

2004 INVENTORY OF GREENHOUSE GAS EMISSIONS FROM SANTA CRUZ COUNTY MOBILE SOURCES

1.0 INTRODUCTION

In 2006, the State Legislature enacted Assembly Bill 32 (AB 32), California Global Warming Solutions Act of 2006⁽¹⁾, to reduce greenhouse gas (GHG) emissions in California. Under AB 32, the California Air Resources Board (ARB) was given the task of developing a statewide inventory of GHGs. The inventory would be used as a basis to develop planning and control strategies to achieve the goals of AB 32, which include reducing the statewide GHG inventory to 1990 levels by 2020 and then by 2050 to reduce 1990 levels by 80%.

While the statewide inventory is a useful tool for the state level program, it does not have sufficient detail to assist county agencies in developing local programs, especially as it relates to reducing mobile source GHG emissions. Consequently, there is a need for information on emissions produced at the local level.

2.0 PURPOSE AND SCOPE

The purpose of this document is to provide the Santa Cruz County Public Works Department, the grantee in this program, with a county level inventory of mobile source GHG emissions. This inventory includes emissions from on-road motor vehicles and various off-road sources. The inventory would be used as a resource for implementation of local programs to reduce GHGs. Grant funding for the project was provided by the MBUAPCD's FY2007-08 AB 2766 Motor Vehicle Emissions Reduction Program. The grant agreement commits the Monterey Bay Unified Air Pollution Control District (MBUAPCD) to develop the subject inventory.

The scope of the project is described in Attachment 1 of the grant agreement⁽²⁾. It requires the MBUAPCD to develop a screening level mobile source GHG inventory for Santa Cruz County in units of carbon dioxide equivalent (CO₂e). The inventory would be 2004 because that is the most recent year fully detailed in ARB's statewide 1990-2004 inventory series⁽³⁾. The inventory would use the same GHGs as used in the statewide mobile inventory.

3.0 METHOD

As described in Attachment 1 of the Grant Agreement, two approaches were to be considered for generating the county level inventory:

- The first would utilize county level GHG results for carbon dioxide (CO₂) and methane (CH₄) from Air Resources Board emission models for on-road motor vehicles (EMFAC2007) and off-road mobile sources (OFFROAD2007). Scaling factors for nitrous oxide (N₂O) for the various vehicle categories would be derived from the statewide inventory.
- For the second more direct approach, the District would request that the ARB run the statewide GHG inventory model with activity data specific to Santa Cruz County, thus producing a county level GHG inventory for Santa Cruz County.

Unfortunately, in responding to our request, ARB⁽⁴⁾ informed us that their inventory system was only capable of developing a statewide inventory at this time, although at some unknown point in the future, they may develop the ability to produce county level inventories. Consequently, it was necessary to develop the inventory with the first more resource intensive approach.

An inventory could have also been developed based on county level fuel usage records. However, this would be of limited value in terms of a planning resource because it would have only resulted in a gross bottom-line figure and would not have provided any breakdown by vehicle class which helps identify specific contributors to total emissions.

3.1 Inventoried Mobile Source GHGs

Although carbon dioxide is by far the largest GHG contributing to climate change, there are several other categories of gases recognized by the Intergovernmental Panel on Climate Change (IPCC), the authoritative scientific body on climate change, as contributing as well. The major groups of GHGs are shown in Table I.

TABLE I - GHGs RECOGNIZED BY THE IPCC

Greenhouse Gas	Abbreviation	Percent of State Inventory*
Carbon Dioxide	CO₂	90%
Methane	CH₄	6%
Nitrous Oxide	N₂O	4%
Sulfur Hexafluoride	SF ₆	0.6%
Hydrofluorocarbons	HFC's	<0.1%
Perfluorocarbons	PFC's	<0.1%

* Percent of ARB's 1990 Statewide Inventory in terms of Global Warming Potential

The three major greenhouse gases, CO₂, CH₄, and N₂O, may be emitted naturally or through human activities (e.g., the combustion of fossil fuels used in motor vehicles). The other three, SF₆, HFCs, and PFCs, are synthetic halogenated gases produced for industrial purposes. Many of the halogenated gases are being phased out under the Montreal Protocol on Substances that Deplete the Ozone Layer and are a very small component of the inventory. Consequently, the statewide ARB mobile source inventory, as well as this county level mobile source inventory, only includes the major GHGs CO₂, CH₄ and N₂O.

