each equipment. Thus, the GHG emissions Reference Report of Sao Paulo State was prepared by PETROBRAS itself with the purpose to support the elaboration of the GHG emissions Inventory of Sao Paulo State by Energy Sector (PETROBRAS, 2011). This inventory includes the following gases: CO_2, CH_4 e N_2O. The emissions reported include the operation of the installations of PETROBRAS in the period evaluated, the quantities may be lower than those resulting from the calculation for the full load.

The activities that cover the Inventory in aggregation of data are: refining activity, transportation and distribution of oil and derivatives activity, and electricity generation activity. The report follows the IPCC Method (1996, 2000a), which establishes three levels of rigor for the estimates of atmospheric emissions. Tier 1 which estimates atmospheric emissions by approximation of aggregated factors, Tier 2 and Tier 3 that approaches atmospheric emissions inventory with disaggregated information details. It was also used a decision tree, and its understanding was mapped in accordance with the procedures adopted in the Refining and Transportation of Oil and Derivatives Emissions Inventory (PETROBRAS, 2011).

The emissions are divided into two categories: refining and transportation of oil and derivatives. Refining emissions occur by combustion and transportation of oil, and derivatives emissions occur by CH_4 fugitives during the transportation and distribution at the pipelines, and during the processing in refineries.

To estimate the sources of emission of CO_2 from refining process was considered a decision tree (IPCC) that defined the level of rigor of Tier 3. For the sources of emission of CH_4 and N_2O from refining, the decision tree directed the use of Tier 2. The emission of CH_4 and N_2O due to the transportation of oil and derivatives were estimated according to the emission factors of the appropriate literature and detailed data on local infrastructure (PETROBRAS, 2011).

For sources of emissions by refining and transportation of oil and derivatives, in the period 1990 to 2002, the estimate is made by activity and takes into account specific factors. For sources of emissions for transportation of oil and derivatives, between the years 2003 and 2008, are considered: hydrogen (H_2), flare, supply flares, fugitive by components, ventilated gas, depressurization of line, and pigging. In the period 2003 to 2008 were used data from the SIGEA®, and the CO_2 emissions from furnaces, boilers, engines and turbines were

[37] The cooperation was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

calculated by stoichiometry. Emissions of CH_4 and N_2O were calculated from emission factors for each type of source: furnaces and boilers, engines, turbines, regenerators Fluid Catalytic Cracking (FCC) and the Sulfur Recovery Units (SRU).

Finally, the calculations of CO_2 emissions were performed based on the average characteristics of the following fuels: diesel, fuel oil, fuel gas or refinery gas, natural gas, purging gas, acid gas, ammonia gas and coke. The method of inventory, according to PETROBRAS (2011), identifies which fuel is used in burning by source of emissions, increasing the integrity of the data.

The results were presented by category, and for each one, are included the activities developed in Sao Paulo State, the fuel consumption per type of emission source and the description of the characteristics of the fuels. The categories have their results divided into periods, because the methods used in the periods 1990 to 2002 and from 2003 to 2008 were different. In Table II.23, Table II.24 and Table II.25 were presented the total GHG emissions in the Refining and Transportation of Oil and Derivatives in Gg and Gg_{CO2eq}, respectively.

Table II.23. GHG Emissions from Combustion in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CO_2	4,997	4,903	5,043	5,021	5,590	5,724	5,956	6,461	6,876	6,689
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
N_2O	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CO_2	7,412	7,309	7,032	7,252	7,339	7,306	7,477	7,986	7,971	
CH_4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	
N_2O	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	

Table II.24. Fugitive GHG Emissions in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CO_2	93	91	94	93	104	107	111	120	128	124
CH_4	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.045
N_2O	0.00004	0.00004	0.00004	0.00004	0.00005	0.00005	0.00005	0.00006	0.00006	0.00006

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CO_2	137	134	129	132	147	143	141	142	130	
CH_4	0.234	0.409	0.420	0.002	0.615	2.069	4.398	1.605	0.898	
N_2O	0.00006	0.00006	0.00006	0.00000	0.00001	0.00001	0.00001	0.00001	0.00001	

Table II.25. Total GHG Emissions from Combustion and Fugitive Emissions in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.$year^{-1}$]									
CO_2	5,090	4,994	5,137	5,115	5,694	5,831	6,066	6,582	7,004	6,813
CH_4	1	1	1	1	1	1	2	2	2	3
N_2O	17	16	17	17	19	19	20	21	23	22
Total	**5,108**	**5,012**	**5,155**	**5,133**	**5,714**	**5,851**	**6,088**	**6,605**	**7,029**	**6,838**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.$year^{-1}$]									
CO_2	7,549	7,443	7,161	7,384	7,486	7,448	7,618	8,128	8,102	
CH_4	7	10	11	2	15	45	94	39	24	
N_2O	25	25	24	22	25	24	25	27	28	
Total	**7,580**	**7,478**	**7,195**	**7,408**	**7,526**	**7,518**	**7,737**	**8,195**	**8,154**	

Scope:
1. The results do not include the power generation activities (UTE Fernando Gasparian).
2. The transportation of oil and derivatives includes terminals, bases, compression and pumping stations, old-ducts and gas-ducts.
3. Does not include land transportation by vehicles.
Corrections:
4. The figures were corrected by the exclusion of the double counting of the torch emissions (flare + supply flare). The figures of the torches were eliminated in the refining escape results.

5.1.5 Transportation

In the Transportation Subsector were inventoried the modes of transport include air, rail, water and road in the State.

5.1.5.1 Air Transport

The GHG emissions inventory from Air Transport of Sao Paulo State was accomplished as agreement signed between CETESB and Maua Institute of Technology (IMT)[38]. The GHG emissions were addressed: CO_2, CH_4 and N_2O, and from the Indirect GHG: CO, NOx and VOC, relating to civil aviation, which according to the IPCC (2000a) include all emissions from civilian aircraft with the purpose of commercial use, both international and domestic, including regular and charter flights, including the air taxi and general aviation. It was not possible to collect data related to military aviation in Sao Paulo State and, therefore, their emissions were not estimated.

According to the IPCC (2000a), the flight is divided into two stages: the cycle of landing and takeoff (LTO), which includes all the activities close to the airport with altitude below 914m; and the cruise, which occurs in altitude above 914m. The gases emitted from aircraft engines are composed of approximately 70% of CO_2, a little less than 30% of water vapor and less than 1% of NOx, CO, Sulfur Oxides (SOx), particulate and traces of other compounds. Modern turbines emit little or no amount of N_2O (IPCC, 2006).

[38] The agreement was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

To estimate the GHG emissions from the combustion fuel of aviation, we used the methods of the IPCC (1996, 2000a, 2006). According to the last one, there are three routes to the calculations of GHG emissions, based on the degree of rigor, called Tier 1, Tier 2 and Tier 2b. The Tier 1 is based on the quantity of fuel consumed by civil aviation multiplied by an average factor of emission calculated which considers all phases of flight, assuming that 10% of the fuel is used during the stage of LTO. The Tier 2, in addition to considering the fuel consumed, draws a distinction between the emissions released above and below 914m, i.e., divide the emissions in stages of LTO and cruise (IPCC, 2000a). The Tier 2 is subdivided into Tier 2a, based on aggregate movement of aircraft and Tier 2b, based in the movement of individual aircraft.

The estimates of GHG emissions to the Air Transportation Sector were calculated separately according to the type of fuel – Aviation Kerosene (AVK) and Aviation Gasoline (AVGAS) – reporting the emissions from international flights separately of the total national emissions. As recommended by the IPCC (2006), for the calculation of GHG emissions from aircraft powered by AVGAS, was used the Tier 1, because there are no detailed data on the types of aircraft, nor on the accumulated LTO. In this case, there is no difference between domestic and international flight, because the consumption was considered as being exclusively in Sao Paulo State, since, according to IPCC (1996), the AVGAS is only used in small aircraft with piston engine. In addition, the Tier 2 applies only to the AVK, used in jet engines (IPCC, 2000a).

GHG emissions from aircraft powered by AVK were divided into two groups, regular[39] and non-regular[40] aviation, and in two periods (1990 to 1998 and 1999 to 2008). For non-regular aviation, due to the lack of more detailed information, we used the Tier 1. For regular aviation (domestic and international flights), were applied different Tiers for each period. In the period 1999 to 2008, due to the existence of data of LTO by type of aircraft, we used the Tier 2b. For the previous years was adopted the Tier 1.

To report separately the emissions originated in domestic flights from originated on international flights, it is necessary, in the obtaining of the data, to disaggregate the uses of fuel in domestic and international. For the period 1999 to 2008, there are data of fuel used in domestic flights and international flights. For the period 1990 to 1998, by the impossibility of access to these data, an estimate was made by calculating the ratio between the use of fuel for domestic and international flights based on consumption of the period in which the data were available.

We used the emission factors default from the IPCC, and it is necessary to adopt some assumptions to compensate for the lack of specific information and the lack of recommendations for inventories of the State, since the guidelines of the IPCC are focused on national inventories. In future, it is expected that some of these assumptions can be discarded, as the obtaining of data is improved (IMT, 2011a).

[39] In this inventory is considered regular aviation the flights performed by regular airlines, in order to fit to the data collected by the National Civil Aviation Agency (ANAC), which subdivides its data based on information from regular airlines , and not on regular flights.
[40] It is considered not non-regular aviation, the flights performed by air taxi, specialty air services and additional aviation.

In domestic flights with origin or destination in Sao Paulo, we assumed that half of the fuel consumed belongs to Sao Paulo State. This assumption is justified due to the fact that the states of origin and destination of flights are "benefited" with these trips, and therefore should share the responsibility for this emission (FABER et al, 2007 apud IMT, 2011a).

According to the IPCC (2000a), the international flights with stopovers must have each of its stages classified in domestic or international. On international flights with stopover within the same country, this stage was considered domestic only for flights made by Brazilian companies (IMT, 2011a).

The data for non-regular aviation were removed from the Yearbooks of Air Transportation (ANAC, 2010), where are presented the fuel consumption for non-regular aviation (divided by regions and the headquarters of companies discriminated by the Federation Unit).

According to the IMT (2011a), the BEESP offers the consumption of AVK and AVGAS. These data are presented in Table II.26. The data for the sale of AVK fuel are used to quantify the fuel consumed on international flights and the data of AVGAS to estimate directly the GHG emissions through the Tier 1.

Table II.26. Consumption of Aviation Fuel in the Sao Paulo State (tOE)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[10^3 tOE]									
AVGAS	10	10	9	9	10	12	16	21	21	20
AVK	497	627	680	843	977	1249	1515	1612	1870	1731
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	
	[10^3 tOE]									
AVGAS	20	22	13	8	10	13	14	9	9	
AVK	1543	1299	1382	1564	1617	1699	1621	1746	1887	

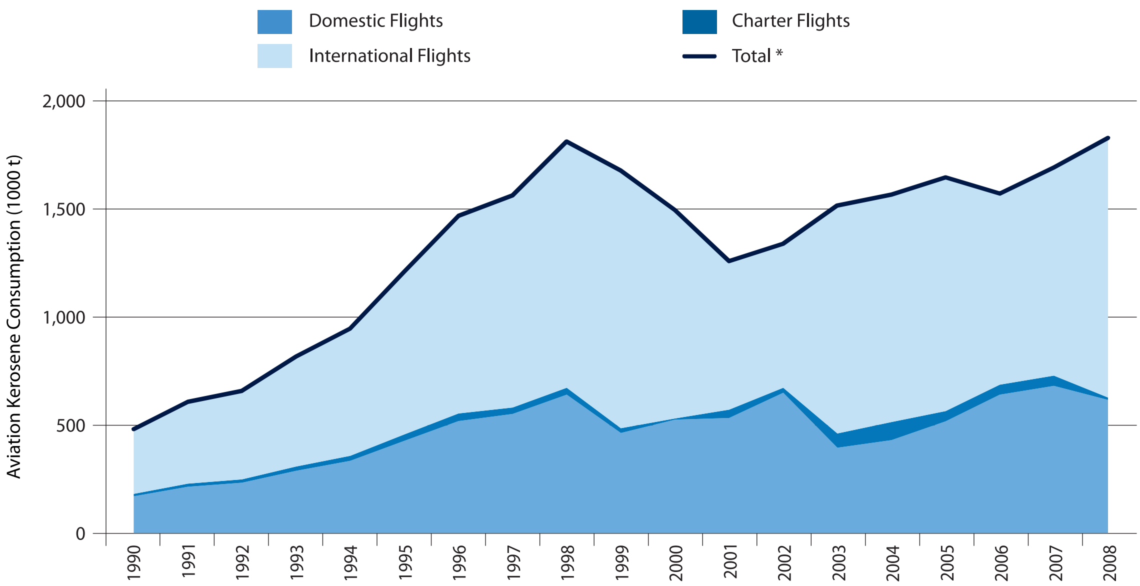
Source: SÃO PAULO (2009c) apud IMT (2011a).

The ANAC (2010, apud IMT, 2011a) has data on fuel consumption of Brazilian companies by type of aircraft for the period 1999 to 2008, for flights from and within Sao Paulo State and interstate flights with origin or destination in Sao Paulo State. The data for years prior to 1999 are not available, as well as the data of LTO. For this reason, it was necessary to estimate the fuel consumption for domestic flights in the years prior to 1999. Figure II.28 shows the fuel consumption for the period 1990 to 2008.

The results of the estimates of GHG emissions were calculated separately, according to the degree of rigor adopted, the type of fuel (AVGAS and AVK), and the type of classification (domestic and international). According to the IPCC (2006), to form a consistent temporal series of results for regular aviation, we must combine the Tier 1 and Tier 2b. For this, the estimates were compared and their results matched and consolidated. Considering the GWP of GHG emitted in domestic and international flights, estimated by means of the data of ANAC and BEESP and applying the method of the IPCC (1996), we can conclude that the

CO_2 is the GHG with higher emission, being responsible for 99% of emissions; N_2O represents 0.99% of the emissions of CO_{2eq} and CH_4 represents 0.01% (IMT, 2011a).

Figure II.28. Aviation Kerosene Consumption in the Sao Paulo State (t)



* Source: BEESP (SÃO PAULO, 2009c)

According to the IMT (2011a), we can conclude that the quantity of gases emitted on international flights is 1.6 times higher than the domestic, with the exception of the emission of CH_4. Similarly, the consumption of fuel by international flights was 1.7 times higher than domestic flights.

Table II.27. GHG Emissions from Air Transport in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{CO2eq} \cdot year^{-1}]$									
CO_2	600	749	807	994	1,151	1,469	1,786	1,885	2,172	1,582
CH_4	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.02
N_2O	0.02	0.03	0.03	0.03	0.04	0.05	0.06	0.06	0.07	0.05
NOx	2.11	2.66	2.87	3.55	4.12	5.26	6.38	6.71	7.76	5.31
CO	1.56	1.95	2.09	2.57	2.97	3.79	4.62	4.91	5.66	4.56
VOC	0.19	0.23	0.25	0.30	0.35	0.44	0.54	0.56	0.64	0.51

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{CO2eq} \cdot year^{-1}]$									
CO_2	1,725	1,856	2,151	1,469	1,642	1,810	2,198	2,315	1,997	
CH_4	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	
N_2O	0.06	0.06	0.07	0.05	0.05	0.06	0.07	0.08	0.07	
NOx	5.82	6.00	7.78	5.28	5.87	6.59	8.07	8.83	7.93	
CO	4.87	4.95	5.61	3.69	4.05	4.58	5.38	5.53	4.78	
VOC	0.52	0.60	0.61	0.49	0.58	0.55	0.63	0.63	0.49	

Source: SÃO PAULO (2009c) apud CETESB (2011h).

Considering the stage of LTO, landing and take-off, and cruising in the regular domestic aviation, it was found that the emissions of the stage of cruise are, on average, 2.8 times higher than the emissions during the stage of landing and take-off, en masse, except, again, the gas CH_4 which for the stage of cruise, has emission considered null and void.

Regarding to fuel consumption, it was found that the AVK represented 99% of the fuel used during the whole period of study. The AVGAS represented less than 1% of fuel consumption in Sao Paulo State. Table II.27 shows the GHG emissions in Air Transport in Gg.

5.1.5.2 Rail Transport

The GHG emissions inventory from Railway Transportation in Sao Paulo State was performed by CETESB[41]. Currently, the rail network of Sao Paulo State have approximately 5.000 Km, connecting regions from the interior and from other states to the Metropolitan Region of Sao Paulo (RMSP) and to the Port of Santos. The railway for transportation of cargo was privatized, but under Federal control. The utility companies of the Railway Transportation in the State are the America Latina Logistica S.A. (ALL), the Ferrovia Centro-Atlantica S.A. (FCA), MRS Logistica S.A. (MRS) and Companhia Paulista de Trens Metropolitanos (CPTM). Figure II.29 shows the rail network of Sao Paulo State.

Figure II.29. Sao Paulo State Rail Network

Source: SÃO PAULO (2009b) apud CETESB (2011h).

[41] The inventories accomplished by CETESB had resources of the partnership with the British Embassy, and this also to collaborate for the CETESB´s Project to improve State Policy on Climate Change, coordinated by PROCLIMA.

For this inventory were not estimate GHG emissions of metropolitan rail transportation, because this sector consumes only electricity of the National Interconnected System (SIN) Emissions from electricity consumption are presented in the inventory of the Energy Sector.

The estimates of GHG were prepared considering the method presented by IPCC (2006). We used data on the consumption of fuel in the rail industry presented in BEESP (SÃO PAULO, 2009c) and emission factors default. If future studies can rely on consumption data, load and origin and destination, may reflect more accurately the reality of the sector.

The emissions of CH_4 and N_2O from the burning of fuel oil were not considered because there are no emission factors specific to the country or state, and not even emission factors default of IPCC (CETESB, 2011h). Table II.28 presents data on energy consumption in the period 1990 to 2008 in the State for the Rail Industry.

Table II.28. Data on the Railway Sector Power Consumption in the Sao Paulo State (kcal*)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[10^9 kcal]									
Diesel	1,057	875	780	788	832	814	849	910	719	658
Fuel oil	10	10	10	10	10	10	10	10	10	10
Electricity	637	665	679	716	612	630	635	594	533	531

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[10^9 kcal]									
Diesel	736	1,074	1,178	1,282	1,230	1,299	1,291	1,299	1,490	
Fuel oil	10	0	0	0	0	0	0	0	0	
Electricity	541	550	555	568	574	595	632	685	730	

* 1cal = 4,1868J.
Source: SÃO PAULO (2009c) apud CETESB (2011h).

To obtain the estimate of GHG emissions, we used data on fuel consumption in Sao Paulo State. Naturally, the locomotives can transpose the state borders and be supplied both in the State and in other states or countries.

Table II.29. GHG Emissions from Rail Transport in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[$Gg.year^{-1}$]									
CO_2	331	274	245	247	261	256	266	285	226	207
CH_4	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
N_2O	0.13	0.10	0.09	0.09	0.10	0.10	0.10	0.11	0.09	0.08

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[$Gg.year^{-1}$]									
CO_2	231	333	365	398	382	403	401	403	462	
CH_4	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	
N_2O	0.09	0.13	0.14	0.15	0.15	0.16	0.15	0.16	0.18	

These facts create uncertainty about the allocation of emissions, which is not taken into account in this estimate. The emissions are attributed to territorial unit where the supply occurred, in the same way as recommended by the IPCC (2000a) for the estimates of mobile sources road (CETESB, 2011h). Table II.29 shows the GHG emissions in Railway Transportation in Gg.

5.1.5.3 Water Transport

The GHG emissions inventory from Water Transportation in Sao Paulo State was accomplished by CETESB[42]. The environmental impacts of this type of transport are related to the port enterprises and the ships. Sao Paulo State presents Water Transportation by inland waterway (waterways and terminals), lake and river, river crossings and two seaports (SÃO PAULO, 2007 apud CETESB, 2011g).

The estimates of GHG were prepared considering the method of the IPCC (2006). We used data on fuel consumption of the Waterways Sector of BEESP (SÃO PAULO, 2009c) and emission factors default. If future studies can rely on consumption data, load and origin and destination, may reflect more accurately the reality of the sector. Table II.30 presents data on energy consumption in the period 1990 to 2008, in the State for the Waterway Sector.

Table II.30. Data on the Waterway Sector Power Consumption in the Sao Paulo State (kcal*)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[10^9 kcal]									
Diesel	2,720	2,833	2,322	2,452	2,512	2,599	2,686	2,755	2,504	2,686
Fuel oil	5,722	5,245	5,274	5,446	6,247	5,617	6,714	8,564	9,108	9,537
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	
	[10^9 kcal]									
Diesel	2,426	3,032	1,992	1,759	1,594	1,455	866	814	849	
Fuel oil	8,583	5,837	5,245	5,093	5,169	4,692	4,864	4,406	3,748	

* 1cal = 4,1868J.
Source: SÃO PAULO (2009d) apud CETESB (2011h).

To obtain the estimate, we used data on fuel consumption in Sao Paulo State. It is known that the ships can be supplied in a state or country, and that these may cross its borders. These facts generate uncertainty about the allocation of emissions. Consumption data, the way in which they were used in this estimate do not take this issue into account, assigning the emissions to territorial unit where the supply occurred, as recommended by the IPCC (2000a) for the estimates of road mobile sources. Table II.31 shows the GHG emissions in the Water Transportation in Gg.

[42] These estimates were accomplished within the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

Table II.31. GHG Emissions from Water Transport in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CO_2	2,698	2,579	2,429	2,526	2,804	2,627	3,009	3,630	3,728	3,924
CH_4	0.25	0.24	0.22	0.23	0.26	0.24	0.28	0.33	0.34	0.36
N_2O	0.07	0.07	0.06	0.07	0.07	0.07	0.08	0.09	0.1	0.1

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CO_2	3,534	2,832	2,318	2,196	2,170	1,972	1,845	1,680	1,478	
CH_4	0.32	0.26	0.21	0.2	0.2	0.18	0.17	0.15	0.13	
N_2O	0.09	0.07	0.06	0.06	0.06	0.05	0.05	0.04	0.04	

5.1.5.4 Road Transport

The GHG emissions inventory from Road Transport of Sao Paulo State was accomplished as agreement signed between CETESB and Maua Institute of Technology (IMT)[43]. This report includes all types of vehicles with combustion engine subject to licensing for circulating on public roads, which are: cars, motorcycles, trucks and buses. The machines and equipment for construction, agricultural and special use are not part of the scope.

Such vehicles are operating with the following fuels: gasoline, ethanol and vehicular natural gas (VNG) in cars, gasoline in motorcycle, and diesel in the trucks and buses. Vehicles that operate with different fuels than listed above were not included because they are considered insignificant. The GHG inventory in this subsector is: CO_2, CH[44]and N_2O, and Indirect GHG: CO, NOx and VOC. The method for estimating the emissions of GHG and pollutants from the Road Transport follows the following references: IPCC (1996, 2006) and the 1st national inventory of atmospheric emissions by road automotive vehicles (BRASIL, 2010c).

For the estimation of CO_2 emissions from Road Transport was applied the degree of rigor Tier 2, according to IPCC (2000a). The emission of CH_4 and N_2O require a greater degree of detail, because the emission factors depend on the type of technology for pollution control of the vehicle, of the fuel used and of the operation characteristics (IPCC, 2000a). For this reason, we decided to apply the Tier 3. To estimate the emissions of VOC, we used the method presented by the Environment Ministry (BRASIL, 2010c). It must be highlighted that the total emission of VOC is formed by the sum of the emissions of non-methane hydrocarbons (NMHC), leaving from the exhaust of the vehicle, and from the evaporative emissions of VOC.

[43] The agreement was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

[44] According to IPCC (2006), the CO_2 emissions from biofuels should not be counted in the total emissions of the Transport Sector, as they are considered carbon neutral. However, they must be reported separately in order to avoid double counting, since they must be treated in the Sectors of Agriculture, Forestry and Other Land Uses (IMT, 2011b).

Therefore, it was made segregation by type of vehicle to estimate GHG emissions and pollutants of Road Transport. The vehicles were divided into: light weight (TGW [45] less than 3.5 t), heavy weight (TGW exceeding 3.5 t) and motorcycles. The light vehicles were subdivided into cars and light commercial of Otto cycle and the heavy vehicles were subdivided into buses, trucks and light commercial of diesel cycle.

In addition, in order to determine the emission factors of Sao Paulo State were considered data from several entities in order to identify the characteristics of the fleet of the State. In the estimated period, there were no technological changes (flex fuel, biofuels and vehicles converted to CNG) and the technology of the pollution control (with or without catalytic converter) and which were also considered in the method adopted. The data used to estimate GHG emissions and pollutants in Sao Paulo State, as the intensity of use or average distance, are the same used in the 1st national inventory of atmospheric emissions by road automotive vehicles (BRASIL, 2010c).

However, as these data are fixed by type of vehicle, not considering the type of fuel, was made an adjustment according to the consumption of fuel in Sao Paulo State, so that the intensity of use would be as close as possible to the reality of the State.

From the results obtained using methods of the IPCC (1996, 2000a) and BRASIL (2010c), we can observe that both diesel and gasoline are responsible for most of the GHG emissions, as expected due to the greater consumption of these fuels.

Table II.32. GHG Emissions from Road Transport by Type of Vehicle in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.year^{-1}]									
Automobile	7,030	7,756	7,776	7,869	9,481	10,382	12,102	12,827	12,970	13,310
Light commercial vehicle	1,209	1,353	1,405	1,558	1,700	1,867	2,195	2,397	2,446	2,555
Motorcycle	183	203	197	185	199	195	216	233	257	290
Bus	5,428	5,663	5,971	5,957	6,045	6,123	6,748	7,393	7,219	7,346
Truck	6,336	6,447	6,454	6,367	6,764	7,250	8,227	9,276	9,375	9,874
NGV	0	0	6	23	40	32	28	30	42	68
Total	**20,187**	**21,421**	**21,810**	**21,959**	**24,228**	**25,849**	**29,516**	**32,157**	**32,310**	**33,444**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.year^{-1}]									
Automobile	12,223	11,954	11,252	10,669	10,723	11,085	11,103	11,213	10,894	
Light commercial vehicle	2,559	2,601	2,494	2,295	2,253	2,257	2,211	2,304	2,372	
Motorcycle	289	315	332	351	391	461	543	679	798	
Bus	7,411	7,389	7,456	7,149	7,326	7,255	6,871	7,268	7,459	
Truck	10,466	11,003	11,400	10,952	11,364	11,689	11,497	12,539	13,516	
NGV	136	238	423	736	865	1,018	1,214	1,312	1,201	
Total	**33,084**	**33,500**	**33,356**	**32,152**	**32,922**	**33,767**	**33,439**	**35,315**	**36,239**	

[45] TGW: Total Gross Weight.

We noticed that the cars are a significant part of GHG emissions and emissions of CH_4 and CO of trucks and buses are small, if compared to emissions from cars. We also noticed that the NOx emissions have started to decline since mid-1997, but the same is not true for the emission of N_2O, which increased in the period. Regarding to the CH_4, there is a reduction of this GHG emission.

