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California Environmental Protection Agency

Air Resources Board

California Greenhouse Gas Emissions Inventory: 2000-2009

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December 2011

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SUMMARY

This report presents an overview of the California greenhouse gas emissions inventory and trends from 2000 through 2009. As California strives to achieve its benchmark goals under AB 32, the California inventory will become an increasingly valuable tool to keep track of greenhouse gas emissions from each sector. Maintaining and updating greenhouse gas inventory methodologies and data are imperative for a successful greenhouse gas reduction program.

In 2009, total California greenhouse gas emissions were 457 million tonnes of carbon dioxide equivalent ($MMTCO_2e$); net emissions were 453 $MMTCO_2e$, reflecting the influence of sinks (net CO_2 flux from forestry). While total emissions have increased by 5.5 percent from 1990 to 2009, emissions decreased by 5.8 percent from 2008 to 2009 (485 to 457 $MMTCO_2e$). The total net emissions between 2000 and 2009 decreased from 459 to 453 $MMTCO_2e$, representing a 1.3 percent decrease from 2000 and a 6.1 percent increase from the 1990 emissions level. The transportation sector accounted for approximately 38 percent of the total emissions, while the industrial sector accounted for approximately 20 percent. Emissions from electricity generation were about 23 percent with almost equal contributions from in-state and imported electricity.

Per capita emissions in California have slightly decreased from 2000 to 2009 (by 9.7 percent), but the overall 9 percent increase in population during the same period offsets the emission reductions. From a per capita sector perspective, industrial per capita emissions have declined 21 percent from 2000 to 2009, while per capita emissions for ozone depleting substances (ODS) substitutes saw the highest increase (52 percent).

From a broader geographical perspective, the state of California ranked second in the United States for 2007 greenhouse gas emissions, only behind Texas. However, from a per capita standpoint, California had the 46th lowest emissions. On a global scale, California had the 14th largest carbon dioxide emissions and the 19th largest per capita emissions.

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I. Background

As the world develops in the 21st Century, the need to balance increasing natural resource demand with environmental protection goals is becoming the focus of national, state, and local government entities. While there are many environmental protection goals, the attention paid to climate change due to greenhouse gases, has outpaced other initiatives in the past few years. On a global level, governments and organizations at all levels have begun to adopt regulations to reduce greenhouse gases (AB 32, 2006; United Nations, 1998). Central to all of these regulations is the generation of an emissions baseline year and an updated emission inventory to track greenhouse gas emissions and monitor reductions.

The California Legislature and Governor took significant steps to address the concerns raised about climate change with Assembly Bill (AB) 32, the Global Warming Solutions Act of 2006 (AB 32, 2006), with the California Air Resources Board (ARB) as the lead implementation agency. In addition, Executive Order S-3-05 requires California to reduce greenhouse gas emissions to 1990 levels by 2020 and 80 percent below 1990 levels by 2050 (EO, 2005).

Prior to January 1, 2007 the California Energy Commission (CEC) was responsible for maintaining and updating the greenhouse gas emissions inventory. Assembly Bill 1803, which became law in 2006, transferred the responsibility to prepare, adopt, and update California's greenhouse gas inventory from CEC to ARB (AB 1803, 2006). After an extensive review of the existing inventory data, ARB determined the 1990 statewide emission level and updated the CEC inventory through 2004. The 1990 statewide emissions level, as reflected by the inventory, is California's emissions goal for 2020 (CARB, 2007).

The California greenhouse gas inventory serves as a foundation for the State's emission reduction goals. A current and updated inventory is imperative for a successful greenhouse gas reduction program. Proper documentation therefore becomes critical to reflect the updated methodologies and estimates in the inventory. ARB publishes California's greenhouse gas inventory on its Greenhouse Gas Emission Inventory website (http://www.arb.ca.gov/cc/inventory/inventory.htm). Two sets of inventory data covering statewide greenhouse gas emissions and sinks from 1990 through 2004, and 2000 through 2008 were published in 2007 and 2010, respectively. In addition, ARB has also published a staff report titled "*California 1990 Greenhouse Gas Emissions Level and 2020 Emissions Limit*" that discusses the development of the 1990 statewide emissions level and provides a summary of the methodologies and main sources of data used to calculate the greenhouse gas emissions (CARB, 2007). A technical support document detailing the data sources and methods used to develop the 1990 to 2004 inventory was also published in 2009 (CARB, 2009). These past reports and other inventory related documents are available for download from ARB's California Greenhouse Gas Emission Inventory website.

The current inventory compiling statewide anthropogenic greenhouse gas emissions and sinks from 2000 through 2009 is also published on the inventory website. This document presents a summary of the current inventory data, discussing the statewide

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greenhouse gas emission trends and relative contributions of emission sources to the total emissions. It is important to note that the presented inventory data are revised estimates of emissions and sinks for the time series, to reflect the latest updates to the estimation methodologies and data. This is consistent with the Intergovernmental Panel on Climate Change (IPCC) *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC 2000), which states that "It is good practice to recalculate historic emissions when methods are changed or refined, when new source categories are included in the national inventory, or when errors in the estimates are identified and corrected." A comprehensive technical support document detailing the data sources and methods used to develop the 2000 to 2009 inventory is also available on the website.

II. Overview of the Greenhouse Gas Emission Inventory

An emissions inventory is an estimate of the amount and type of pollutant emitted by different sources in a location over a period of time. Inventories provide estimates of past emissions, current emissions, and even future emissions that are based on economic activity, population, and other factors that influence emission-generating activities. Most greenhouse gas inventories are structured in a time-series, which is a sequence of annual inventory estimates.

Greenhouse Gases

The Earth's atmosphere consists of nitrogen (N_2, 78 percent), oxygen (O_2, 21 percent), argon (Ar, ~1 percent), water vapor (H_2O, varies), and carbon dioxide (CO_2, 0.04 percent) (Girard, 2005). The atmospheric composition of these gases is important for human survival because they are vital for global temperature control, human respiration, and precipitation. For example, if there was an absence of atmospheric particles, the Earth would have an average global temperature of -2.2 ºF (-19 ºC) (Girard, 2005). The atmospheric gases that cause the Earth to have warmer temperatures than -2.2 ºF are known as greenhouse gases. They include the natural atmospheric gases of H_2O, CO_2, methane (CH_4), and nitrous oxide (N_2O). Greenhouse gases function by absorbing infrared radiation that has been reflected from the Earth's surface and reradiate the infrared energy back towards the surface of the Earth (Spiro and Stigliani, 2002). The remaining infrared radiation that is not absorbed by these gases (due to incompatible absorption energies) escapes into space. This natural warming process that occurs in the Earth's atmosphere is known as the greenhouse effect.

Prior to 1750 (pre-Industrial Revolution), natural atmospheric concentrations of CO_2, CH_4 and N_2O had remained fairly constant for the past 10,000 years, leading to a relatively constant temperature. Since 1750 (post-Industrial Revolution), the amount of greenhouse gases in the atmosphere has increased mainly due to anthropogenic sources (e.g., combustion of fossil fuel). In addition, synthetic greenhouse gases such as chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perflurocarbons (PFCs) and sulfur hexafluoride (SF_6) have been introduced into the atmosphere. The increase of greenhouse gases in the atmosphere has led to a phenomenon known as the enhanced greenhouse effect. The larger amount of greenhouse gases and the

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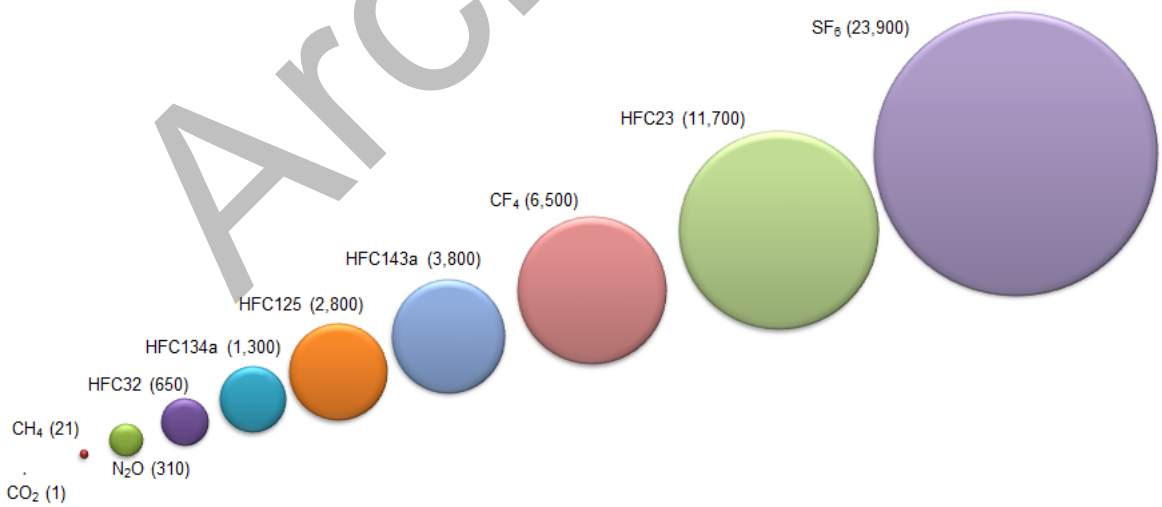
introduction of synthetic greenhouse gases to the atmosphere have led to more infrared radiation getting reradiated to Earth's surface and less radiation escaping to space, which leads to an overall warming of the Earth. In the past years, numerous scientific studies have shown that the enhanced greenhouse effect causes climatic shifts that will have an adverse effect on human survival (Meehl et al., 2005; Patz et al., 2005; Dettinger and Cayan, 1995).

An emissions inventory that identifies and quantifies the sources and sinks of these greenhouse gases is essential for addressing climate change.

Global Warming Potentials

From an inventory perspective it is important to know the amounts of each greenhouse gas emitted into the atmosphere, and to understand the Global Warming Potential (GWP) of each gas. The global warming potential provides a comparison of the warming influence of different greenhouse gases relative to CO_2 and allows for the calculation of a single consistent greenhouse gas emission unit: the "CO_2 equivalent" or CO_2e (IPCC, 2007). A GWP is calculated over a specific time interval, commonly 20, 100 or 500 years. 100year GWPs from IPCC's Second Assessment Report for greenhouse gases defined in AB 32 are shown in Figure 1. For example, the GWP of SF_6 is 23,900, which means that 1 ounce of SF_6 has the same warming effect as 1,494 pounds of CO_2. This is because SF_6 absorbs infrared radiation with a different wavelength and has a much longer lifetime in the atmosphere than CO_2. Thus, small amounts of high GWP gases have a large effect on global warming.

Figure 1: Global Warming Potential of Greenhouse Gases



Source: IPCC Second Assessment Report

Natural and Anthropogenic Emissions

Additionally, for an inventory it is also important to discern between natural and anthropogenic emissions. Anthropogenic emissions are emissions that directly result from human activities or from human influence on natural and other processes subject to human control (U.S.EPA, 2011). Because increases in anthropogenic emissions from

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pre-industrial times have substantially increased atmospheric greenhouse gas concentrations, anthropogenic emissions are the primary focus of the California greenhouse gas inventory. Natural CO_2 emissions are emitted as part of the biogeochemical cycling of carbon and tend to average out over time even though emissions may be significant (IPCC, 2006). These emissions include, for example, CO_2 released from decomposition of plants and wood products and are accounted for in the inventory's net CO_2 flux (CARB, 2012).

III. California Greenhouse Gas Inventory

The California greenhouse gas emissions inventory serves as the foundation for the State's greenhouse gas emission reduction program. The inventory is a living repository of detailed and current methodologies for estimating sources and sinks of greenhouse gas emissions. The inventory is also a time series of emissions, thus providing a platform to compare the relative contribution of different emission sources and gases to climate change over time.

There are two main types of inventory approaches used to determine the amount of greenhouse gas emissions from a region: the top-down and the bottom-up approach. The top-down approach utilizes region-wide activity data to estimate emissions. The bottom-up approach uses facility-specific data to estimate emissions from each source, and then sums up all the emissions for a particular geographic region. For the California statewide inventory, ARB generally uses the top-down approach. The Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (MRR) enables ARB to reconcile some of its top-down emissions inventory with bottom-up emissions data. Verified data from the MRR program for specific sectors such as in-state power generation, specified electricity imports, refineries and cement manufacturing were used in the 2009 emissions inventory.

California Inventory and Other Greenhouse Gas Inventories

The California inventory is consistent with international and national guidelines to the greatest extent possible. Consistency maximizes the comparability of the inventory with similar inventories from other states and nations. This is important as California considers participation in standardized regional, national and international greenhouse gas emission reduction programs.