3.2 Global Warming Potential

Each greenhouse gas has a different capacity to trap heat in the atmosphere, with some much more effective at trapping heat than others. In order to have the inventory of the various gases reflect a common reference point, the IPCC developed the metric of a global warming potential (GWP) for each gas. The GWP allows comparison of the global warming influence of different greenhouse gases relative to CO₂. Total greenhouse gases can then be expressed as CO₂ equivalents or CO₂e.

The state level ARB inventory, as well as this inventory, uses GWPs from the IPCC Second Assessment Report to be compatible with national as well as international inventories.

The GWP factors for the GHGs of concern in this inventory are presented in Table II.

TABLE II - GLOBAL WARMING POTENTIAL (GWP) FACTORS

GHG Gas	GWP
Carbon Dioxide (CO ₂)	1
Nitrous Oxide (N ₂ O)	310
Methane (CH ₄)	21

Ref: ARB Staff Report, California 1990 Greenhouse Gas Emissions Level and 2020 Emissions Limit, page 3, November 16, 2007

The conversion is done by multiplying the gas specific emissions, typically in tons, by its GWP factor to arrive at CO₂e emissions. For instance, N₂O is 310 times more effective at trapping atmospheric heat than CO₂ so each ton of N₂O equates to 310 tons of CO₂e emissions.

3.3 Mobile Source Categories

The structure of the planning inventory mobile source emission inventory is typically divided into two major categories. The first major category is for on-road motor vehicles, which includes all the cars and trucks that travel on the county's paved roadways. The second is for off-road mobile sources, which includes construction and quarry equipment, agricultural equipment, boats etc. On-road sources are the major focus of this inventory, although figures for off-road mobile sources are also included to make the mobile source inventory complete.

The vehicle classes within the on-road and off-road inventories are established by the emission models that are used to develop the mobile source inventory. For on-road and off-road sources, the vehicle classes are defined by ARB's emission models EMFAC2007 and OFFROAD2007, respectively. These emission models are the same as used in the District's 2008 Air Quality Management Plan and 2007 Federal Maintenance Plan for ozone as well as the 2005 Particulate Plan. Use of these common models helps establish a common foundation for an integrated air quality planning process.

3.3.1 Description of the EMFAC2007 On-Road Motor Vehicle Emissions Model

Emissions from on-road motor vehicles at both the state and county level are estimated by the ARB's emission model called EMFAC. EMFAC estimates emissions from a wide variety of vehicles ranging from light duty passenger autos to heavy duty urban buses. This is a complex model which takes into account the composition and age of the vehicle fleet, adopted controls for motor vehicles as well as travel activity data from regional travel models. The current generation of this model is called EMFAC2007.

A key input to EMFAC affecting the estimated quantity of GHGs released to the air each day is the amount of travel activity on the county's network of highways and local roads. The region's Metropolitan Planning Organization, the Association of Monterey Bay Area Governments (AMBAG), develops this information for EMFAC using its regional transportation

model. The travel data used by EMFAC2007 for this inventory as well as the MBUAPCD's 2008 AQMP are from AMBAG's June 2005 Metropolitan Transportation Plan, which is the most recent data available. The activity indicators developed by AMBAG include the number of daily Vehicle Miles Traveled (VMT) by the county's vehicles, the number of daily trips and vehicle speed distributions during the trips. The resulting emissions can be annualized in EMFAC in order to produce emissions in tons per year.

Information regarding the county's on-road motor vehicle fleet, including the number of vehicles, type and age, is derived from Department of Motor Vehicles (DMV) registration data. ARB also includes an adjustment factor for unregistered and out of state vehicles.