Figure II.30. GHG Emissions from Road Transport, by Type of Vehicle in Sao Paulo State (Gg_{CO2eq})

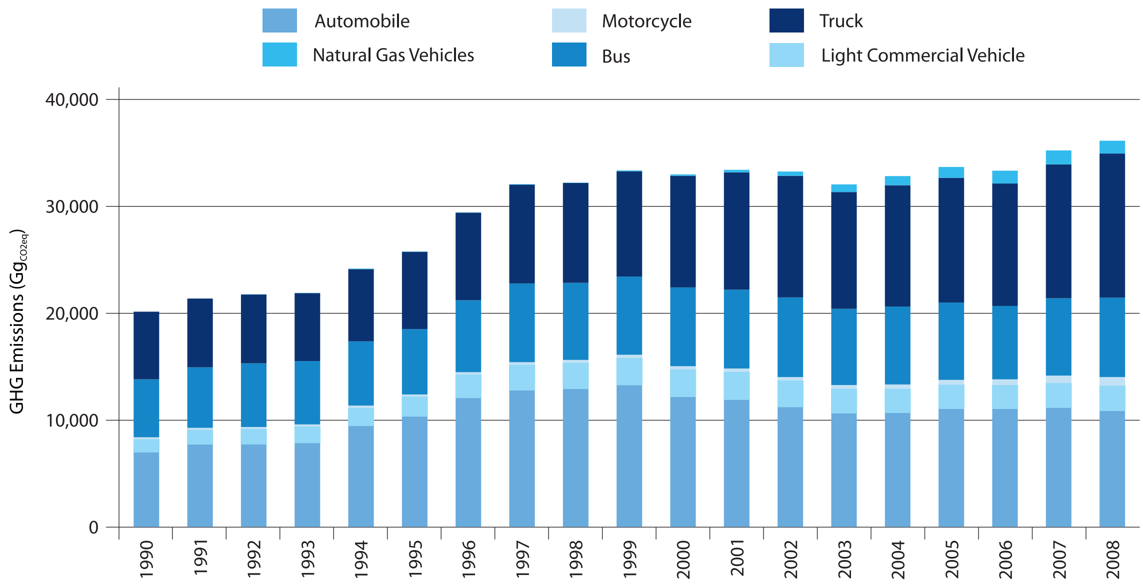
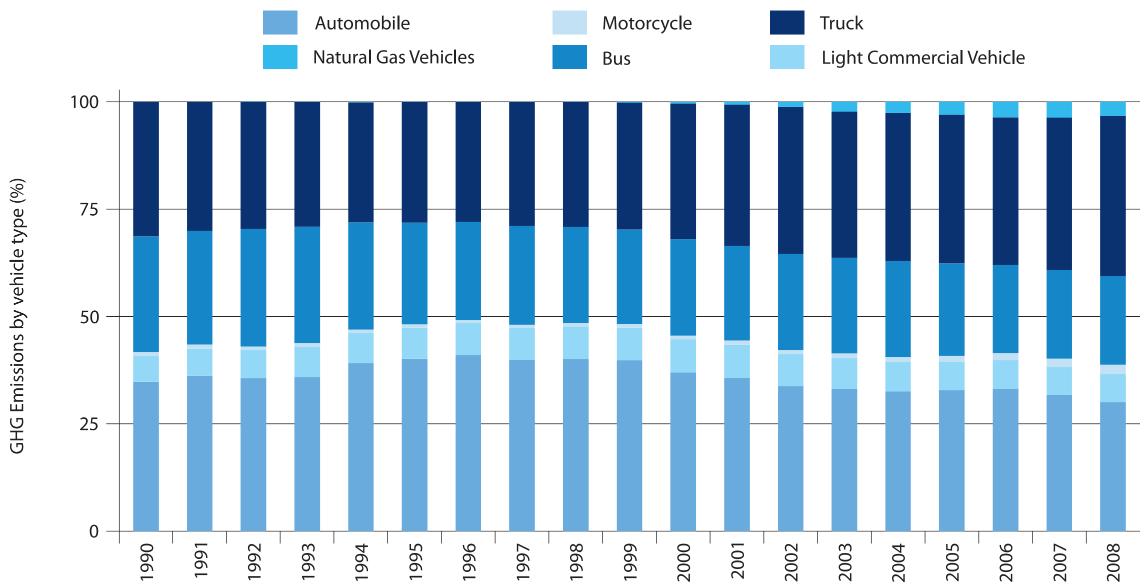


Figure II.31. GHG Emissions from Road Transport by Type of Vehicle in Sao Paulo State (%)



Observing the GWP of GHG emitted by Road Transport, both for light vehicles and heavy vehicles, for the whole period, it can be concluded that the CO_2 is the main GHG and is responsible for 96.9% of the emissions. N_2O represents little more than 2.4% of the emissions of CO_{2eq} and CH_4, 0.7% (IMT, 2011b).

The absence of some specific data of Sao Paulo State, such as the fleet of vehicles circulating in the State, the conversion of vehicles to CNG, the factors of specific emission, intensity of use, among others, made it necessary to adopt some assumptions that may not represent accurately the reality of Sao Paulo State.

It´s expected in future that there will be more appropriate data, enabling the calculation through approaches with greater degree of rigor, minimizing errors to come closer and closer to reality (IMT, 2011b). Table II.32 and Figure II.30 show the GHG emissions of the Road Sector, by type of vehicle in and Gg_{CO2eq}. Figure II.31 presents these emissions in percentage.

5.1.5.5 Total GHG Emissions from the Transport Sector

In short, in Table II.33, Table II.34 and Figure II.32 presents the GHG emissions from Transportation Sector.

Figure II.32. Total GHG Emissions from the Transportation Subsector in Sao Paulo State (Gg_{CO2eq})

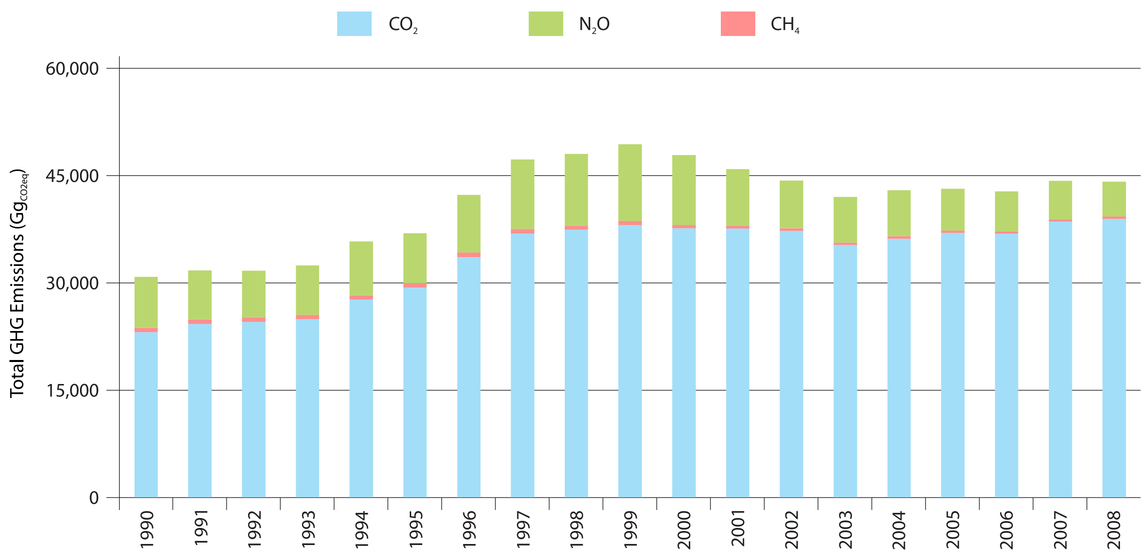


Figure II.33. GHG Emissions from the Transportation Subsector in 2005, in Sao Paulo State (43,065Gg)

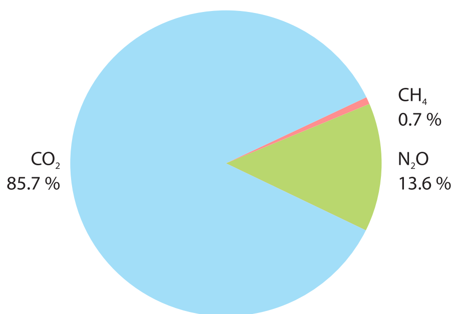


Figure II.34. GHG Emissions from the Transportation Subsector in 2008, in Sao Paulo State (44,037Gg)

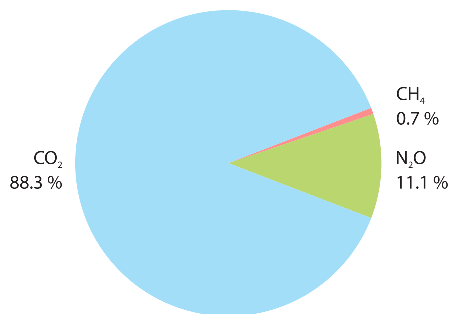


Table II.33. Total GHG Emissions from Transportation Sector in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CO_2	23,038	24,204	24,494	24,836	27,580	29,252	33,494	36,837	37,367	38,015
CH_4	29	31	29	29	30	29	31	30	26	28
N_2O	23	22	21	22	24	23	26	31	32	34
NOx	279	294	297	297	311	319	344	354	338	336
CO	1,885	1,988	1,885	1,827	1,849	1,725	1,678	1,466	1,183	1,177
VOC	327	338	317	303	301	276	264	229	185	184

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CO_2	37,541	37,510	37,171	35,239	36,093	36,895	36,771	38,479	38,872	
CH_4	23	19	17	16	16	15	15	14	14	
N_2O	31	26	22	21	21	19	18	17	16	
NOx	321	310	307	280	282	272	258	263	265	
CO	897	750	712	608	616	550	527	506	468	
VOC	141	118	112	96	98	88	86	84	79	

Table II.34. Total GHG Emissions from Transportation Sector in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.year^{-1}]									
CO_2	23,038	24,204	24,494	24,836	27,580	29,252	33,494	36,837	37,367	38,015
CH_4	613	644	619	605	623	615	649	624	550	578
N_2O	7,136	6,830	6,519	6,939	7,519	6,995	8,050	9,687	10,017	10,694
Total	**30,784**	**31,678**	**31,632**	**32,380**	**35,722**	**36,836**	**42,158**	**47,148**	**47,934**	**49,287**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.year^{-1}]									
CO_2	37,541	37,510	37,171	35,239	36,093	36,895	36,771	38,479	38,872	
CH_4	474	393	363	331	336	322	321	303	296	
N_2O	9,742	7,914	6,697	6,372	6,414	5,847	5,595	5,408	4,868	
Total	**47,757**	**45,817**	**44,231**	**41,942**	**42,844**	**43,065**	**42,687**	**44,190**	**44,037**	

Figure II.33 and Figure II.34 show the GHG emissions by gas in the transportation sector in Sao Paulo State in 2005 and 2008.

5.2 Industrial Processes

5.2.1 Cement Production

The GHG emissions inventory from Cement Production in Sao Paulo State was prepared by CETESB in partnership with the National Union of the Cement Industry (SNIC) and the Brazilian Association of Portland Cement (ABCP)[46].

[46] The inventory was accomplished within the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

In the Production of Cement, about 90% of CO_2 emissions occur during the clinker production either in calcination/decarbonation of raw material, or in the burning of fuels in the interior of the furnace (SNIC; ABCP, 2010). The 1st Direct ans Indirect GHG Anthropogenic Emissions Inventory of Sao Paulo State considers two methods to estimate the emissions from Cement Sector they are the sectorial method of the Initiative for the Sustainability of Cement (CSI, 2005 apud CETESB; SNIC; ABCP, 2011), and the method of the IPCC (2006), Tier 3 approach.

Compared to the IPCC method, the one used in this inventory shows a higher level of detailing because of the studies carried out since 2001, on the basis of the sectorial method adopted by CSI, compatible with the degree of rigor Tier 3 of the IPCC (2006). In which the CO_2 emission is estimated on the basis of the raw materials consumed in the production of cement clinker, discounting dust emission from furnace of the cement (CKD), non-calcined (system losses) and considering the emissions of raw material not energetic containing carbon.

We estimated the emissions in the process of cement production in Sao Paulo State for the period 1990 to 2008 addressing only the emissions of the process of decarbonation of limestone, which occur in calcination furnace for the manufacture of the clinker. Emissions from the combustion of fuel in the interior of the furnace are dealt in the reports of the Energy Sector, according to the methodological guidelines of the IPCC (SNIC; ABCP, 2011).

For the cases of manufacturing plants that do not have specific data on the levels of calcium oxide (CaO) and magnesium oxide (MgO) contained in the clinker, the emission factor default can be applied, recommended by CSI, of 0.525 $t_{CO2}(t_{clinquer})^{-1}$, which already has the correction by the contents of MgO, suggested both by CSI (around 2%) and by the IPCC (2006) (between 1 and 2%). The data is similar to the emission factor of reference used by the IPCC (2000a), of 0.51 $t_{CO2}(t_{clinquer})^{-1}$, if added the correction of the content of the MgO (2% x 1.0918 = 0.022 $t_{CO2}(t_{clinquer})^{-1}$). In both cases, do not include correction for the CKD (SNIC; ABCP, 2010).

Table II.35. Data on the Emission Factor for Organic Carbon Contained in the Raw Material

Data	Description	Quantity	Unit
F_{FC}	Standard dust/ clinker factor	1.550	$[t_{dust}.t_{clinker}^{-1}]$
TOC	Proportion of organic carbon in the dust	2.000	$[kg_{TOC.}T_{dust}^{-1}]$
$CO_2/_C$	Relation among molecular weights	3.664	$[kg_{CO2}.kg_{C}^{-1}]$

Source: IPCC (2006).

The CO_2emissions referring to the Organic Carbon (OC) contained in the raw material, are calculated on the basis of information from the mills themselves. The emissions of CO_2, referring to the Organic Carbon (OC) contained in the raw material, are calculated on the basis of information from the factories themselves. The data used, linked to the factor of issuance of Organic Carbon (OC) contained in the raw material are present in Table II.35.

Table II.36. State Production of Cement and Clinker (t)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Clinker [10^3 t]	4,144	4,412	3,357	3,243	3,499	4,244	5,222	5,492	5,586	5,470
Cement [10^3 t]	5,224	5,555	4,747	4,745	4,968	5,890	7,639	8,078	7,806	7,827
Quantity of clinker in the cement [$t_{clinker} \cdot (t_{cement})^{-1}$]	0.793	0.794	0.707	0.683	0.704	0.721	0.684	0.68	0.716	0.699
	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Clinker [10^3t]	5,160	4,304	3,870	3,078	2,844	3,137	4,007	4,407	4,612	
Cement [10^3t]	7,753	7,133	6,575	5,386	5,327	5,837	7,195	7,453	8,180	
Quantity of clinker in the cement [$t_{clinker} \cdot (t_{cement})^{-1}$]	0.665	0.603	0.589	0.571	0.547	0.595	0.613	0.596	0.564	

Source: CETESB; SNIC; ABCP (2011).

Table II.36 contains data from the production of cement and clinker. Table II.37 presents the results of CO_2 emissions from the cement production process, occurring within the kiln of clinker in Sao Paulo State, from 1990 to 2008. CO_2 emissions per ton of cement had a significant reduction in the period, caused by high use of additions of slag in Sao Paulo State.

Table II.37. CO_2 Emissions from Cement Production by Decarbonation Process in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[$Gg_{CO2} \cdot year^{-1}$]									
Total	2,293	2,441	1,854	1,791	1,934	2,345	2,893	3,041	3,087	3,026
	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[$Gg_{CO2} \cdot year^{-1}$]									
Total	2,853	2,384	2,128	1,705	1,564	1,734	2,229	2,459	2,500	

5.2.2 Lime Production

The GHG emissions inventory from Lime Production in Sao Paulo State was accomplished by CETESB[47]. Lime is classified according to the percentage of total calcium oxide in high calcium lime (90-100%), magnesium (65-90%) and dolomitic (58.2 -65%) (BRASIL, 2010b). It is a product with various applications, among which we highlight metallurgy, civil construction, pulp and paper industry, water and sewage treatment, control of pH and soil stabilization. The term lime is used to designate the product composed of calcium oxide (CaO) and calcium oxide and magnesium oxide (CaO and MgO), resulting from the calcination of limestone, magnesium and dolomitic calcareous (BRASIL, 2010b).

[47] These estimates were accomplished within the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

Another type of lime is the hydrated lime, a white powder resulting from the chemical combination of anhydrous oxides of quicklime with water. It is classified according to the quicklime that is its origin: calcific hydrated lime, magnesium and dolomitic.

CO_2 emissions from the production of lime occur during the processing of the limestone to quicklime, through the process of calcination/decarbonation of raw material and the fuel combustion in the interior of the furnace, as well as in the transport of lime and the consumption of electric power in the factories. This report presents the emissions from the lime production process between the years 1990 and 2008, addressing only the emissions of the decarbonation process of limestone (CETESB, 2011d). According to the Brazilian Association of Producers of Lime (ABPC, 2010 apud CETESB, 2011d), the producers of lime are classified according to Table II.38. Table II.39 shows the lime production data of State adopted in this report, derived from an estimate based on the national production.

Table II.38. Classification of the ABCP Lime Producers

Producers	Type of Production
Integrated	Produce quicklime and hydrated lime from limestone produced in their own mines
Non-integrated	Produce quicklime and hydrated lime from limestone purchased from others
Transformers	Grind and/or produce hydrated lime from purchased quicklime
Captive	Produce lime for their own use, such as the iron manufacturers

Source: ABPC (2010) apud CETESB (2011d).

Table II.39. Production of Quicklime and Hydrate Lime in the Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg]									
Quicklime										
ABPC members	27	27	27	27	30	29	29	31	28	27
Captive producers	231	222	272	303	303	314	323	341	335	323
ABPC non-members	-	-	-	-	-	-	-	11	10	-
Subtotal	**257**	**249**	**299**	**329**	**333**	**343**	**352**	**383**	**374**	**350**
Hydrated Lime										
ABPC members	372	405	385	400	426	484	538	510	496	466
ABPC non-members	-	-	-	-	-	-	-	293	279	-
Subtotal	**372**	**405**	**385**	**400**	**426**	**484**	**538**	**803**	**775**	**466**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg]									
Quicklime										
ABPC members	32	32	34	36	43	44	48	49	51	
Captive producers	340	306	343	350	350	306	79	84	82	
ABPC non-members	30	28	28	28	27	30	23	25	25	
Subtotal	**402**	**367**	**404**	**413**	**420**	**380**	**150**	**158**	**157**	
Hydrated Lime										
ABPC members	473	464	471	483	486	443	440	467	456	
ABPC non-members	259	259	231	223	315	274	284	295	310	
Subtotal	**732**	**723**	**702**	**706**	**801**	**716**	**724**	**761**	**766**	

Source: ABPC (2010) apud CETESB (2011d).

According to the IPCC (1996), the estimate of CO_2 emissions resulting from the lime production is performed through the application of an emission factor in kg_{CO2} per ton of lime on the basis of annual production.

The strategy adopted to estimate the emissions of this inventory considered a decision tree (IPCC 2000a). Thus, it was defined that would be used the default for the emission factors of CO_2 emissions for each predominant oxide in lime, the main categories of source. Table II.40 shows the CO_2 emissions from lime production in Sao Paulo State. It was observed an increase of 51% in CO_2 emissions of dolomitic and magnesium limes in the year of 2008, compared to 1990. For the production of calcite lime, there was a reduction of 14% in emissions due to the deactivation of the Steel Company of Sao Paulo (COSIPA) in 2006 (CETESB, 2011d).

Table II.40. CO_2 Emissions from Lime Production in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[$Gg_{CO2eq}.year^{-1}$]									
Limy	253	250	288	314	320	335	349	407	397	339
Dolomitic	79	86	82	85	91	103	115	171	165	99
Magnesium	125	136	129	134	143	163	181	270	261	156
Total	**457**	**472**	**499**	**533**	**554**	**601**	**645**	**848**	**823**	**594**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[$Gg_{CO2eq}.year^{-1}$]									
Limy	414	384	412	419	437	395	211	222	222	
Dolomitic	156	154	150	150	171	153	154	162	163	
Magnesium	246	243	236	237	269	241	243	256	257	
Total	**816**	**781**	**798**	**806**	**877**	**789**	**608**	**640**	**642**	

5.2.3 Chemical Industry

The GHG emissions inventory from Chemical Production in Sao Paulo State was accomplished by the Brazilian Chemical Industry Association (ABIQUIM) with a review of CETESB[48]. Several production processes in the national chemical industry result in GHG emissions: CO_2, CH_4 and N_2O, as well as indirect GHG: CO, NOx and VOC (ABIQUIM, 2011). This report presents the estimates of GHG emitted during the production processes for the period 1990 to 2005.

The methods used for the calculation of GHG atmospheric emissions during the production processes, which adopt the approach Tier 1, correlate, by means of emission factors, the quantities of GHG emitted with the quantities produced by chemicals. The majority of emission factors from CO_2 and N_2O were obtained through the mass balance of productive units. Other factors, such as the emission factor from CH_4, were calculated based on emission factors listed by the IPCC (2006).

[48]The inventory was accomplished within the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change. The GHG emissions inventory from Chemical Industry Processes covers the period between 1990 and 2005.

For the estimates of GHG emissions of chemical industry processes is considered the Subsectors for which the IPCC (2006) presented method for the realization of the estimates, which are representative in the State, being the only exception to the emissions of phosphoric acid process (H_3PO_4), for which the IPCC (2006) has no method, but it is of relevance in the State. The estimate made by ABIQUIM includes the associated companies; these represent more than 90% of the estimated, in accordance with the guidelines of the IPCC.

The industrial typologies analyzed were: production of adipic acid, production of phosphoric acid, nitric acid production, production of ammonia, production of dichloroethane and vinyl chloride, ethylene production, production of carbon black and the production of ethylene oxide (ABIQUIM, 2011).

Adipic Acid

In Brazil, specifically in Sao Paulo State, there is a factory of adipic acid ($C_6H_{10}O_4$)[49], which uses a process of production based on the oxidation by means of nitric acid (HNO_3), which generates N_2O (BRASIL, 2010a). The emission factor established after a series of measurements is 270 $kg_{N2O}.(t_{C6H10O4})^{-1}$. Table II.41 displays the data for the production of $C_6H_{10}O_4$ and GHG emission in Sao Paulo State for the period 1990 to 2005. Considering the maximum licensed capacity to $C_6H_{10}O_4$, is estimated a potential generation of 23,490 $t_{N2O}.ano^{-1}$.

Table II.41. Production of Adipic Acid and GHG Emissions in Sao Paulo State, between 1990 and 2005 (t)

	1990	1991	1992	1993	1994	1995	1996	1997
	[t.year^{-1}]							
Production	31,951	41,676	38,538	51,264	51,825	55,864	41,554	35,767
N_2O emission	8,627	11,252	10,405	13,841	13,993	15,083	11,220	9,657

	1998	1999	2000	2001	2002	2003	2004	2005
	[t.year^{-1}]							
Production	62,055	61,572	64,862	51,486	65,931	59,979	71,438	75,147
N_2O emission	16,755	16,624	17,513	13,901	17,801	16,194	19,288	20,290

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.
Source: ABIQUIM (2011).

Phosphoric Acid

The IPCC (2006) has no method for estimating emissions of GHG in the processing of phosphate rock in the processing of phosphoric acid[50] (H_3PO_4). As result, the CO_2 emissions were calculated based on the quantity of carbon in concentrated phosphate, estimated at 0.6% (ABIQUIM, 2011).

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[49] The $C_6H_{10}O_4$ is a white crystalline solid that is used as an intermediate in the manufacture of synthetic fibers, plastics, polyurethanes and synthetic lubricants. The most important, commercially, is the Aliphatic Dicaborxylic Acid, used in the manufacture of polyester and nylon (IPCC, 2006).

[50] Phosphoric Acid (H_3PO_4) is used mainly for the production of phosphate fertilizers. The raw materials used for the production of phosphoric acid are the sulfuric acid and phosphate rock (fluorapatite) as a source of phosphorus (P). The phosphate rock contains inorganic carbon in the form of calcium carbonate (CaCO3), which reacts with sulfuric acid producing as agricultural gypsum by-products and CO_2 (ABIQUIM, 2011).

The maximum consumption of phosphate rock estimated, depending on the installed capacity in the processing of the concentrated phosphoric acid, was 1.3 million tons in 2005. The data for concentrated phosphoric production, as well as the emission of greenhouse gases, were estimated for the period 1990 to 2005 and are presented in Table II.42. Considering the installed capacity of processing of phosphate rock in 2005, the maximum potential emission is up to 28.600$t_{CO2}.year^{-1}$.

Table II.42. Production of Phosphoric Acid and GHG Emissions in Sao Paulo State, between 1990 and 2005 (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997
	[Gg.year^{-1}]							
Production	779	838	630	783	785	904	971	1,101
CO_2 emission	17	18	14	17	17	20	21	24

	1998	1999	2000	2001	2002	2003	2004	2005
	[Gg.year^{-1}]							
Production	1,042	1,004	1,146	1,159	1,181	1,379	1,286	1,278
CO_2 emission	23	22	25	25	26	30	28	28

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.
Source: ABIQUIM (2011).

Nitric Acid

The process of traditional production and commercially available of HNO_3[51] involves the catalytic oxidation of ammonia (NH_3) with air and the subsequent reactions of the products of oxidation with water, with generation of N_2O as a by-product.

Table II.43. Production of Nitric Acid and GHG Emissions in Sao Paulo State, between 1990 and 2005 (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997
	[Gg.year^{-1}]							
Production	392	403	398	422	476	477	499	512
N_2O emission	1.89	1.99	1.96	2.07	2.18	2.21	2.27	2.32
CO_2 emission	6.06	5.30	7.01	6.77	7.10	7.07	11.10	8.02

	1998	1999	2000	2001	2002	2003	2004	2005
	[Gg.year^{-1}]							
Production	499	488	506	512	527	466	485	545
N_2O emission	2.26	2.24	2.28	2.28	2.37	2.26	2.33	2.47
CO_2 emission	7.36	4.29	3.90	3.83	3.51	2.84	3.08	3.67

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.
Source: ABIQUIM (2011).

In production units in Sao Paulo State, there is control of the emission of nitrogen oxide (NOx) and nitric oxide (NO_2), in accordance with the standards established by CETESB. The technologies used in Brazil for the control of emissions are: non-selective catalytic

[51] The HNO_3 is an inorganic compound primarily used in the manufacture of synthetic fertilizers. It is the most important compound used as a raw material in the manufacture of $C_6H_{10}O_4$, as an intermediate in the production of concentrated HNO_3 for agent of nitration of organic compounds, and also in the manufacture of explosives (ABIQUIM, 2011).

destruction and selective catalytic destruction. These technological conditions are emitted N_2O and CO_2 (ABIQUIM, 2011). There are 5 industrial plants producing HNO_3 in Sao Paulo State. The CO_2 emissions were estimated by mass balance. The characteristics of the input used in catalytic destruction of NOx were considered, which are reduced to Nitrogen (N_2).

In 2005, the estimate is that the licensed production capacity of HNO_3 in Sao Paulo has been 555,360 t. $year^{-1}$. Table II.43 displays the production data of HNO_3 and GHG emission for the period 1990 to 2005. Considering the licensed capacity in 2005 for each of the technologies evaluated, there was, on the basis of the average quantity calculated above in the production of HNO_3 to 4.57 $kg_{N2O}.(t_{HNO3})^{-1}$, a maximum potential emission of 2,538 $t_{N2O}.year^{-1}$ and 5,000 $t_{CO2}.year^{-1}$.

Ammonia

Sao Paulo has only one plant of ammonia[52] (NH_3), which uses the refinery residual gas as raw material; this process is patented and has valued a waste gas produced by oil refinery, reducing the emission of CO_2. The emission factor is 1.3 $t_{CO2}.(t_{NH3})^{-1}$ (ABIQUIM, 2011). The licensed capacity for production of ammonia in the Sao Paulo State is 216,000 $t.year^{-1}$. Table II.44 presents the licensed capacity for its production and emission of GHG in the State between 1990 and 2005. Considering the licensed capacity for the production of ammonia is estimated a maximum generation of 280,800 $t_{CO2}.year^{-1}$.

Table II.44. Production of Ammonia and GHG Emissions in Sao Paulo State, between 1990 and 2005 (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997
	[$Gg.year^{-1}$]							
Production	142	105	148	107	166	159	137	162
CO_2 emission	185	137	193	139	215	206	177	211

	1998	1999	2000	2001	2002	2003	2004	2005
	[$Gg.year^{-1}$]							
Production	154	162	171	126	210	124	193	194
CO_2 emission	201	210	223	164	272	161	251	252

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.
Source: ABIQUIM (2011).

Dichloroethane and Vinyl Chloride

In Brazil, the production of vinyl chloride (CH_2CHCl)[53] and dichloroethane ($C_2H_4Cl_2$)[54] uses the directly chlorination procedure and oxychloration of ethylene, using the hydrogen chloride generated in the cracking of dichloroethane.

[52] The NH_3 is produced in large quantities, used as a source of nitrogen. It is the raw material for the production of urea, the main nitrogen fertilizer, and for the production of HNO_3. As a by-product of the manufacture of NH_3 is generated the CO_2, released in the atmosphere (ABIQUIM, 2011).
[53] Vinyl chloride, in turn, participates as an intermediate in the production of polyvinyl chloride, widely used in the manufacture of materials and electrical wires, construction materials, pipes, fittings and packaging (ABIQUIM, 2011).
[54] Dichloroethane (1.2 dichloroethane) or ethylene dichloride is one of the first chlorinated hydrocarbons, synthesized in 1795. It is used as an intermediate in the production of vinyl chloride (MVC), Solvents, polychlorinated hydrocarbons, ethylene glycol and others. The dichloroethane is also used as a solvent for greases, oils and fats, industrial cleaning, additive for fuels and in Solvents formulations. In addition, it is very widespread in the extraction of natural products such as steroids, vitamin A, caffeine and nicotine. Vinyl chloride, in

In Sao Paulo, the production plant of vinyl chloride and dichloroethane can operate between the two products as "balanced process". Because the process does not reach 100% conversion of ethylene, a small percentage of the raw material is not converted. Thus, the exhausted gases of the process are treated to remove the chlorinated compounds (formed in secondary reactions) and unreacted ethylene.