At an international level, the IPCC has developed standard international guidance for emission inventories (IPCC, 2006). Nations that have adopted the United Nations Framework Convention on Climate Change (UNFCCC) must prepare and report their emissions and sinks of CO_2, CH_4, N_2O, SF_6, PFCs, and HFCs using IPCC methodologies to ensure comparability among national inventories. The IPCC guidelines delineate the sectors and processes for which nations must report their greenhouse gas emissions and sinks, and how they should report these emissions. They also describe various methodologies to estimate emissions depending on the available data sources (IPCC, 2006). The guidelines allow for use of state-specific data and methodologies rather than the more generic international ones when available. In the California inventory, state-specific emissions data were used whenever possible.

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As a nation, the United States follows the IPCC guidelines (with the United States Environmental Protection Agency (U.S.EPA) acting as the lead agency) and submits its national greenhouse gas inventory to UNFCCC Secretariat annually. The U.S.EPA supplements the widely applicable IPCC methodologies with more US-specific methodologies and data (U.S.EPA, 2011).

Inventory Organization

The California inventory presents its emissions estimates in two ways. One version uses the IPCC categorization, which is based on groupings of related emission processes and sinks (IPCC, 2006), to ensure comparability with international and national inventories. This version includes five main sectors based on the IPCC categorization: energy; industrial processes and product use; agriculture, forestry and other land use; waste; and other.

The inventory is also loosely categorized into traditional economic sectors based on economic activity within California as defined by North American Industry Classification System (NAICS) (NAICS, 2007). These sectors include: agriculture and forestry, commercial, in-state electricity generation, imported electricity, industrial, residential, and transportation. Each sector contains different types of emission sources called categories. For example, the industrial sector includes petroleum refining, cement manufacture and landfills categories, to name a few. This categorization of the inventory based on economic sectors includes emissions from international and domestic ships within California waters under the transportation sector. The aviation category, located within the transportation sector, only includes emissions for intrastate flights. Interstate and international flight emissions are calculated and included as an informational item, but their greenhouse gas emissions are not counted in California's overall inventory. Unless otherwise indicated, emissions and sink estimates in this report are presented by these economic sectors and categories. A small portion of the total emissions could not be attributed to any of the economic sectors and are therefore grouped as unspecified emissions.

The economic sector categorization allows for comparison with other ARB emissions inventories, which are similarly categorized. This categorization scheme also provides a familiar reference for readers accustomed to reviewing emission estimates generated by national, state, and local air agencies.

While the California inventory is divided into these economic sectors, the Climate Change Scoping Plan is divided into categories that focus on areas for emission reductions. All emissions estimates in the Scoping Plan and the 2000 to 2009 inventory use the same emissions dataset; the totals are therefore the same. The difference is only in the way emission sources are grouped.

Changes in the 2000-2009 Inventory

Updates to the methodologies used in the California inventory are an ongoing process. ARB staff regularly evaluates scientific developments in greenhouse gas inventories. In general, the majority of the methodologies and calculations used to generate the emission values have remained constant. However, there have been some minor

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changes to the methods used to determine greenhouse gas emissions, the classification system within each sector or improvements to the emission factors used in the existing methods. For detailed discussions on the updated methodologies and changes to the emission estimates, refer to the Technical Support Document for the 2000 to 2009 inventory (CARB, 2012).

IV. Statewide Emission Estimates and Emission Trends

This report summarizes the latest information on greenhouse gas emission trends in California and reflects revisions to methodologies and data for the 2000 to 2009 time series. Detailed discussions on emission calculations and methodologies are not in the scope of this report and are comprehensively discussed in the technical support documents.

General Emissions Trends

The total statewide greenhouse gas emissions decreased from 464 million tonnes of carbon dioxide equivalent ($MMTCO_2e$) in 2000 to 457 $MMTCO_2e$ in 2009, a decrease of 1.5 percent. Carbon sinks in 2009 removed an estimated 4 $MMTCO_2e$, resulting in net statewide emissions of approximately 453 $MMTCO_2e$. The emissions in 2009 are the lowest in the ten year period, with the highest gross emissions of 489 $MMTCO_2e$ occurring in 2007. Table 1 shows the total statewide greenhouse gas emissions by gas type and Figure 2 depicts the general trend in the emissions from 2000 to 2009. Figure 3 illustrates the annual percent change in emissions and Figure 4 shows the absolute change in emissions from 2000 through 2009.

Table 1: California Greenhouse Gas Emissions by Gas

Greenhouse Gas	Greenhouse Gas Gross Emissions ($MMTCO_2e$)*										% Change	
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2000-2009	2008-2009
CO_2	408.9	424.1	421.0	419.6	429.7	423.0	420.9	426.9	421.1	393.2	-3.8%	-6.6%
CH_4	28.0	28.4	29.1	27.3	28.5	29.6	30.7	31.7	32.1	32.0	14.1%	0.5%
N_2O	16.0	15.4	17.2	16.6	16.6	16.0	15.8	15.4	15.7	15.2	-4.7%	-3.1%
SF_6	1.3	1.3	1.2	1.2	1.2	1.2	1.1	1.0	1.1	1.1	-17.8%	0.04%
Other halogenated gases	9.5	10.0	10.7	11.4	12.2	12.7	13.4	13.8	14.7	15.3	61.2%	3.8%
Gross Total	**463.7**	**479.2**	**479.2**	**476.1**	**488.2**	**482.5**	**481.9**	**488.8**	**484.7**	**456.8**	**-1.5%**	**-5.8%**

* All greenhouse gases are weighted relative to CO_2 based on the IPCC's 2nd Assessment Report.

While emissions of methane and halogenated gases increased from 2000 to 2009, CO_2, N_2O, and SF_6 decreased during the same period. Overall, CO_2 emissions decreased 3.8 percent from 2000 to 2009, and by 6.6 percent from 2008 to 2009. N_2O and SF_6 emissions also decreased by 4.7 and 17.8 percent, respectively, while CH_4 and halogenated gas emissions increased by 14.1 and 61 percent, respectively, during the same period. Though the magnitude of emissions increase from 2000 to 2009 of SF_6 and halogenated gases are comparatively smaller, their emissions are significant because of their high GWPs and longer atmospheric lifetimes.

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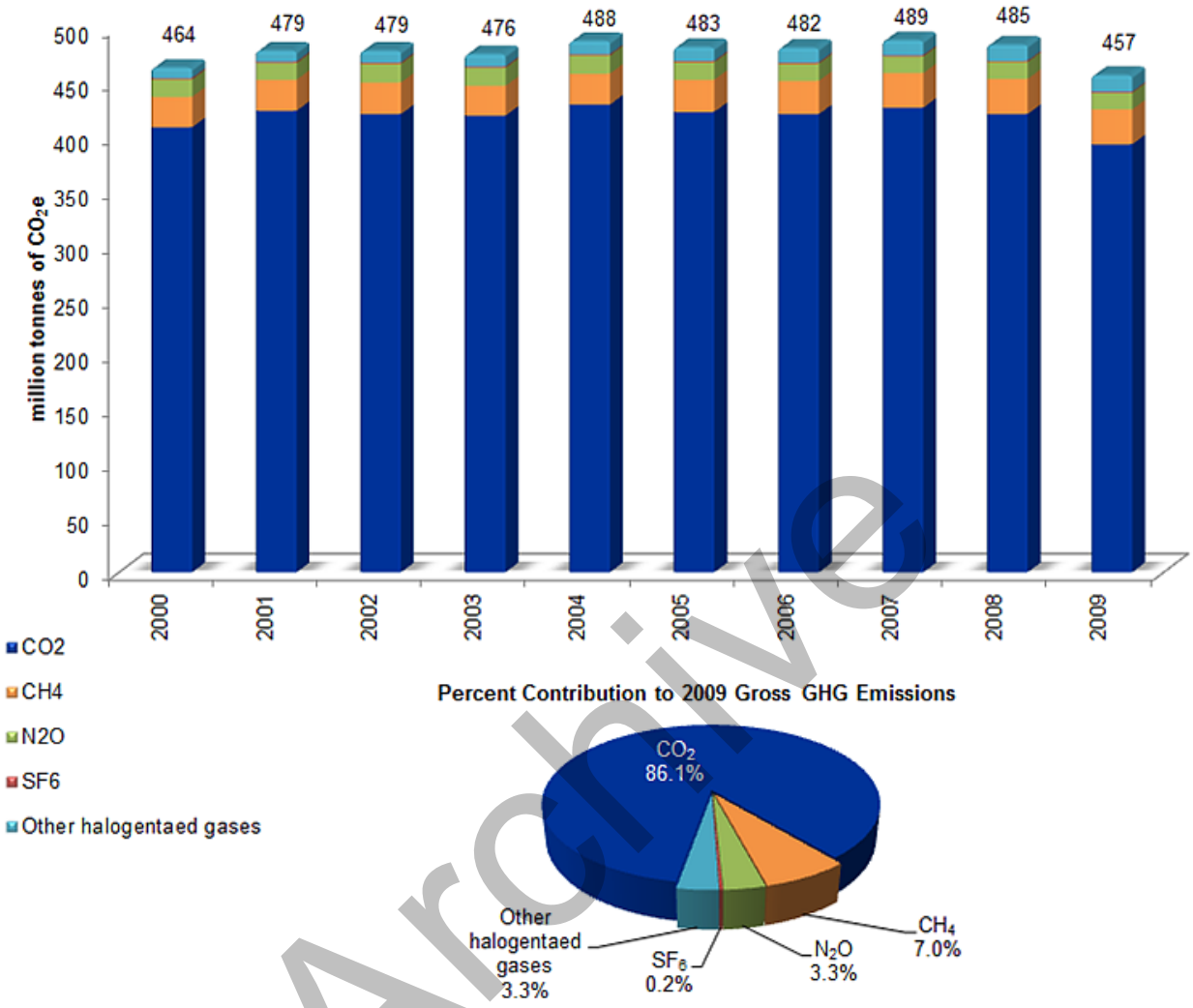
Figure 2: California Greenhouse Gas Emission by Gas



As the largest contributor to greenhouse gas emissions, CO_2 accounts for approximately 87 percent of the emissions since 2000, from 88 percent of total emissions in 2000 to 86 percent in 2009. CH_4 and N_2O account for seven and three percent of the total emissions in 2009, while SF_6 emissions accounts for 0.2 percent of the total emissions. Other halogenated gases constitute approximately 3.3 percent of the total emissions, of which 3.2 percent are ozone depleting substance (ODS) substitutes. Halogenated gases used as ODS substitutes result in almost 95 percent of the total halogenated gas emissions in 2009.

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Figure 3: Annual Percent Change in California Greenhouse Gas Emissions