3.3.2 On-Road Motor Vehicle Classes

The EMFAC model performs separate calculations for thirteen classes of vehicles, which are defined by weight and vehicle type. Emissions from each vehicle class are further broken down by fuel type and contain numerous technology sub-groups, which represent common emissions characteristics such as emission standards, technologies, or in-use emissions. The vehicle classes used by the model are shown in Table III.

TABLE III ON-ROAD MOTOR VEHICLE CLASSES MODELED IN EMFAC2007

Vehicle Class	Description	Weight Class (lbs)	Abbreviation
1	Passenger Cars	All	LDA
2	Light-Duty Trucks	0-3,750	LDT1
3	Light-Duty Trucks	3,751-5,750	LDT2
4	Medium-Duty Trucks	5,751-8,500	MDV
5	Light-Heavy-Duty Trucks	8,501-10,000	LHDT1
6	Light-Heavy-Duty Trucks	10,001-14,000	LHDT2
7	Medium-Heavy-Duty Truck	14,001-33,000	MHDT
8	Heavy-Heavy-Duty Trucks	33,001-60,000	HHDT
9	Line-Haul Vehicles	60,001+	LHV
10	Urban Buses	All	UB
11	Motorcycles	All	MCY
12	School Buses	All	SBUS
13	Motor Homes	All	MH

Ref – ARB's EMFAC Model User's Guide, Calculating Emissions Inventories for Vehicles in California, page 7.

It should be noted that the vehicle classes developed in EMFAC are more detailed than the IPPCC classes used in the statewide inventory. For instance, there is only a single Heavy Duty Vehicle category in the state inventory whereas EMFAC separates this single category into four classes including LHDT1, LHDT2, MHDT and HHDT. Consequently, some vehicle classes need to be combined when comparing to the state inventory.

3.3.1 Description of the OFFROAD Mobile Source Emissions Model

Emission estimates from a large spectrum of off-road equipment are developed by the ARB's emission model called OFFROAD. Many of the source categories involve heavy duty diesel engines that are used to power various equipment such as agricultural tractors, pumps and sprayers, as well as construction and mining equipment. OFFROAD uses information related to equipment population, activity, engine specific emissions and applicable control factors to estimate emissions. The model uses a tops-down approach to allocate state level equipment populations to the county level. This inventory uses the latest version of the model called OFFROAD2007.

3.3.2 Off-Road Equipment Classes

ARB's OFFROAD model estimates emissions for a wide array of off-road vehicles and equipment at both the state and county level. The categorical hierarchy of the model is determined by the distribution of off-road sources statewide, so some of the categories have little or no application to Santa Cruz County. The equipment categories used in OFFROAD, as well as examples of the equipment type, are summarized in Table IV.

TABLE IV - OFFROAD2007 EQUIPMENT TYPES BY CATEGORY

OFFROAD Equipment Category	Typical Examples
Lawn and Garden Equipment	Trimmers/Edgers/Brush cutters, Lawn mowers, Leaf blowers, Chainsaws, Lawn and garden tractors, Chippers/Stump grinders, Commercial turf equipment
Light Commercial Equipment ≤ 50 HP	Generator sets, Pumps, Air compressors, Gasoline compressors, Welding machines, Pressure washers
Recreational Equipment	All Terrain Vehicles, Off-road motorcycles
Industrial Equipment	Forklifts, Sweepers, Abrasive blasting equipment
Construction and Mining Equipment	Pavers, Tampers/Rammers, Rollers, Scrapers, Paving equipment, Surfacing equipment, Signal boards, Trenchers, Bore/Drill rigs, Excavators, Concrete/Industrial saws, Cement and Mortar mixers, Cranes, Grader, Off-Highway trucks, Crushers, Rough terrain forklifts, Rubber tire loaders, Rubber tire dozers, Tractors, Loaders, Backhoes, Crawler tractors, Off-Highway tractors
Agricultural Equipment	Agricultural tractors, Agricultural mowers, Sprayers, Balers, Tillers > 5 HP, Swathers, Hydro power units, Irrigation Pumps
Logging Equipment	Chain saws > 5 HP, Shredders > 5 HP, Log skidders, Fellers/Bunchers
Airport Ground Support Equipment	Cargo Loader, Forklift, Fuel Truck, Generator, Lift, Service Truck, Sweeper
Pleasure Craft	Powerboats, Auxiliary Sailboat Engines
Commercial Marine Vessels	Commercial in/outboard boats
Transport Refrigeration Units	Small units < 25 HP, Large units > 25 HP
Dredging	Compressor, Crane, Deck/door engine, Dredger, Generator, Hoist/swing/winch, Pump
Oil Drilling	Not Applicable
Military Tactical Support	Not Applicable
Locomotive and Rail Operations	Line haul operations, Yard operations
Commercial and General Aviation	Commercial and General Aviation Landing and Takeoff Ops
Agricultural Aircraft	Aircraft operations below 3,000 ft.