The unreacted ethylene is converted to CO_2 and the chlorinated compounds are reduced through a process of catalytic reduction or incineration. Depending on the characteristics of the feedstock used in the process of destruction of chlorinated compounds mentioned (incineration reaction) is also calculated, fugitive emissions of CH_4.

The installed capacity for dichloroethane and vinyl chloride production in the Sao Paulo State is 420,000 t.year^{-1}. Table II.45 presents data on the production and GHG emission of Dichloride and Vinyl Chloride for the period 1990 to 2005. It is possible, considering the installed capacity, a maximum emission of 119,760 t_{CO2}.year^{-1} and 9.5 t_{CH4}.year^{-1} in 2005.

Table II.45. Production of Dichloroethane and Vinyl Chloride and GHG Emissions in Sao Paulo State, between 1990 and 2005 (Gg)

	1990*	1991*	1992*	1993*	1994*	1995*	1996*	1997
	[Gg.year^{-1}]							
Production	41	41	41	41	41	41	41	106
CH_4 emission	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0024
CO_2 emission	12	12	12	12	12	12	12	25

	1998	1999	2000	2001	2002	2003	2004	2005
	[Gg.year^{-1}]							
Production	110	129	113	76	92	222	223	234
CH_4 emission	0.0025	0.0029	0.0025	0.0017	0.0021	0.005	0.005	0.0053
CO_2 emission	25	29	26	19	22	47	59	62

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.

* Between 1990 and 1996, the production data are calculated by using the installed capacity due to the lack of consolidated data. From 1997 on the data are calculated by using the installed capacity plus the production factor, as well as the declared production.

Ethylene

The main GHG emissions associated with the production of ethylene (C_2H_6)[55] are CO_2 and CH_4. The emission of CO_2 is associated with the type of raw material used, which in the case of Sao Paulo is the naphtha. CH_4 emissions in ethylene production units may be fugitive emissions or generated by the systems of relief of the units of process (ABIQUIM, 2011).

turn, participates as an intermediate in the production of polyvinyl chloride, widely used in the manufacture of materials and electrical wires, construction materials, pipes, fittings and packaging (ABIQUIM, 2011).

[55] The ethylene is the primary hydrocarbon produced in large scale and one of the main of the value chain of the petrochemical industry, used in the production of plastics, including the polyethylene of high and low density, polyvinyl chloride and raw material for the manufacture of vinyl chloride, ethylene oxide, benzene and dichloroethene (ABIQUIM, 2011).

The licensed capacity for ethylene production in 2005 in the Sao Paulo State was 700,000 $t.year^{-1}$, with an expected expansion of production capacity of petrochemical ethylene in 2014 for up to 1,200,000 $t.year^{-1}$. Table II.46 displays the production data and GHG emission for the period 1990 to 2005. Considering the installed capacity, the maximum generation of CO_2 would be 1,330 $t_{CO2}.year^{-1}$ and 2,100 $t_{CH4}.year^{-1}$. If expansion of the installed capacity occurs, the maximum emissions will be up to 2,280 $t_{CO2}.year^{-1}$ and 3,600 $t_{CH4}.year^{-1}$.

Table II.46. Production of Ethylene and GHG Emissions in Sao Paulo State, between 1990 and 2005 (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997
	[$Gg.year^{-1}$]							
Production	348	261	271	312	319	316	367	447
CH_4 emission	1.04	0.78	0.81	0.94	0.96	0.95	1.10	1.34
CO_2 emission	0.66	0.50	0.52	0.59	0.61	0.60	0.70	0.85

	1998	1999	2000	2001	2002	2003	2004	2005
	[$Gg.year^{-1}$]							
Production	459	478	473	454	416	464	488	466
CH_4 emission	1.38	1.43	1.42	1.36	1.25	1.39	1.46	1.40
CO_2 emission	0.87	0.91	0.90	0.86	0.79	0.88	0.93	0.89

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.
*Production calculated by using the installed capacity and the production factor.
Source: ABIQUIM (2011)

Carbon Black

To calculate the CH_4 emissions originated from the production of carbon black[56] we adopted the emission factor of 0.06 $kg_{CH4}.t^{-1}$ recommended by the IPCC (2006). For CO_2, was constructed an emission factor obtained by average mass balance. Thus, the emission factor is: until 2003, 1.989 $t_{CO2}.t^{-1}$ of carbon black; and from 2004 1.618 $t_{CO2}.t^{-1}$ of carbon black. The existence of two emission factor is associated with the beginning of operation, over this period, of a plant with an emission of CO_2 different from the other existing (ABIQUIM, 2010).

The productive capacity installed in 2005 for production of carbon black in the Sao Paulo State was 322 $Gg.year^{-1}$. However, there is provision for expansion of production capacity in 2014, up to 362 $Gg.year^{-1}$ of carbon black. Table II.47 presents the production of carbon black and GHG emission in the period from 1990 to 2005. Considering the present installed production capacity, we have a maximum generation of 521 $Gg_{CO2}.year^{-1}$ and 0.02 $Gg_{CH4}.year^{-1}$. If expansion of the installed capacity occurs, the maximum emissions will be up to 586 $Gg_{CO2}.year^{-1}$ and 0.02 $Gg_{CH4}.year^{-1}$.

[56] The main use of carbon black is as an additive in rubber in the manufacture of tires. Another important use is as pigment in the manufacture of paints (BRASIL, 2010a). During the production process is generated a purging gas containing CO and VOC which are processed in the presence of atmospheric air to the conversion of the pollutants mentioned in CO_2. In addition, there is the release of CH_4 in production units of carbon black, which may be fugitive emissions or generated by the systems of relief of the units of process (ABIQUIM, 2011).

Table II.47. Production of Carbon Black and GHG Emissions in Sao Paulo State, between 1990 and 2005 (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997
	[Gg.year^{-1}]							
Production	178	183	186	197	204	201	202	208
CH_4 emission	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CO_2 emission	355	363	371	392	406	399	402	213

	1998	1999	2000	2001	2002	2003	2004	2005
	[Gg.year^{-1}]							
Production	211	222	230	215	222	230	278	280
CH_4 emission	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
CO_2 emission	420	441	457	428	442	457	450	453

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.
* Production calculated by using the installed capacity and the production factor.
Source: ABIQUIM (2011).

Ethylene Oxide

In Sao Paulo State, the ethylene[57] oxide is produced from the direct oxidation of ethylene by means of the air, a process that emits CO_2. The emission factors used in the estimate for CO_2 and CH_4 are the default of the IPCC (2006), equal, respectively, 0.863 $t_{CO2}.(t_{ethylene\ oxide})^{-1}$ and 1.79 $kg_{CH4}.(t_{ethylene\ oxide})^{-1}$.

The licensed capacity of production of ethylene oxide in the Sao Paulo State in 2005 was 52,000 t.year^{-1}. However, it was licensed a new level of annual production up to 95,000 t. Table II.48 displays the production data of ethylene oxide and GHG emission for the period 1990 to 2005.

Table II.48. Production of Ethylene Oxide and GHG Emissions in Sao Paulo State, between 1990 and 2005 (Gg)

	1990	1991*	1992*	1993*	1994*	1995*	1996*	1997
	[Gg.year^{-1}]							
Production	34	41	36	38	37	35	34	49
CH_4 emission	0.061	0.073	0.065	0.068	0.067	0.063	0.062	0.087
CO_2 emission	29.169	34.852	31.345	32.650	32.014	30.424	29.585	41.821

	1998	1999	2000	2001	2002	2003*	2004*	2005*
	[Gg.year^{-1}]							
Production	45	49	48	50	45	49	52	52
CH_4 emission	0.081	0.089	0.086	0.090	0.081	0.088	0.093	0.093
CO_2 emission	38.722	42.518	41.186	43.058	39.008	42.456	44.465	44.718

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.
* Production calculated by using the installed capacity and the production factor.
Source: ABIQUIM (2011).

[57] The ethylene oxide or ethylene is one of the most important derivatives of ethylene, produced from its reaction of catalytic oxidation. Its peculiar structure makes it one of the main raw materials of chemical and petrochemical industry. Ethylene oxide is used mainly as a raw material in the production of ethylene glycols, glycol ethers, ethoxylate, ether acetates and chemicals specialty (ABIQUIM, 2011).

Table II.49. Total GHG Emissions from Chemical Industry by Subsector, in Sao Paulo State, between 1990 and 2005 (Gg_{CO2eq})

	1990	1991*	1992*	1993*	1994*	1995*	1996*	1997
	$[Gg_{CO2eq}.year^{-1}]$							
Adipic acid	2,674	3,488	3,226	4,291	4,338	4,676	3,478	2,994
Phosphoric acid	17	18	14	17	17	20	21	24
Nitric acid	592	621	615	649	684	692	714	728
Ammonia	185	137	193	139	215	206	177	211
Dichloroethane and vinyl chloride	12	12	12	12	12	12	12	25
Ethylene	23	17	18	20	21	20	24	29
Carbon black	355	363	371	393	407	399	402	413
Ethylene oxide	30	36	33	34	33	32	31	44
Total	**3,889**	**4,693**	**4,480**	**5,555**	**5,727**	**6,057**	**4,861**	**4,467**

	1998	1999	2000	2001	2002	2003*	2004*	2005*
	$[Gg_{CO2eq}.year^{-1}]$							
Adipic acid	5,194	5,153	5,429	4,309	5,518	5,020	5,979	6,290
Phosphoric acid	23	22	25	25	26	30	28	28
Nitric acid	706	699	712	710	737	703	725	770
Ammonia	201	210	223	164	272	161	251	252
Dichloroethane and vinyl chloride	26	29	26	19	22	48	60	62
Ethylene	30	31	31	29	27	30	32	30
Carbon black	420	441	457	429	442	457	451	454
Ethylene oxide	40	44	43	45	41	44	46	47
Total	**6,640**	**6,631**	**6,946**	**5,731**	**7,086**	**6,494**	**7,572**	**7,933**

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.

Considering the production capacity installed for each industrial typology presented maximum emission of CO_{2eq} for installed capacity and/or licensed in 2005 was 9,160,905 t_{CO2eq}. Considering the productive capacity licensed in 2005, the potential emission is up to 44.876$t_{CO2}.year^{-1}$ and 93,1 $t_{CH4}.year^{-1}$. Depending on the license of the production capacity expansion, the maximum emissions will be in 2010 up to 81.985 $t_{CO2}.year^{-1}$ and 170 $t_{CH4}.year^{-1}$. In Table II.49, Table II.50 and Table II.51 shows the GHG emissions of the Chemical Industry by Subsector and emissions in Gg in Gg_{CO2eq} respectively.

Table II.50. Emissions from Chemical Industry in Sao Paulo State, between 1990 and 2005 (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997
	$[Gg.year^{-1}]$							
CO_2	605	571	628	601	691	675	654	724
CH_4	1	1	1	1	1	1	1	1
N_2O	11	13	12	16	16	17	13	12

	1998	1999	2000	2001	2002	2003	2004	2005*
	$[Gg.year^{-1}]$							
CO_2	716	750	777	685	806	743	838	845
CH_4	1	2	2	1	1	1	2	2
N_2O	19	19	20	16	20	18	22	23

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.

Table II.51. Emissions from Chemical Industry in Sao Paulo State, between 1990 and 2005 (Gg_{CO2eq})

	1990	1991*	1992*	1993*	1994*	1995*	1996*	1997
	$[Gg_{CO2eq}{\cdot}year^{-1}]$							
CO_2	605	571	628	601	691	675	654	724
CH_4	23	18	19	21	22	21	25	30
N_2O	3,261	4,103	3,833	4,933	5,015	5,361	4,182	3,713
Total	**3,889**	**4,693**	**4,480**	**5,555**	**5,727**	**6,057**	**4,861**	**4,467**

	1998	1999	2000	2001	2002	2003*	2004*	2005*
	$[Gg_{CO2eq}{\cdot}year^{-1}]$							
CO_2	716	750	777	685	806	743	838	845
CH_4	31	32	32	31	28	31	33	32
N_2O	5,893	5,848	6,137	5,015	6,252	5,720	6,701	7,057
Total	**6,640**	**6,631**	**6,946**	**5,731**	**7,086**	**6,494**	**7,572**	**7,933**

Note: The GHG emissions from the Chemical Industry Subsector were estimated for the period from 1990 to 2005.

5.2.4 Metallurgical Industry

The GHG emissions inventory from Metallurgical Subsector of Sao Paulo State was conducted by the Brazil Steel Institute (IABr) and the IMT, with consolidation of information by CETESB[58]. Depending on the availability of data, this inventory counted only the emissions of the industries of steel and aluminum, the most representative of the Sector. The emissions of the steel industry were estimated using the method developed by WSA called Climate Change Emissions Calculation Tool or GHG Tool. GHG emissions in the aluminum industry were estimated using the method presented by the IPCC (2006). In the preparation of the inventory of metallurgical industry, the IPCC warns about the risks of performing double-counting of emissions, because the carbon used as a reagent of the processes is used as a source of heat to drive the chemical reactions are often related (IPCC, 2006).

Steel Production

The main GHG emitted by steel activities is the CO_2. Other GHG, such as the CH_4 and N_2O, are not relevant to this industrial typology. The steel industry uses carbon for energy generation and as a reducing agent of the iron ore (the latter in the case of integrated plants). Subsequently, a fraction of that carbon is incorporated into the products and the other part, after combustion, is emitted as CO_2 (CETESB; IABr; IMT, 2011).

Up to 75% of CO_2 emissions from the manufacture of steel occur during the production of pig iron in the blast furnace, i.e. in the stage of reduction of iron ore, which occurs only in integrated plants. The remaining percentage is due to the transport of raw materials, the generation of electricity and heat (BRASIL, 2010a).

[58] The agreement was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

CO_2 emissions from the plants for the production of coke and lime are accounted for in the Energy Sector and Subsector of Mineral Production, respectively. Emissions from the use of fuel for energy production (thermoelectric power plants) are included in the Energy Sector.

The emissions related to the use of dolomite and limestone is encompassed by the Subsector of Mineral Production. In the Metallurgical Sector, are accounted the emissions of the sintering/pelletizing and blast furnace/steelworks (BRASIL, 2010a).

For the completion of the Inventory of emissions of CO_2 in the steel industry located in Sao Paulo State, were established, initially, the scopes of which the CO_2 emissions would be submitted, as described below:

– Scope 1: direct emissions of CO_2 derived from own sources or controlled by the companies, including emissions from combustion of fuels and manufacturing processes.

– Scope 2: emissions from the generation of electricity acquired by the company.

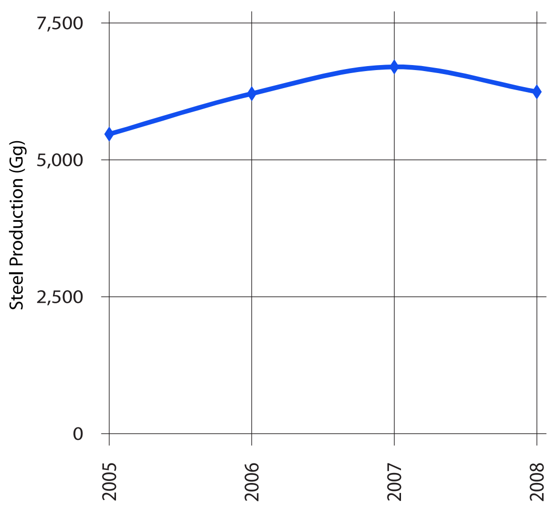
– Scope 3: indirect emissions arising from the activities of companies in the acquisition of raw materials or transport of products and services. The presentation of this scope is optional, because it reports indirect emissions which will consist of direct emissions of other inventories.

Table II.52. Steel Production in Sao Paulo State, between 2005 and 2008 (Gg)

	2005	2006	2007	2008
	[Gg.year^{-1}]			
Steel	5,650	6,314	6,753	6,344
Sinter	5,130	5,168	5,878	5,389

Note: The production of the Steel Industry Subsector are presented for the period from 2005 to 2008.

Figure II.35. Steel Production in Sao Paulo State, between 2005 and 2008 (Gg)



The emissions of Scopes 2 and 3 were not considered in this survey, in order to enable the comparison with the method of the IPCC (2006). Table II.52 and Figure II.35 present the steel production in the Sao Paulo State in the period from 2005 to 2008.

Aluminum Production

The primary aluminum industries are considered to be the main sources of emissions of two PFC compounds: CF_4 and C_2F_6, both contribute to the increase of the greenhouse effect (IAI, 2003 apud CETESB; IABr; IMT, 2011). In an operation of an electrolytic cell for aluminum production, these gases are produced during a brief disturbance of the conditions of operation of the cell known as the anode effect (FUJIMOTO, 2007 apud CETESB; IABr; IMT, 2011).

The electrolysis of aluminum oxide produces cast aluminum, which are deposited on the cathode, and oxygen, which is deposited in anode. By reacting with carbon, CO_2 emissions occur. Some amount of CO_2 is also produced when the anode reacts with other sources of oxygen, such as air (BRASIL, 2010a). There are different types of technology for the production of primary aluminum, depending on the type of the anode. In Sao Paulo State, however, only one technology is used, called Soderberg. According to the method of the IPCC (2006), it is possible to calculate the CO_2 emissions from the consumption of carbon anodes and PFC emissions produced during the process. Other emissions are monitored, as the CO, sulfur dioxide (SO_2) and the VOC, but according to the guidance of the IPCC (2006) are not included in the estimates.

Table II.53. Aluminum Production in the Sao Paulo State (t)

Ano	2005	2006	2007	2008
	[t]			
Aluminium production	370,368	404,922	450,872	465,700

Source: ABAL (2005, 2007, 2010) apud CETESB; IABr; IMT (2011).
Note: The production of the Aluminum Industry Subsector are presented for the period from 2005 to 2008.

Table II.54. Total GHG Emissions from Metallurgy Sector in Sao Paulo State (Gg_{CO2eq})

Year	2005	2006	2007	2008
	[Gg_{CO2eq}.year^{-1}]			
Metallurgy	9,459	9,587	10,023	9,224
Total	**9,459**	**9,587**	**10,023**	**9,224**

Note: GHG emissions from Metallurgical Subsector were estimated for the period from 2005 to 2008.

The production of aluminum in the Sao Paulo State is presented in Table II.53. There was a growth of more than 25% of production between 2005 and 2008. The determination of emission factors was based on the studies presented in the second report of reference for the National Inventory of Greenhouse Gas Emissions (BRASIL, 2010a). Table II.54 presents the total emission of GHG in the metallurgical sector in Gg_{CO2eq}.

5.2.5 Food and Beverage Industry

The atmospheric emissions inventory from Food and Beverage Industry in Sao Paulo State was conducted by CETESB. This report is presented the estimates of VOC emissions in Sao Paulo State, for the period 1990 to 2008[59]. These estimates were calculated based on the method of the IPCC (1996). The VOC are Indirect GHG.

In the production of food, the VOC are emitted during processes of heating, cooking and fermentation. In the production of beverages, the emission occurs during the use of cereals and fruits in the fermentation process. To estimate the emissions generated by Food Subsector, was considered the production of meat, sugar, biscuits, cereals, pastries, cakes and coffee.

To estimate the VOC emissions from Beverage Subsector, it was considered the production of beer and distilled. The primary data of the production of food and beverages in the Sao Paulo State were supplied by the Brazilian Food Industries Association (ABIA, 2010 apud CETESB, 2011c). However, many data to calculate the emissions of the Beverage Sector were not available. The lack of data, made impossible on this inventory, to consider the production of margarine, solid fats, animal food and wine.

Table II.55. Primary Data from Food Production in the Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
Beef	774	808	845	882	922	963	1,006	1,051	1,098	1,085
Pork	127	128	129	130	130	131	132	133	135	126
Poultry	645	688	733	782	834	889	948	1,010	1,077	1,153
Sugar	5,397	5,803	6,240	6,709	7,214	7,757	8,340	8,968	8,705	11,788
Cookies, cereals and cakes	158	167	177	187	198	210	222	235	221	264
Bread	74	77	81	84	88	92	96	101	113	110
Coffee roasting	94	97	99	102	104	107	109	112	103	117

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
Beef	1,198	1,252	1,439	1,366	1,427	1,491	1,494	1,627	1,699	
Pork	133	150	133	135	138	142	141	141	136	
Poultry	1,224	1,305	1,381	1,484	1,582	1,686	1,804	1,917	2,044	
Sugar	13,091	9,675	12,350	14,348	15,172	16,495	16,834	19,503	19,139	
Cookies, cereals and cakes	279	296	397	331	351	371	349	416	440	
Bread	115	120	108	131	137	143	160	156	163	
Coffee roasting	120	122	149	127	130	133	123	138	140	

Sources: ABIA; IBGE; IEA-SP; UBABEF; CNPC; ABIPECS; ABIEC apud ABIA, (2010).

Tables II.55 and II.56 present respectively primary data from Production of Food and beverages Sector for the period 1990 to 2008. Some of these data was estimated by CETESB by linear regression of the data supplied by Brazilian Food Industries Association (ABIA).

[59] These estimates were accomplished within the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

Table II.56. Estimated Primary Data from Beverage Production in the Sao Paulo State (hl)[60]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[hL]									
Beer	1,596	1,685	1,779	1,879	1,984	2,095	2,212	2,335	2,466	2,403
Distilled beverage	493	497	500	504	508	511	515	519	535	526

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[hL]									
Beer	2,749	2,903	3,527	3,237	3,418	3,609	3,589	4,024	4,249	
Distilled beverage	530	533	512	541	544	548	564	555	559	

Sources: ABIA; IBGE; IEA-SP; UBABEF; CNPC; ABIPECS; ABIEC apud ABIA, (2010).

The estimates of atmospheric emissions of VOC for the year 2005 are 168 $Gg.year^{-1}$, for food and 0.01 $Gg.year^{-1}$ for drinks. Table II.57 shows the estimate of atmospheric emissions of VOC for the period 1990 to 2008.

In all cases, there is an increase in the emission of VOC. The most expressive increase is in the production of sugar, which is the activity with higher emission level. In addition, more accurate estimates can be achieved if there is commitment with the systematization of primary data relating to the production of food and beverage, as well as the development of local emission factors.

Table II.57. Emissions from Food and Beverage Subsector in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{VOC}.year^{-1}]$									
Food	55	59	64	69	74	79	85	91	89	120
Beverage	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	**55**	**59**	**64**	**69**	**74**	**79**	**85**	**91**	**89**	**120**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{VOC}.year^{-1}]$									
Food	133	99	126	146	154	168	171	198	194	
Beverage	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Total	**133**	**99**	**126**	**146**	**154**	**168**	**171**	**198**	**194**	

5.2.6 Glass Industry

The GHG emissions inventory from Glass Industry in Sao Paulo State was accomplished by CETESB[61]. According to the Brazilian Technical Association of Automatic Glass Industries (ABIVIDRO, 2010 apud CETESB, 2011f), glass is the result of the merged composition and transformed in the smelling furnace. The dominant production process in the glass industry is the flat glass. In addition to this, there are three other product segments: the hollow glass (or packaging), the special glasses and domestic.

[60] 1 hl = 10^2l

[61] This inventory was accomplished within the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

The emission of CO_2 of Glass Production process occurs during the merger process of their raw materials. The main raw materials responsible for this emission are: limestone ($CaCO_3$), dolomite ($CaMg(CO_3)_2$) and soda ash (Na_2CO_3).

Sao Paulo State has great importance in the Glass Industry Sector, since its production accounted for 55% of National production in 2005 (ABIVIDRO, 2010b). Table II.58 presents the data for the glass production of the State for the period 1990 to 2008.

In the production of glass, in addition to CO_2, there is also emission of NMVOC[62]. According the IPCC, the emission of NMVOC on a global scale probably is not relevant to the global warming; however, it may be in national or local conditions (IPCC, 1996).

For the estimates of atmospheric emissions from Glass Production was used the method of the IPCC (1996, 2006). This report used the Tier 1, by the absence of available data on the production process of the glass and on the carbonate used in manufacture. For the Tier 1 applies an emission factor based on a "mix of raw materials" from the state production data and a statistic ratio of broken glass used in national scope.

Table II.58. Data from Glass Production in the Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{VOC}.year^{-1}]$									
Glass	408	564	652	864	887	1,030	1,081	1,248	1,180	1,246

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{VOC}.year^{-1}]$									
Glass	1,310	1,284	1,323	1,399	1,386	1,417	1,383	1,432	1,410	

Source: ABIVIDRO (2010b).

Table II.59. NMVOC and CO_2 Emissions from Glass Production in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{VOC}.year^{-1}]$									
VOC	2	3	3	4	4	5	5	6	5	6
CO_2	41	56	65	86	89	103	108	125	118	125

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{VOC}.year^{-1}]$									
VOC	6	6	6	6	6	6	6	6	6	
CO_2	131	128	132	140	139	142	138	143	141	

[62] Non Methane Volatile Organic Compound.

According to the IPCC (2006), the ratio of broken glass refers to its fraction co-processed along the raw material for the glass production. So, the more broken glass used in the process, the lower their emission factor. In the absence of this data, was used default the proposed by method (CETESB, 2011f). The estimates of atmospheric emissions of NMVOC[63] and CO_2 for the period 1990 to 2008 are shown in Table II.59. Atmospheric emissions of NMVOCS for the year of 2005 were 6 $Gg.year^{-1}$, and the estimates of CO_2 emissions for the same year were 142 $Gg.year^{-1}$.

5.2.7 Pulp and Paper Industry

The GHG emissions inventory from Pulp and Paper Industry in Sao Paulo State was accomplished by CETESB. The pulp and paper production has three main stages: pulping, bleaching and paper production. The type of pulping and the quantity of bleaching used depend on the nature of the raw material and the desired quality of the final product. Kraft pulping (sulfate process) is the most widely used and is typically used in the production of more resistant paper (BRASIL, 2010a).

The IPCC method (1996) was used to estimate the atmospheric emissions from kraft pulp production for the period 1990 to 2008. Under this method, the percentage of GHG emissions is demonstrated in relation to the production of cellulose in Sao Paulo State. Table II.60 shows the estimate of pulp production in Sao Paulo State.

It is important to emphasize that the estimates of atmospheric emissions contained in this document are Indirect GHG. They are conventional pollutants that were included in the method of IPCC inventory (CETESB, 2011). The estimates of atmospheric emissions in the period 1990 to 2008 are shown in Table II.61. NOx emissions were 5 $Gg.year^{-1}$, VOC emissions were 11 $Gg.year^{-1}$ and emissions of CO were 17 $Gg.year^{-1}$.

Table II.60. Estimation of Pulp Production in the Sao Paulo State (Gg)

	1990*	1991*	1992*	1993*	1994	1995	1996	1997	1998	1999
	[$Gg.year^{-1}$]									
National	2,216	2,711	3,206	3,701	5,117	5,170	5,473	5,637	5,989	6,498
State	632	790	948	1,106	1,598	1,628	1,576	1,787	1,833	1,948

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[$Gg.year^{-1}$]									
National	6,669	6,645	7,191	8,289	8,845	9,545	10,462	11,328	12,021	
State	2,026	2,006	2,062	2,538	2,948	3,056	3,372	3,549	3,608	

* The data from 1990 to 1993 were estimated by interpolation.
Source: BRACELPA (2009) apud CETESB (2011e)

[63] This document considers NMVOC (Non Methane Volatile Organic Compound) equals VOC (Volatile Organic Compound) because the VOC are precursors of greenhouse gases, and methane (CH_4) is a greenhouse gas just reactive. The specification NM is only a guarantee that the substances are only estimated the precursors, because the methane is reported separately.

Table II.61. Emissions from Pulp and Paper Industry in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year-1]									
NOx	1	1	1	2	2	2	2	3	3	3
VOC	2	3	4	4	6	6	6	7	7	7
CO	4	4	5	6	9	9	9	10	10	11

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year-1]									
NOx	3	3	3	4	4	5	5	5	5	
VOC	8	7	8	9	11	11	12	13	13	
CO	11	11	12	14	17	17	19	20	20	

5.2.8 Solvent and Other Product Use

The reference reports of Solvent and Other Products Use Subsector, represented by Fugitive Emissions from Electricity Transmission and Distribution, Foams, Aerosols, Solvents, Refrigeration and Air Conditioning, were performed as agreement signed between CETESB and IMT[64].

5.2.8.1 Fugitive Emissions from Electricity Transmission and Distribution

The SF_6 is a GHG used by the electricity transmission and distribution companies as an insulator and arc-extinguisher medium in circuit breakers. SF_6 is also used in magnesium industry, for hospital use in ophthalmic surgery, and as a fire-fighting agent. These applications are not relevant in the State and thus, their emissions were not considered in the inventory.

The SF_6 has enabled the development of electrical equipment of high capacity and performance in addition they are more compact and safe. In a transformer, the SF_6 gas occupies 30% less space for insulation and, therefore, substantially reduces the costs for construction of substations, when compared to conventional transformers, which use oil for isolation.