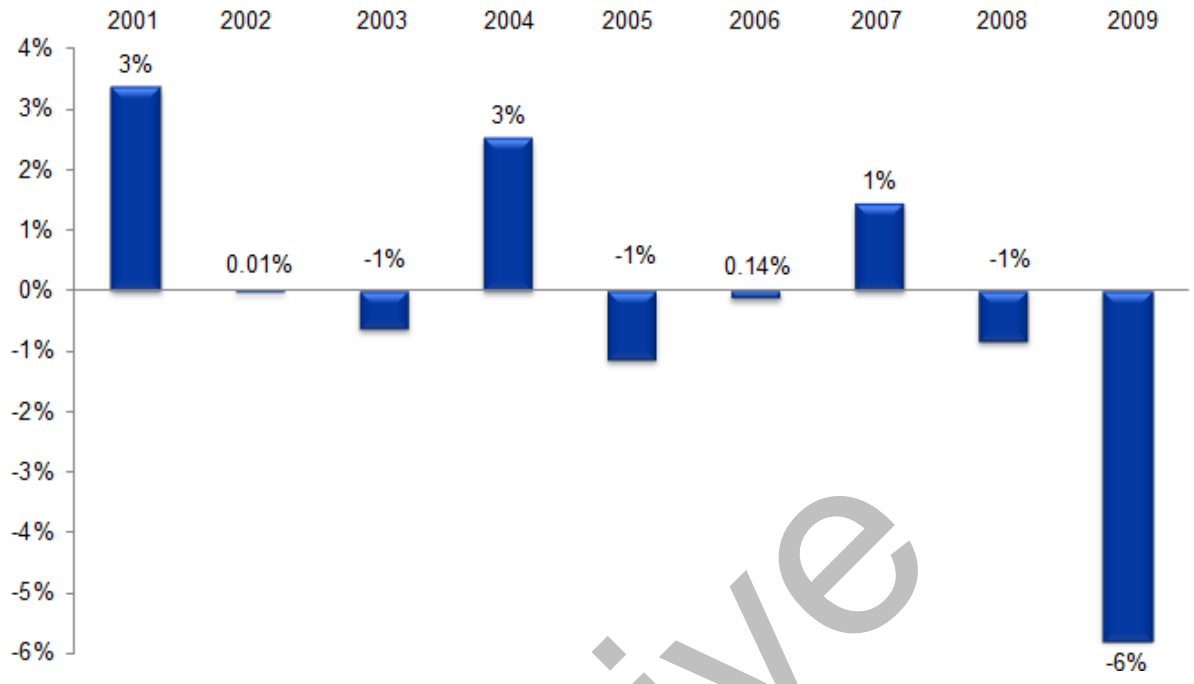
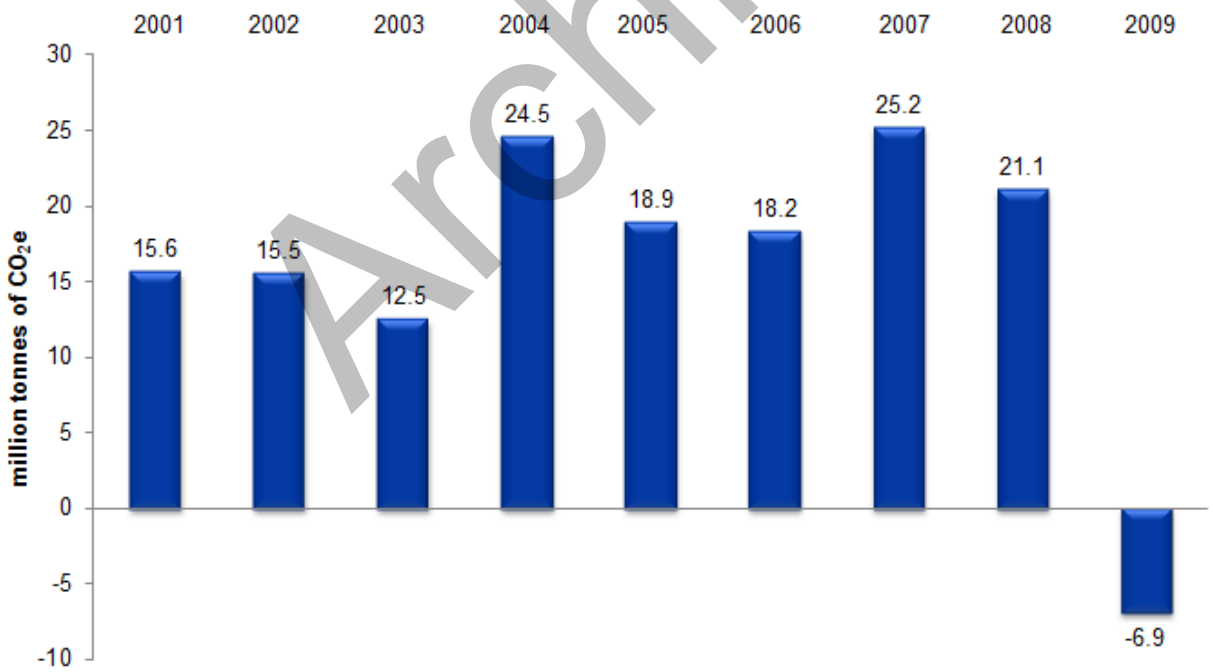


Figure 4: Cumulative Change in Greenhouse Gas Emissions Relative to 2000



While the total gross emissions in 2009 increased by 5.5 percent from 1990 (433 $MMTCO_2e$), the emissions decreased 5.8 percent from 2008, the likely effect of the economic recession that began in late 2007. This decrease in emissions from 2008 to 2009 is also observed in the national emissions, a 6.1 percent decline from 2008 to 2009. Figure 5 illustrates the trends in greenhouse gas emissions at the national and state level between 2000 and 2009.

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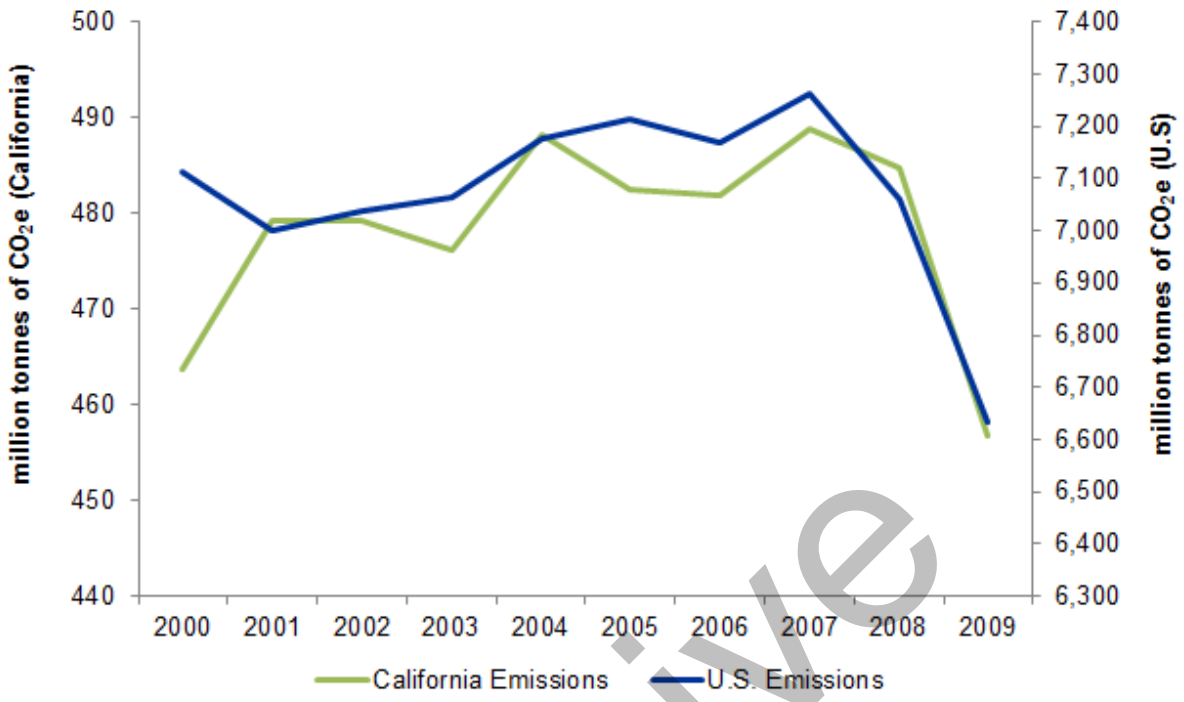
Figure 5: Recent Trends in Greenhouse Gas Emissions (U.S. and California)



Source: U.S emissions from Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009 (U.S.EPA, 2011)

Emissions by Economic Sectors

This section presents the greenhouse gas emissions by California inventory economic sectors: agriculture, commercial, electricity generation, forestry, industry, residential, transportation and unspecified. Table 2 summarizes the emissions and sinks from these economic sectors in the California inventory in weighted units of $MMTCO_2e$. The table also presents the percent change in emissions for each of the sectors between 2000 and 2009. Change in emissions with respect to 2008 is also shown to reflect likely effects of the recent economic downturn. Statewide emissions decreased in 2009, driven by a decline in on-road transportation, electricity generation, and industrial emissions. Table 3 presents the same 2000 to 2009 emissions by scoping plan categories.

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Table 2: Recent Trends in California Greenhouse Gas Emissions and Sinks by Inventory Economic Sectors

Economic Sector	Greenhouse Gas Emissions ($MMTCO_2e$)[1]										% of Total in 2009	% Change in Emission	
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**		**2000-2009**	**2008-2009**
Agriculture	28.9	29.1	32.3	30.7	32.3	32.6	33.7	32.9	33.7	32.1	7.0%	11%	-4.6%
Commercial	12.8	12.4	14.2	13.0	13.3	13.0	13.3	13.3	13.4	14.3	3.1%	12%	6.9%
Electricity Generation (imports)	46.2	59.4	59.4	64.9	66.4	63.2	55.0	60.1	66.2	48.4	10.6%	4.7%	-26.9%
Electricity Generation (in-state)	61.0	64.8	51.5	49.9	51.0	47.0	51.8	56.0	56.1	56.2	12.3%	-7.8%	0.2%
Forestry	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.04%	-0.7%	-0.1%
Industrial	103.8	100.5	101.4	98.7	100.6	100.2	99.9	97.3	94.9	89.3	19.5%	-14%	-6%
Residential	30.1	28.6	28.8	28.3	29.3	28.1	28.4	28.6	28.1	28.6	6.3%	-5.0%	1.7%
Transportation	171.7	174.8	181.3	179.4	183.2	186.1	186.6	187.1	178.0	172.9	37.9%	0.7%	-2.8%
Unspecified[2]	8.9	9.6	10.3	11.0	11.7	12.3	12.9	13.3	14.2	14.7	3.2%	65.2%	3.8%
Total Gross Emissions[3]	**463.7**	**479.2**	**479.2**	**476.1**	**488.2**	**482.5**	**481.9**	**488.8**	**484.7**	**456.8**	**--**	**-1.5%**	**-5.8%**
Forestry Net Emissions	*-4.5*	*-4.3*	*-4.2*	*-4.2*	*-4.2*	*-4.0*	*-3.9*	*-3.9*	*-3.8*	*-3.8*	--	--	--
Total Net Emissions[3]	**459.2**	**475.0**	**475.0**	**472.0**	**484.0**	**478.5**	**478.0**	**484.9**	**480.9**	**453.0**	**--**	**-1.3%**	**-5.8%**

Table 3: Recent Trends in California Greenhouse Gas Emissions and Sinks by Scoping Plan Categories

Scoping Plan Categories	Greenhouse Gas Emissions ($MMTCO_2e$)[1]										% Change	
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2000-2009**	**2008-2009**
Agriculture	28.9	29.1	32.3	30.7	32.3	32.6	33.7	32.9	33.7	32.1	11%	-5%
Commercial and Residential	42.9	41.0	43.0	41.3	42.7	41.0	41.7	41.9	41.5	42.9	0%	3%
Electric Power (In-state)	60.1	63.9	50.7	49.1	50.2	46.2	51.0	55.3	55.4	55.5	-8%	0%
Electric Power (Imports)	45.9	59.0	59.0	64.6	66.0	62.8	54.7	59.8	65.8	48.0	5%	-27%
Forestry	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	-1%	0%
Industrial	96.6	93.3	94.3	91.6	93.5	92.8	92.3	89.8	87.1	81.4	-16%	-7%
Transportation	171.7	174.8	181.3	179.4	183.2	186.1	186.6	187.1	178.0	172.9	1%	-3%
Recycling and Waste	6.5	6.6	6.6	6.7	6.7	7.0	7.1	7.1	7.3	7.3	12%	1%
High GWP	10.8	11.3	11.9	12.6	13.3	13.9	14.5	14.8	15.8	16.3	52%	3%
Total Gross Emissions[3]	**463.7**	**479.2**	**479.2**	**476.1**	**488.2**	**482.5**	**481.9**	**488.8**	**484.7**	**456.8**	**-1%**	**-6%**
Forestry Net Emissions	*-4.5*	*-4.3*	*-4.2*	*-4.2*	*-4.2*	*-4.0*	*-3.9*	*-3.9*	*-3.8*	*-3.8*	--	--
Total Net Emissions[3]	**459.2**	**475.0**	**475.0**	**472.0**	**484.0**	**478.5**	**478.0**	**484.9**	**480.9**	**453.0**	**-1%**	**-6%**

[1] All greenhouse gases are weighted relative to CO_2 based on the IPCC's 2nd Assessment Report.
[2] Unspecified includes emissions from evaporative losses and ODS substitute use, which could not be attributed to an individual sector.
[3] The sector emissions may not add up exactly to the above listed gross and net total emissions due to rounding.

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Figure 6 shows the trend in emissions and Figure 7 the percent contribution of each inventory economic sector to the total emissions from 2000 through 2009.