Ref. – ARB Mobile Source Mail Out MSC #99-32, Appendix A. (<http://www.arb.ca.gov/msei/offroad/pubs.htm>)

In all, there are 94 equipment types aggregated into the 14 categories shown in Table IV. Since the categories used are determined by the statewide array of off-road equipment, some of the categories have little or no application to Santa Cruz Co. Consequently, categories having inconsequential emissions are combined in the summary in order to consolidate minor contributors to the inventory. It should be noted that the emissions estimates do not include emissions from seagoing vessels traveling offshore in the international shipping lanes as these are outside the geographic boundaries of Santa Cruz Co.

4.0 RESULTS

Consistent with the statewide inventory, the results for the base year 2004 are presented in term of thousands of metric tons per year of equivalent CO₂ emissions (kilo-metric tons/yr CO₂e). For reference, one metric ton is 2,205 lbs or 1.103 tons

4.1 GHG Emissions from On-Road Motor Vehicles

Results by vehicle class are presented in Table V.

TABLE V 2004 GHG EMISSIONS FROM SANTA CRUZ COUNTY ON-ROAD MOTOR VEHICLES

CLASS	ON-ROAD VEHICLE DESCRIPTION	Abbr.	EMISSIONS	
			Kilo-Tons/Yr CO ₂ e	% On-Road GHG
1	Passenger Cars	LDA	422.9	37.6%
2	Light-Duty Trucks	LDT1	214.9	19.1%
3	Light-Duty Trucks	LDT2	225.1	20.0%
4	Medium-Duty Trucks	MDV	119.1	10.6%
5	Light-Heavy-Duty Trucks	LHDT1	27.7	2.5%
6	Light-Heavy-Duty Trucks	LHDT2	17.2	1.5%
7	Medium-Heavy-Duty	MHDT	47.1	4.2%
8 & 9	Heavy-Heavy-Duty Trucks	HHDT	16.9	1.5%
10	Urban Buses	UB	20.0	1.8%
11	Motorcycles	MCY	3.5	0.3%
12	School Buses	SBUS	3.4	0.3%
13	Motor Homes	MH	7.1	0.6%
ALL	ON-ROAD TOTAL	ALL	1,124.9	100.0%

As shown in the table, total emissions of GHGs in Santa Cruz County in 2004 are estimated to be 1,125 Kilo-Tons/Yr CO₂e. The represents about 0.7 % of the 2004 statewide on-road motor vehicle GHG inventory and is approximately the same % as the county to statewide VMT ratio. As can be seen from the table, LDAs are the largest single categorical contributor to on-road GHG emissions, accounting for about 38% of 2004 county's emissions.

The combined light duty autos and truck categories accounted for over three quarters of on-road GHG emissions.

Figure 1 further illustrates the relative contribution by vehicle class.