The substations are responsible for receiving and distributing the energy to the consumer, connecting the transmission lines to different locations and, when necessary, making the elevation or reduction of the applied voltage. The current Brazilian distribution of electricity is formed by 64 concessionaires, responsible for the treatment of more than 61 million consumer units. These concessionaires are responsible for maintenance, monitoring and operation of the substations. There are in the State 15 concessionaires that manage the transmission and distribution of electric energy (ANEEL, 2010 apud IMT, 2011c).

[64] The agreement was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

It was not possible to use the guidelines of the IPCC for estimates of emissions of SF_6 in the Electric Sector because of the impossibility of obtaining the required data of activity. Thus, for the preparation of the inventory, we used an alternative procedure which considered the State's participation in the national electrical energy for the distribution/consumption of electric energy. According to the Secretary of Energy of Sao Paulo State, consumes of the State more than 32% of national production of electric energy, percentage confirmed by data from the National Electric Energy Agency (ANEEL) of 2010. Table II.62 presents the estimated emissions of SF_6 in Sao Paulo State.

The energy distributors in the Sao Paulo State must develop correct procedures regarding the monitoring and maintenance of the equipment with SF_6, in order to avoid uncontrolled emissions. One of the actions is to acquire equipment for treatment and reuse/recovery of gas used in the circuit breakers (CTEEP, 2010 apud IMT, 2011c).

Table II.62. SF_6 Emissions from Electric Appliances in Sao Paulo State (Gg)

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
SF_6 emissions (Gg_{SF6})	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0015	0.0016
SF_6 emissions (Gg_{CO2eq})	31.1	31.1	31.1	31.1	31.1	31.1	31.1	31.1	35.9	38.2

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	
SF_6 emissions (Gg_{SF6})	0.0016	0.0016	0.0017	0.0018	0.0019	0.002	0.002	0.0021	0.0022	
SF_6 emissions (Gg_{CO2eq})	38.2	38.2	40.6	43.0	45.4	47.8	47.8	50.2	52.6	

5.2.8.2 Foams

Estimates of emissions include the three main gases used by the Industry in Sao Paulo State, in the period 1990 to 2008: the CFC-11, HCFC-141b and the HFC-134a. The foams, because of its complexity, have been classified according to their cellular morphology, mechanical behavior, chemical nature and density. Its industry of manufacture is composed of four subsectors: rigid foams, flexible, molded and polystyrene. Due to the wide variety of application, several segments of industry are using foams as part of its products, segments such as the automotive, furniture, construction, refrigeration, and other (PNUD BRASIL, 2007 apud IMT, 2011c).

In the foam manufacturing companies, CFC and HCFC have been used as blowing agents for both rigid foams and flexible foams. After the Montreal Protocol, the main blowing agent used, the CFC-11, was replaced by HCFC-141b[65] and the cyclopentane. Several agents to alternative expansion are now in global use, including HFC, cyclo/isopentane, methylene chloride, CO_2 and water (UNEP, 2006 apud IMT, 2011c).

The method used to estimate the emissions of HFC in the Foam Segment was proposed by the IPCC (1996), and applied to the emissions of CFC and HCFC. For the cell open foam, the HFC emissions that occur during its manufacture are equal to 100% of the quantity of chemical substance used as the blowing agent. For the closed cell foams, 10% of the

[65] The HCFC-141b will be eliminated by 2030.

blowing agent is released during the foaming process. The rest is contained in the isolation and released over the 20/25 years of its life time. For the estimates of CFC-11 and HCFC-141b, it was not possible to obtain data on the consumption of Sao Paulo State.

Thus, for the estimation of emissions in foam of closed cells in the considered period, it was necessary to calculate the emissions caused by foams manufactured since 1970 (adopting 20 years as an average life time of the foam). In the absence of information on the consumption of CFC-11 for foam production in Brazil and for Sao Paulo State for the period 1970 to 1989, the data were estimated from information from 1990 to 2001 by adopting a linear behavior for the period from 1970 to 2001.

Initially, a survey of national data on the consumption of CFC-11 in the Foam Segment, concluding that after 2002, this consumption was very small due to its replacement by HCFC-141b. There are no statistics on the use of CFC-11 in the Foam Segment in Sao Paulo State. We adopted the hypothesis that the State is responsible for 60% of national production of foam and the consequent consumption of CFC-11. It is estimated that 35% of these foams are consumed or used locally. Regarding to the application, other projections indicate that 75% of the consumption of CFC-11 was used for the manufacture of closed cells foam and 25% for the manufacture in open cells foams, in the period 1990 to 2002. For the emission of GHG in closed cells foams production, all the data on the consumption of CFC-11 (1970 to 2008) were estimated.

The elimination of the use of CFC-11 promoted its replacement by HCFC-141b. As well as the previously adopted gas, the HCFC-141b is also destroyer of stratospheric ozone, however, with a lower destruction potential, and therefore, a longer period for its eradication. There are no statistics about the use of HCFC-141b in the State in the Foam Segment, which led to the adoption of the same assumptions and projections stipulated for the consumption of CFC-11. As For the HFC, its use in the Foam Segment in Brazil and Sao Paulo State is zero or very small. It was identified only the use of HFC-134a in a company that consumes 50 $t.year^{-1}$ since 2006, in the production of rigid foam (closed cell). The Table II.63 presents the emission in the Foam Segment in Gg.

Table II.63. GHG Emissions from Foam Subsector in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[$Gg.year^{-1}$]									
CFC-11	0.7	0.6	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1
HCFC-141b	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
HFC-134a	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[$Gg.year^{-1}$]									
CFC-11	1.4	1.4	0.3	NE	NE	NE	NE	NE	NE	
HCFC-141b	NE	NE	0.6	0.7	0.8	0.8	0.8	1.1	1.1	
HFC-134a	NE	NE	NE	NE	NE	NE	0.006	0.008	0.011	

Note: NE: Not estimated.
The emissions from the Foam Subsector were estimated for the period from 1990 to 2002 for CFC-11; from 2002 to 2008 for HCFC-141b; and from 2006 to 2008 for HFC-134a.

5.2.8.3 Aerosols

The aerosol is a system which consists of a package, usually metal, pressurized, containing a mixture of a product (deodorant, ink, insecticide, medications, etc.) with a propellant gas. Its content is released through a valve, which, when pressed, emits the mixture and the propellant in the form of spray. Its operating principle is based on the self-propelled products, where the propellant is the driving force behind the aerosol (IMT, 2011c).

The aerosol industry includes the production of cosmetics, pharmaceutical, veterinary, cleaning products and industrial. Since the beginning of production of aerosols, various propellants were used, such as CO_2, methyl chloride, dimethyl ether, isobutane and vinyl chloride. However, only with the beginning of the use of propellants consisting of CFC was possible to have production of Aerosols in large scales and its consolidation in the application of cosmetics and medicinal.

From the discovery of harmful action of CFCs on the ozone layer and the prohibition of its use in aerosols by the Montreal Protocol, old and new propellants began to be used, among them the Liquefied Petroleum Gas (LPG) (a mixture of gases, butane, isobutane, propane and other unsaturated gases), CO_2 and N_2. These gases are currently used in 95% of aerosols. The remaining uses HFC-134a, chosen for its special properties, mainly for use in Metered Dose Inhalers (MDI), which are medicinal aerosols. However, the HFC propellants which are not harmful to the Ozone Layer are GHG (IMT, 2011c).

In Brazil, according to the Ordinance n. 534, September 19, 1988[66], manufacturers of non-medicinal aerosols concluded that conversion to technologies of propellants without CFC in 1989. Thus, for the period considered in this study (1990 to 2008), only the medicinal aerosols emitted CFC. This ordinance has not limited the use of CFC for medical applications because, according to the Montreal Protocol, Substances Which Deplete the Ozone Layer (ODS) is permitted only for "essential uses", where there is no alternative technology commercially available. The consumption of medicinal aerosols continues until today, but it is now being held to replace CFC with HFC-134a or other forms of packaging for that application. Brazilian agencies such as the National Environmental Council (CONAMA), Brazilian Institute for the Environment and Renewable Nature Resources (IBAMA) and the Sanitary Surveillance National Agency (ANVISA), has acted in order to control and reduce gradually, until the total ban on the production and importation of MDI-CFC.

The CFC emissions for the period between 1990 and 2008 were estimated on the basis of the methodology established by the IPCC (2000a). The estimation of emissions of HFC, in turn, has still not been completed due to the fact that the researches have not allowed, up to the moment, to obtain the necessary data.

For the calculation of emissions is necessary to obtain the data of CFC consumption over the period considered. However, some difficulties were encountered. It was not possible;

[66] This ordinance prohibits the manufacture of cosmetics, toiletries, perfumes and sanitizing and cleaning products (aerosols) containing the propellants based on CFC (IMT, 2011c).

for example, locate data for the first 5 years of the period of preparation of this inventory (1990 to 1994). In addition, there are no statistics on the use of CFC in aerosols in Sao Paulo State. We adopted, then, an estimate from the Country consumption data, presented in Table II.64, through a proportion relationship between the State population and National population. Table II.65 presents the emission from Aerosols Segment, in Gg.

Table II.64. Estimated Consumption of CFC-11 and CFC-12 from Aerosols in Brazil (t)

	1995	1996	1997	1998	1999	2000	2001
	[t.year^{-1}]						
CFC-11	54	57	61	70	77	85	95
CFC-12	105	114	124	143	155	170	192

	2002	2003	2004	2005	2006	2007	2008
	[t.year^{-1}]						
CFC-11	110	125	140	155	173	194	216
CFC-12	200	220	240	265	278	302	328

Source: PNUD (2007) apud IMT (2011c).

Table II.65. Emissions from Aerosols Subsector in Sao Paulo State (Gg)

	1995	1996	1997	1998	1999	2000	2001
	[Gg.year^{-1}]						
CFC-11	0.01	0.01	0.01	0.01	0.02	0.02	0.02
CFC-12	0.02	0.02	0.03	0.03	0.03	0.03	0.04

	2002	2003	2004	2005	2006	2007	2008
	[Gg.year^{-1}]						
CFC-11	0.02	0.03	0.03	0.03	0.04	0.04	0.04
CFC-12	0.04	0.05	0.05	0.05	0.06	0.06	0.07

Note: The emissions from the Aerosols Subsector were estimated from 1995.

5.2.8.4 Solvents

Solvents are volatile liquids that have the property of dissolve ligands, resins or any other solid materials and/or liquids without any changes in their original chemical structures. They are indispensable to the production chain of various industrial segments and are used, for example, in the manufacture of plastics and resins, varnishes, paints, pesticides, adhesives, cosmetics and detergents, among many other products. In addition, they are used for cleaning and sterilization of equipment components and products (SINDSOLV, 2010 apud IMT, 2011c).

The solvents are the raw material for the manufacture of adhesives, rubber artifacts, cosmetics, pesticides, detergents, among others. Most of the hydrocarbon solvent, such as aromatic hydrocarbons used in Brazil, derives from the refining of petroleum (physical process) or the processing of naphtha (chemical process).

The Southeast Region consumes approximately 70% of the National production (SINDSOLV, 2010 apud IMT, 2011c). At the end of the 1940s, there was an increase in the use of solvents consisting of CFC, methyl chloroform (MCF) and carbon tetrachloride (CTC). However, it was subsequently found that these substances were affecting the ozone layer and, with the adoption of the Montreal Protocol, its consumption in new products was stopped. New alternative technologies were presented, such as chlorinated solvents which do not attack the ozone layer, aqueous solutions, semi-aqueous solutions, organic solvents, HCFC, PFC, and HFC.

HFC and PFC are controlled substances by the Kyoto Protocol. At the same time, these are technological alternatives to the elimination of ODS. Uses of these substances in the Solvents Segment in the Sao Paulo State were not identified (IMT, 2011c).

To estimate the GHG emissions containing alternative substances to ODS investigated in this study, we followed the IPCC method (1996; 2006). It is noteworthy that the estimate is restricted to the evaluation of past emission of CFC. From contacts with companies, associations and industry experts, we adopted the hypothesis that Sao Paulo State was responsible for 60% of the consumption of CFC-113 as a solvent in the Southeast Region, representing 42% of National consumption. These considerations make it possible to obtain the use of CFC-113 in Sao Paulo State, as shown in Table II.66 (IMT, 2011c).

Table II.66. Estimated Consumption of CFC-113 from Solvent Subsector in Sao Paulo State, between 1990 and 2000 (t)

Consumption of CFC-113 (t)										
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
256.200	197.400	134.400	89.250	84.525	49.350	31.500	16.800	19.425	17.325	15.225

Note: CFC-113 consumption was presented for the period from 1990 to 2000, due to elimination process of their use in Solvent Subsector.

Table II.67 presents the estimation of emissions of CFC-113 in the Solvents Segment, from 1990 to 2000. After the year 2000, the consumption of CFC-113 as a solvent was eliminated, and its use replaced by technological alternatives that do not emit GHG.

Table II.67. CFC-113 Emissions from Solvent Subsector in Sao Paulo State (Gg)

Consumption of CFC-113 (Gg)										
1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
0.26	0.23	0.17	0.11	0.09	0.07	0.04	0.02	0.02	0.02	0.02

Note: The emissions of CFC-113 emissions were estimated for the period from 1990 to 2000, due to the elimination process of their use in the Solvent Subsector.

5.2.8.5 Refrigeration and Air Conditioning

The estimates of GHG emissions as HCFC, CFC and HFC from Refrigeration and Air Conditioning Segment considered the following applications: domestic refrigerators and freezers, commercial refrigerators and freezers, vehicle air conditioning systems, buses air conditioning systems, water drinkers, and emissions of HCFC-22 used on initial load of equipment and maintenance.

Since the adoption of the Montreal Protocol in 1987, the refrigeration industry has been seeking for substitutes for the CFC and HCFC refrigerants. In the past 15 years, the refrigerant fluids most commonly used evolved from four ODS (CFC-11, CFC-12, HCFC-22 and R-502) for approximately fifty fluids, including HFC, NH_3, CO_2 and hydrocarbons (HC).

HFC were developed in the years 1980 and 1990 as an alternative to CFC and HCFC. The HFC do not contain Chlorine (Cl), so they do not destroy the ozone layer, but contribute to the process of global warming. CFC and HCFC, in addition to being ozone depleting substances are also GHG, although they are not included in the Kyoto Protocol, because they are controlled by the Montreal Protocol (IMT, 2011c).

The refrigeration and air conditioning systems and equipment (RAC) can be classified into six essential sub-applications or categories:

– Domestic refrigeration;

– Commercial refrigeration, including different types of equipment, vending machine to centralized systems of refrigeration in supermarkets;

– Industrial processes, including chillers, refrigerated storage and heat pumps used in the industries of food, petrochemicals and other;

– Refrigerated transport, including equipment and systems used in refrigerated trucks, containers and wagons;

– Stationary air conditioning, including compact systems, heat pumps and chillers for residential applications and buildings;

– Vehicular air conditioning systems, used in cars, passenger cabins for trucks, buses and trains.

The refrigerants HFC replaced the CFC and are replacing the HCFC without any changes to the fundamental aspects of the technologies used in the equipment of the applications under study. Thus, the proposed methods to assess the emissions of HFC were also used for CFC and HCFC.

The estimates were performed following the guidelines of industrial processes and the use of products made by the IPCC (1996; 2000a), using the Tier 2. The data of activity for the implementation of Tier 2 are on annual data on the amount of equipment produced (assembly), number of installed equipment (operation), amount of scrapped (final disposal). It was adopted the emission factors suggested by the IPCC (2000a; 2006).

Domestic Refrigeration

In the global picture, the HC-600a and HFC-134a continue to be the dominant alternative to substitute refrigerants of CFC-12 in new domestic refrigeration equipment. Refrigerators manufactured in Brazil until the year 1999 wore CFC-12 as refrigerant and CFC-11 as the blowing agent of polyurethane foam, used for thermal insulation. According to the determinations of the Montreal Protocol, to which Brazil is a signatory, this fluid was replaced in the manufacturers of refrigerators by HFC-134a and isobutene (R-600a).

The current capacity for manufacture of refrigerators is around 6 million units. Currently, according to an estimate by the Mines and Energy Ministry (MME, 2009 apud IMT, 2011c), it is estimated that 50 million refrigerators are in use in the Country. For the realization of this inventory was considered the emissions of the stages of assembly, operation, scrap and the type of gas used (CFC-12 or HFC-134a).

Commercial Refrigeration

Commercial refrigeration consists of three types of equipment:

– Compact devices (stand-alone): all components are integrated in the unit by the manufacturer, for example, troughs, exhibitors, freezers and commercial ice cream machines. These equipment along with the domestic refrigerators, were the first to adopt the refrigerant HFC-134a;

– Remote systems: condensing units separated from the cooling equipment (evaporator) as countertop chilled, cold chambers, among others. There is a great use of HCFC-22 and in some new installations there is a small use of refrigerants HFCs, such as HFC-134a and R-404a;

– Centralized systems of direct expansion: in these systems, the compressors are mounted on racks located in engine rooms. This type of system is used in supermarkets, where the refrigerant circulates by evaporators located in gondolas and goes back to the engine room.

Vehicle Air Conditioning

The vehicular air conditioning systems have used HFC-134a in new vehicles produced in Brazil since 1996, and this is the only refrigerant used in new systems. In systems produced before this date the refrigerant used was the CFC-12, replaced by the determinations of the Montreal Protocol.

The emissions of refrigerant fluids for vehicular air conditioning systems were estimated considering only those related to the vehicles in operation, as they are considered the most significant. The other two stages, assembly and scrap, were not taken into account. In this inventory were considered the emissions from the phase of operation and type of gas used (CFC-12 or HFC-134a).

Bus Air Conditioning

The air conditioning systems installed in intercity buses and charter buses show a similar situation to the air conditioning systems installed in cars. CFC-12 was replaced by HFC-

134a. The estimate of the number of buses equipped with air conditioning in the Sao Paulo State was performed considering that 80% of intercity and charter buses contains air conditioning system, according to data from representatives of manufacturers of air conditioning systems for buses.

Due to the absence of data on the plot of the fleet with CFC-12 and with refrigerant HFC-134a, was adopted the same distribution determined for cars. To carry out this inventory, were considered the emissions from operation and type of gas used (CFC-12 or HFC-134a).

Water Drinkers

Water drinkers, as well as the domestic refrigerators, have used HFC-134a as refrigerant alternative to CFC-12. There are no statistics available on the annual production of water drinkers in Sao Paulo State. Thus, we estimated the production of drinkers in the State considering that this production is a constant fraction of National production. In this inventory was considered the emissions of the stages of assembly, operation, scrap and the type of gas used (CFC-12 or HFC-134a).

Emissions of HCFC-22

HCFC-22 is used in stationary and refrigeration air conditioning systems. In air conditioning systems, is used in compact window devices, split, multi-split, as well as in refrigeration systems such as chillers, scroll or screw. It is used the HCFC-22 mainly in systems of commercial refrigeration, both in condensing units in small installations, such as bakeries, butchers and restaurants, as well as in centralized refrigeration systems for supermarkets with rack of compressors.

For the estimates of emissions, it was considered that 75% of the consumption of HCFC-22 in the Sao Paulo State corresponds to the maintenance and the initial load of equipment and systems for refrigeration and air conditioning. The initial load of equipment newly manufactured can be performed both in the plant itself, in the case of window air conditioning units, and during the installation in the field, in the case of split air conditioning and commercial refrigeration equipment (condensing units and systems of supermarket).

Table II.68. GHG Emissions from Refrigeration and Air Conditioning Subsector in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CFC-12	0.11	0.12	0.14	0.16	0.21	0.23	0.22	0.20	0.19	0.21
HFC-134a	NE	NE	NE	NE	NE	NE	0.04	0.10	0.14	0.19
HCFC-22	0.66	0.72	0.78	0.84	0.92	0.99	0.99	1.07	1.17	1.55

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CFC-12	0.21	0.16	0.17	0.15	0.14	0.13	0.14	0.13	0.11	
HFC-134a	0.26	0.33	0.40	0.46	0.53	0.61	0.70	0.81	0.94	
HCFC-22	1.79	1.61	1.93	1.91	2.05	2.09	2.35	2.37	2.97	

Note: NE: Not estimated.

The consumption of HCFC-22 for the maintenance, during repair activities and technical assistance, aims to complete, total or partially, the required load of substance for the operation of the equipment and systems. This is necessary due to possible fugitive emissions of the equipment during its normal operation, when failures occur, or as intentional losses of repairs procedures. Table II.68 and Table II.69 show the estimates of GHG emissions of the subsector of Refrigeration and Air Conditioning in Gg and Gg_{CO2eq}. HFC-134a was estimated from 1996, as an alternative to CFC and HCFC uses.

Table II.69. GHG Emissions from Refrigeration and Air Conditioning Subsector in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[$Gg_{CO2eq}.year^{-1}$]									
CFC-12	1,153	1,322	1,532	1,761	2,278	2,517	2,378	2,182	2,108	2,255
HFC-134a	NE	NE	NE	NE	NE	NE	54	125	180	245
HCFC-22	1,198	1,298	1,408	1,528	1,656	1,796	1,783	1,928	2,125	2,807
Total	**2,352**	**2,620**	**2,941**	**3,289**	**3,934**	**4,312**	**4,215**	**4,234**	**4,413**	**5,307**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[$Gg_{CO2eq}.year^{-1}$]									
CFC-12	2,267	1,736	1,843	1,591	1,578	1,385	1,522	1,467	1,204	
HFC-134a	334	435	517	599	689	789	904	1,053	1,217	
HCFC-22	3,233	2,916	3,497	3,463	3,709	3,779	4,261	4,292	5,381	
Total	**5,833**	**5,087**	**5,857**	**5,652**	**5,976**	**5,953**	**6,686**	**6,812**	**7,802**	

Note: NE: Not estimated.

5.2.9 Total GHG Emissions from the Industrial Processes Sector

Table II.70, Table II.71 and Figure II.36, shows the emissions in the Industrial Processes Sector.

Figure II.36. GHG Emissions from Industrial Processes Sector in Sao Paulo State (Gg_{CO2eq})

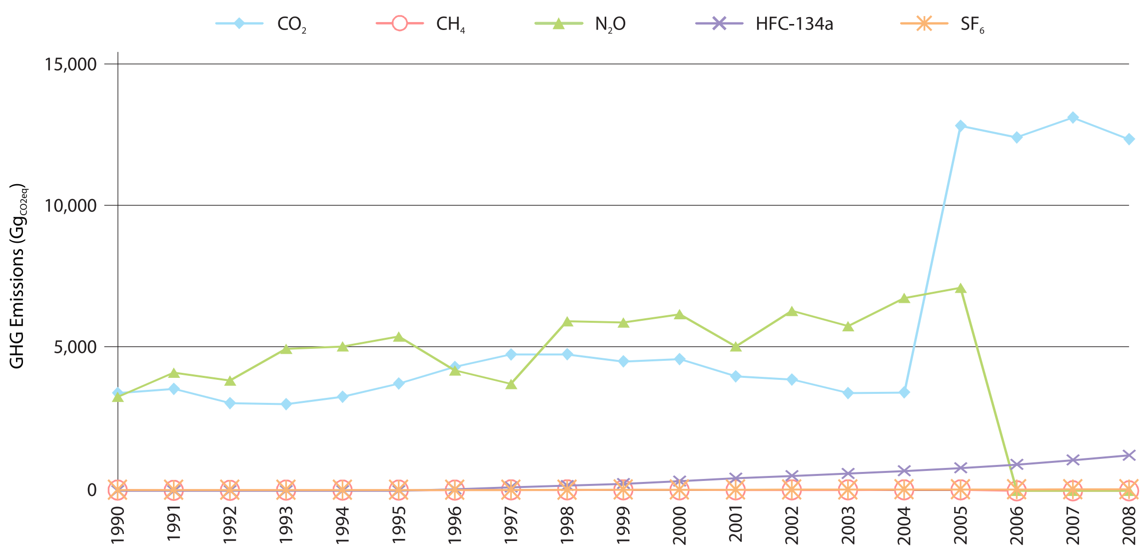


Table II.70. GHG Emissions from Industrial Processes Sector in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CO_2	3,396	3,540	3,046	3,011	3,268	3,724	4,300	4,738	4,744	4,495
CH_4	1.12	0.87	0.89	1.02	1.04	1.02	1.18	1.44	1.47	1.54
N_2O	11	13	12	16	16	17	13	12	19	19
HFC-134a	NE	NE	NE	NE	NE	NE	0.0	0.1	0.1	0.2
SF_6	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0015	0.0016
CFC-11	0.67	0.61	1.23	1.23	1.24	1.23	1.08	1.10	1.14	1.14
CFC-12	0.11	0.12	0.14	0.16	0.21	0.25	0.24	0.23	0.22	0.24
CFC-113	0.26	0.23	0.17	0.11	0.09	0.07	0.04	0.02	0.02	0.02
HCFC-22	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.6
HCFC-141b	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
VOC	59	65	70	77	84	90	96	104	101	133
NOx	1.0	1.2	1.4	1.7	2.4	2.4	2.4	2.7	2.8	2.9
CO	3.5	4.4	5.3	6.2	9.0	9.1	8.8	10.0	10.3	10.9

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CO_2	4,577	3,978	3,864	3,394	3,418	12,685	12,281	12,968	12,218	
CH_4	1.52	1.47	1.34	1.50	1.58	1.51	NE	NE	NE	
N_2O	20	16	20	18	22	23	NE	NE	NE	
HFC-134a	0.3	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.9	
SF_6	0.0016	0.0016	0.0017	0.0018	0.0019	0.0020	0.0020	0.0021	0.0022	
CFC-11	1.39	1.39	0.34	0.03	0.03	0.03	0.04	0.04	0.04	
CFC-12	0.24	0.20	0.21	0.19	0.19	0.18	0.20	0.20	0.18	
CFC-113	0.02	NE	NE	NE	NE	NE	NE	NE	NE	
HCFC-22	1.8	1.6	1.9	1.9	2.0	2.1	2.4	2.4	3.0	
HCFC-141b	NE	NE	0.6	0.7	0.8	0.8	0.8	1.1	1.1	
VOC	146	112	139	162	171	185	190	217	214	
NOx	3.0	3.0	3.1	3.8	4.4	4.6	5.1	5.3	5.4	
CO	11.4	11.2	11.6	14.2	16.5	17.1	18.9	19.9	20.2	

Note: NE: Not estimated.

Table II.71. Total GHG Emissions from Industrial Processes Sector in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.year^{-1}]									
CO_2	3,396	3,540	3,046	3,011	3,268	3,724	4,,300	4,738	4,744	4,495
CH_4	23	18	19	21	22	21	25	30	31	32
N_2O	3,261	4,103	3,833	4,933	5,015	5,361	4,182	3,713	5,893	5,848
HFC-134a	NE	NE	NE	NE	NE	NE	54	125	180	245
SF_6	31	31	31	31	31	31	31	31	36	38
Total	**6,711**	**7,693**	**6,929**	**7,996**	**8,335**	**9,137**	**8,592**	**8,637**	**10,884**	**10,659**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.year^{-1}]									
CO_2	4,577	3,978	3,864	3,394	3,418	12,685	12,281	12,968	12,218	
CH_4	32	31	28	31	33	32	NE	NE	NE	
N_2O	6,137	5,015	6,252	5,720	6,701	7,057	NE	NE	NE	
HFC-134a	334	435	517	599	689	789	911	1,064	1,231	
SF_6	38	38	41	43	45	48	48	50	53	
Total	**11,118**	**9,497**	**10,702**	**9,787**	**10,887**	**20,610**	**13,240**	**14,082**	**13,502**	

The emission of CH_4 and N_2O were estimated up to 2005 according to the emissions of the Chemical Industry Subsector; the emissions of CFC-113 were estimated from 1990 to 2000, due to the process of elimination of its use in Solvent Segment; The emissions of HFC-134a were estimated since 1996, because it started to be used as an alternative to the use of CFC and HCFC; emissions of HCFC-141b were estimated from 2002 on. CH_4 and N_2O emissions were estimated up to 2005 according to the emissions of the subsector of the Chemical Industry; HFC-134a emissions were estimated since 1996, because it started to be used as an alternative to the use of CFC and HCFC; HCFC-141b emissions were estimated from 2002.

Figure II.37 and Figure II.38 show the distribution of GHG emissions from Industrial Processes Sector, in the year 2005 by subsector and by gas. Because there are not estimates of Chemical Production Subsector in year 2008, this representation is not presented. Table II.72 and Table II.73 show GHG Emissions from Industrial Processes Sector, by gas and by subsector, including substances controlled by the Montreal Protocol.

