

## **Appendix F**

### **Emission Inventory Description**

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# 1. Introduction

## **Purpose**

This **Emission Inventory Appendix** describes the emission inventory and the role it plays in the State Implementation Plan (SIP) development process. An emission inventory is an estimate of the amount and type of pollutants emitted into the atmosphere over a defined period of time. Emission inventories serve three principal roles in the development of the SIP:

- They provide the emissions data used for developing control strategies;
- They are a primary input to photochemical modeling used in attainment demonstrations; and
- They are used to track progress in meeting the emission reduction commitments.

This document will discuss the requirements for SIP development as it pertains to emission inventories, describe the elements (or sectors) that make up an emission inventory, provide an overview of the methodologies used to derive emission estimates, summarize the recent improvements to the emission inventory, and explain how the emission inventory is documented through Quality Assurance (QA) and Quality Control (QC).

## **Statutory Requirements**

The federal Clean Air Act (CAA) contains the statutory requirements for attaining clean air (air quality standards). The U.S. Environmental Protection Agency (U.S. EPA) regulations list requirements pertaining to emissions information that must be included as part of the SIP submittal package. The regulations require that the SIP emission inventory contain the pollutants for which an area is nonattainment. For an 8-hour ozone SIP, the emission inventory must contain the two ozone precursors: oxides of nitrogen (NO<sub>x</sub>) and reactive organic gases (ROG). (The terms, ROG and VOC (volatile organic compounds), are used interchangeably in this document.) For the PM<sub>2.5</sub> SIP, the emission inventory must contain directly emitted PM<sub>2.5</sub> and PM precursors: NO<sub>x</sub>, ROG, sulfur oxides (SO<sub>x</sub>), and ammonia (NH<sub>3</sub>).

## **Emission Inventory Overview**

### **Basic Elements of the Emission Inventory**

An emission inventory is a critical tool in the evaluation of air pollution. Very simply, an emission inventory is a systematic listing of the sources of air pollution along with the amount of pollution emitted from each source or category over a given time period. Emission inventories are an estimate of the air pollution emissions that are actually released into the environment—they are not measurements of ambient concentrations. The following are examples of pollution sources by key sectors:

- Industrial sources—power plants and oil refineries;
- Area-wide sources—consumer products and residential fuel combustion for heating homes;
- On-road sources—passenger vehicles and heavy-duty trucks;
- Off-road mobile sources—aircraft, trains, ships, recreational boats, construction equipment and farm equipment; and
- Non-anthropogenic (natural) sources—biogenic (or vegetation), geogenic (petroleum seeps), and wildfires.

The first four sectors listed are examples of anthropogenic, or human caused, emission sources. California's statewide emission inventory includes over 17,000 individual facilities (or point sources) where business addresses are specifically identified. These facilities comprise approximately 14,000 process/industry types.

The emission inventory also includes approximately 450 area-wide source categories. The area-wide source categories include aggregated point sources, or facilities, that are not inventoried individually but are estimated as a group and reported as a single source category, for example, gas stations and dry cleaners. Area-wide sources typically are associated with human activity and take place over a wide geographic area. Consumer products and unpaved road dust are additional examples of area-wide sources. The complete methodologies for these and all area-wide source categories can be found at: <http://www.arb.ca.gov/ei/areasrc/areameth.htm>.

The mobile source emission inventory is developed by ARB's emission factor models - EMFAC and OFFROAD. EMFAC estimates on-road emissions from all on-road motor vehicles, from passenger cars through heavy duty diesel trucks, and groups them in 250 categories (or technology groups). Off-road categories include emissions from all vehicles and equipment that operate off-road which includes aircraft, locomotives, lawn and garden, cargo handling, construction, and ships and harbor-craft. OFFROAD groups these equipment into 1300 categories. For each category in EMFAC and OFFROAD, emissions are given by emission mode (e.g. running exhaust, starts, evaporative losses, and tire and brake wear).

Non-anthropogenic sources generally include source categories with naturally occurring emissions such as wildfires and geogenic sources (e.g., petroleum seeps).

### **Agency Responsibilities**

ARB works jointly with the thirty-five local air pollution control and air quality management districts (districts) to develop a comprehensive statewide emission inventory. Districts are responsible for developing emission estimates for major facilities (point sources) in their jurisdictions by working closely with facility owners. Districts are also responsible for developing emission estimates for approximately one-third of the non-point (or area-wide) sources.