FIGURE 1

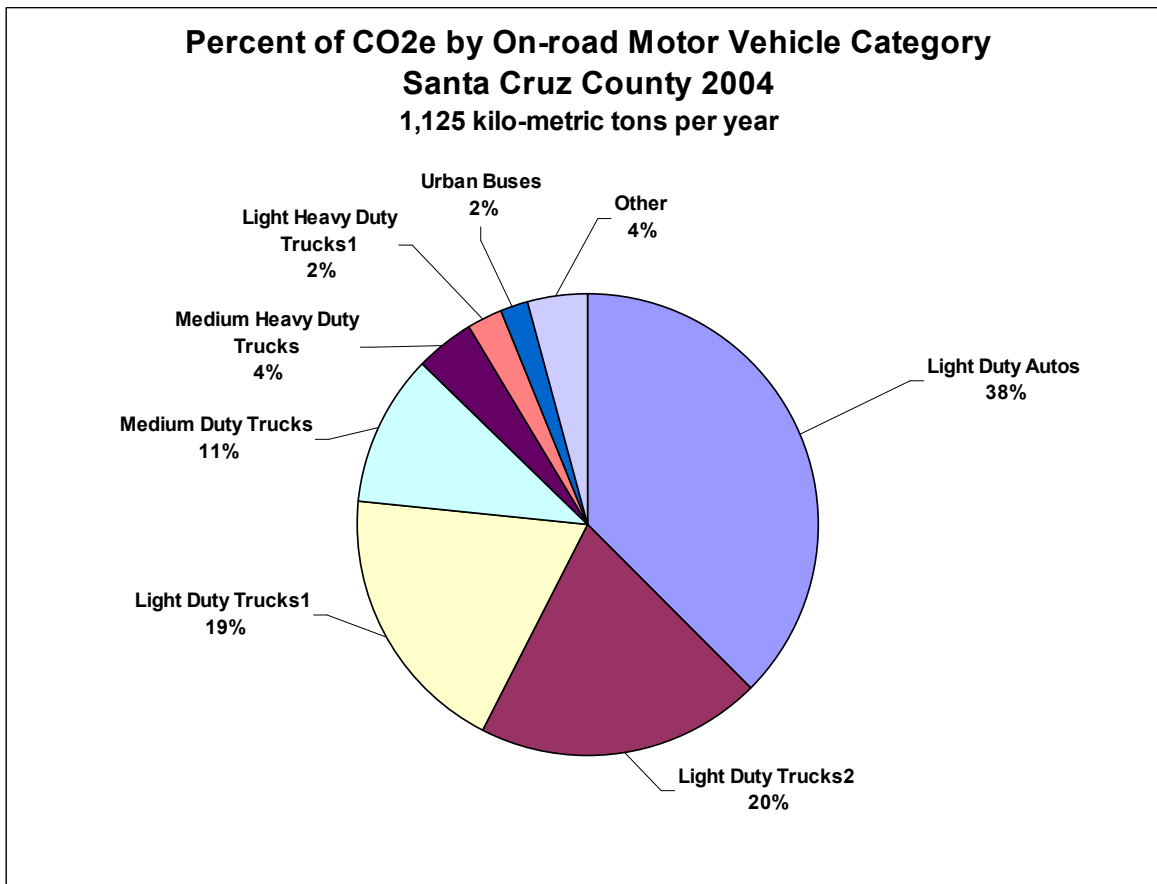


Table VI shows the contribution to Santa Cruz County on-road motor vehicles GHGs by component gas.

TABLE VI CONTRIBUTION TO ON-ROAD MOTOR VEHICLE GHG EMISSIONS BY COMPONENT GAS

Component Gas	EMISSIONS	
	Kilo-Tons/Yr CO ₂ e	% On-Road GHG
Carbon Dioxide (CO ₂)	1,092.7	97.1 %
Nitrous Oxide (N ₂ O)	28.0	2.5 %
Methane (CH ₄)	4.2	0.4 %
TOTAL	1,124.9	100.0%

As shown, the dominant component gas contributing to on-road motor vehicle CO₂e emissions of GHGs is direct CO₂, accounting for 97% of all CO₂e emissions. Direct CO₂ accounts for about 97% of GHGs from on-road motor vehicles at the state level as well.