Figure 6: Greenhouse Gas Emission Trends by Economic Sector

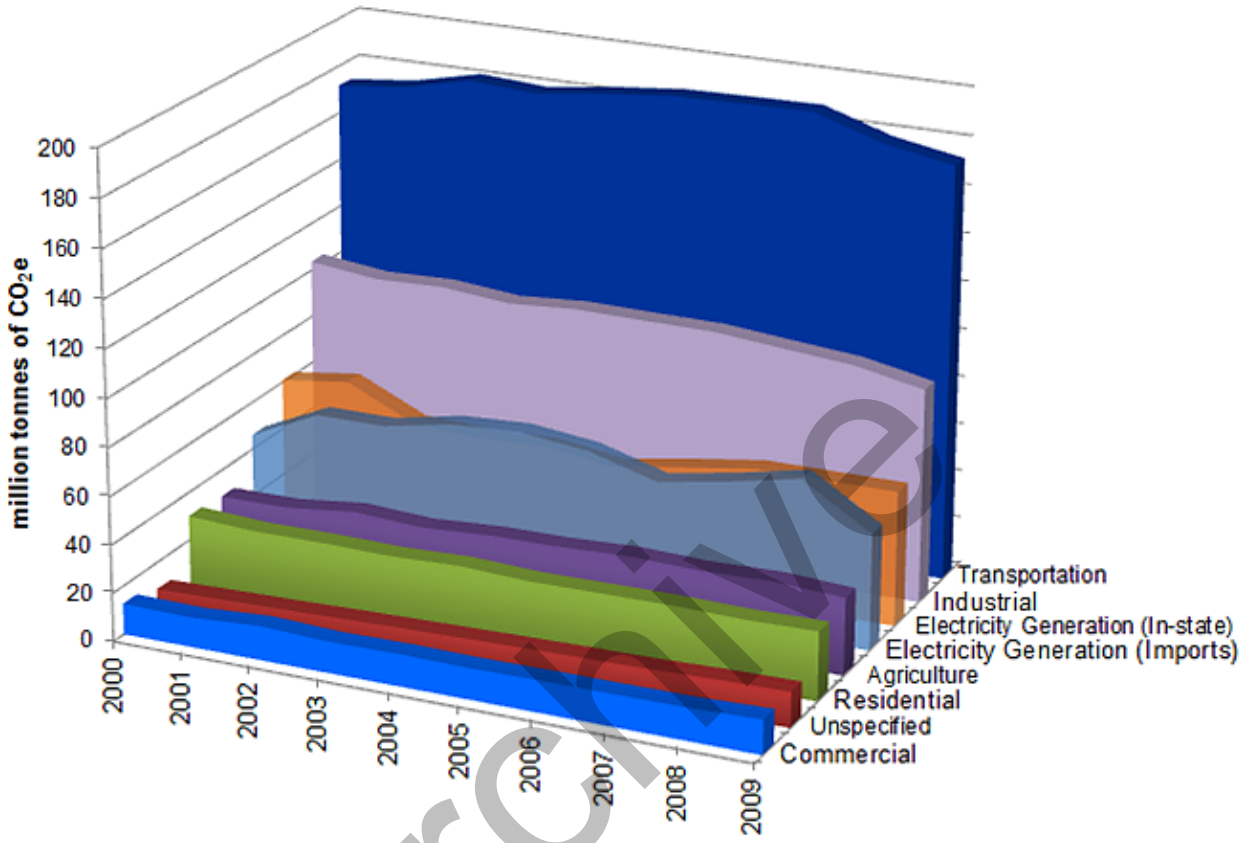
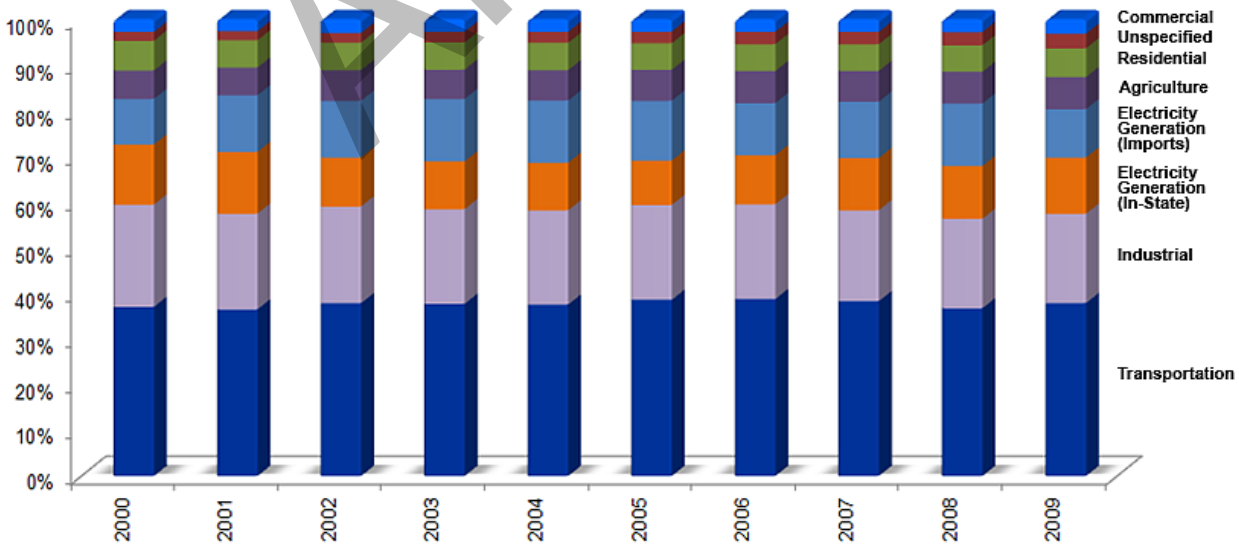


Figure 7: Contribution of Economic Sectors to Greenhouse Gas Emissions



The relative contribution of each sector remained comparable over the time series. The statewide emissions profile by sector was to some extent similar in 2000 and

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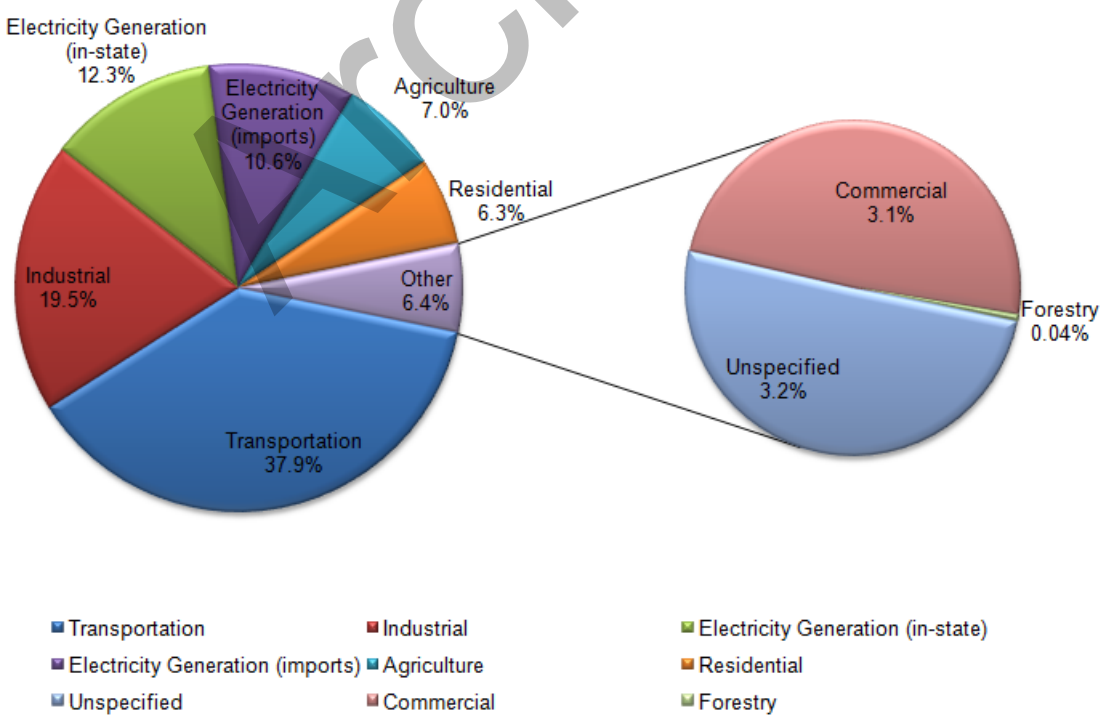
2009. Transportation was the major emitter of greenhouse gases in both 2000 and 2009, producing 173 $MMTCO_2e$ in 2009. The electricity generation sector, which includes both in-state generation and imported electricity, was the next largest greenhouse gas contributor in both the years, emitting approximately 105 $MMTCO_2e$ in 2009.

Figure 8 displays the contribution by sector to the total 2009 gross emissions, with transportation at approximately 38 percent of statewide emissions, and electricity generation at approximately 23 percent. In 2009, the transportation sector accounted for approximately 38 percent of the total statewide greenhouse gas emissions, thus making it the largest contributor to the total statewide emissions. Emissions from electricity generation, the second largest, accounted for 23 percent of the total emissions with almost equal contributions from in-state and imported electricity, while the industrial sector accounted for approximately 20 percent of the total in 2009. These three sectors accounted for approximately 80 percent of the statewide greenhouse gas emissions in 2009. Emissions from agriculture (7 percent), residential (6.3 percent), and commercial (3.1 percent) sectors accounted for approximately 16.5 percent of the total. CH_4 and N_2O emissions from wildfires and soil disturbances (forestry) accounted for approximately 0.04 percent of the total statewide greenhouse gas emissions. The remaining 3.5 percent of the gross emissions were mainly due to evaporative losses and use of ODS substitutes, which could not be assigned to any specific economic sector in the inventory (unspecified emissions).

Figure 8: 2009 Greenhouse Gas Emissions by Economic Sector (457 MMTCO2e Gross Emissions)



* Totals may not add up to due to rounding. Unspecified includes evaporative losses and emissions from use of ODS substitutes, which could not be attributed to an individual sector.

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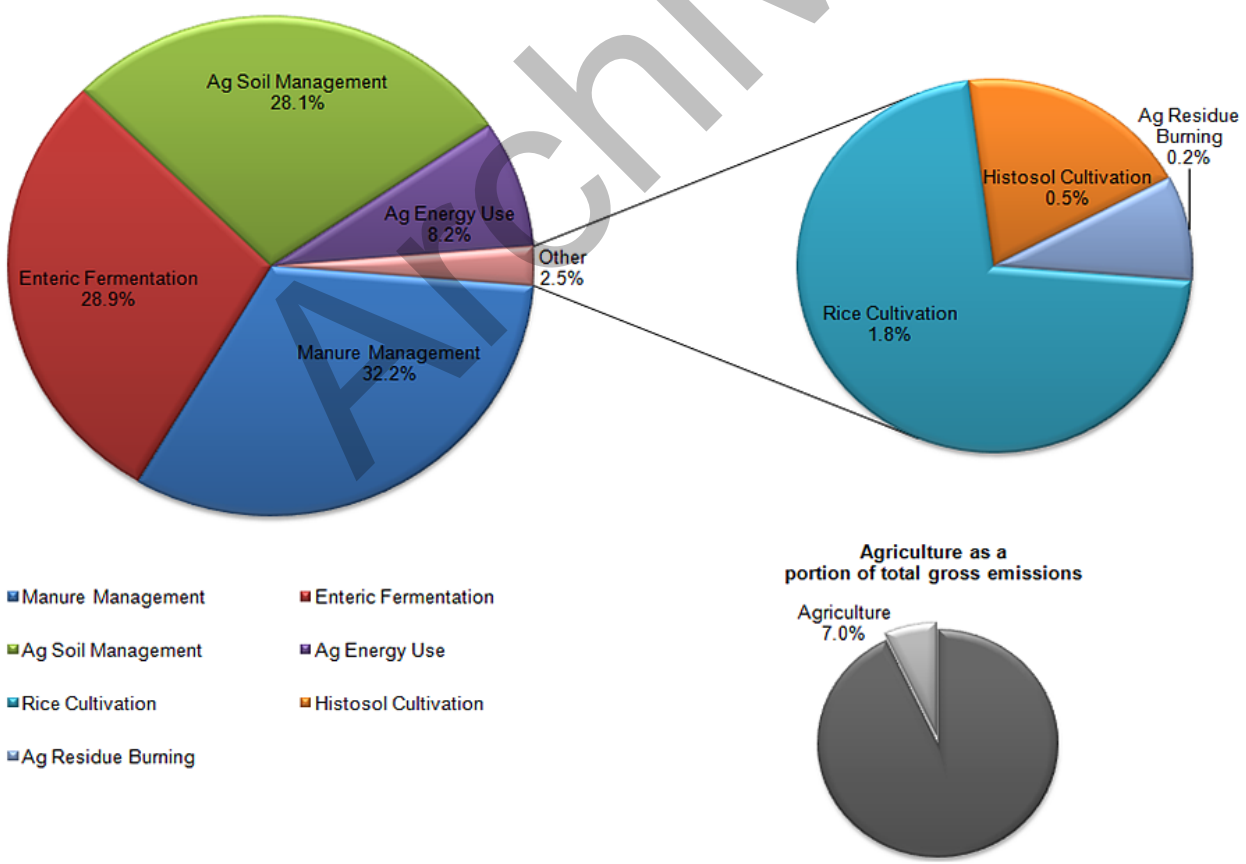
The majority of statewide greenhouse gas emissions were tied to fuel use activities, ranging from transportation to electricity generation to heating buildings. In fact, emissions from fuel combustion comprised 73 percent of overall statewide greenhouse gas emissions in 2009. Primary fuels combusted include natural gas, which was used primarily for in-state electricity generation, residential and industrial uses, and gasoline, which was consumed almost entirely by the transportation sector.

Detailed breakdown of the emissions from each of the economic sectors and their relative contribution to the total emissions is discussed in the following sections.

Agriculture

Emissions from agricultural activities were responsible for emissions of 32.1 $MMTCO_2e$, approximately 7 percent of total statewide greenhouse gas emissions. Agricultural emissions represent the sum of emissions from agricultural energy use, agricultural residue burning, agricultural soil management (the practice of utilizing fertilizers, soil amendments, and irrigation to optimize crop yield), enteric fermentation (fermentation that takes place in the digestive system of animals, e.g. cows and sheep), histosols (soils that are composed mainly of organic matter) cultivation, manure management and rice cultivation.