Figure II.37. GHG Emissions from Industrial Processes Sector by Subsector, in 2005, in Sao Paulo State (20,610Gg)

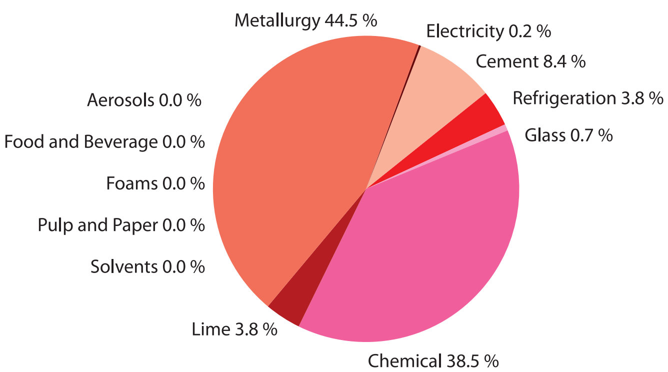


Figure II.38. GHG Emissions from Industrial Processes Sector by GHG, in 2005, in Sao Paulo State (20,610Gg)

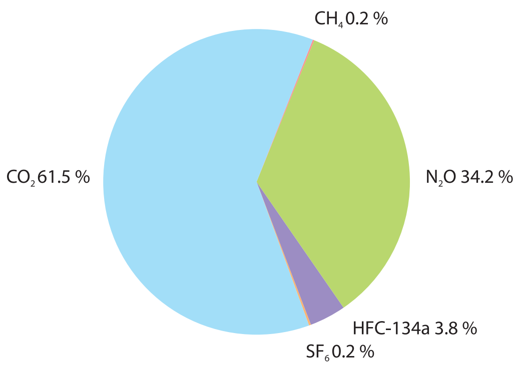


Table II.72. Emissions of GHG Controlled by the Montreal Protocol from Industrial Processes Sector in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{CO2eq}.year^{-1}]$									
CFC-11	3,164	2,888	5,833	5,857	5,890	5,864	5,134	5,224	5,401	5,414
CFC-12	1,153	1,322	1,532	1,761	2,278	2,763	2,635	2,460	2,421	2,604
CFC-113	1,571	1,390	1,017	685	533	410	248	148	111	113
HCFC-22	1,198	1,298	1,408	1,528	1,656	1,796	1,783	1,928	2,125	2,807
HCFC-141b	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Total	**7,086**	**6,898**	**9,791**	**9,831**	**10,357**	**10,833**	**9,800**	**9,760**	**10,058**	**10,938**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{CO2eq}.year^{-1}]$									
CFC-11	6,609	6,585	1,606	120	135	151	167	187	209	
CFC-12	2,648	2,161	2,302	2,083	2,117	1,976	2,158	2,147	1,942	
CFC-113	100	NE	NE	NE	NE	NE	NE	NE	NE	
HCFC-22	3,233	2,916	3,497	3,463	3,709	3,779	4,261	4,292	5,381	
HCFC-141b	NE	NE	406	477	592	592	579	798	787	
Total	**12,589**	**11,662**	**7,811**	**6,142**	**6,552**	**6,499**	**7,165**	**7,424**	**8,319**	

Note: NE: Not estimated.

CFC-113 emissions were estimated from 1990 to 2000, due to the process of elimination of its use in Solvent Segment, and HCFC-141b emissions were estimated from 2002.

Table II.73. GHG Emissions Including the Montreal Protocol Gases from Industrial Processes Subsectors in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{CO2eq}.year^{-1}]$									
Cement	2,293	2,441	1,854	1,791	1,934	2,345	2,893	3,041	3,087	3,026
Chemical	3,889	4,693	4,480	5,555	5,727	6,057	4,861	4,467	6,640	6,631
Metallurgy	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Food and beverage	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pulp and paper	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Foam	3,164	2,888	5,833	5,857	5,890	5,809	5,078	5,163	5,334	5,339
Refrigeration	2,352	2,620	2,941	3,289	3,934	4,312	4,215	4,234	4,413	5,307
Others										
Lime	457	472	499	533	554	601	645	848	823	594
Glass	41	56	65	86	89	103	108	125	118	125
Electricity	31	31	31	31	31	31	31	31	36	38
Aerosols	NE	NE	NE	NE	NE	301	313	339	380	424
Solvent	1,571	1,390	1,017	685	533	410	248	148	111	113
Total	**13,796**	**14,591**	**16,720**	**17,827**	**18,692**	**19,971**	**18,392**	**18,396**	**20,942**	**21,597**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{CO2eq}.year^{-1}]$									
Cement	2,853	2,384	2,128	1,705	1,564	1,734	2,229	2,459	2,500	
Chemical	6,946	5,731	7,086	6,494	7,572	7,933	NE	NE	NE	
Metallurgy	NE	NE	NE	NE	NE	9,459	9,587	10,023	9,224	
Food and beverage	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Pulp and paper	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Foam	6,527	6,493	1,907	477	592	592	586	809	800	
Refrigeration	5,833	5,087	5,857	5,652	5,976	5,953	6,686	6,812	7,802	
Others										
Lime	816	781	798	806	877	789	608	640	642	
Glass	131	128	132	140	139	142	138	143	141	
Electricity	38	38	41	43	45	48	48	50	53	
Aerosols	464	516	564	612	674	742	804	867	948	
Solvent	100	NE	NE	NE	NE	NE	NE	NE	NE	
Total	**23,707**	**21,158**	**18,513**	**15,929**	**17,439**	**27,392**	**20,686**	**21,803**	**22,110**	

Note: NE: Not estimated, NA: Not applicable.

The Metallurgy Subsector emissions were estimated from 2005; the emissions from Food and Beverage and Pulp and Paper Subsectors are not listed in Table II.73 because they emit only indirect GHG. Aerosols emissions were estimated from 1995; and the GHG emissions from Solvent Segment were estimated from 1990 to 2000. Figure II.39 and Figure II.40 shows the GHG emissions from Industrial Processes by Subsector, including those controlled by the Montreal Protocol in Sao Paulo State.

According to Figure II.40 is possible to observe the fluctuations in GHG emissions during the period 1990 to 2008. These oscillations are mainly due to changes in the activity of the economy, changing the data in the production of goods. In addition, developments in the technology used in the processes changes the emission factors. This occurred, for example, in the aluminum production, which has reduced its specific emissions in that period, and the chemicals production, which promoted the recovery of N_2O in projects under the Clean

Development Mechanism (CDM). In addition, an international treaty, of which the country is a signatory, has forced the banning and reduction of the use of substances, especially those which destroy the ozone layer.

Figure II.39. GHG Emissions from Industrial Processes Sector by Subsector Including the Montreal Protocol Gases in Sao Paulo State (Gg_{CO2eq})

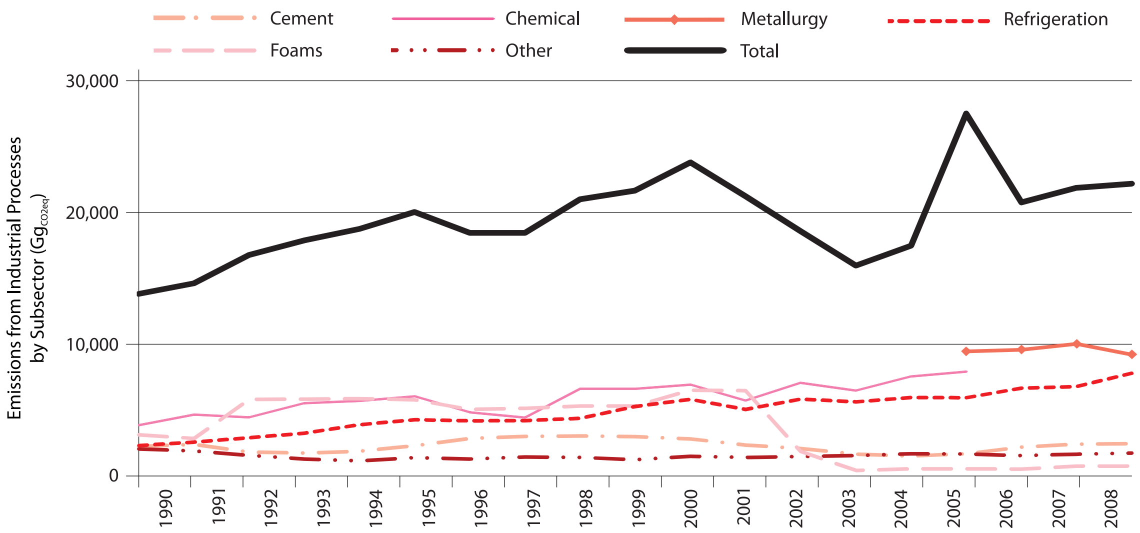
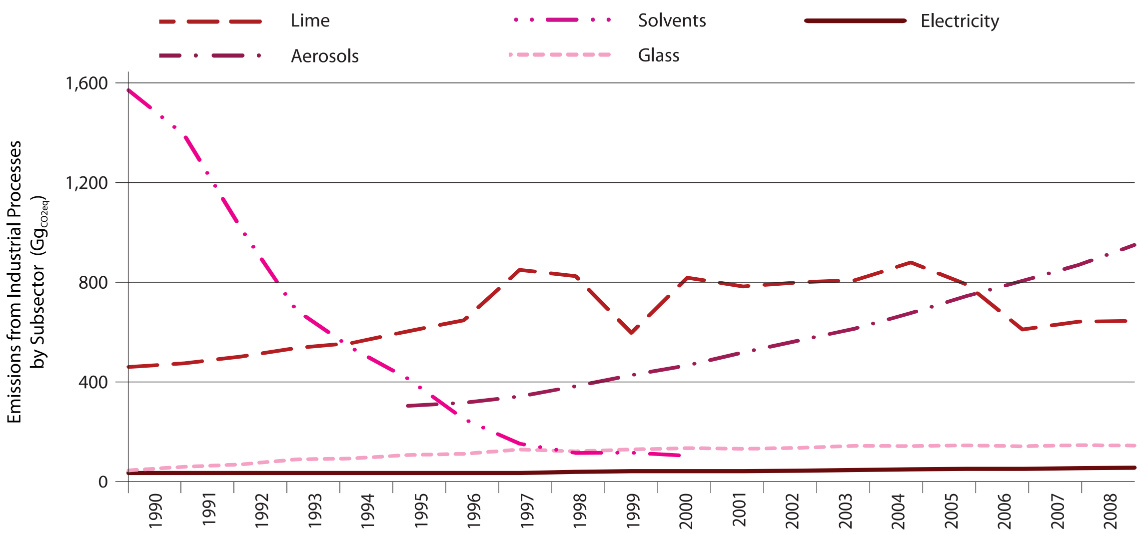


Figure II.40. GHG Emissions from Industrial Processes Sector below 2000 Gg_{CO2eq} in Sao Paulo State



Between 1990 and 1997, total GHG emissions fell due to a reduction of GHG emissions from Foam, Solvent, and Chemical Industries. Between 1998 and 2000, total GHG emissions have increased as a result of GHG emissions from Cement, Refrigeration, Aerosols, Chemical, and Foam Industries, and Fugitive Emissions in Electricity Sector. The total emissions of GHG decreased between 2000 and 2003 due to a reduction of emissions from Cement, Lime, Chemical, Glass, Foam, Refrigeration and Solvent Industries.

The peak observed in 2005 is related to the increase of GHG emissions from Cement, Chemical, Glass, and Aerosols Industries, and Fugitive of Electricity; in addition to coincide with the beginning of the period of emissions of the subsector of metallurgy. The decline observed after the year of 2005 was mainly due to the lack of information of GHG emissions from Chemical Industry.

5.3 Agriculture

5.3.1 Livestock: Enteric Fermentation and Manure

The GHG emissions inventory from Livestock in Sao Paulo State is a product of the arrangement between CETESB, Brazilian Agricultural Research Corporation (EMBRAPA) and Arthur Bernardes Foundation (FUNARBE)[67]. This report provides estimates of CH_4 emissions from Livestock in Sao Paulo State, in the period from 1990 to 2008.

The Livestock Sector contributes with CH_4 emissions through the enteric fermentation, which is part of the anaerobic digestive process of ruminant herbivores, and the animal manure management (BRASIL, 2006 apud EMBRAPA, 2011b). According to IPCC method (1996), is part of the category of ruminant animals: the dairy cattle, beef cattle, buffalo, sheep and goats. The contribution of non-ruminants, such as horses, mules, asses and pigs (IPCC, 1996) is considered irrelevant to the overall emissions of CH_4, representing 5% of the total emissions of CH_4 in domestic animals (JENSEN apud BRASIL, 2010a). The category of birds is included only in the emission estimations from animal manure management (IPCC, 1996).

Regarding to the animal manure management, when the organic material is decomposed under anaerobic conditions, it can produce a large quantity of CH_4, especially when the manure is stored in liquid form (in lakes, ponds and tanks). However, due to the characteristics of livestock in Sao Paulo State, led by pasture, the lagoons of anaerobic treatment are a small fraction in terms of animal manure management systems. Animal manure deposited in the pasture dry and decomposes in the fields, so that they are expected minimum quantities of emissions of CH_4 from this source.

According to the database of the Municipal Livestock Production (PPM), of IBGE, in 1990, excluded the bird population, 78.9% of the Livestock Sector in the State was represented by cattle, followed by 13.0% of pigs and 3.9% of horses. In 2008, these percentages were 80.5, 12.2 and 2.8%, respectively. Sheep are equivalent to 3.3%, buffaloes to 0.4%, mules and donkeys to 0.04% and goats to 0.5%. Table II.74 is presented the numbers per year and per animal, excluded the population of birds (IBGE, 2010 apud EMBRAPA, 2011b).

[67] The agreement was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

For most of the flocks, we used the Tier 1 in the calculation of GHG emissions, with the adoption of emission factors default IPCC (1996). However, the IPCC advises to develop a higher level of detail for the calculations of CH_4 emissions from herds of dairy cattle, beef and pork. For these cases, we calculated the emission factors by approach Tier 2 (IPCC, 1996). In this calculation, the beef cattle were subdivided in males (2%), female (34%) and young (64%), according to the specialists. The method of the IPCC (1996) also takes into account the climate of the region for the creation of the animals. The climatic types of Sao Paulo State were obtained from climate normal data (INMET apud BRASIL, 2010a). The result was a range between 15 and 25°C, which corresponds to the temperate climate.

Table II.74. Population of Animals in Sao Paulo State

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[10^3 animals]									
Cattle	12,263	12,262	12,394	12,690	12,974	13,148	12,798	12,827	12,753	13,069
Horses	612	609	624	615	621	615	581	564	553	539
Buffalo	68	66	65	64	63	63	57	53	53	56
Asses	6	7	7	9	8	9	6	7	7	7
Mules	221	203	196	183	170	163	93	101	94	87
Swine	2,027	2,081	2,036	2,015	2,099	2,143	1,849	1,835	1,934	1,913
Goats	110	108	106	107	101	102	65	76	75	73
Sheep	239	233	224	217	210	224	257	239	229	233

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[10^3 animals]									
Cattle	13,092	13,258	13,701	14,046	13,766	13,421	12,790	11,791	11,186	
Horses	542	540	532	516	500	494	473	422	382	
Buffalo	56	59	57	69	71	72	71	67	61	
Asses	7	7	7	7	7	7	6	6	5	
Mules	86	84	80	80	78	76	74	54	45	
Swine	1,902	1,904	1,845	1,709	1,699	1,707	1,728	1,724	1,691	
Goats	70	70	70	72	73	75	76	70	63	
Sheep	234	253	258	288	303	345	378	415	453	

Source: IBGE/PPM (2010) apud EMBRAPA (2011b).

Enteric Fermentation

The GHG emissions by enteric fermentation depends on the type of animal, the type and amount of food, the degree of their digestibility and the intensity of physical activity of the animal, depending on the various practices of creation. The consumption of food is related to the size of the animal, the environmental conditions, and the rate of growth and the production of milk, meat, wool and pregnancy. Generally, the greater the consumption, the greater will be the emission of CH_4 and the better the quality of the diet, the lower the emission per unit of food ingested (EMBRAPA, 2011b).

IBGE publishes annually the effective livestock of Sao Paulo in PPM, and reports the numbers of cattle, pigs, buffalo, sheep, goats, horses, donkeys, mules and birds. The number of milked cows is also reported. For this study, we used the numbers of effective for the period 1990 to 2008, and for the years 2000 and 2008 the numbers of effective were detailed by municipality, according to the PPM database (IBGE, 2010 apud EMBRAPA, 2011b).

Manure Management

Manure management is defined by how the feces and urine of animals are collected and stored until its use in crops and pastures. The GHG emissions inventory of Sao Paulo State was based on the Agricultural Census 2006 IBGE (apud EMBRAPA, 2011b), which raised information from the producers on manure management. The results were associated with the management systems described by the IPCC (2000a), which lists different systems and their emission factors in CH_4.

Creators of pigs in large and small producers were classified depending on the size of the property (IBGE, 2010 apud EMBRAPA, 2011b). In Sao Paulo, 9% of producers are small. For the herds of cattle, horses, donkeys, mules, sheep, goats and buffaloes, the deposition of manure directly in the pasture predominates. According to available data, statistical information and the opinion of experts were considered four periods for the manure management systems: 1990 to 2003; 2004 to 2005; and 2006 to 2008.

Table II.75. CH_4 Emissions from Livestock (Enteric Fermentation) in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{CH4}.year^{-1}]$									
Dairy Cattle	142	144	148	150	148	147	128	134	126	121
Adult Male	12	11	12	12	12	12	12	12	12	13
Adult Female	231	229	230	237	240	244	251	245	251	260
Young	285	283	285	293	301	307	306	303	305	316
Echinus	11	11	11	11	11	11	10	10	10	10
Buffalo	4	4	4	4	3	3	3	3	3	3
Asinine	0.06	0.07	0.07	0.09	0.08	0.09	0.06	0.07	0.07	0.07
Mule	2.2	2.0	2.0	1.8	1.7	1.6	0.9	1.0	0.9	0.9
Swine	2.0	2.1	2.0	2.0	2.1	2.1	1.9	1.8	1.9	1.9
Caprine	0.6	0.5	0.5	0.5	0.5	0.5	0.3	0.4	0.4	0.4
Ovine	1.2	1.2	1.1	1.1	1.1	1.1	1.3	1.2	1.2	1.2
Roosters	0	0	0	0	0	0	0	0	0	0
Hens	0	0	0	0	0	0	0	0	0	0
Total	**689**	**688**	**695**	**711**	**722**	**730**	**715**	**712**	**712**	**727**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{CH4}.year^{-1}]$									
Dairy Cattle	122	118	115	117	114	111	110	104	98	
Adult Male	13	13	13	14	14	13	13	12	11	
Adult Female	261	266	273	285	280	272	263	241	229	
Young	318	325	330	339	333	324	308	283	269	
Echinus	10	10	10	9	9	9	9	8	7	
Buffalo	3	3	3	4	4	4	4	4	3	
Asinine	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.05	
Mule	0.9	0.8	0.8	0.8	0.8	0.8	0.7	0.5	0.5	
Swine	1.9	1.9	1.9	1.7	1.7	1.7	1.7	1.7	1.7	
Caprine	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	
Ovine	1.2	1.3	1.3	1.4	1.5	1.7	1.9	2.1	2.3	
Roosters	0	0	0	0	0	0	0	0	0	
Hens	0	0	0	0	0	0	0	0	0	
Total	**731**	**739**	**748**	**772**	**757**	**739**	**711**	**656**	**622**	

Data were used for the production of milk from PPM (IBGE, 2010 apud EMBRAPA, 2011b) for each year in the period from 1990 to 2008, for both the dairy herd and flock cutting. No statistics are available to inform data of the production of milk distinctly for the categories of cattle. The other zoo technical data from the cattle were divided into three periods: 1990 to 1995, from 1996 to 2001, and 2002 to 2006.

In Table II.75 and Table II.76 shows the estimates of the total emissions of CH_4 from enteric fermentation and manure management systems from livestock of Sao Paulo State, respectively, in the period from 1990 to 2008 (EMBRAPA, 2011b).

According to EMBRAPA (2011b), in 2008 the CH_4 emissions from livestock of Sao Paulo were estimated at 675.96 Gg, being 92.4% allocated to the process of enteric fermentation and 7.6% for the manure management.

This result represents a reduction of 7.6% compared to the year of 1990 (731.61 Gg_{CH4}), because of the reduction of the flock. In 2008, the categories of cattle (dairy and beef) contributed with 97.6% of CH_4 emissions from enteric fermentation, while the other animal classes contributed with 2.4% of emissions.

Table II.76. CH_4 Emissions from Livestock (Animal Manure Management) in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CH4}.$year^{-1}$]									
Dairy Cattle	4.5	4.66	4.79	4.83	4.79	4.75	3.89	4.12	3.83	3.67
Adult Male	0.32	0.32	0.32	0.33	0.34	0.35	0.35	0.34	0.35	0.36
Adult Female	4.82	4.78	4.81	4.94	5.09	5.18	5.17	5.13	5.16	5.35
Young	13.6	13.5	13.59	13.96	14.37	14.63	13.89	13.78	13.87	14.38
Echinus	0.98	0.98	1.00	0.98	0.99	0.98	0.93	0.9	0.89	0.86
Buffalo	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.06
Asinine	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Mule	0.2	0.18	0.18	0.16	0.15	0.15	0.08	0.09	0.08	0.08
Swine	7.09	7.28	7.13	7.05	7.35	7.5	6.47	6.42	6.77	6.7
Caprine	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Ovine	0.04	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.04
Roosters	6.84	7.19	7.47	7.76	8.01	9.22	11.44	13.39	13.07	13.23
Hens	4.12	4.32	4.47	4.23	4.29	4.48	4.35	4.47	4.47	4.76
Total	**42.61**	**43.35**	**43.89**	**44.36**	**45.5**	**47.37**	**46.69**	**48.75**	**48.6**	**49.51**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CH4}.$year^{-1}$]									
Dairy Cattle	3.58	3.46	3.43	3.45	3.35	3.27	3.2	3.02	2.85	
Adult Male	0.36	0.37	0.36	0.37	0.36	0.35	0.34	0.31	0.29	
Adult Female	5.38	5.49	5.71	5.87	5.76	5.61	5.33	4.89	4.65	
Young	14.47	14.75	15.34	15.77	15.48	15.08	14.33	13.16	12.49	
Echinus	0.87	0.86	0.85	0.82	0.8	0.79	0.76	0.67	0.61	
Buffalo	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.06	
Asinine	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	
Mule	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.05	0.04	
Swine	6.66	6.66	6.46	5.98	5.95	5.97	6.05	6.03	5.92	
Caprine	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Ovine	0.04	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	
Roosters	12.46	12.84	12.8	13.5	13.68	15.64	16.36	19.76	22.05	
Hens	4.63	4.56	4.49	4.59	4.73	4.58	4.72	4.64	5.01	
Total	**48.61**	**49.19**	**49.63**	**50.56**	**50.32**	**51.51**	**51.31**	**52.69**	**54.05**	

5.3.2 Irrigated Rice Cultivation

The GHG emissions inventory from Irrigated Rice Cultivation in Sao Paulo State between 1990 and 2008 is a product of agreement between CETESB, FUNARBE and EMBRAPA[68]. According to Pereira and Machado (1987 apud EMBRAPA, 2011d) the rice can be grown under the following systems of production:

– Irrigated rice planted in systematized flooded areas;

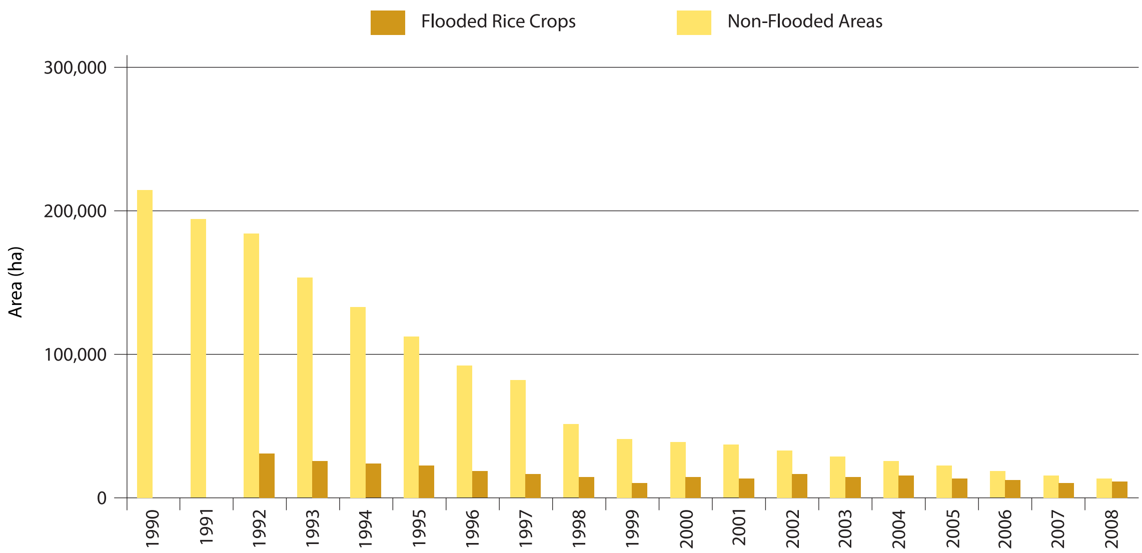
– Upland rice planted in higher land;

– Rice grown planted in floodplain wetlands and areas favored by sprinkler irrigation.

The anaerobic decomposition of organic matter present in the water from irrigated rice fields or flooded is an important source of emission of CH_4. This process does not occur when the rice is cultivated in uplands (upland rice) (BRASIL, 2010a). According to available data on the Institute of Agricultural Economics website (IEA), the Figure II.41 shows the evolution of the area of upland and floodplain rice, and irrigated rice in the State. Data from irrigated rice are presented only since 1992. In 2008, the total area of rice production in the State has suffered a reduction of 89% compared to 1990, with total area of 20,606 ha, 39% being grown under upland and floodplain conditions and 61% under irrigation.

Environmental legislation provides for the preservation of floodplain areas, which limits its use for rice cultivation. The production of upland rice has shown signs of recovery due to the development of new varieties more productive and economically viable. According to data from the IEA, between 1983 and 2009, there was a 22% increase in the productivity of upland rice. The irrigated rice, with a large part of its mechanized cultivation areas and using chemical fertilizers, also showed an increase of 42% in productivity.

Figure II.41. Evolution of the Harvest Area of Rice in the Sao Paulo State (ha)



Source: EMBRAPA (2011d), with adaptations.

[68] The agreement was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

The information of IEA about the cultivation of rice do not discriminate the areas occupied by upland rice and floodplain rice. In addition, for the areas of irrigated rice, irrigation systems are not differentiated, which makes difficult the distinction between the areas of cultivation under the regime of flooding and meadows and, consequently, the preparation of the estimates of GHG emission (EMBRAPA, 2011d). CH_4 emissions from cultivation of irrigated rice by flooding in the State were estimated for the period 1990 to 2008 using the method of inventory of GHG emissions from IPCC (1996; 2000a). CH_4 emissions generated by the cultivation of flooded rice in the State were estimated from the data of areas by municipality of IEA, having as a subsidy to consultation with the regional offices of Integral Technical Assistance Coordination (CATI) and experts in the Sector.

The annual emissions of CH_4 correspond to the sum of the emissions of different crops of rice. According to studies conducted in various countries, the emission of CH_4 is influenced by several factors such as temperature, solar radiation, soil fertility, type of cultivars and soil types (BRASIL, 2010a). For Sao Paulo State, there are no studies to determine the specific emission factor. For this reason, they were used default emission factor by the IPCC. The emission factor used is still multiplied by a factor of emission scale, concerning the different ecosystems under which the CH_4 emissions may vary according to their water regime (IPCC, 1996):

– Upland (or dry land): the fields are never flooded;

– Low lands: the fields are flooded by a significant period of time. Present the following types of water regime: irrigated[69], fed by rain (dry or humid floodplain) or deep water rice[70].

The annual emissions generated under each condition are summed to obtain the emission of CH_4 in the State in the period from 1992 to 2008, considering the area of irrigated rice was only made available in 1992. The total emissions, according to the IPCC method (1996) were estimated as 1.45 $Gg_{CH4}.year^{-1}$ for the year 2005. The result of emissions in 2005, shown in Table II.77, corresponds to 39% of the CH_4 emission in 1992.