4.2 VMT to CO₂e Emissions for On-Road Motor Vehicles

Although beyond the scope of the initial project, which was to develop a county level GHG emission inventory, the usefulness of the inventory could be enhanced if a tool were available to allocate emissions to the sub-county or jurisdictional level. A primary driver of GHG emissions is VMT. Consequently, the District has developed a series of emissions to VMT scalars by vehicle class which can be used for this purpose. If VMT travel data are available at the jurisdictional or institutional level of concern, the user can simply multiply the VMT by the appropriate CO₂e/VMT factor to estimate the lbs of CO₂e emitted.

Table VII summarizes these relationships for the major vehicle classes:

TABLE VII 2004 GHG VMT TO GHG EMISSION FACTORS FOR SANTA CRUZ COUNTY ON-ROAD MOTOR VEHICLES

CLASS	ON-ROAD VEHICLE DESCRIPTION	Lbs CO ₂ e/VMT	Ratio to LDA
1	Passenger Cars (LDA)	0.88	1.00
2 & 3	Light-Duty Trucks	1.03	1.17
4	Medium-Duty Trucks	1.11	1.27
5 to 9	Heavy Duty Trucks	4.14	4.72
10	Urban Buses	5.49	6.26
11	Motorcycles	0.28	0.32
12	School Buses	2.57	2.93
ALL	ON-ROAD TOTAL	1.06	1.21

Interestingly, a convenient rule of thumb emerges from the results and that is for the light duty vehicle classes, the primary classes of concern, there is approximately 1 lb of CO₂e emitted for each Vehicle Mile Traveled. Additional detail on VMT by vehicle class is provided in Appendix A.

4.3 GHG Emissions from Off-Road Mobile Sources

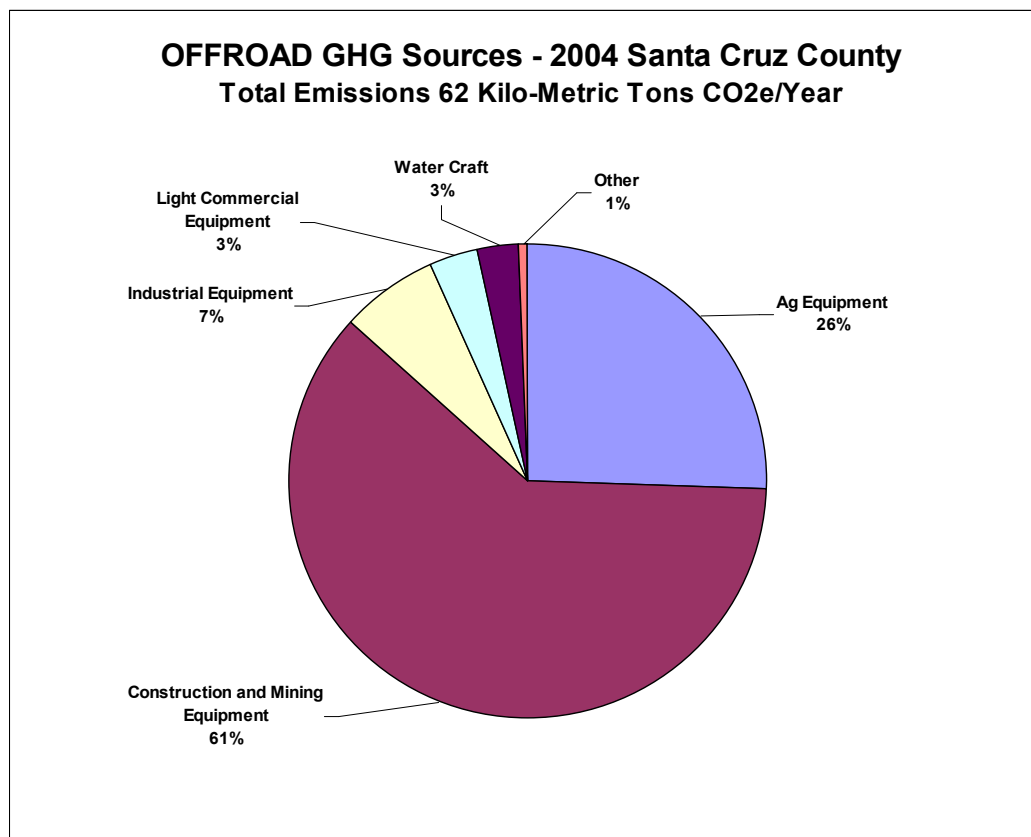
Results by equipment class are presented in Table VIII.