Figure 9: 2009 Greenhouse Gas Emissions from Agriculture (32 MMTCO2e Gross Emissions)



While CO_2 constitutes the majority of emissions in other economic sectors, most of agriculture's emissions are N_2O from agricultural soil management and CH_4 from

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enteric fermentation and manure management. The majority of the emission contributions (89 percent) are due to agricultural soil management (28 percent), enteric fermentation (29 percent) and manure management (32 percent). The remaining 11 percent of the agricultural emissions was dominated by emissions from agriculture fuel use (8.2 percent). The contribution of these categories towards the 2009 agricultural greenhouse gas emissions is shown in Figure 9.

Figure 10: Greenhouse Gas Emission Trends for Agriculture

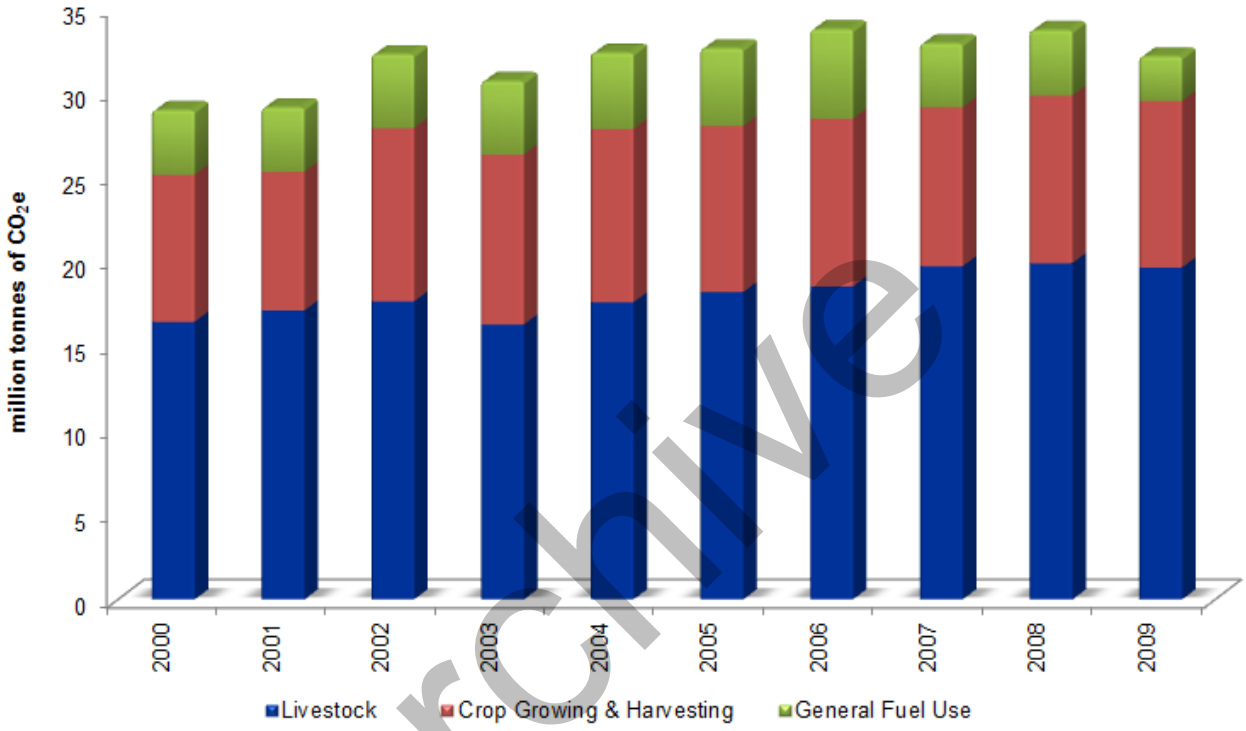

Figure 10 shows the trend in the emissions from each of these categories from 2000 through 2009. The agriculture sector increased its emissions from 28.9 $MMTCO_2e$ in 2000 to 32.1 $MMTCO_2e$ in 2009, an 11 percent increase. All agricultural sector categories increased their greenhouse gas emissions from 2000 to 2009, except agriculture fuel use and agriculture residue burning. Agricultural fuel use emissions decreased by 31 percent from 2000 to 2009, while manure management emissions increased 26 percent during the same period.

Commercial Sector

The commercial sector accounted for approximately 3.1 percent of the total statewide emissions in 2009. Greenhouse gas emissions from the commercial sector increased from 12.8 $MMTCO_2e$ in 2000 to 13.4 $MMTCO_2e$ in 2008 and 14.3 $MMTCO_2e$ in 2009. Commercial sector emissions grew approximately 12 percent from 2000 to 2009 and, approximately 7 percent from 2008 to 2009.

The emission contributions from the commercial sector are from commercial CHP[1]

[1] A combined heat and power (CHP) system generates electricity and utilizes the waste heat for steam generation, heating or drying.

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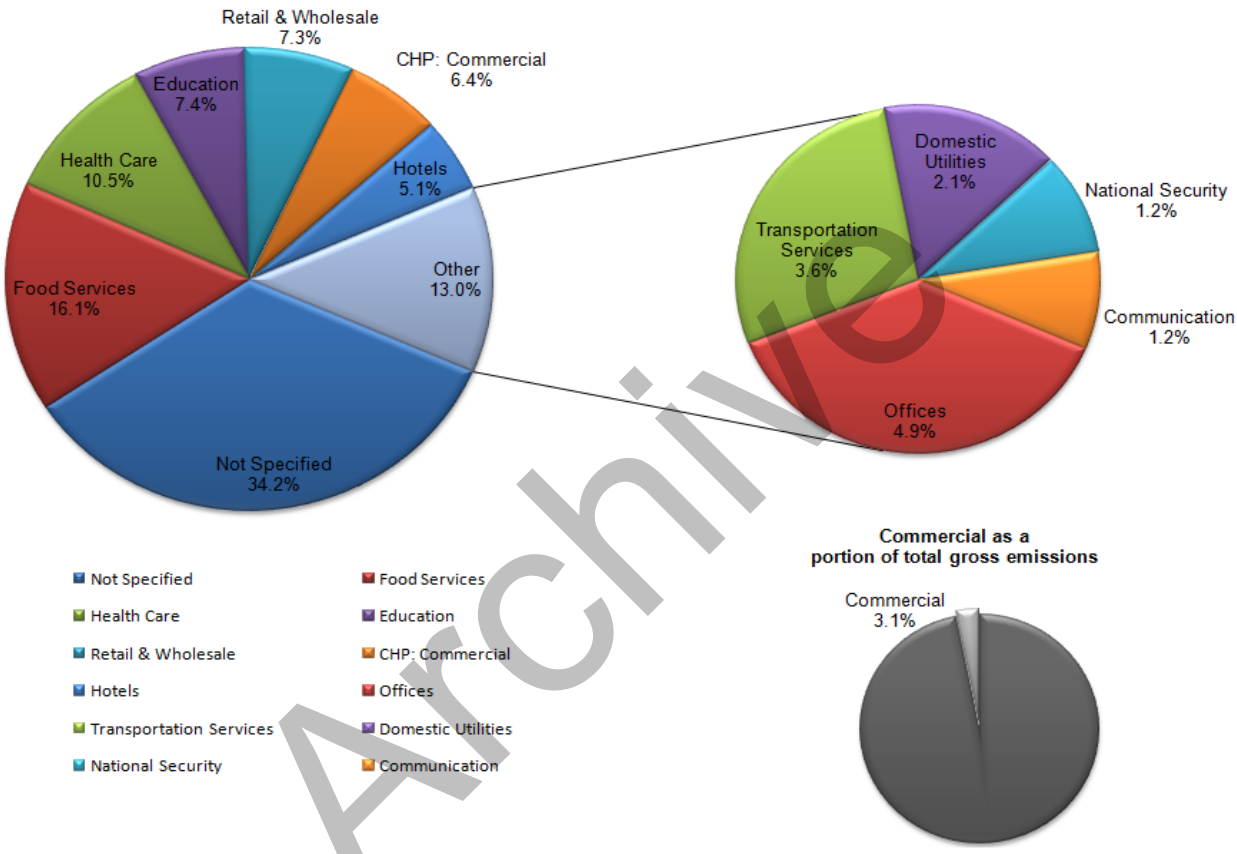
useful heat, domestic utilities, education, food services, health care, hotels, national security, offices, retail and wholesale, transportation services, and unspecified sources. The sector includes fuel combustion for all commercial activities such as heating buildings, hot water and steam, and energy for natural gas transmission through pipelines. The primary fuel combusted was natural gas. Approximately 86 percent of the total emissions from this sector are due to natural gas combustion.

Figure 11: 2009 Greenhouse Gas Emissions from Commercial Sector (14 MMTCO2e Gross Emissions)



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The percent contributions of each of these categories to the total 2009 emissions for this sector are shown in Figure 11. The largest contributor to emissions from the commercial sector is the combustion of fuels from unspecified sources (34 percent). These fuels include diesel, natural gas, and liquefied petroleum gas (LPG). The food services (16 percent) and health care (11 percent) categories are the next two major contributors in this sector.

Electricity Generation

Electricity generation, transmission, and distribution accounted for 23 percent of total statewide greenhouse gas emissions in 2009. This sector was the second highest emitting sector in 2009, emitting 104.6 $MMTCO_2e$ that year. This sector includes power plants and cogeneration facilities that generate electricity for on-site use and for sale to the power grid. This sector specifically includes greenhouse gas emissions from both in-state generated power and imported generation of electricity delivered to

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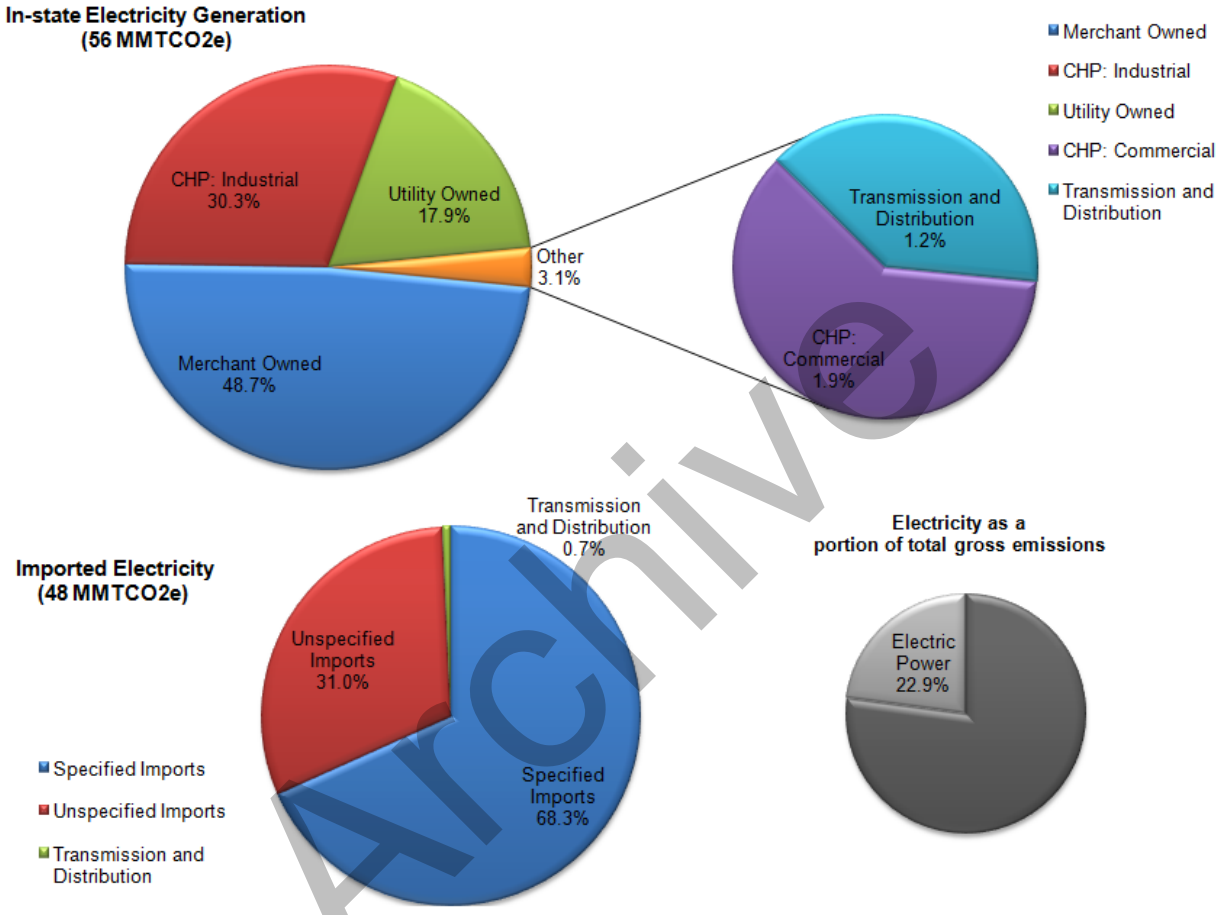
and consumed in California. Emissions from transmission line losses of electricity, as well as SF6 emissions from transmission equipment, are also included. Figure 12 shows the contribution of electricity generation sector to the total emissions and Figure 13 the trends in the emissions.