Table II.77. CH_4 Emissions from Flooded Rice Cultivation in Sao Paulo State, between 1990 and 2008 (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	$[Gg_{CH4}.year^{-1}]$									
Lowland systems	1.60	1.52	0.36	0.18	0.22	0.19	0.17	0.16	0.18	0.18
Flooded rice fields	NE	NE	3.39	3.27	3.04	2.96	2.82	2.65	2.13	2.29
Total	**1.60**	**1.52**	**3.75**	**3.45**	**3.26**	**3.15**	**2.99**	**2.81**	**2.31**	**2.47**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	$[Gg_{CH4}.year^{-1}]$									
Lowland systems	0.10	0.06	0.05	0.03	0.03	0.03	0.04	0.01	0.02	
Flooded rice fields	2.22	2.30	2.08	2.13	2.14	1.42	1.40	1.39	2.12	
Total	**2.32**	**2.36**	**2.13**	**2.16**	**2.17**	**1.45**	**1.44**	**1.40**	**2.14**	

Note: NE: Not estimated.

[69] The system of irrigated water is classified as continuously flooded or intermittently flooded (with single aeration or multiple aerations).
[70] The rice fields of deep water may be subdivided into fields flooded with water depths of 50 to 100cm, or with depth of water above 100cm.

The estimates for CH_4 emissions from floodplain and irrigated rice cultivation in Sao Paulo State differ from those presented in the Reference Report, for the National Inventory (EMBRAPA ENVIRONMENT, 2008 apud EMBRAPA, 2011d), due to more detailed information collected for Sao Paulo State, from consultations with experts and literature available.

5.3.3 Burning of Agricultural Residues

The GHG emissions inventory from Burning of Agricultural Residues in Sao Paulo State between 1990 and 2008 is a product of agreement between CETESB, FUNARBE and EMBRAPA[71]. This report presents estimates emissions of CH_4, CO, N_2O and NOx, originated from the burning of agricultural residues from preharvest of sugarcane, in the period from 1990 to 2008.

Sao Paulo State is the main producer of sugar and alcohol of Brazil, responsible for more than 60% of National production (BRASIL, 2010a). The practice of burning of the sugarcane in the preharvest is used in order to increase the performance of the manual cutting and to help to prepare the ground for new plantations. However, according to the environmental legislation and the improvement of technology of mechanized harvest, this practice has been progressively reduced. The State Law 11,241 /2002 (SÃO PAULO, 2002), provides on the elimination of sugarcane straw burning in the State, determines that the areas in which the slope is less than 12%, the use of fire should be replaced gradually by 2021 by mechanized harvest. For the other areas, the burning should be totally eliminated until 2031 (EMBRAPA, 2011c).

Table II.78. Emissions from Burning of Sugarcane Residues in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CH_4	0.061	0.060	0.065	0.066	0.077	0.078	0.077	0.061	0.061	0.059
N_2O	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.003	0.003	0.003
CO	1.288	1.273	1.360	1.389	1.627	1.635	1.617	1.285	1.291	1.242
NOx	0.109	0.108	0.115	0.118	0.138	0.139	0.137	0.109	0.110	0.105

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CH_4	0.051	0.054	0.059	0.065	0.066	0.070	0.073	0.067	0.075	
N_2O	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.003	0.004	
CO	1.069	1.141	1.237	1.362	1.393	1.482	1.537	1.419	1.581	
NOx	0.091	0.097	0.105	0.116	0.118	0.126	0.131	0.121	0.132	

For the preparation of the estimates, we used the method of the IPCC (1996, 2000a). The information of harvest area and production of sugarcane were obtained from the Systematic Survey of Agricultural Production (LSPA), of the IBGE, in the period from 1990 to 2008, by region and state of the Country. For the years 2006 and 2007 were used municipal data, due to the availability of data of burned cane fraction by the National Institute for Space Research (INPE) (EMBRAPA, 2011c). Table II.78 presents the estimates of emissions of

[71] The agreement was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

CO, CH_4, N_2O and NOx emissions from sugarcane straw burning in Sao Paulo State for the period 1990 to 2008.

The harvested area and the productivity of sugarcane in the Sao Paulo State increased by 150 and 12% respectively, between 1990 and 2008, promoting an increase of 180% in production. In the same period, there was an increase of only 22.7% in atmospheric emissions, a fact attributed to the increase of mechanization of the harvest in the State (EMBRAPA, 2011c).

5.3.4 Agricultural Soils and Manure Management

The GHG emissions inventory from Agricultural Soils and Manure Management in Sao Paulo State is a product of agreement between CETESB, EMBRAPA and FUNARBE[72]. This report presents estimates of N_2O emissions from the manure management of the herd species and agricultural soils for Sao Paulo State, in the period from 1990 to 2008. The method used for the completion of the inventory of N_2O emissions from agricultural soils and manure management is the IPCC (1996; 2000a).

It is considered as manure management the way in which they are collected and stored until their application in agricultural soils. The considered management systems were: dunghill, with or without the use of beds in aviaries, anaerobic lagoon bio digesters and others not identified. N_2O emissions from agricultural soils are divided into direct and indirect, the direct emissions occur by adding synthetic fertilizers to the soils (F_{NS}) and organic fertilizer (manure managed) (F_{AM}), by the cultivation of fixing plants N_2 (F_{BN}), residues disposal of harvest (F_{CR}), and the mineralization of nitrogen associated with the cultivation of organic soils ($_{FOS}$), in addition to the N contained in manure directly deposited in pastures. The indirect emissions of N_2O are calculated on the portion of N added to soils as a fertilizer and organic fertilizer (manure) and volatilized as NH_3 and NOx and, subsequently, deposited in the soil and water bodies, and also that lost by leaching and superficial runoff.

In addition, they must be reported as N_2O emissions from agricultural soils those direct and indirect from the deposition of excreta (feces and urine) from animals on pasture (EMBRAPA, 2011a). In the light of the results of research in Brazil and also of the revision of the method of the IPCC (2006), it was decided not to consider the emissions from cultivation of nitrogen fixing plants (F_{BN}) as a direct source of N_2O and use a factor of direct emission (EF_1) of 0.010, which is applied on the total amounts of N fertilizers and organic fertilizers applied to the soil.

As to the results obtained between 1990 and 2008, N_2O emissions from manure management are practically doubled. The management of birds in a system with bed accounts for a large part of the emissions of N_2O. In other management systems, some more associated with the pigs, as well as the dunghills, no increase in the quantity of slurry

[72] The agreement was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

and, therefore, their contributions to the total emissions remained stable, at lower levels. N_2O emissions in bio digesters have increased from 2004, but the quantities are still very low compared to other systems (EMBRAPA, 2011a).

Table II.79. N_2O Emissions from Manure Management Systems in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
Manure storage	0.044	0.045	0.045	0.046	0.046	0.046	0.046	0.047	0.047	0.047
Aviary (with or without bed)	0.449	0.467	0.484	0.502	0,519	0.563	0.608	0.652	0.696	0.741
Anaerobic lagoon	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.008	0.008
Biodigestor	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Others	0.454	0.460	0.466	0.472	0.478	0.475	0.472	0.470	0.467	0.464
Total	**0.956**	**0.980**	**1.004**	**1.028**	**1.052**	**1.094**	**1.135**	**1.177**	**1.218**	**1.260**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
Manure storage	0.047	0.046	0.046	0.045	0.045	0.044	0.045	0.046	0.047	
Aviary (with or without bed)	0.785	0.822	0.860	0.897	0.935	0.972	1.099	1.227	1.354	
Anaerobic lagoon	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	
Biodigestor	0.000	0.000	0.001	0.001	0.002	0.002	0.002	0.003	0.003	
Others	0.461	0.461	0.462	0.462	0.463	0.463	0.459	0.455	0.451	
Total	**1.301**	**1.339**	**1.376**	**1.414**	**1.451**	**1.489**	**1.614**	**1.738**	**1.863**	

Table II.80. Direct and Indirect N_2O Emissions in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
Direct	21.68	22.25	22.82	23.39	23.96	24.1317	24.3033	24.475	24.6467	24.8183
Fertilizers and manure	6.28	6.6325	6.985	7.3375	7.69	7.76333	7.83667	7.91	7.98333	8.05667
Agricultural residues	2.44	2.47	2.5	2.53	2.56	2.69333	2.82667	2.96	3.09333	3.22667
Organic soils	1.91	1.96	2.01	2.06	2.11	2.16	2.21	2.26	2.31	2.36
Excrement disposed of in pastures	11.04	11.18	11.32	11.46	11.6	11.5167	11.4333	11.35	11.2667	11.1833
Indirect	8.12	8.2325	8.345	8.4575	8.57	8.53667	8.50333	8.47	8.43667	8.40333
Total	**29.800**	**30.483**	**31.165**	**31.848**	**32.530**	**32.668**	**32.807**	**32.945**	**33.083**	**33.222**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
Direct	24.99	25.55	26.11	26.67	27.23	27.79	27.9633	28.1367	28.31	
Fertilizers and manure	8.13	8.446	8.762	9.078	9.394	9.71	9.94	10.17	10.4	
Agricultural residues	3.36	3.538	3.716	3.894	4.072	4.25	4.72	5.19	5.66	
Organic soils	2.41	2.46	2.51	2.56	2.61	2.66	2.72667	2.79333	2.86	
Excrement disposed of in pastures	11.1	11.116	11.132	11.148	11.164	11.18	10.58	9.98	9.38	
Indirect	8.37	8.398	8.426	8.454	8.482	8.51	8.21667	7.92333	7.63	
Total	**33.360**	**33.948**	**34.536**	**35.124**	**35.712**	**36.300**	**36.180**	**36.060**	**35.940**	

Regarding to agricultural soils, the total of N_2O emitted in Sao Paulo State increased from 1990 to 2008. The different sources have remained in the same order of importance as contribution to the total emissions of N_2O in agricultural soils, with the exception of the emissions resulting from the direct deposition of N in pastures, which reduced in 2008, mainly due to the reduction of the herd cattle. Unlike the downward trend of N_2O

emissions of excreta in pastures, the increase of N_2O emissions from crop residues shows the trend of land-use change in pastures for plowing, more specifically the sugarcane (EMBRAPA, 2011a).

The total emissions of N_2O in agricultural soils have a tendency to increase in the direction North-South and East-West of the State. To the South, the increase in emissions of N_2O is explained by the management of organic soils, and to the North by the concentration of crops. In the West of the State, are the areas of pastures with N_2O emissions by direct deposition of nitrogen (N) of cattle. In the East region, the emissions are lower due to the low use of the area for production (EMBRAPA, 2011a). In Table II.79 are presented the N_2O emissions from manure management systems, and in Table II.80, are presented the N_2O emissions emitted directly and indirectly by agricultural land, due to the use of synthetic nitrogen fertilizers, soil fertilization with animal manure, crop residues, and cultivation of organic soil and deposition of animal excreta directly in pastures.

5.3.5 Liming Soil

The GHG emissions inventory from Liming Soil in Sao Paulo State was accomplished by CETESB. Liming soil is an agricultural practice that contributes to the increase in productivity because, among other effects, corrects the acidity of the soil[73], provides calcium and magnesium as nutrients, improves the efficiency of fertilizers, increases the availability of nutrients, reduces or eliminates the toxic effects of aluminum[74] and magnesium, improves the root system of plants and also improve microbial soil activity (SINDICAL, 2010a apud CETESB, 2011a).

To estimate the CO_2emissions, we used the method of the IPCC (1996, 2000a). Although the effect of liming soil generally has lasting for some years after the new addition of limestone, the guidelines of the IPCC (2000a) consider the CO_2 emissions of the entire limestone added in the year of application.

The IPCC method (2000a) is divided into three levels of detailing the estimates of CO_2 by liming soil, but for the estimates of this document we use the Tier 1. It was considered the $CaCO_3$ as amount of carbonate applied annually in agriculture, due to lack of data by type of carbonate. Consequently, it applies an emission factor provided by the IPCC (2000a) without any differentiation between the variable compositions of the carbonates.

To measure the amount of limestone used in agriculture, we used the annual data for marketing in the Sao Paulo State in the period from 1990 to 2008, as shown in Table II.81. Table II.82 presents the estimates of CO_2 emissions related to the process of liming soil in the Sao Paulo State in the period from 1990 to 2008. The results show that, with a few

[73] The acidification of the soil can be influenced by the following factors: leaching of soil nutrients through precipitation; use of some types of fertilizers; decomposition of organic matter; removal of surface layers of soil by erosion (SINDICAL, 2010a apud CETESB, 2011a).
[74] Aluminum toxicity is associated with nutritional deficiencies, causing a disqualification in the growth of roots in depth, which reduces the absorption of water and nutrients, mainly of P, Ca and Mg (BARBOSA FILHO, 2010 apud CETESB, 2011a).

exceptions, the use of limestone in agriculture has increased each year, which explains the increase in estimated emissions in the period.

Table II.81. Amount of Limestone for Agriculture in the Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
Limestone	2,117	2,200	3,430	3,611	4,567	3,362	3,437	3,724	3,597	3,205
	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
Limestone	3,323	3,136	3,199	3,843	3,016	3,354	4,101	4,239	3,322	

Source: SINDICAL (2010b) apud CETESB (2011a).

Table II.82. CO_2 Emissions from Liming Soil in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2}.year^{-1}]									
CO_2	931	968	1,509	1,589	2,009	1,479	1,512	1,639	1,583	1,410
	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2}.year^{-1}]									
CO_2	1,462	1,380	1,408	1,691	1,327	1,476	1,805	1,865	1,462	

5.3.6 Total GHG Emissions of the Agricultural Sector

Table II.83, Table II.84 and Table II.85, and Figure II.42 and Figure II.43 present the emissions of the Agricultural Sector.

Table II.83. Total GHG Emissions from Agriculture Sector in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.year^{-1}]									
CO_2	931	968	1,509	1,589	2,009	1,479	1,512	1,639	1,583	1,410
CH_4	15,405	15,386	15,607	15,932	16,179	16,399	16,061	16,035	16,016	16,357
N_2O	9,535	9,754	9,973	10,192	10,412	10,467	10,523	10,579	10,634	10,690
Total	**25,872**	**26,108**	**27,089**	**27,713**	**28,600**	**28,345**	**28,097**	**28,253**	**28,232**	**28,457**
	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.year^{-1}]									
CO_2	1,462	1,380	1,408	1,691	1,327	1,476	1,805	1,865	1,462	
CH_4	16,425	16,605	16,802	17,331	17,001	16,627	16,032	14,910	14,242	
N_2O	10,746	10,940	11,134	11,328	11,522	11,716	11,717	11,719	11,720	
Total	**28,633**	**28,924**	**29,343**	**30,349**	**29,850**	**29,818**	**29,554**	**28,493**	**27,423**	

Table II.84. Total GHG Emissions from Agriculture Sector in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CO_2	931	968	1,509	1,589	2,009	1,479	1,512	1,639	1,583	1,410
CH_4	734	733	743	759	770	781	765	764	763	779
N_2O	31	31	32	33	34	34	34	34	34	34
CO	1.3	1.3	1.4	1.4	1.6	1.6	1.6	1.3	1.3	1.2
NOx	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CO_2	1,462	1,380	1,408	1,691	1,327	1,476	1,805	1,865	1,462	
CH_4	782	791	800	825	810	792	763	710	678	
N_2O	35	35	36	37	37	38	38	38	38	
CO	1.1	1.1	1.2	1.4	1.4	1.5	1.5	1.4	1.6	
NOx	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	

Table II.85. GHG Emissions from Agriculture by Subsector in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.year^{-1}]									
Rice cultivation	34	32	79	72	68	66	63	59	49	52
Sugarcane burning	2	2	2	2	3	3	3	2	2	2
Agricultural soil	9,238	9,450	9,661	9,873	10,084	10,127	10,170	10,213	10,256	10,299
Manure management	1,191	1,214	1,233	1,250	1,282	1,334	1,332	1,388	1,398	1,430
Enteric fermentation	14,475	14,443	14,605	14,927	15,153	15,336	15,016	14,951	14,945	15,264
Liming soil	931	968	1,509	1,589	2,009	1,479	1,512	1,639	1,583	1,410
Total	**25,872**	**26,108**	**27,089**	**27,713**	**28,600**	**28,345**	**28,097**	**28,253**	**28,232**	**28,457**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.year^{-1}]									
Rice cultivation	49	50	45	45	46	30	30	29	45	
Sugarcane burning	2	2	2	2	2	3	3	2	3	
Agricultural soil	10,342	10,524	10,706	10,888	11,071	11,253	11,216	11,179	11,141	
Manure management	1,424	1,448	1,469	1,500	1,507	1,543	1,578	1,645	1,713	
Enteric fermentation	15,354	15,521	15,713	16,222	15,898	15,513	14,923	13,772	13,060	
Liming soil	1,462	1,380	1,408	1,691	1,327	1,476	1,805	1,865	1,462	
Total	**28,633**	**28,924**	**29,343**	**30,349**	**29,850**	**29,818**	**29,554**	**28,493**	**27,423**	

Figure II.42. GHG Emissions from Agriculture Sector in Sao Paulo State (%)

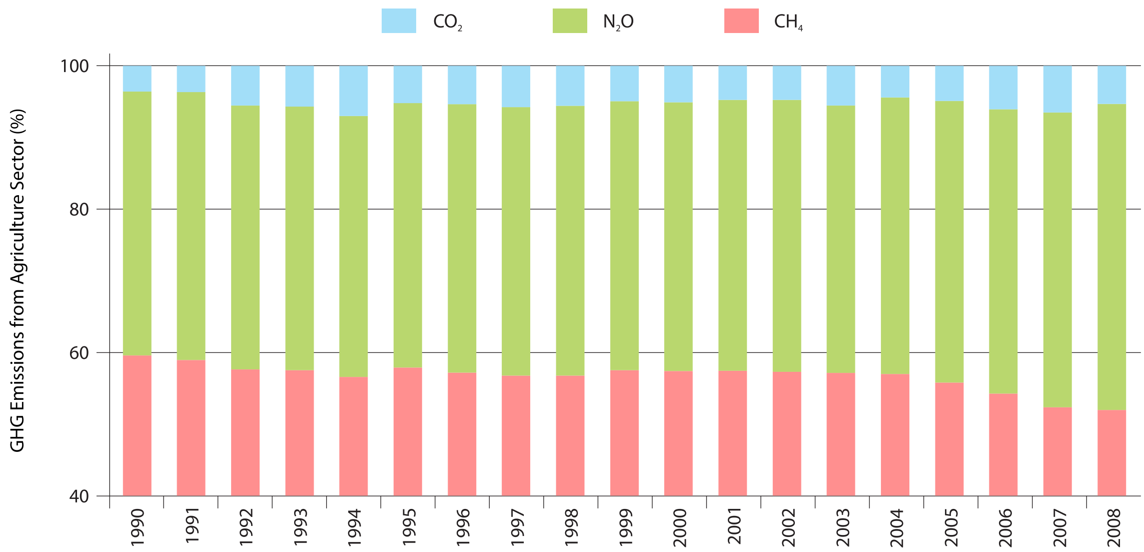


Figure II.43. GHG Emissions from Agriculture Sector by Subsector in Sao Paulo State (Gg_{CO2eq})

Below, in Figure II.44 and Figure II.45 are presents the GHG emissions by Agricultural Sector in the years 2005 and 2008.

Figure II.44. GHG Emissions from Agriculture by Subsector, in 2005, in Sao Paulo State (29,818 Gg_{CO2eq})

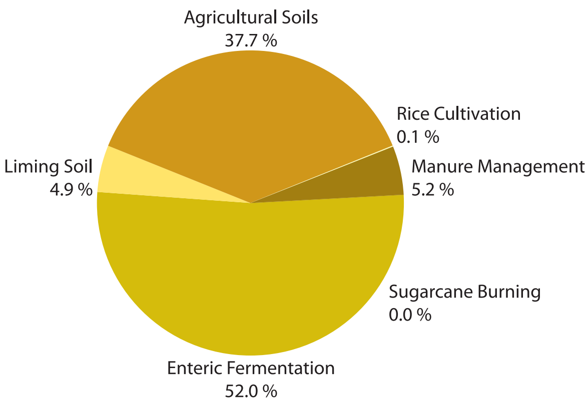
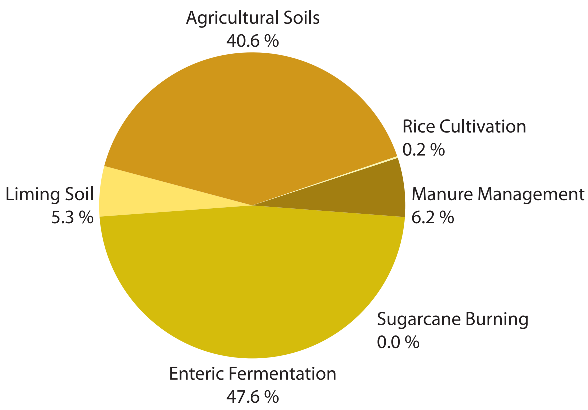


Figure II.45. GHG Emissions from Agriculture by Subsector, in 2008, in Sao Paulo State (27,423 Gg_{CO2eq})



5.4 Land Use, Land-use Change, and Forestry

The GHG emissions inventory from Land Use, Land-use Change, and Forestry (LULUCF) Sector was conducted in accordance with contract signed between CETESB and the Foundation for Space Science, Technology and Applications (FUNCATE), with the support of INPE[75].

This report presents estimates of net anthropogenic emissions result from the sources of emissions and removals of CO_2 from the atmosphere, associated with the LULUCF in Sao Paulo State, for the periods 1994 to 2002, from 2002 to 2005 and from 2005 to 2008. For the generation of the information contained in this work, it was necessary to identify the areas under different categories of land use and categorized according to the presence or not of these areas in the same category of use, in different periods of time analyzed.

The work has applied the approach suggested by the IPCC to separate the anthropogenic emissions of the non-anthropogenic. Thus, all emissions and removals of carbon occurred in managed areas are considered to be of anthropogenic origin. In this work it was also considered all the area of forest and non-forest native vegetation (grassland) contained in indigenous lands and in the National System of Units of Nature Conservation (SNUC), according to the Law 9,985 / 2000, except for the Private Reserves of Natural Preservation (RPPN) (BRASIL, 2000), as part of the areas handled in territory of Sao Paulo State.

The used categories of land use were those suggested in the Good Practice Guidance for Land Use, Land-use Change and Forestry of the Intergovernmental Panel on Climate Change (IPCC, 2003), which include: forest, grassland, cropland, wetlands, settlements and other land. The category forest was sub-divided into unmanaged forest, managed forest, secondary forest and reforestation, while the grassland class was sub-divided into unmanaged grassland, managed grassland, grassland with secondary vegetation and planted pasture. This Good Practice Guidance recognizes that some of the categories

[75] The contract was signed with resources of the partnership between the British Embassy and CETESB, to collaborate for the CETESB´s Project to improve State Policy on Climate Change.

above relate to the coverage of the earth (example: forest, wetlands), and other land use (example: agriculture, settlements). However, this document refers to both categories as land-use categories, summarized in Table II.86.

Table II.86. Land-use Categories

Acronym	Category	IPCC Category
FNM	Unmanaged forest	Forest
FM	Managed forest	
FSec	Secondary forest	
Ref	Reforestation	
GNM	Unmanaged grassland	Grassland
GM	Managed grassland	
GSec	Grassland with secondary vegetation	
Ap	Planted pasture	
Ac	Cropland area	Cropland
S	Urban area	Settlements
A	Rivers and lake (unmanaged wetlands)	Wetlands
Res	Sinks (managed wetlands)	
O	Other uses	Other land
NO	Not observed	

Source: FUNCATE (2011).

It was used also some national definitions to classify the land-use categories, and they are (FUNCATE, 2011):

Forest

Land-use category with the following characteristics:

a) Minimum tree crown coverage: 10%;

b) Minimum area: 0.5 ha;

c) Minimum tree height: 5 meters.

Forest category was divided in the following subcategories:

i) Primary forest: forests in which human action did not cause significant alterations in its original structure and species. It is also denominated as Climax Forest.

ii) Reforestation: includes planted areas or areas being prepared for the planting of forest essentials (Black Acacia, *Eucalyptus*, *Pinus*, etc.), and included the occupied areas by forest essential sapling nurseries.

Grassland

i) Primary grassland vegetation: grassland where human actions did not cause significant alterations in its original structure and species.

ii) Pasture: includes designated areas for grazing and that have been established by planting.

Cropland

Include all areas cultivated with annual and perennial crops.

Wetlands

Extension of natural or artificial, permanent or temporary, stagnant or running, fresh, brackish or salted salt marshes, swamps, peat bogs or waters, including extensions of sea waters, whose depths at low tide do not exceed 6 (six) meters. Includes:

i) Lakes and rivers;

ii) Reservoirs.

Settlements

Internal area of an urban perimeter of a city or village defined by municipal law and characterized by continuous construction and the existence of social equipment for basic functions such as housing, work, recreation and circulation.

Other land

(Example: rock formations, mining activities, dunes, etc.).

Not observed

(Areas not assessed by remote sensing due to continuous cloud cover).

The GHG emissions inventory from LULUCF Sector uses an approach that requires observations of land use and land-use change for the representation of areas. Regarding the representation of the areas, we used an approach which divides Sao Paulo State in spatial units in the form of polygons, resulting in the integration of the following sources:

– Soil Map on a scale of 1:5,000,000 (IBGE, 2003 apud FUNCATE, 2011);

– Vegetation Map of the Brazilian Institute of Geography and Statistics (IBGE, 2004 apud FUNCATE, 2011), which reconstitutes the situation of the vegetation in Brazilian territory at the time of its discovery, on a scale of 1:5,000,000;

– Municipal borders (IBGE apud FUNCATE, 2011);

– Limits of Brazilian Biomes in the Sao Paulo State (IBGE, 2004 apud FUNCATE, 2011);

– Maps of land use and cover for each year tallied on a scale of 1:250,000 (FUNCATE, 2011).

For the compilation and interpretation of data, we used the system *TerraAmazon*, a tool designed for editing vector geographical databases, stored in a Database System (SGDB) model *TerraLib* (<www.terralib.org>), in a corporate environment, distributed and current use. *TerraAmazon* is free software available at <www.terraamazon.org>. The images from *Landsat Satellite 5,* used for interpretation of the images were matched by comparison with images from NASA (*Geocover*).

Maps of land use were generated from the interpretation of the images of the American *Landsat Satellite 5*. The 1994 and 2002 consist of a crop of Sao Paulo State from maps generated for the Second National Communication (BRASIL, 2010). These maps are attached in Chapter 7 (Annexes).

An analysis was performed on the basis of the specific biomass and carbon stocks associated with each biome in the Sao Paulo State (Cerrado and Atlantic Forest). It was prioritized the use of specific emission factor of Sao Paulo State instead of the default (Tier 1) provided by IPCC (2003). The associated emission factors to the Cerrado and the Atlantic Forest were obtained from the literature described in Table II.87 and Table II.88.

In addition to the emissions and removals of carbon by the change in the stock of carbon in live biomass (above and below the ground), were also estimated the net emissions associated with loss or increase of carbon in the soil, resulting from land-use change (conversion of a given category of use for another type of category).

Table II.87. Carbon Content of Vegetation in the Atlantic Forest Biome in the Sao Paulo State

Vegetal Physiognomy	Forest/Cropland	C ($t_C.ha^{-1}$) Content	Reference
Montane Decidous Seasonal Forest (Cm)	Forest	104.95	BRITEZ, R. M. et al., 2006
Submontane Decidous Seasonal Forest (Cs)	Forest	116.27	BRITEZ, R. M. et al., 2006
Alluvial Dense Humid Forest (Da)	Forest	166.93	BRITEZ, R. M. et al., 2006
Lowland Dense Humid Forest (Db)	Forest	135.76	BRITEZ, R. M. et al., 2006
Montane Dense Humid Forest (Dm)	Forest	122.92	BRITEZ, R. M. et al., 2006
High Montane Dense Humid Forest (Dl)	Forest	122.92	BRITEZ, R. M. et al., 2006
Submontane Dense Humid Forest (Ds)	Forest	122.92	BRITEZ, R. M. et al., 2006
Alluvial Semi Decidous Seasonal Forest (Fa)	Forest	140.09	BRITEZ, R. M. et al., 2006
Montane Semi Decidous Seasonal Forest (Fm)	Forest	140.09	BRITEZ, R. M. et al., 2006
Sub Montane Semi Decidous Seasonal Forest (Fs)	Forest	140.09	BRITEZ, R. M. et al., 2006
Montane Mixed High Humid Forest (Ml)	Forest	118.81	BRITEZ, R. M. et al., 2006
Montane Mixed Humid Forest (Mm)	Forest	118.81	BRITEZ, R. M. et al., 2006
Fluvial and/or Lacustre Influenced Vegetation (Pa)	Forest	105.64	BRITEZ, R. M. et al., 2006
Pioneer Formation Fluviomarine Influenced (Mangroves) (Pf)	Forest	98.16	COGLIATTI-CARVALHO & FONSECA, 2003
Pioneer Formation Marine Influenced (Restinga) (Pm)	Forest	94.48	BRITEZ, R. M. et al., 2006
High Montane Vegetation Refuge (Rl)	Grassland	6.55	BRITEZ, R. M. et al., 2006
Montane Refuge (Rm)	Grassland	6.55	BRITEZ, R. M. et al., 2006
Wooded Savanna (Sa)	Forest	47.10	ABDALA, G. C. et al., 1998
Forested Savanna (Sd)	Forest	77.80	ABDALA, G. C. et al., 1998
Woody-grass Savanna (Sg)	Grassland	16.30	ABDALA, G. C. et al., 1998
Park Savanna (Sp)	Grassland	24.10	ABDALA, G. C. et al., 1998

Source: FUNCATE (2011), with adaptations.