TABLE VIII 2004 GHG EMISSIONS FROM SANTA CRUZ COUNTY OFF-ROAD MOBILE SOURCES

OFF-ROAD EQUIPMENT CATEGORY	EMISSIONS	
	Kilo-Tons/Yr CO ₂ e	% Off-Road GHG
Construction and Mining	38.0	61 %
Ag Equipment	16.0	26 %
Industrial Equipment	4.3	6.9 %
Light Commercial Equipment	2.1	3.4 %
Water Craft	1.7	2.7 %
Other	0.3	<0.0 %
OFFROAD TOTAL	62.4	100 %

The table shows that there was approximately 62.4 kilo-metric tons of CO₂e GHGs emitted by off-road mobile sources in 2004, which is a small fraction of that emitted by on-road mobile sources. The primary contributor is emissions from construction and mining equipment, which accounted for over 60% of the off-road emissions, followed by ag equipment, which accounted for over a quarter of all off-road emissions of GHGs. This distribution is further illustrated in the Figure 2 pie chart.

FIGURE 2



4.4 GHG Emissions from All Mobile Sources

Table IX summarizes the combined mobile source emissions from both on-road and off-road sources.

TABLE IX 2004 GHG EMISSIONS FROM ALL SANTA CRUZ COUNTY MOBILE SOURCES

MOBILE CATEGORY	EMISSIONS	
	Kilo-Tons/Yr CO ₂ e	% Mobile GHGs
On-Road Motor Vehicles	1,124.9	94.7 %
Off-Road Mobile Sources	62.4	5.3%
TOTAL	1,187.3	100.0 %

Combining the two inventories reveals that the mobile source inventory of GHGs in Santa Cruz County is dominated by emissions from on-road motor vehicles, accounting for nearly 95% of total mobile emissions. These occur primarily in the form of direct emissions of CO₂ from light duty cars and trucks traveling on the counties roadways.

REFERENCES

- (1) Assembly Bill No. 32, California Global Warming Solutions Act of 2006, Chapter 488, Division 25.5, California Health and Safety Code.
- (2) Grant Agreement 08-26, Attachment 1, Santa Cruz County Study of Vehicular GHG Emissions FY 2007-08 AB 2766 Motor Vehicle Emissions Reductions Program.
- (3) Air Resources Board, Draft California 1990-2004 Greenhouse Gas Inventory by IPCC Category, November 19, 2007.
- (4) Email Correspondence with Webster Tasat, Manager ARB Emission Inventory Branch, October 11, 2007.
- (5) ARB User's Guide, EMFAC Version 2.08/Version 2.20, Calculating Emissions Inventories for Vehicles in California
- (6) ARB Technical Support Document, OFFROAD Model, Adoption of the Proposed Regulation for In-Use OFF-ROAD Diesel Vehicles, May 24, 2007.
- (7) Appendix E, Emissions Inventory – Methodology and Results, ARB Technical Support Document, OFFROAD Model, Adoption of the Proposed Regulation for In-Use OFF-ROAD Diesel Vehicles, May 24, 2007.
- (8) Appendix I, Climate Change Impacts, ARB Technical Support Document, OFFROAD Model, Adoption of the Proposed Regulation for In-Use OFF-ROAD Diesel Vehicles, May 24, 2007.
- (9) Air Resources Board Mobile Source Mail out Document MSC #99-32, Appendix A (<http://www.arb.ca.gov/msei/offroad/pubs.htm>)
- (10) ARB Staff Report, California 1990 Greenhouse Gas Emissions Level and 2020 Emissions Limit, page 3, November 16, 2007.

APPENDIX A

*Emission Inventory Detail for On-Road Motor Vehicles
Standard 2004 BURDEN Summary from EMFAC2007*