ARB is responsible for developing the mobile source inventory (both on-road and off-road sources) and the remaining two-thirds of the area-wide sources. ARB works with other state agencies including the California Department of Transportation (CalTRANS), the Department of Motor Vehicles (DMV), and local councils of government (COGs) to assemble motor vehicle activity information necessary for the mobile source emission estimation models. To estimate emissions for the remaining two-thirds of the area-wide sources, ARB works jointly with State agencies, such as the Department of Pesticide Regulation (DPR) which develops the emission estimates for pesticides and the California Energy Commission which maintains power production and energy demand data that are critical for estimating future emissions growth from power plants.

### **Pollutants and Precursors**

California's ozone attainment strategy is to reduce emissions of ozone precursors – NO<sub>x</sub> and VOC. The strategy for reducing PM<sub>2.5</sub> focuses on reducing NO<sub>x</sub>.

### **Oxides of Nitrogen (NO<sub>x</sub>)**

NO<sub>x</sub> from anthropogenic sources occurs primarily when fossil fuels are combusted at high temperatures. The table below shows that in 2006, 85 percent of NO<sub>x</sub> emissions in California are generated from mobile sources such as cars, trucks, buses, aircraft, and trains, while area-wide and stationary sources contribute the remaining 15 percent.

### **2006 Statewide Emission Inventory – Nitrogen Oxides**

<b>NO<sub>x</sub> Emissions (Annual Average)</b>		
<b>Source</b>	<b>Tons/day</b>	<b>Percent</b>
<b>Stationary</b>	<b>419</b>	<b>12 percent</b>
<b>Area-wide</b>	<b>96</b>	<b>3 percent</b>
<b>On-road Mobile</b>	<b>1848</b>	<b>51 percent</b>
Gasoline vehicles	679	19 percent
Diesel vehicles	1169	32 percent
<b>Other Mobile</b>	<b>1235</b>	<b>34 percent</b>
Gasoline vehicles	76	2 percent
Diesel vehicles	825	23 percent
Other	333	9 percent
<b>Total Statewide</b>	<b>3598</b>	<b>100 percent</b>

## Reactive Organic Gases (ROG)

Reactive Organic Gases<sup>1</sup> are any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participate in atmospheric photochemical reactions to form ozone and particulate matter (PM10 and PM2.5) in the atmosphere. References ii and iii provide information on the differences between ROG and VOCs.

The primary anthropogenic sources of ROG in California, as shown in the table below, are on-road mobile which includes exhaust, fuel evaporation, and incomplete fuel combustion, and area-wide sources which includes solvents from dry-cleaning, degreasing, and coating operations.

### 2006 Statewide Emission Inventory – Reactive Organic Gases

ROG Emissions (Annual Average)		
Source	Tons/day	Percent
<b>Stationary</b>	<b>389</b>	<b>17 percent</b>
<b>Area-wide</b>	<b>654</b>	<b>28 percent</b>
<b>On-road Mobile</b>	<b>743</b>	<b>32 percent</b>
Gasoline vehicles	670	29 percent
Diesel vehicles	73	3 percent
<b>Other Mobile</b>	<b>541</b>	<b>23 percent</b>
Gasoline vehicles	389	17 percent
Diesel vehicles	111	5 percent
Other	41	2 percent
<b>Total Statewide</b>	<b>2327</b>	<b>100 percent</b>

## Particulate Matter (PM2.5)

Particulate matter (PM) is a complex mixture of varying sized particles and liquid droplets including components such as acids, organic chemicals, metal, and soil or dust. There are two types of PM: primary and secondary. Primary PM is emitted directly from a source, such as unpaved roads, fires, and demolition or construction sites. Secondary PM is formed by complex reactions in the atmosphere with chemicals such as sulfur and nitrogen dioxides. The majority of “fine particles” (PM2.5) is formed by these complex reactions. A subset of PM2.5 of particular concern are those that are emitted by diesel engines.

## 2006 Statewide Emission Inventory – PM2.5

<b>PM Emissions (Annual Average)</b>		
<b>Source</b>	<b>tons/day</b>	<b>Percent</b>
<b>Stationary</b>	<b>103</b>	<b>13 percent</b>
<b>Area-wide</b>	<b>568</b>	<b>70 percent</b>
<b>On-road Mobile</b>	<b>66</b>	<b>8 percent</b>
Gasoline vehicles	15	2 percent
Diesel vehicles	43	5 percent
Break & Tire wear	8	1 percent
<b>Other Mobile</b>	<b>81</b>	<b>10 percent</b>
Gasoline vehicles	10	1 percent
Diesel vehicles	41	5 percent
Other	29	4 percent
<b>Total Statewide</b>	<b>817</b>	<b>100 percent</b>

### Geographic Considerations

In California, the emission inventory is constructed at the district, air basin, and county levels. This provides the flexibility needed to meet the jurisdictional requirements of local and State governments while addressing the spatial aspects of air quality issues. In cases where nonattainment areas do not line up with these geographic boundaries, ARB further resolves the inventory to estimate the portion of emissions that occur within nonattainment area boundary lines. This is done by selecting only the point sources that fall within the nonattainment area boundaries, and estimating the emissions contribution of each area-wide and mobile source category to the nonattainment area.