For each of the associations soil-vegetation, was adopted the same stock of carbon in the soil under natural vegetation used in the First National Inventory. In this report, we use the median of the data reported in the report of the 1st inventory from LULUCF Sector (BRASIL 2006 apud FUNCATE, 2011), shown in Table II.89.

The method used to estimate the change of carbon stock in biomass and soil considers that the gain or loss of carbon in the soil, a result of the land-use change, occurs during the period of 20 years (IPCC, 2003 apud FUNCATE, 2011).

Table II.88. Carbon Content of Vegetation in the Cerrado Biome in the Sao Paulo State

Vegetal Physiognomy	Forest/Cropland	C ($t_C.ha^{-1}$) Content	Reference
Montane Decidous Seasonal Forest (Cm)	Forest	104.95	BRITEZ, R. M. et al., 2006
Submontane Decidous Seasonal Forest (Cs)	Forest	116.27	BRITEZ, R. M. et al., 2006
Montane Dense Humid Forest (Dm)	Forest	139.03	BRITEZ, R. M. et al., 2006
Alluvial Semi Decidous Seasonal Forest (Fa)	Forest	140.09	BRITEZ, R. M. et al., 2006
Montane Semi Decidous Seasonal Forest (Fm)	Forest	140.09	BRITEZ, R. M. et al., 2006
Sub Montane Semi Decidous Seasonal Forest (Fs)	Forest	140.09	BRITEZ, R. M. et al., 2006
Montane Mixed High Humid Forest (Ml)	Forest	118.81	BRITEZ, R. M. et al., 2006
Montane Mixed Humid Forest (Mm)	Forest	118.81	BRITEZ, R. M. et al., 2006
Fluvial and/or Lacustre Influenced Vegetation (Pa)	Forest	105.64	BRITEZ, R. M. et al., 2006
Wooded Savanna (Sa)	Forest	47.10	ABDALA, G. C. et al., 1998
Forested Savanna (Sd)	Forest	77.80	ABDALA, G. C. et al., 1998
Woody-grass Savanna (Sg)	Grassland	16.30	ABDALA, G. C. et al., 1998
Park Savanna (Sp)	Grassland	24.10	ABDALA, G. C. et al., 1998

Source: FUNCATE (2011), with adaptations.

Table II.89. Soil Carbon Stock ($kg_C.m^{-2}$)

Categories						
	Soil					
Vegetation	Soils with High Clay Activity (S1)	Oxisoils with Low Clay activity (S2)	Non-oxisoils with Low Clay Activity (S3)	Sandy Soils (S4)	Organic Soils (S5)	Other Soils (S6)
	$kg_C.m^{-2}$					
Open Amazon Forest (V1)	5.09	4.75	4.89	4.11	4.36	
Dense Amazon Forest (V2)	3.22	5.19	4.69	5.06	5.27	4.81
Atlantic Forest (V3)	5.83	5.23	4.29	6.33	3.58	41.78
Deciduous Seasonal Forest (V4)	4.67	3.08	4.00	2.59	3.27	3.18
Semi-deciduous Seasonal Forest (V5)	4.09	4.43	3.74	2.70	5.36	3.16
Mixed Humid Forest (V6)	9.88	10.25	5.68		8.54	
Southern Savanna (V7)	6.42	9.09	5.16		7.42	3.28
Amazon Savanna (V8)	4.80	1.98	3.81	4.37	3.46	2.90
Cerrado (V9)	2.44	4.31	3.60	1.92	6.65	3.29
Southern Steppe (V10)	6.60	4.66	6.12		3.38	4.99
Northeastern Steppe (Caatinga) (V11)	2.42	2.58	2.62	1.51	2.51	2.09
Western Steppe (Pantanal) (V12)	3.38	—	3.52	3.54	10.52	2.17
High Montane Vegetation Refuge (V13)	3,41	5,04	3,99	—	—	—
Pioneer Formation Areas (V14)	7.30	4.13	3.31	5.02	5.92	3.72
Woody Oligotrophic Vegetation of Swamps and Sandy Areas (V15)	5.09	4.68	4.81	6.17	9.05	12.09

Note: –: Non existing category.
Source: FUNCATE (2011), with adaptations.

To estimate the annual removal of carbon in Native Vegetation with Forest Physiognomy in Managed Land (Remf), was adopted the factor of $0.62T_C.(ha.year)^{-1}$ (PHILLIPS et al, 1998 apud FUNCATE, 2011). For the Areas managed with Native Vegetation with Non-forest Physiognomy in Managed Land (Remg), was adopted the zero for Remg, because there is no information about the occurrence of removing these physiognomies.

To obtain the average carbon stock in reforestation (AvRef) and the average annual increment of carbon in reforestation under formation (IncrRef), was necessary to differentiate the planted areas with *Pinus* from areas planted with *Eucalyptus*, dominant species in the country, using the statistical information for the participation of these cultures in the State. For Sao Paulo State was collected the data presented, reproduced in Table II.90.

Finally, for the reforestation with *Eucalyptus,* we adopted the factor of $41m^3.(ha.year)^{-1}$ as the net annual average increment of appropriate volume for industrial processing (BRACELPA, 2010 apud FUNCATE, 2011). This value corresponds to an increment (IncrRef) of $14.11t_c.(ha.year)^{-1}$.

Table II.90. Reforested Area in the Sao Paulo State (ha)

Area planted with *Eucalyptus* and *Pinus* in 2005		
	[ha]	[%]
Eucalyptus	798,522	84
Pinus	148,020	16
Total	**946,542**	**100**

Source: ABRAF (2010) apud FUNCATE (2011).

As For the average stock carbon in planted pasture, annual agriculture and perennial agriculture, the following data was used (Table II.91).

Table II.91. Average Carbon Stock in Planted Pasture and Agricultural Areas (Annual and Perennial Crops) ($t_C.ha^{-1}$)

Description	Quantity
	$t_C.ha^{-1}$
Planted pasture	8.05
Annual agriculture	5.00
Perennial agriculture	21.00

Source: IPCC (2003).

For the areas of perennial agriculture, was adopted 2.6 $t_c.(ha.year)^{-1}$ for the average annual increment in newly formed areas. However, it is only based on satellite interpretations; it was not possible to distinguish areas of perennial or annual agriculture.

We used auxiliary data from the IBGE (1990-2006 apud FUNCATE 2011), to estimate the relative contribution of annual and perennial crops in the Sao Paulo State and thus estimate the average stock of carbon in cropland (AvAgr), and the average annual increment of carbon in cropland in formation (IncrAgr), obtaining the data presented in Table II.92.

Table II.92. Average Carbon Stock and the Annual Increment in Biomass in Agricultural Areas

Fraction		IncrAgr	AvAgr
Permanent crops	Annual crops	t_C.(ha.year)-1	t_C.ha-1
0.18	0.82	6.00	7.90

Source: FUNCATE (2011).

In the areas of the reservoirs, settlements and other lands, we assumed that the carbon in biomass is equal to zero. As regards the correction factors to estimate changes in the stock of carbon in the soil due to management practices (fMG), land use (fLU), addition of fertilizers (fI) were used the factors listed in Table II.93, where (fc) is the product of three correction factors, using default values of the Good Practice Guidance for Land Use, Land-use Change and Forestry (IPCC, 2003) or specific values generated by consulting the experts.

Table II.93. Modification Factor of the Soil Carbon with the Land-use Change

Land use	fLU	fMG	fI	fc
FNM	1.00	—	—	1.00
FM	1.00	—	—	1.00
FSec	1.00	—	—	1.00
Ref	0.58	1.16	1.00	0.673
GNM	1.00	—	—	1.00
GM	1.00	—	—	1.00
GSec	1.00	—	—	1.00
Ap	1.00	0.97	1.00	0.97
Ac	0.58	1.16	0.91	0.612
S	0.00	—	—	0
A	0.00	—	—	0
Res	0.00	—	—	0
O	0.00	—	—	0

Note: –: Does not apply.
Source: IPCC (2003) apud FUNCATE (2011).

Finally, a matrix of possible transitions of land-use categories was generated, exemplified in Table II.94, where the main diagonal (bounded with thick edges) indicates the presence in the same land-use category, and in the cells, outside the diagonal the transition between land-use categories. The hatched cells represent the states of permanence or transition of land use not observed in the analyzed periods.

Table II.94. Possible Land-use Transitions Matrix[76]

		Year N+M											
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO
Year N	FNM												
	FM												
	Ref												
	GNM												
	GM												
	Ap												
	Ac												
	S												
	A												
	Res												
	O												
	NO												

Table II.95. Total CO_2 Emissions in Sao Paulo State, between 1994 and 2002 (Gg)[76]

CO_2 (Gg)		Land use in 2002											
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO
Land use in 1994	FNM	-	-929.61				637.66	2,625.01	4,666.96		7,394.10	13.54	
	FM		-23,109.22					3.47	560.13		0.43		
	Ref			-									
	GNM			-	-	-	0.15	17.2			5.43		
	GM							2.24					
	Ap			-2,917.80			-		3.6		19.5		
	Ac							-	255.17		72.84	15.91	
	S												
	A									-	-		
	Res										-		
	O											-	
	NO	-	-					-	-	-			
Total = -10,663.29													

Source: FUNCATE (2011), with adaptations.

From the results obtained, it was observed that in the first period, from 1994 to 2002, there was a land-use change corresponding to 62,480 ha (0.25% of 24,823,681 ha mapped). In the second period, from 2002 to 2005, there was a land-use change of 46,426 ha (0.19% of the total mapped), and in the third period, from 2002 to 2005 there was a land-use change to 64,618 ha (0.26% of the total mapped). Table II.95, Table II.96, and Table II.97 shows the net emissions of CO_2 from the LULUCF Sector in the Sao Paulo State, corresponding to the period from 1994 to 2002, 2002 to 2005 and 2005 to 2008. The average net annual anthropogenic emissions were -10,663.29 Gg_{CO2}, -11,753.35 Gg_{CO2} and -9,846.08 Gg_{CO2} in

[76] Key: FNM –Unmanaged forest; FM – Managed forest; Ref – Reforestation; GNM –Unmanaged grassland; GM – Managed grassland; Ap – Planted pasture; Ac – Cropland area; S –Urban area; A – Rivers and lake (unmanaged wetlands); RES –Reservoirs (managed wetlands); O – Other uses; NO –Not observed. N – Any year; M – Any number of years of the transition period.

the first, second and third periods respectively. The negative number indicates that there was net removal of CO_2.

Table II.96. Total CO_2 Emissions in Sao Paulo State, between 2002 and 2005 (Gg)[76]

CO_2 (Gg)		Land use in 2005											
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO
Land use in 2002	FNM	-	-38.77					373.56			10.56		
	FM		-9,356.71				0.54						
	Ref												
	GNM												
	GM												
	Ap			-3,573.72									
	Ac								831.19				
	S												
	A												
	Res												
	O												
	NO												
Total = -11,753.35													

Source: FUNCATE (2011), with adaptations

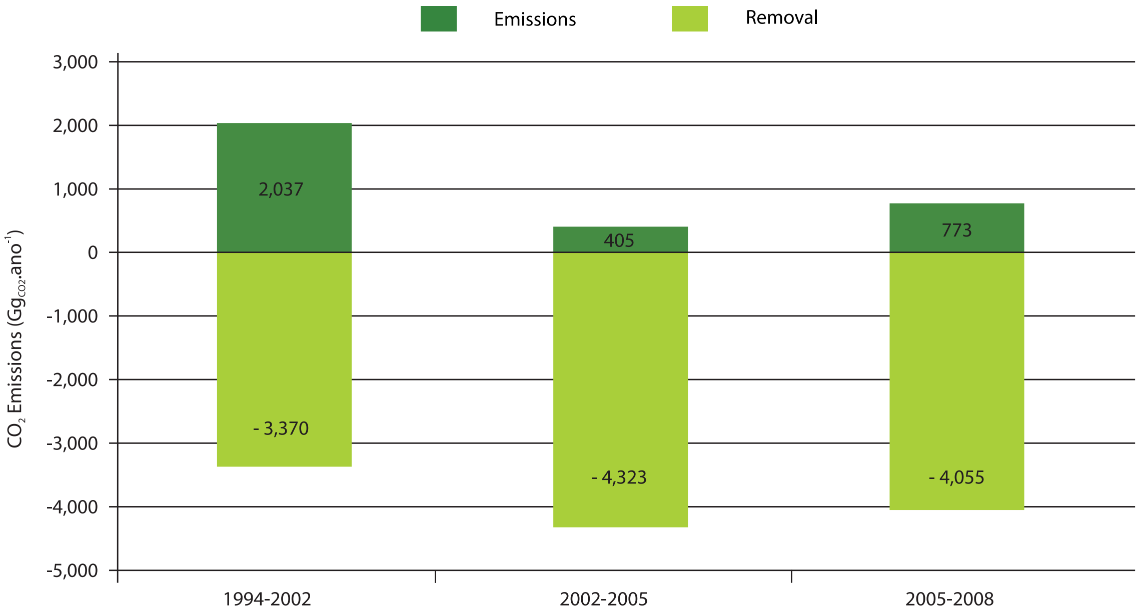
Table II.97. Total CO_2 Emissions in Sao Paulo State, between 2005 and 2008 (Gg)[76]

CO_2 (Gg)		Land u se in 2008											
		FNM	FM	Ref	GNM	GM	Ap	Ac	S	A	Res	O	NO
Land use in 2005	FNM	-	-150.23				44.22	402.60			10.56		
	FM		-9,432.32					54.76					
	Ref								1399.74		24.26		
	GNM												
	GM												
	Ap			-2583.56					147.42				
	Ac			-0.33			-0.01		246.41			0.96	
	S												
	A												
	Res												
	O												
	NO												
Total = -9846.08													

Source: FUNCATE (2011), with adaptations.

From the data in Tables II.95, II.96 and II.97 was generated the Figure II.46, below, which shows the CO_2 balance (emissions and removals) in the three periods analyzed. The result obtained for each period in Gg_{CO2}, was divided by the duration of each period, resulting in an average of the balance of CO_2 per year. For the calculation, we considered the period as the interval between the years, excluding the first year, and including the last one, that is, in the interval between 1994 and 2002 were accounted for eight years (1995-2002).

Figure II.46. CO_2 Annual Average Balance in Periods: 1994-2002, 2002-2005, and 2005-2008, in the Sao Paulo State (Gg.year^{-1})



In the Figure II.46, we can observe that the emission of CO_2 decreases in the period from 1994 to 2002 for the following period, showing an increase in the period 2005 to 2008, which, however, is still lower than the emission of the first period. It is also noticed an increase in the removal of CO_2 in the State, from the first to the second period, and a decrease in the following period.

The following figures show the CO_2 emission from the period 1994 to 2002, 2002 to 2005 and 2005 to 2008, respectively. Figure II.47, in the first period, land-use change that most influenced the emission of CO_2 was the transition of non-managed forest to reservoir, followed by the transition of non-managed forest to urban area, non-managed forest to cropland, and non-managed forest area to planted pasture.

Figure II.48 shows that, in the second period, the land-use change that most delivered CO_2 were related to the transition of cropland converted to urban area, followed by the transition of non-managed forest to cropland, non-managed forest to reservoir, and managed forest to planted pasture.

Figure II.49, shows that, in the third period, the land-use change more relevant to the total emissions of CO_2 was associated with the transition of reforestation in urban area, followed by the transition of non-managed forest to cropland, cropland to urban area, and planted pasture to urban area.

Figure II.47. CO_2 Emissions between 1994 and 2002 in Sao Paulo State (16,293 Gg)

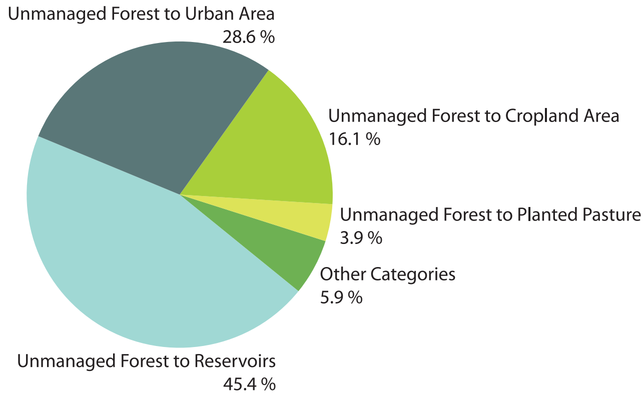


Figure II.48. CO_2 Emissions between 2002 and 2005 in Sao Paulo State (1,216 Gg)

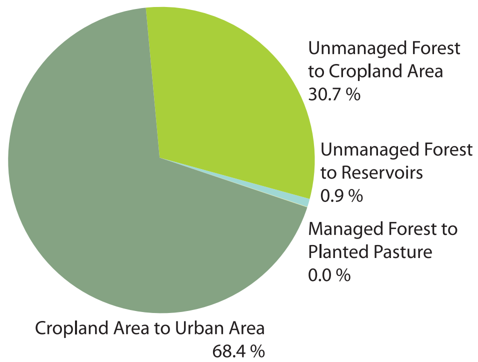
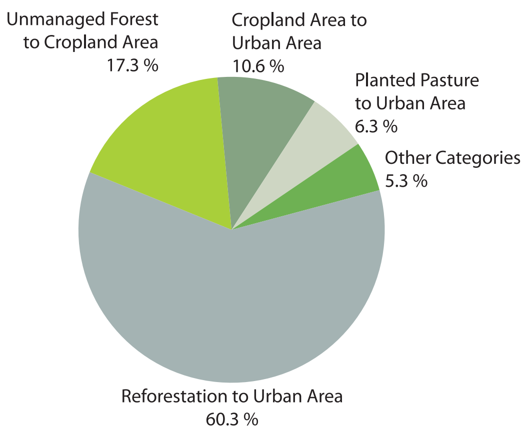


Figure II.49. CO_2 Emissions between 2005 and 2008 in Sao Paulo State (2,320 Gg)



Figures II.50, II.51, and II.52 shows the removals of CO_2 for the analyzed periods. The three graphs show the same pattern, being the land-use category that most contributes to the removal of CO_2 in the atmosphere was the permanence of managed forest, followed by the transition of planted pasture to reforestation, and non-managed forest to managed forest.

Figure II.50. CO_2 Removals between 1994 and 2002 in Sao Paulo State (26,957 Gg)

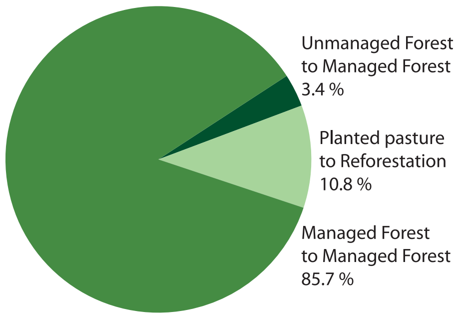


Figure II.51. CO_2 Removals between 2002 and 2005 in Sao Paulo State (12,969 Gg)

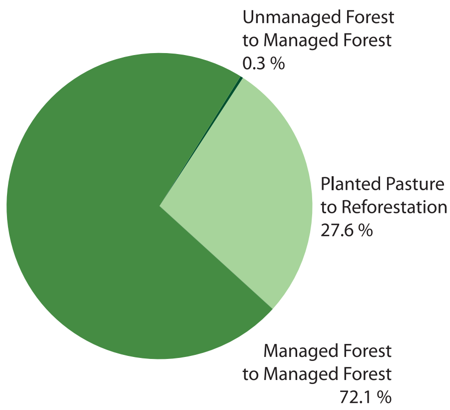
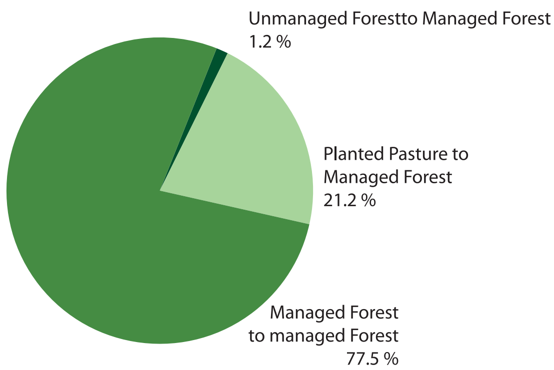


Figure II.52. CO_2 Removals between 2005 and 2008 in Sao Paulo State (12,166 Gg)



5.5 Waste

The GHG emissions inventory from the Waste Sector was performed by CETESB. According to the Brazilian Association of Technical Standards (ABNT) (2004 apud CETESB, 2011b), the solid or semi-solid wastes are results of activities of the sectors: industrial, domestic, hospital, commercial, agricultural, services of sweeping and the sludge from water treatment systems.

They are classified as hazardous and non-hazardous according to the same standard. However, for the creation of this inventory, was adopted the classification of waste suggested in the IPCC methods.

The ten major generators of organic load of the country in the Industrial sectors are: production of alcohol, sugar, beer, raw milk, cotton, paper and pasteurized milk, and the effluents from the processing of pigs, poultry and cattle. In the year 2005, the industrial production in the Sao Paulo State generated $5.4.10^9$ $t_{DBO}.year^{-1}$. In the same year, an urban population of $38.5.10^6$ people generated 9.7.106 t of waste, and $758,10^3$ $t_{DBO}.year^{-1}$.

The estimates considered the following variables:

– Urban population (for grounding of solid waste) and urban and rural population (for domestic effluents);

– Generation rate of urban solid waste and the composition associated to each municipality;

– Generation rate of organic matter in the effluent in the Sao Paulo State.

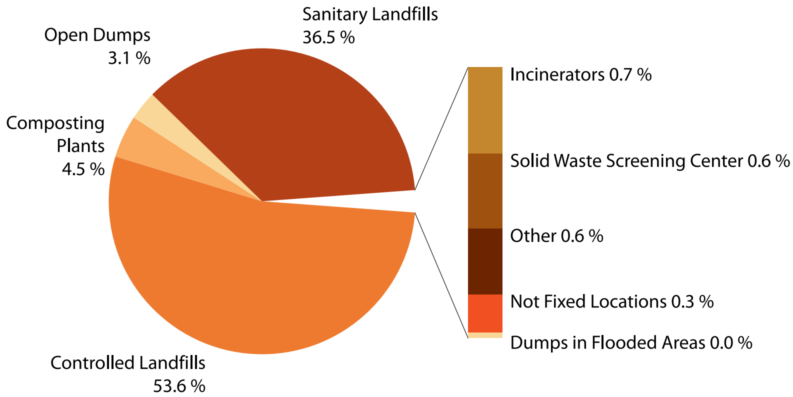
In Sao Paulo State, from 1,022 districts, 941 have cleaning services or urban garbage collection. These 941 use one or more destination units. Every day, according to the National Survey of Basic Sanitation (PNSB) in 2000, 105,582 $t.day^{-1}$ of trash was collected in the Sao Paulo State (IBGE, 2002 apud CETESB, 2011b). Figure II.53 shows the percentage distribution of the garbage collected per unit of final destination.

The domestic effluent are originated from the use of water in residences, clothes washing, bathing, discharges and also the commercial activities and industrial. The effluents are collected through links that form the collecting networks in residences and commercial and industrial establishments. These collectors are connected to the stem, which receive the sewers from several networks. The sewers go to the interceptors, which may have as final destination a Wastewater Treatment Plant (WWTP).

According to PNSB, from 1,022 districts in the Sao Paulo State, 948 had collection of sanitary sewage in year 2000. Of these, 177 used sewer to dispose of their wastewater, being the rivers the main water recipient. In addition, 387 of 948 districts that collected the sewage did not treat them, launching them *in natura* in water bodies. 345 Districts used to dump the sewage in rivers, and from those that were collecting the sewage, 561 had treatment systems. On the other hand, 74 municipalities had no collection, and as an alternative to septic tanks, sink and dry drain (IBGE, 2002 apud CETESB, 2011b).

It should be considered that, even with the improvement in the management and disposal of waste, there are still indicators that reveal the need for actions such as recycling, among others, to reduce the amount of disposed waste, which means a better use of natural resources and reduction of disposal costs (CETESB, 2011b).

Figure II.53. Percentage of the Daily Amount of Garbage Collected per Target Unit, in 2000, in the Sao Paulo State



The method used for estimating emissions from landfills is the first-order decay (IPCC 1996, 2000a). The emission factors were obtained in the literature, properly referenced, and in the IPCC (2006). The definition of the strategy for the preparation of each of the estimates of this inventory was made considering the tree of decision suggested by the IPCC (2000a). The reproduction of the trees, along with the strategy adopted by the team executing this inventory, and the data used are in the Reference Report of the Waste Sector (CETESB, 2011b).

The data gathered for the application of the IPCC method were obtained from the State literature. For cases in which these data did not exist, we used the default emission factor provided by the IPCC, which are divided by themes to which they relate (IPCC 1996, 2000a):

– CH_4 emission in landfills;
– CO_2 and N_2O emission by solid waste incineration;
– CH_4 emission by the treatment of domestic wastewater;
– CH_4 emission by the treatment of industrial effluents.

In Figure II.54 and Figure II.55 are presented to the percentage of contributions of activities of the Waste Sector in the years 2005 and 2008, the largest source of GHG in the Sector from the solid waste disposal in landfills.

Between 1990 and 2008, the annual emissions *per capita*[77] of CH_4, due to the disposal of solid wastes in disposal sites, anaerobic treatment of domestic wastewater and anaerobic treatment of industrial effluents rose from 9.77 to 11.14 kg_{CH4} $(inhabitant.year)^{-1}$. Similarly, the annual emissions *per capita* of GHG, in other words, of CH_4, N_2O and CO_2, multiplied by their respective GWP and summed, went from 205.16 to 234.38 kg_{CO2eq} $(inhabitant.year)^{-1}$.

In Table II.98, Table II.99 and Figure II.56 are shown the total GHG emissions in the Waste Sector in Gg and Gg_{CO2eq} and in the Table II.100, the emission of Waste Sector by type of destination.

[77] Emissions *per capita* considers the urban population and the total emission of greenhouse gases in the sector of wastes in the year (CETESB, 2011b).