Figure 12: 2009 Greenhouse Gas Emissions from Electricity Generation (105 MMTCO2e Gross Emissions)



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<u>*Electricity Generation (imports):*</u> Emissions from imported electricity generation are from specified imports (68 percent), unspecified Imports (31 percent) and transmission and distribution (< 1 percent).

<u>*Electricity Generation (in-state):*</u> Emissions from in-state electricity generation are from categories such as CHP commercial, CHP industrial, merchant owned (privately owned power plant), transmission and distribution, and utility owned (investor-owned power plant). The percent contributions from each of these categories to the total 2009 emissions from this sector are shown in Figure 12. The merchant owned (48 percent) and CHP industrial (30 percent) contribute most to the in-state electricity generation emissions. Emissions from the combustion of natural gas constitute 87 percent of in-state electricity generation emissions.

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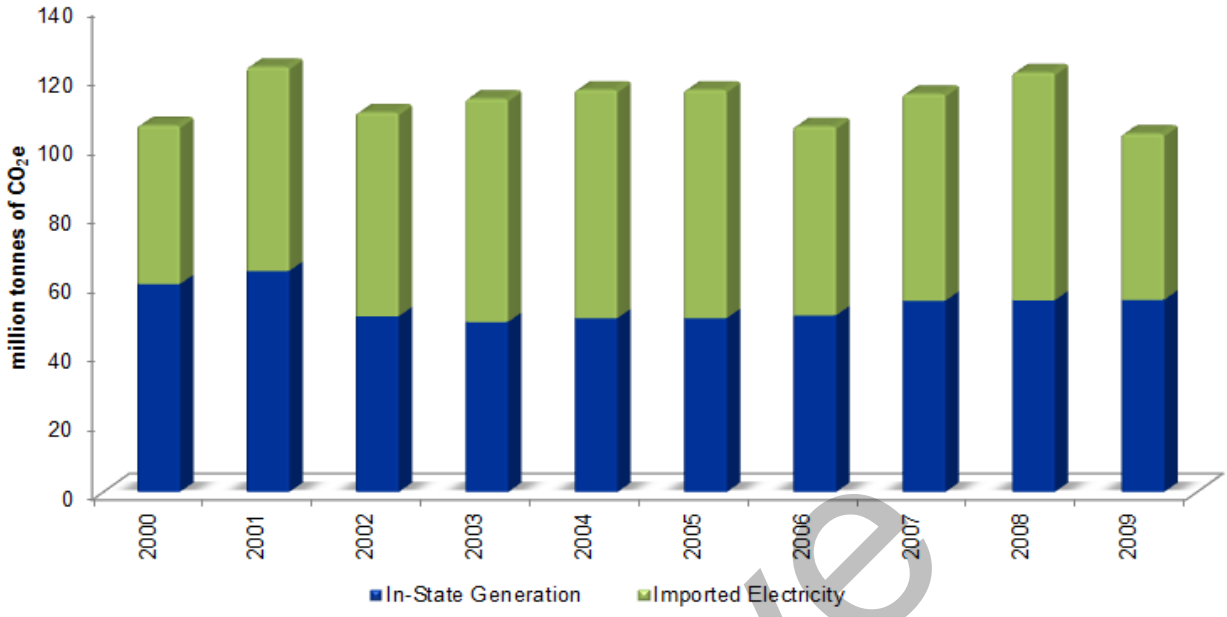
Figure 13: Greenhouse Gas Emission Trends for Electricity Generation



Forestry

The forestry sector was the smallest emitter of greenhouse gases from 2000 through 2009. Due to current limitations in methodology, the greenhouse gas emissions from the forestry sector were estimated to be constant, at 0.19 $MMTCO_2e$ per year, over the 2000 to 2009 period (Table 2). This estimate includes emissions from rangelands and reflects emissions of CH_4 and N_2O only. Emissions of CH_4 are a consequence of fire and soil disturbance during logging and other anthropogenic activities that disturb the forest floor. Emissions of N_2O are the result of fires both in forests and on rangelands.

Fires and disturbances also released CO_2, but these emissions were tracked separately since plants also remove CO_2 from the atmosphere. CO_2 emissions associated with combustion or decomposition of biomass from the forest sector are accounted for in the inventory net CO_2 flux from forested lands and wood products (see Figure 14). This net CO_2 flux is obtained by summing CO_2 sinks (forest and rangeland woody biomass growth) with CO_2 emissions from combustion and decomposition of biomass and wood products (landfilled paper/wood waste, etc.). The largest emissions of CO_2 within the forest sector are from fires, land disturbances, and landfilling of wood and wood products. The net sum of these emissions and sinks is located on the far right of Figure 14.

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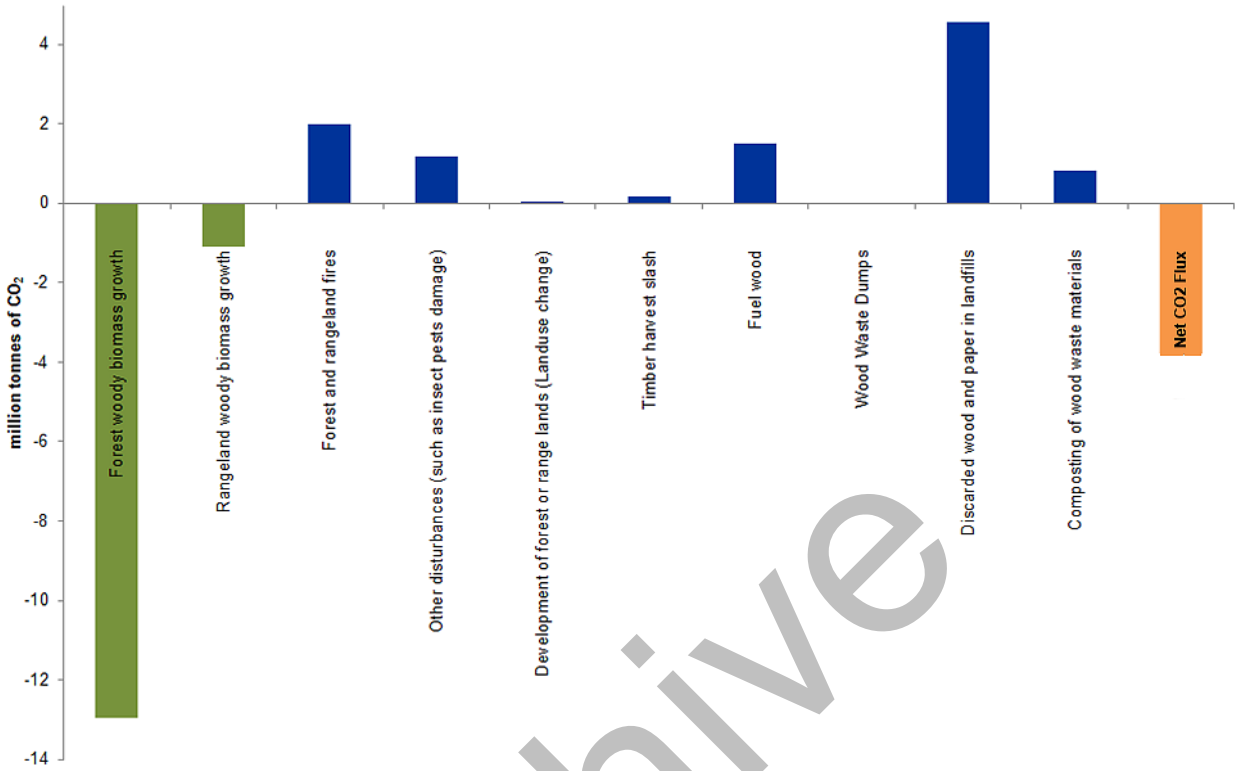
Figure 14: Net CO_2 flux from forested lands and wood products in 2009



The forestry sector constitutes a net sink of -3.8 $MMTCO_2$ in 2009. In 2000, forestry's net CO_2 flux was -4.5 $MMTCO_2$ (Table 2) but the magnitude of the net sink is diminishing due to losses of forest area and emission increases from decomposing wood products consumed in the State. See the technical support document for an in-depth discussion on the emissions and sinks associated with CO_2 accounting for the forest sector.

Industrial Sector

The industrial sector is the third largest contributor to the statewide greenhouse gas emissions. This sector's categories include industrial CHP useful heat, landfills[1], manufacturing, mining, oil and gas extraction, petroleum refining, petroleum marketing, pipelines, wastewater treatment, and other sources. The percent contributions from each of these categories to the 2009 total emissions from this sector are shown in Figure 15. Major emitters in this sector are petroleum refining (32 percent), manufacturing (25 percent), oil and gas extraction (15 percent), CHP (12 percent), and landfills (8 percent). Approximately 92 percent of the total emissions from this sector can be attributed to these major categories. For the petroleum refining category, the combustion of fuels is the main source of emissions. Fuel combustion and clinker process emissions from cement plants are the two largest

[1] Landfill emissions are primarily due to the release of CH_4 (anaerobic decomposition). Carbon dioxide from paper/wood decomposition and from the combustion of landfill gas is included in the net CO_2 flux (See the Technical Support Document for more details).

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sources in the manufacturing category. Landfills, wastewater treatment, and solid waste treatment (composting), while serving an important societal function, account for only 11 percent of the total emissions from this sector.

Figure 15: 2009 Greenhouse Gas Emissions from Industry (89 MMTCO2e Gross Emissions)

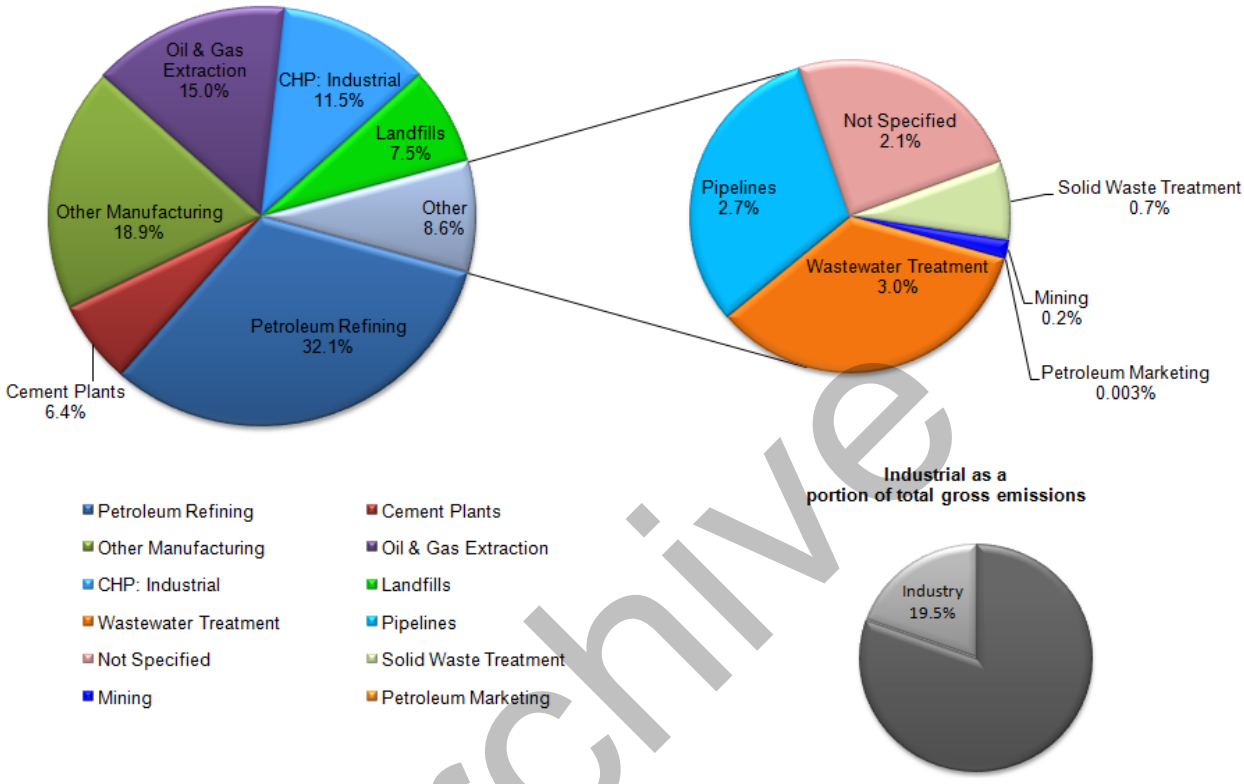
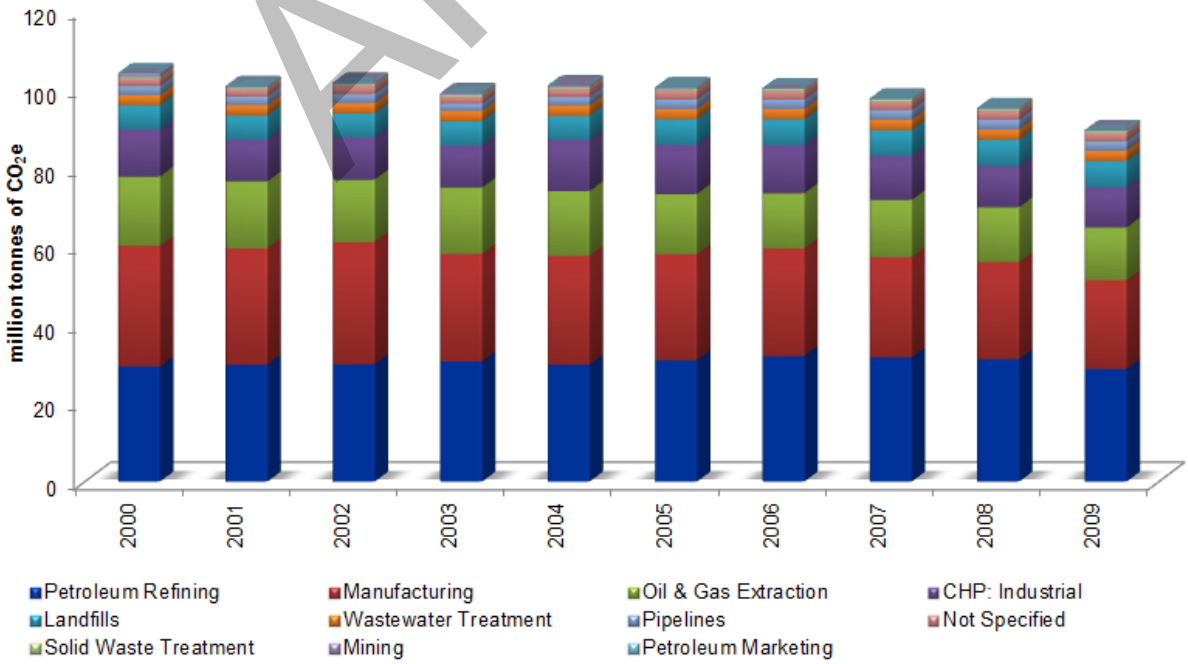