California recently approved the statewide Emission Reduction Plan for Ports and Goods Movement that extends the off-shore boundaries for estimating the emission impact from shipping activities, thus leading to a modification in the geographic accounting of the off-shore emissions in the inventory. Formerly, only marine emissions occurring within a 3-mile range were included as part of California's emission inventory. The SIP emission inventory now includes emissions from shipping activities out to 100 miles. In the new definition, emissions occurring within three miles of the shore line are assigned to the nearest air basin (e.g., emissions occurring within three miles of the Los Angeles County shore line are assigned to Los Angeles County in the South Coast Air Basin). Emissions occurring outside the 3-mile boundary are assigned to the Outer Continental Shelf Air Basin, but are still associated with the responsible county and district (e.g. the emissions occurring outside of the 3-mile boundary of Los Angeles County would be assigned to the Outer Continental Shelf Air Basin and would be the responsibility of the South Coast Air District).



## **Base Year Inventory Selection for the SIP**

The SIP is based on emission projections that are linked to a base year inventory. U.S. EPA identified 2002 as the emission inventory base year for the 8-hour ozone and PM<sub>2.5</sub> SIPs. This selection was announced by memoranda to the States in November 18, 2002<sup>2</sup>.

## **Emission Estimation Concepts**

The key to the emission inventory is found in what is termed the “emission process”. The emission process defines the fundamental level at which emissions are calculated, stored, and maintained in the inventory. The total emissions for each emission process are calculated by applying a process rate (i.e., the number of emission activity units) to the emission factor (i.e., the amount of emissions per activity unit).

In principle, this simple concept holds for all emission sectors (i.e., point, area-wide, on-road mobile, and off-road mobile). Differences lie in the method or approach used to derive the process rate and emission factors. For example, the emissions from a power plant could be calculated by applying an emission factor (pounds of emissions per megawatt-hour) times the number of megawatt-hours of electrical energy generated. The emissions from the light-duty passenger car fleet could be calculated by applying an emission factor (grams of emissions per mile traveled) times the total vehicle miles traveled (VMT) for that mobile category. It should be noted that the examples above are simplified—particularly for on-road and off-road emissions. These emission factors are specific to model year, technology and fuel type, and are adjusted for temperature, humidity, and operating speed.

## **Emission Forecasting Overview**

Emissions forecasting depends on two independent variables: growth and control. For stationary sources, socioeconomic growth profiles are developed and linked to the inventory via the inventory process and/or industry types. For example, power plant growth is estimated based on the combined effects of economic growth in the sector along with the projected energy utilization by the California Energy Commission (CEC). Growth for consumer products is estimated by population growth at the county level. These growth profiles are constructed for the entire timeframe addressed in the SIP.

The California Emission Forecasting System (CEFS) includes growth data for the period 1990–2030 for SIP forecasting exercises. Similarly, control profiles are constructed to reflect adopted emission control measures. A control profile is developed that describes the implementation of the rule and the profile is included as part of the baseline CEFS forecasts. CEFS projections are run for the entire State by applying the growth and control profiles to the 2002 base year inventory to obtain the projections needed for SIP analysis.

EMFAC and OFFROAD do not use a base year projection approach. Rather, the emission models employ sophisticated routines that predict vehicle fleet turnover by vehicle model year. As with stationary sources, EMFAC and OFFROAD include control

algorithms that account for all adopted regulatory actions (e.g., an amended emission standard to be implemented by a certain year, or increased stringency on a roadside inspection program to be implemented in a future year) which, when combined with the fleet turnover algorithms, provide baseline projections.

CEFS integrates the projected inventories for stationary and mobile sources into a single database to provide a comprehensive statewide forecast inventory. Nonattainment area inventories are extracted from this comprehensive inventory. This establishes the baseline projections from which the SIP inventory is constructed. The data are accessible to ARB and district planners via user-friendly web reporting tools.

## **Types of Inventories (Annual Average, Seasonal, Modeling)**

### Annual Average

Annual average emissions data by major source category in tons per day are derived from a simple average by taking the annual emissions reported (or estimated) in tons per year and dividing the emissions by 365 days.

### Seasonal Inventories

Summer and winter planning emissions take into account the temporal variation (e.g. activity variation) of emissions at a facility or a source category throughout the year. This is accomplished by collecting throughput or activity data from point source facilities where available, and developing temporal profiles for area sources to estimate monthly variation of the emissions. CEFS calculates summer and winter planning emissions based on these temporal data. The summer planning season for California is May-October, and the winter planning season is November-April. (Note: U.S. EPA assumes a shorter summer planning period (June-August) in its temporal data collection schema.) California requires planning evaluations to be based on a longer summer because it experiences longer periods in which temperatures are warm enough to contribute to ozone formation than most other states). The summer season planning emission inventory is used in ozone SIP planning.