Figure II.54. GHG Emissions from Waste Sector by Subsector in 2005, in Sao Paulo State (9,365Gg)

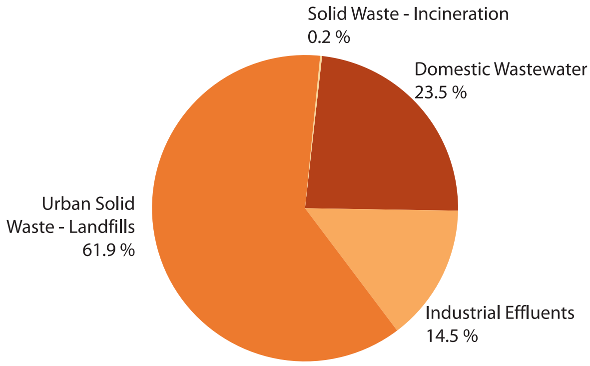


Figure II.55. GHG Emissions from Waste Sector by Subsector in 2008, in Sao Paulo State (9,219Gg)

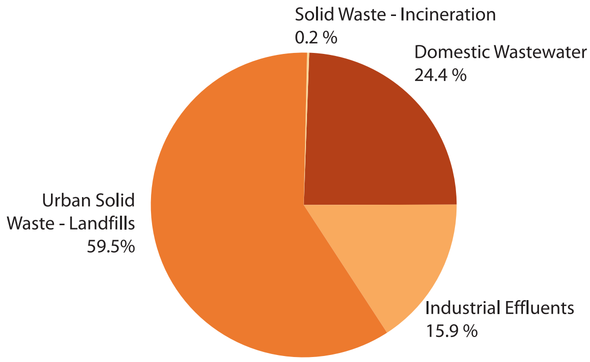


Figure II.56. Total GHG Emissions from Waste Sector in Sao Paulo State (Gg_{CO2eq})

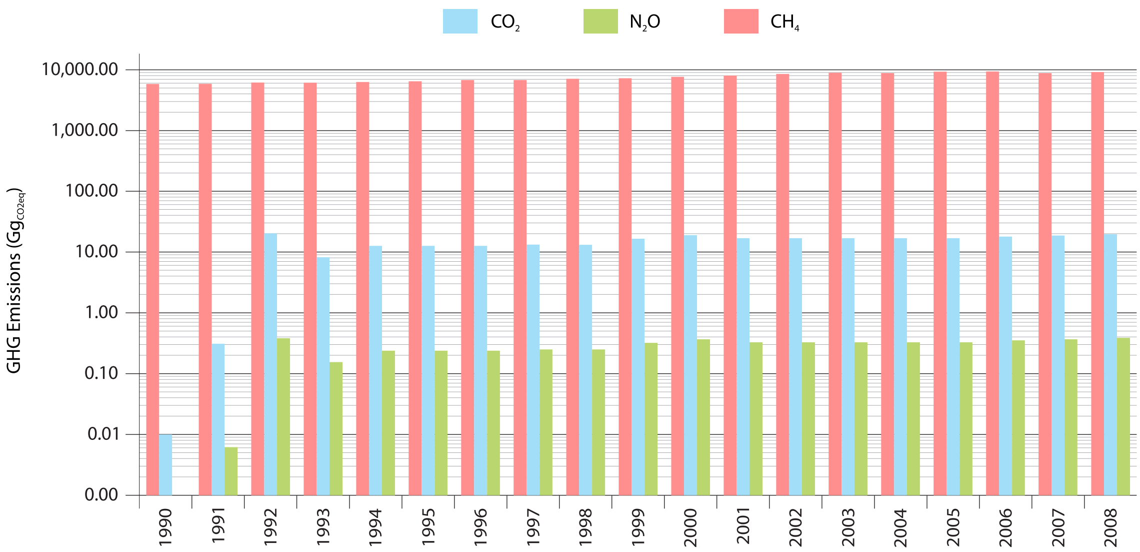


Table II.98. Total GHG Emissions from Waste Sector in Sao Paulo State (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg.year^{-1}]									
CO_2	0.01	0.31	20.36	8.21	12.70	12.70	12.70	13.31	13.22	16.58
CH_4	278	281	294	292	301	309	323	324	340	345
N_2O	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg.year^{-1}]									
CO_2	19.04	16.92	16.92	16.92	16.92	16.92	17.98	18.84	19.69	
CH_4	365	382	407	426	422	445	446	420	438	
N_2O	0.001	0.001	0,001	0.001	0.001	0.001	0.001	0.001	0.001	

Table II.99. Total GHG Emissions from Waste Sector in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.year^{-1}]									
CO_2	0.01	0.31	20.36	8.21	12.70	12.70	12.70	13.31	13.22	16.58
CH_4	5,838	5,905	6,175	6,128	6,315	6,492	6,790	6,799	7,136	7,255
N_2O	0	0.1	0.4	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Total	**5,838**	**5,906**	**6,196**	**6,137**	**6,328**	**6,504**	**6,803**	**6,813**	**7,149**	**7,272**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.year^{-1}]									
CO^2	19.04	16.92	16.92	16.92	16.92	16.92	17.98	18.84	19.69	
CH_4	7,658	8,023	8,552	8,950	8,868	9,349	9,375	8,818	9,199	
N_2O	0.4	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	
Total	**7,678**	**8,040**	**8,569**	**8,967**	**8,885**	**9,366**	**9,394**	**8,837**	**9,219**	

Table II.100. Emissions from Waste Sector by Type of Destination in Sao Paulo State (Gg_{CO2eq})

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2eq}.year^{-1}]									
Urban solid waste - landfills	2,618	2,783	2,936	3,079	3,213	3,339	3,460	3,576	3,843	4,078
Solid waste - incineration	1	1	21	8	13	13	13	14	13	17
Domestic wastewater	1,626	1,675	1,724	1,773	1,822	1,871	1,920	1,969	2,018	2,067
Industrial effluents	1,594	1,447	1,515	1,276	1,280	1,281	1,409	1,254	1,275	1,110
Total	**5,838**	**5,906**	**6,196**	**6,137**	**6,328**	**6,504**	**6,803**	**6,813**	**7,149**	**7,272**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2eq}.year^{-1}]									
Urban solid waste - landfills	4,317	4,590	5,193	5,603	5,384	5,794	5,773	5,158	5,487	
Solid waste - incineration	19	17	17	17	17	17	18	19	20	
Domestic wastewater	2,116	2,133	2,149	2,166	2,182	2,198	2,215	2,231	2,248	
Industrial effluents	1,225	1,301	1,210	1,181	1,302	1,356	1,387	1,428	1,464	
Total	**7,678**	**8,040**	**8,569**	**8,967**	**8,885**	**9,366**	**9,394**	**8,837**	**9,219**	

6

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7

Annexes

7.1 Annexes

7.1 CO_2 Emissions in 2005 in Sao Paulo State

CO_2 Emissions According to the Involved Sectors in Sao Paulo State, in the Period 1990-2008 – Highlights for the Year 2005 (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	[Gg_{CO2}.$year^{-1}$]									
Energy	56,395	58,043	58,629	59,725	64,795	67,095	74,634	79,800	80,748	81,278
Industrial Processes	3,396	3,540	3,046	3,011	3,268	3,724	4,300	4,738	4,744	4,495
Agriculture	931	968	1,509	1,589	2,009	1,479	1,512	1,639	1,583	1,410
Waste	0.01	0.31	20.36	8.21	12.70	12.70	12.70	13.31	13.22	16.58
LULUCF	NE	NE	NE	NE	NE	0	0	0	0	0
Total	**60,722**	**62,552**	**63,205**	**64,333**	**70,085**	**72,311**	**80,460**	**86,189**	**87,088**	**87,200**

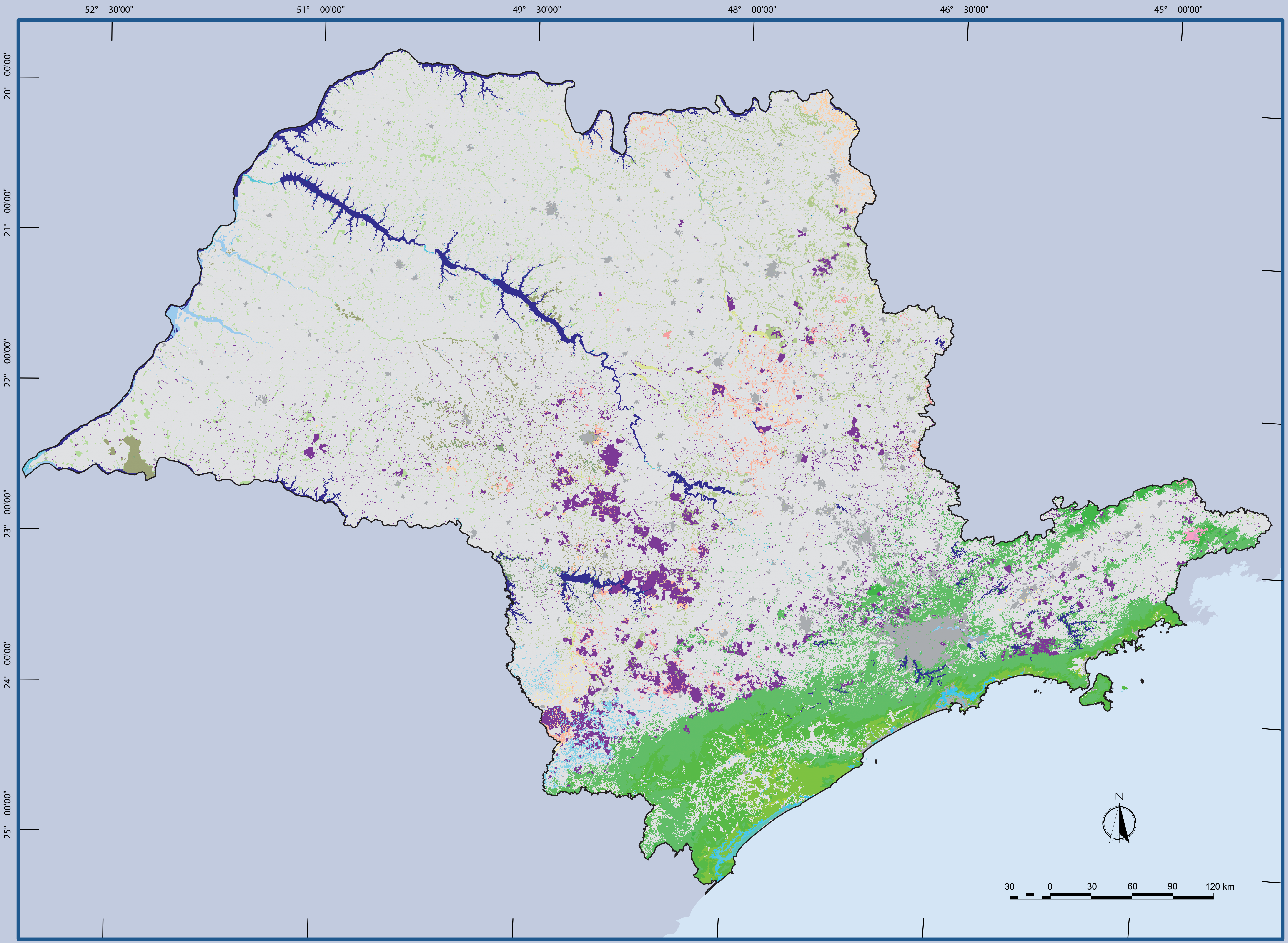
	2000	2001	2002	2003	2004	2005	2006	2007	2008	
	[Gg_{CO2}.$year^{-1}$]									
Energy	80,161	78,298	75,852	76,636	77,996	78,584	79,375	83,221	85,335	
Industrial Processes	4,577	3,978	3,864	3,394	3,418	12,685	12,281	12,968	12,218	
Agriculture	1,462	1,380	1,408	1,691	1,327	1,476	1,805	1,865	1,462	
Waste	19.04	16.92	16.92	16.92	16.92	16.92	17.98	18.84	19.69	
LULUCF	0	0	0	0	0	0	0	0	0	
Total	**86,219**	**83,672**	**81,140**	**81,738**	**82,758**	**92,762**	**93,478**	**98,074**	**99,034**	

Note - NE: Not estimated; LULUCF: Land Use, Land-use Change, and Forestry.
Reproduction of Table II.2 of this publication, p. 54.

CO_2 emissions in 2005 in Sao Paulo State is 92,762,000 t.

7.2 Land Use and Land Cover Maps in Sao Paulo State

Maps of land use were generated by the Foundation of Science, Applications and Space Technology (FUNCATE), from the interpretation of the images of the American *Landsat Satellite 5*, for the years 1994, 2002, 2005 and 2008. The 1994 and 2002 consist of a crop of Sao Paulo State from maps generated for the Second National Communication (BRASIL, 2010).



LAND USE AND LAND COVER MAP IN 1994, IN SAO PAULO STATE

FUNCATE
Fundação de Ciência, Aplicações e Tecnologia Espaciais

MAP LEGEND

PHYTOECOLOGICAL REGIONS

Dense Humid Forest - D
- Da Alluvial Dense Humid Forest
- Db Lowland Dense Humid Forest
- Ds Submontane Dense Humid Forest
- Dm Montane Dense Humid Forest
- Dl High Montane Dense Humid Forest

Dense Humid Forest - M
- Mm Montane Mixed Humid Forest
- Ml High Montane Mixed Humid Forest

Semi Deciduous Seasonal Forest - F
- Fa Alluvial Semi Deciduous Seasonal Forest
- Fs Submontane Semi Deciduous Seasonal Forest
- Fm Montane Semi Deciduous Seasonal Forest

Deciduous Seasonal Forest - C
- Cs Submontane Deciduous Seasonal Forest
- Cm Montane Deciduous Seasonal Forest

Savanna - S
- Sd Forested Savanna
- Sa Wooded Savanna
- Sp Park Savanna
- Sg Woody-grass Savanna

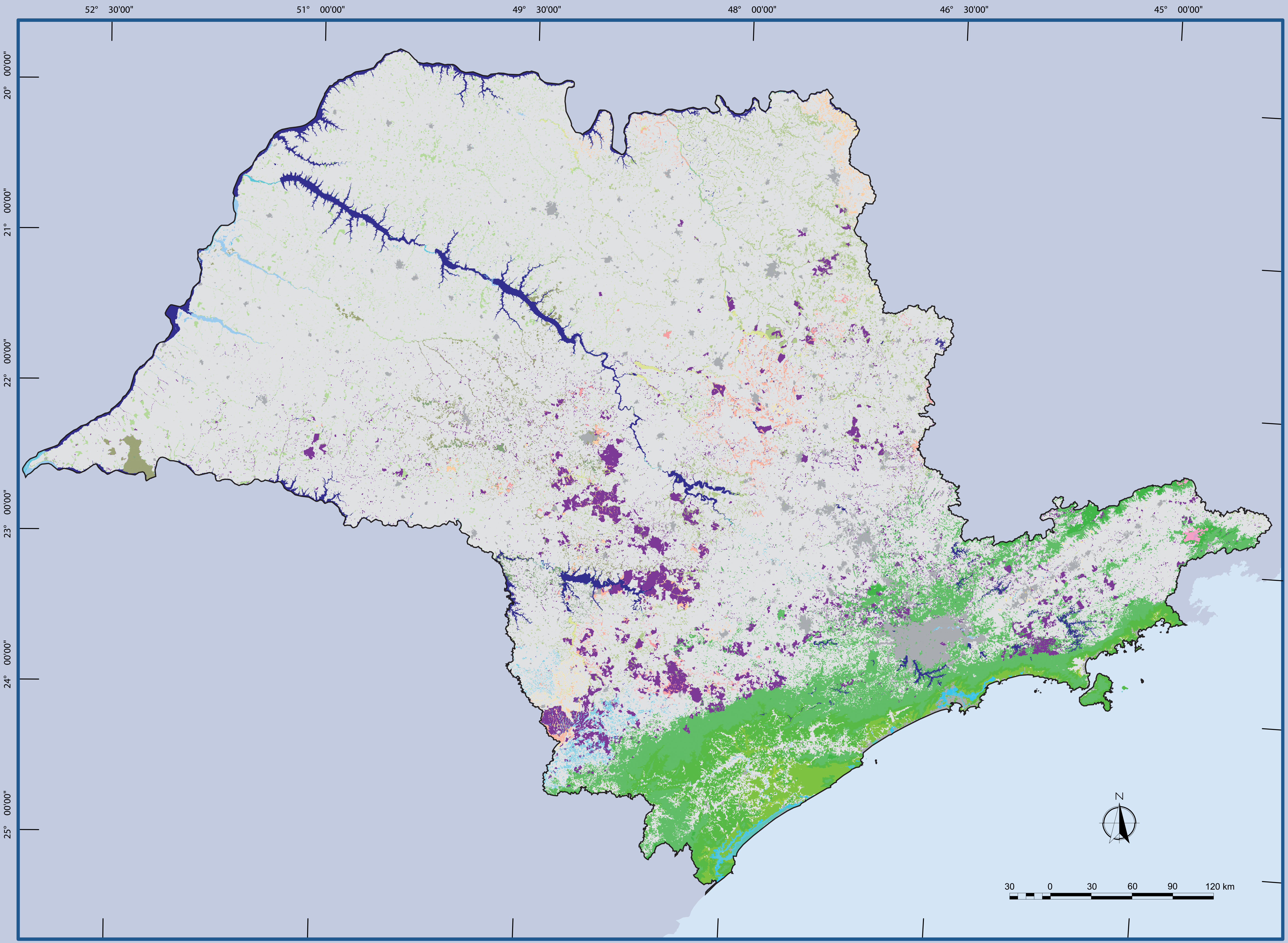
Pioneer Formations Area - P
- Pm Pioneer Formations Marine Influenced (Restinga)
- Pf Pioneer Formations Fluviomarine Influenced (Mangrooves)
- Pa Fluvial and/or Lacustre Influenced Vegetation

Vegetation Refuge - r
- rm Montane Refuge
- rl High Montane Vegetation Refuge

Hydrography
- Rivers and Lakes
- Reservoirs

Anthropogenic Areas
- Agriculture - Ac; Pasture Land (Livestock) - Ap
- Afforestation/Reforestation - R
- Urban Area; Mining Field

Non Observed Areas
- NO Cloud Covered Area - NO



LAND USE AND LAND COVER MAP IN 2002, IN SAO PAULO STATE

FUNCATE
Fundação de Ciência, Aplicações e Tecnologia Espaciais

MAP LEGEND

PHYTOECOLOGICAL REGIONS

Dense Humid Forest - D
- Da Alluvial Dense Humid Forest
- Db Lowland Dense Humid Forest
- Ds Submontane Dense Humid Forest
- Dm Montane Dense Humid Forest
- Dl High Montane Dense Humid Forest

Dense Humid Forest - M
- Mm Montane Mixed Humid Forest
- Ml High Montane Mixed Humid Forest

Semi Deciduous Seasonal Forest - F
- Fa Alluvial Semi Deciduous Seasonal Forest
- Fs Submontane Semi Deciduous Seasonal Forest
- Fm Montane Semi Deciduous Seasonal Forest

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- Cs Submontane Deciduous Seasonal Forest
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- Pa Fluvial and/or Lacustre Influenced Vegetation

Vegetation Refuge - r
- rm Montane Refuge
- rl High Montane Vegetation Refuge

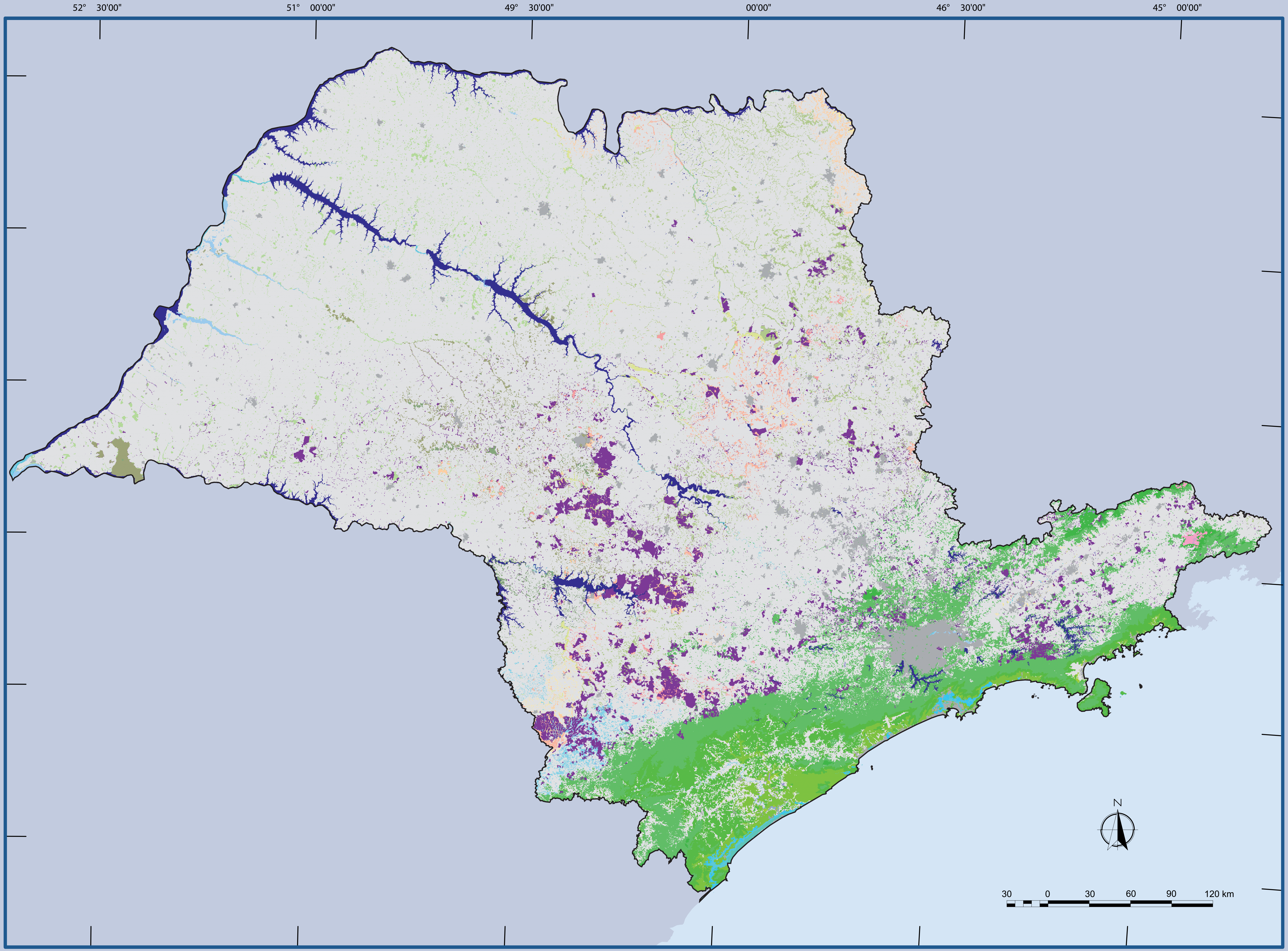
Hydrography
- Rivers and Lakes
- Reservoirs

Anthropogenic Areas
- Agriculture - Ac; Pasture Land (Livestock) - Ap
- Afforestation/Reforestation - R
- Urban Area; Mining Field

Non Observed Areas
- NO Cloud Covered Area - NO

LAND USE AND LAND COVER MAP IN 2005, IN SAO PAULO STATE

FUNCATE
Fundação de Ciência, Aplicações e Tecnologia Espaciais



MAP LEGEND

PHYTOECOLOGICAL REGIONS

Dense Humid Forest - D

Da	Alluvial Dense Humid Forest
Db	Lowland Dense Humid Forest
Ds	Submontane Dense Humid Forest
Dm	Montane Dense Humid Forest
Dl	High Montane Dense Humid Forest

Dense Humid Forest - M

Mm	Montane Mixed Humid Forest
Ml	High Montane Mixed Humid Forest

Semi Deciduous Seasonal Forest - F

Fa	Alluvial Semi Deciduous Seasonal Forest
Fs	Submontane Semi Deciduous Seasonal Forest
Fm	Montane Semi Deciduous Seasonal Forest

Deciduous Seasonal Forest - C

Cs	Submontane Deciduous Seasonal Forest
Cm	Montane Deciduous Seasonal Forest

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Sd	Forested Savanna
Sa	Wooded Savanna
Sp	Park Savanna
Sg	Woody-grass Savanna

Pioneer Formations Area - P

Pm	Pioneer Formations Marine Influenced (Restinga)
Pf	Pioneer Formations Fluviomarine Influenced (Mangrooves)
Pa	Fluvial and/or Lacustre Influenced Vegetation

Vegetation Refuge - r

rm	Montane Refuge
rl	High Montane Vegetation Refuge

Hydrography

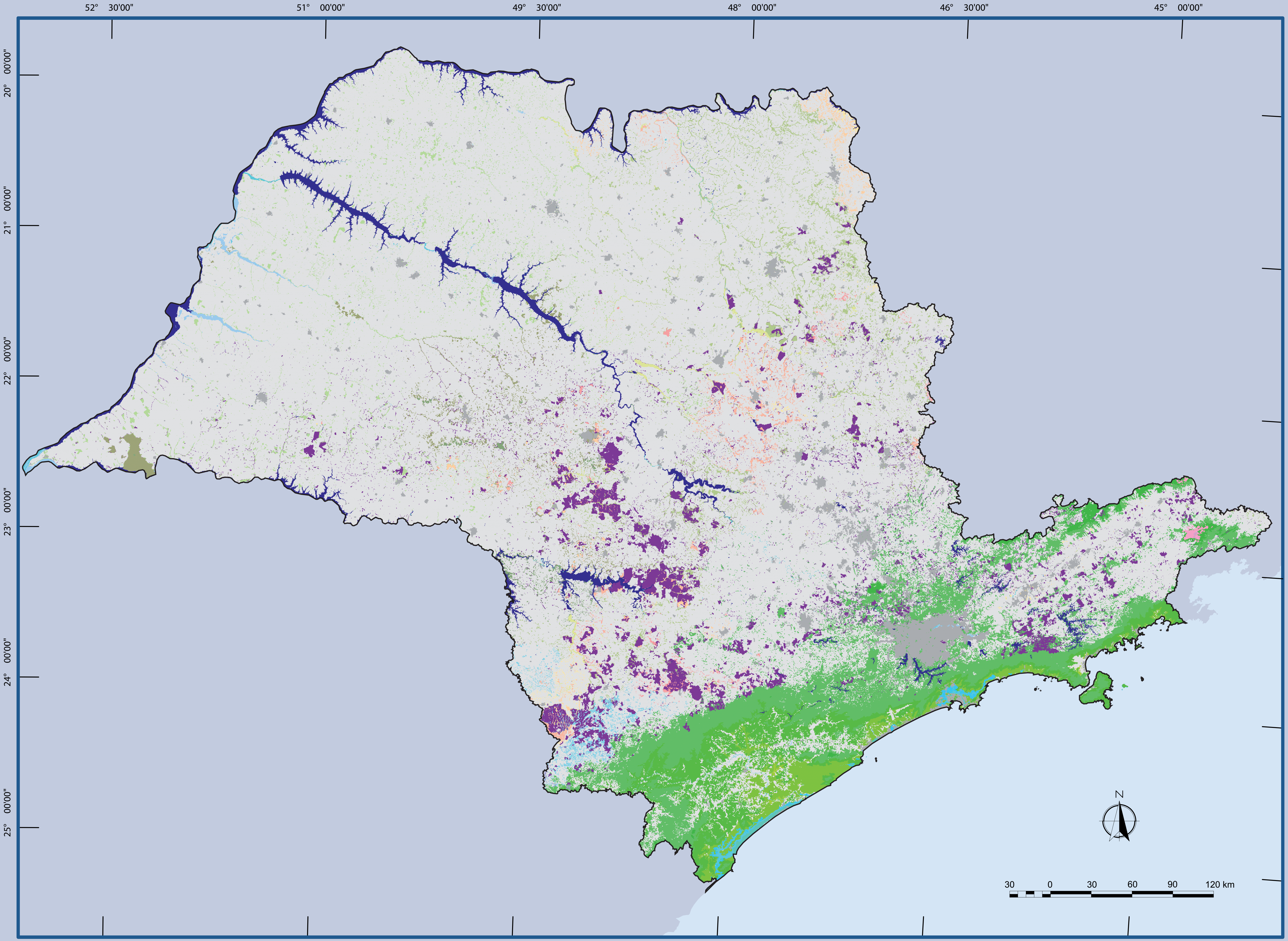
- Rivers and Lakes
- Reservoirs

Anthropogenic Areas

- Agriculture - Ac; Pasture Land (Livestock) - Ap
- Afforestation/Reforestation - R
- Urban Area; Mining Field

Non Observed Areas

NO	Cloud Covered Area - NO



LAND USE AND LAND COVER MAP IN 2008, IN SAO PAULO STATE

FUNCATE
Fundação de Ciência, Aplicações e Tecnologia Espaciais

MAP LEGEND

PHYTOECOLOGICAL REGIONS

Dense Humid Forest - D
- Da Alluvial Dense Humid Forest
- Db Lowland Dense Humid Forest
- Ds Submontane Dense Humid Forest
- Dm Montane Dense Humid Forest
- Dl High Montane Dense Humid Forest

Dense Humid Forest - M
- Mm Montane Mixed Humid Forest
- Ml High Montane Mixed Humid Forest

Semi Deciduous Seasonal Forest - F
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- Reservoirs

Anthropogenic Areas
- Agriculture - Ac; Pasture Land (Livestock) - Ap
- Afforestation/Reforestation - R
- Urban Area; Mining Field

Non Observed Areas
- NO Cloud Covered Area - NO

7.3 Photo Mosaic











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SECRETARIA DO MEIO AMBIENTE
GOVERNO DO ESTADO

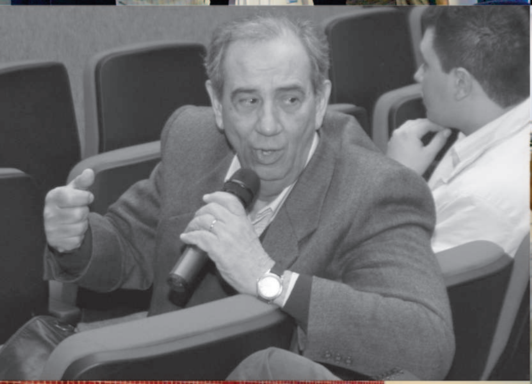



SECRETARIA DO MEIO AMBIENTE
SEMANA DO MEIO AMBIENTE
JUNTOS CULTIVAMOS O FUTURO
SECRETARIA DO MEIO AMBIENTE
GOVERNO DE SÃO PAULO







SECRETARIA DO
MEIO AMBIENTE
GOVERNO DO ESTADO
SÃO PAULO
CADA VEZ MELHOR






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