Figure 16: Greenhouse Gas Emission Trends for Industry



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Overall, emissions from this sector decreased from 104 $MMTCO_2e$ in 2000 to 89 $MMTCO_2e$ in 2009, a 14 percent decrease (see Figure 16). Emissions from cement plants decreased 34 percent from 2008 to 2009, reflecting a large decrease in demand for cement.

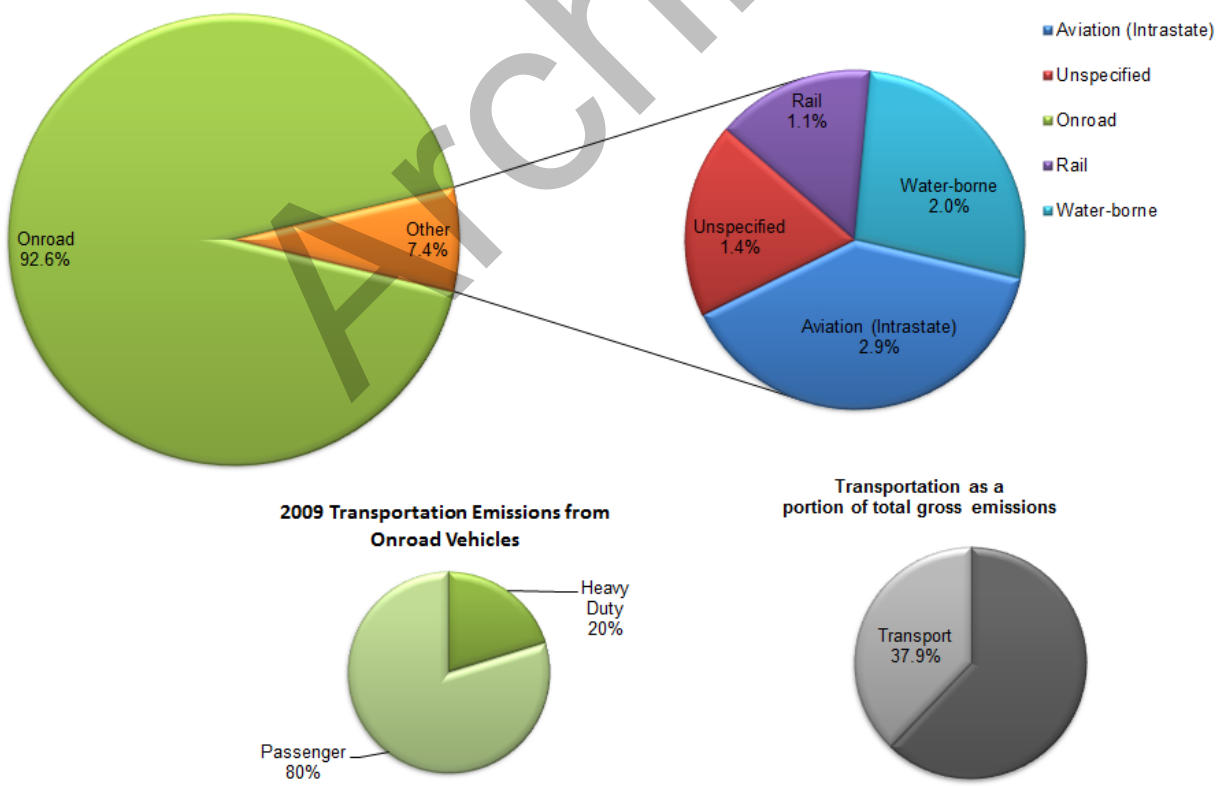
Residential Sector

The residential sector accounted for 6.3 percent of the total emissions in 2009, and primarily consisted of CO_2 emissions from fossil fuel combustion. Residential emissions are related to the use of fuel for general household needs. Approximately 99 percent of the emissions are related to the burning of natural gas and LPG, with the majority attributed to the burning of natural gas. Emissions from residential fuel use declined from 30.1 $MMTCO_2e$ in 2000 to 28.6 in 2009.

Transportation

Transportation activities accounted for 37.9 percent of the statewide greenhouse gas emissions in 2009. Contributions from the transportation sector include emissions from aviation, on-road, rail and water-borne and other unspecified sources. Emissions from military transportation activities are not included in the inventory total for the State. The percent contributions from each of these categories to the total emissions from this sector are shown in Figure 17 for 2009.

Figure 17: 2009 Greenhouse Gas Emissions from Transportation (173 MMTCO2e Gross Emissions)



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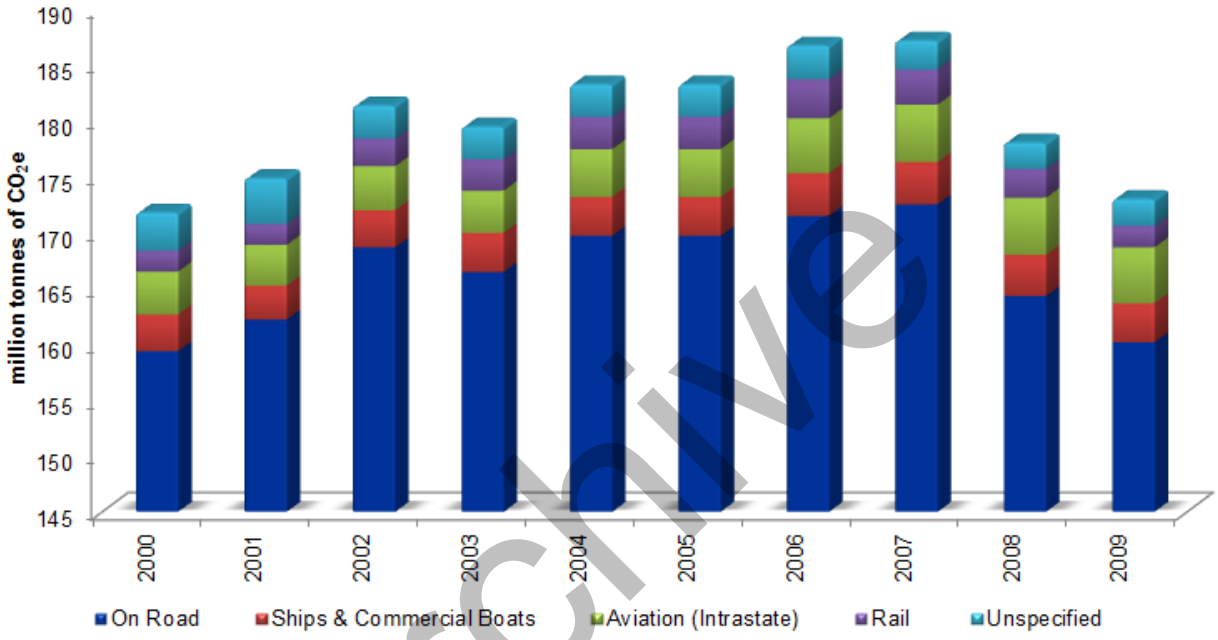
An overwhelmingly large majority of emissions from this sector is due to on-road transportation (92.6 percent). Of the on-road vehicles, light duty passenger vehicles accounted for approximately 74 percent of the total sector emissions in 2009. The on-road category also accounts for approximately 35 percent of the statewide 2009 greenhouse gas emissions. Figure 18 shows the trend in emissions for this sector from 2000 through 2009. Transportation emissions showed a marked decline since 2007 (from a high of 187 $MMTCO_2e$ in 2007 to 173 $MMTCO_2e$ in 2009).

Figure 18: Greenhouse Gas Emission Trends for Transportation



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Emissions not attributable to a specific sector

Summed together, emissions from the above sectors along with the emissions in the inventory that cannot be attributed to any sector, equal the total emissions accounted for in the California inventory. Unspecified sector emissions include emissions from evaporative losses and use of ODS substitutes. In 2009, this “sector” contributed 3.2 percent of the total emissions. This sector had the highest increase in emissions from 2000 to 2009, a 65 percent increase from 8.9 $MMTCO_2e$ in 2000 to 14.7 $MMTCO_2e$ in 2009. Emissions of halogenated gases (ODS substitutes) comprised almost 98 percent of the unspecified sector emissions during 2000 to 2009. The ODS substitute category includes hydrofluorocarbon (HFC) and perfluorocarbon (PFC) emissions, which are substitutes to chlorofluorocarbons (CFCs), compounds that were phased out under the Montreal Protocol due to their ozone depleting ability. ODS substitutes are used throughout society and data are not currently available to allocate them to individual sectors.

Per Capita Emissions

Total statewide gross greenhouse gas emissions varieded from 433 $MMTCO_2e$ in 1990 to 464 $MMTCO_2e$ in 2000 and 457 $MMTCO_2e$ in 2009. This equates to a 7.1

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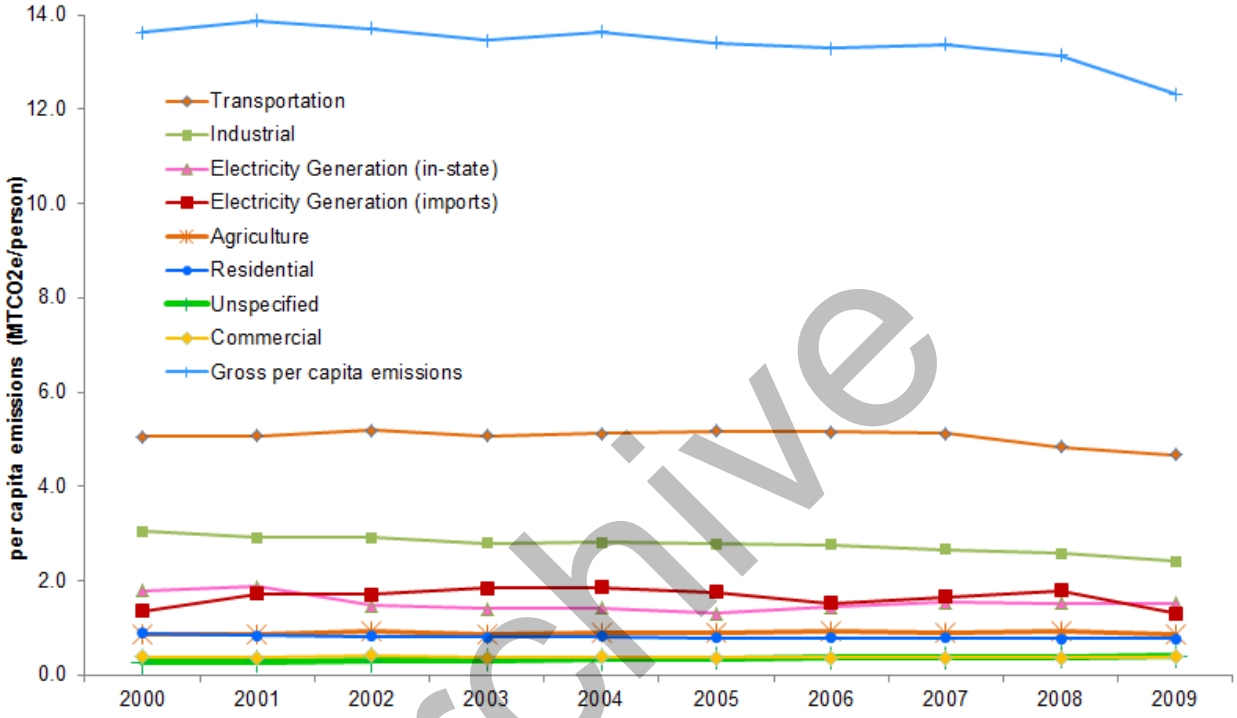
percent increase in the emissions from the 1990 to 2000, and a 5.5 percent increase in emissions from 1990 to 2009. For the same time period, the population increased from 29.8 million in 1990 to 34 million in 2000 (a 14 percent increase from 1990) and 37 million in 2009 (a 24.3 percent increase from 1990, and a 9 percent increase from 2000) (DOF, 2011).

Figure 19: Per Capita Greenhouse Gas Emissions Trends by Economic Sector



For the year 2009, California has a gross per capita emission of 12.3 $MTCO_2e$/person (Figure 19). This compares favorably with a value of 14.5 $MTCO_2e$/person in 1990 and 13.6 $MTCO_2e$/person in 2000 (Figure 19). Per capita emissions from industrial, residential, and electricity generation (in-state) have considerably decreased from 2000 to 2009, with a 21 percent decrease in the 2009 industrial per capita emissions from 2000. In contrast, emissions of halogenated gases used as ODS substitutes increased approximately 51 percent in 2009 from the 2000 level. Per capita emissions in California have decreased by 9.7 percent from 2000 to 2009, but the overall 9 percent increase in population during the same period offsets the emission reductions. The per capita comparison is a useful metric for emission evaluation because it shows that emissions have not grown consistently with population, indicating that energy conservation may have led to significant emission reductions.

V. A Broader Perspective on the California Greenhouse Gas Emissions

Even though the California inventory was designed to facilitate comparability with other nations and states, difficulties still arise. In some instances, international

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emission data is incomplete due to difficulties in bookkeeping at a global level. Additionally, United States' emission data is presented on a national level and disaggregating the data to the state level can lead to problems. For this reason, this section uses data from the World Resources Institute (WRI) Climate Analysis Indicators Tool (CAIT) for comparing California's inventory to other states in the United States and other countries around the world (WRIa, 2008; WRIb, 2010). It is important to note that the greenhouse gas emissions estimation methods in CAIT are not the same as those used in the California inventory.

California and Other States

The 2007 greenhouse gas emissions data from CAIT-US (WRIc, 2011) were used to compare emissions from California with emissions from other states in the United States. CAIT-US includes greenhouse gas emissions data from the U.S.EPA, which is derived from the State Inventory Tool (SIT) of the Emissions Inventory Improvement Program (EIIP). The emissions factors used in SIT are default factors that were generated by the U.S.EPA. The CAIT-US software does not include emissions from fugitive oil and gas emissions from refining and processing, industrial processes (some chemicals and mining practices process emissions), and methane emissions from industrial wastewater. Because of these omissions, CAIT-US tends to underestimate emissions from individual states in the United States (WRIc, 2011). However, it does allow for a comparison of emissions between states.

Figure 20 shows the total and per capita greenhouse gas emissions for 2007 for all the states in the country (WRIc, 2011). In 2007, California accounted for 6.7 percent of all emissions in the country and ranked second highest among the states with total emissions of 474 $MMTCO_2e$, only behind Texas with 785 $MMTCO_2e$. From a per capita standpoint, California has the 46th lowest emissions with 13.1 $MTCO_2e$/person.

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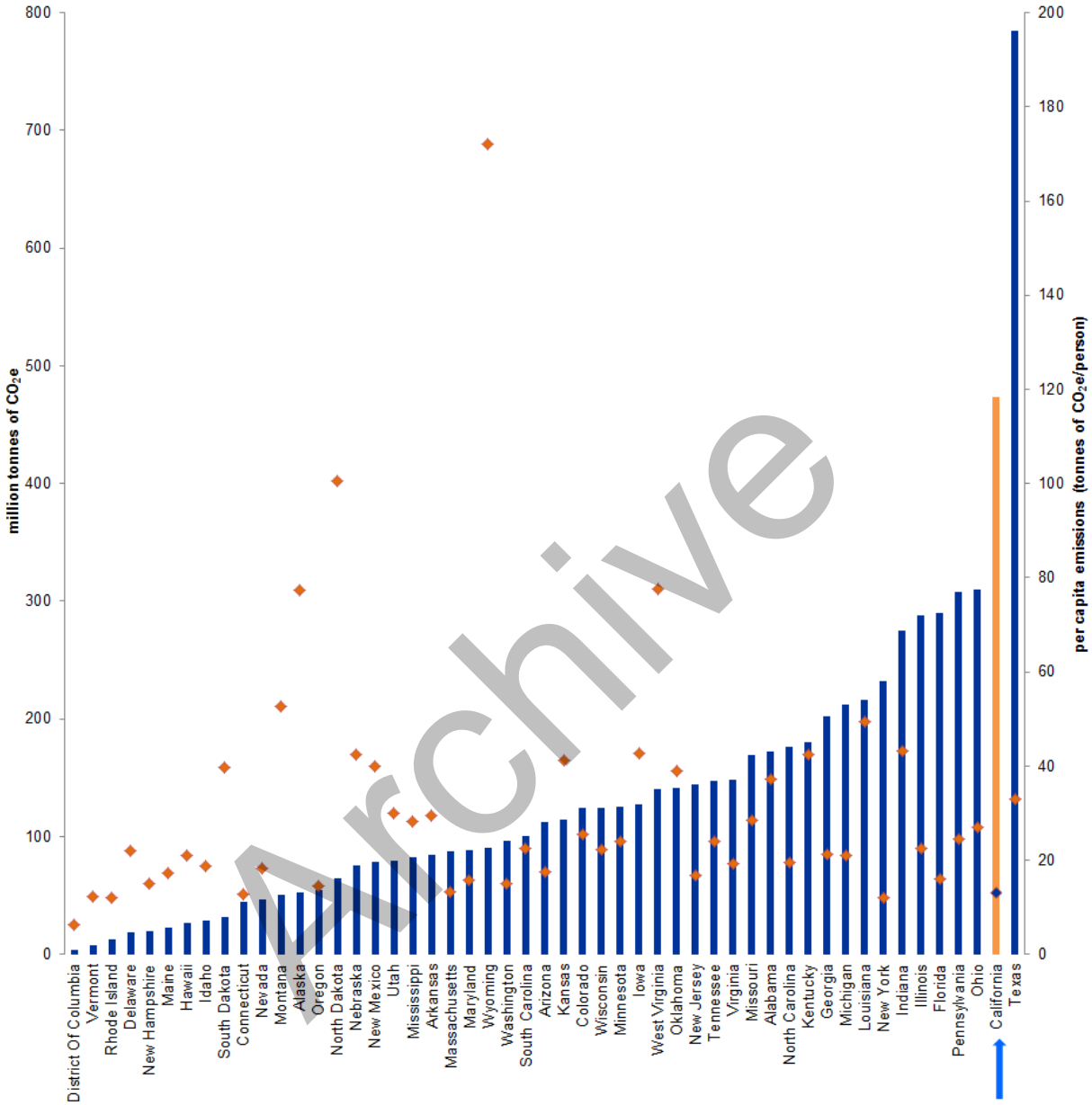
Figure 20: Total (bars) and Per Capita (markers) California and Other States Greenhouse Gas Emissions in 2007 (CAIT-U.S. v4.0)



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California and the Rest of the World

California has substantial greenhouse gas emissions when compared with the nations of the world. CAIT was used to compare 2007 California emissions against 2007 emissions from countries of the world, including the United States (WRId, 2011). The 2007 national totals from CAIT do not include non-CO_2 gases, due to the lack of non-CO_2 data availability (WRIb, 2010). A comparison of 2007 total and per capita CO_2 emissions as obtained from CAIT for California and the rest of the world is shown in Figure 21. If California were a country, it would have ranked 14th highest in CO_2 emissions worldwide. On a per capita emissions basis, California would have

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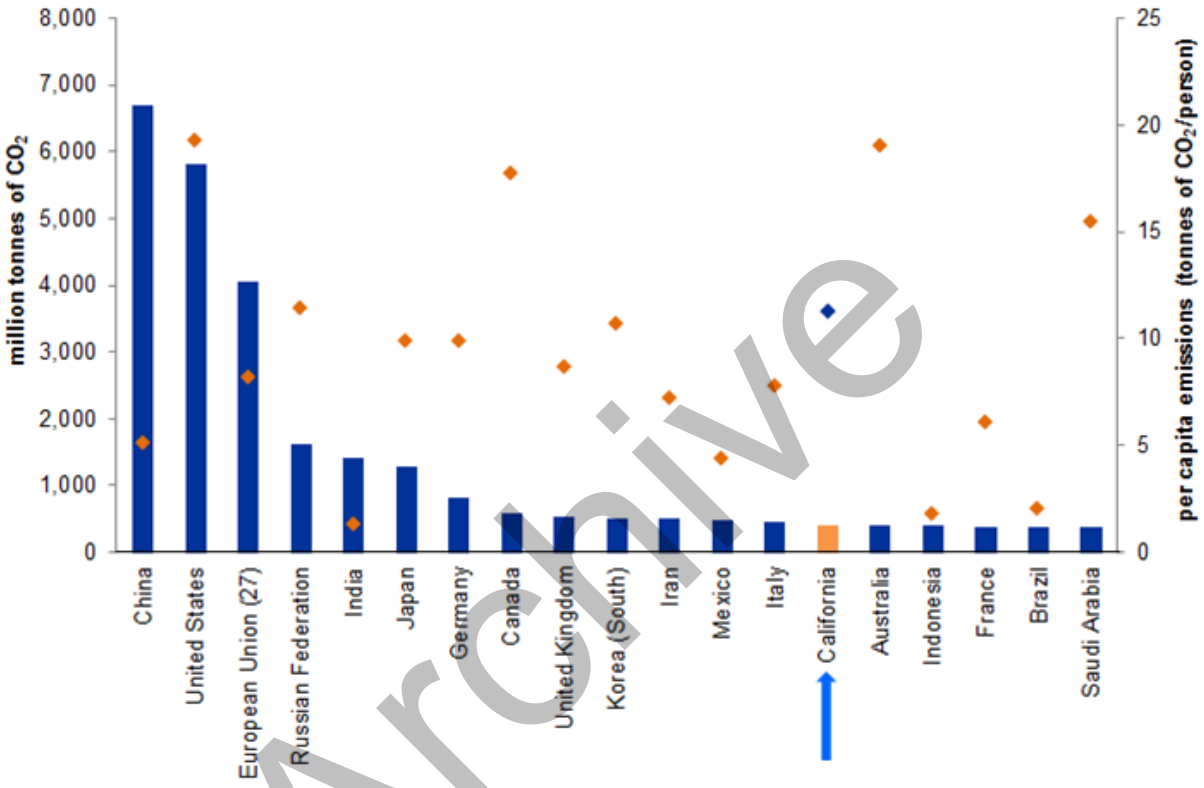
ranked 19th in the world with 11.3 $MTCO_2$/person, behind the United States (including California) at rank 7 with 19.3 $MTCO_2$/person. Qatar had the highest per capita emissions at 48.8 $MTCO_2$/person. The top 10 emitters (individual nations, excluding data for European Union) accounted for more than half of the total global CO_2 emissions in 2007 (approximately 58 percent).

Figure 21: Total (bars) and Per Capita (markers) CO2 Emissions of California and Selected Countries in 2007 (CAIT v9.0 and CAIT-U.S. v4.0)



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VI. Ongoing Work

ARB staff routinely evaluates the methodology used to develop the emissions estimates used in the inventory. In addition, data from a variety of sources are reviewed and compiled for use in updating the inventory each year. ARB regularly releases updated emissions inventory data, summary reports, and technical support documents that detail the emissions inventory for public use. It is anticipated that ARB staff will continue to release updates in the future. All reports are available on ARB's greenhouse gas emission inventory webpage.

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