### Modeling Inventories

CEFS also generates emission inputs for photochemical modeling exercises. The categories handled by CEFS are stationary, area-wide and off-road mobile sources. (Note: Modeling emissions for the on-road sector are generated with EMFAC/DTIM, and these modeling inputs are handled outside of CEFS.) Modeling inventories are month/day-specific estimates that are temporally and spatially resolved at a finer level than planning inventories—CEFS calculates emissions for a typical weekday or a typical weekend day based on weekly operation profiles identified for the emissions processes. Point source locations are identified in CEFS by the Universal Transverse Mercator (UTM--North American Datum (NAD83) version) geographic coordinate system. Modeling inventory projections include facility level emissions at the facility, device, and process level with stack locations and associated flow characteristic as applicable. Area source emissions are maintained at the county level and are further resolved

based on spatial surrogates as a post-processing step prior to modeling. The day specific emissions are generated for typical weekday and weekend periods.

### Planning and Modeling Inventory Differences

The temporal information used to determine seasonal planning inventories is also used to develop month/day-specific modeling inventories—the data are just further resolved for modeling inventories. It should be noted that modeling inventories generated by CEFS are not actual day specific emissions based on field studies—they are estimates of emissions for “typical” operating conditions. In some cases, “actual” day-specific information is available and this can be used to overwrite the results of the CEFS emission modeling inventory outputs. It is important to note that because modeling inventories are month/day-specific, the emission numbers will not match the planning inventory emissions.

## **2. Emission Inventory Improvements**

### Overview

ARB devotes substantial effort to continually improve the emission inventory. Updates to the inventory occur through three processes: planning and development, regulatory support, and special studies. The new information acquired and methodologies developed are folded back into the models as well as the methodologies for sources not previously included. This is a dynamic process and ARB will continually work to improve its methodologies through research and stakeholder feedback.

### Improvement Process

#### **Planning and Development - SIP**

The planning process is undertaken to develop strategies for meeting air quality goals. The SIP inventory is the centerpiece data element for determining future attainment in photochemical modeling exercises, and the basis for defining control strategies.

#### **Regulatory Support**

The regulatory process identifies potential emission reductions. This typically involves new surveys to gather the most up-to-date data (e.g. equipment activity and populations). These improved data allow for more accurate emission estimates and identify key areas where reductions can be achieved. The planning and regulatory processes are also used to solicit peer review and stakeholder input.

#### **Special Studies / Research**

Another mechanism through which improvements are made is special studies. These studies may or may not be associated with the SIP or regulatory support processes but are used to further the understanding of emission modeling and verification. Special studies include funding or participating in cutting edge research projects, developing

innovative emission inventory methodologies, and collaborating with industry, academia and the public to better understand emissions processes. Examples of special studies include, but are not limited to, Southern California Ozone Study and Central California Ozone Study related research. The results from these projects have provided data that allow validation checks between observed air quality and emission trends<sup>3</sup>, and emissions associated with air quality exceedances<sup>4</sup>.

### **Stakeholder Outreach**

ARB works jointly with other State agencies, districts, and stakeholders to develop a comprehensive emission inventory on an annual basis. Comprehensive inventories are submitted triennially and partial inventories are submitted annually to U.S. EPA for the National Emission Inventory<sup>5</sup> (NEI). ARB also publishes the most current emission inventory in the annual Almanac of Emissions and Air Quality<sup>6</sup>.

### **Quality Assurance/Quality Control (QA/QC)**

QA/QC is a formal process focused specifically on ensuring the integrity and accuracy of the inventories for the California 2007 8-hour ozone SIP and PM2.5 SIP in California. ARB formally initiated this comprehensive effort in September 2004 through its Emission Inventory Technical Advisory Committee (EITAC). This started an iterative process of continual updates to the 2002 base year emission inventory for stationary point and area-wide sources (including growth and control data), leading up to the finalization of the SIP inventory. In addition, ARB emission inventory staff worked jointly with the ARB's modeling staff through the Gridded Emission Coordination Group that includes district modeling staff and industry representatives. A principle aim of this group is to provide a critical feedback loop to emission inventory staff to ensure that inventory inputs have been reliably prepared for use in photochemical modeling.

The statewide emissions inventories are assembled and maintained by ARB in the California Emission Inventory Development and Reporting System (CEIDARS) and California Emission Forecasting and Planning Inventory System (CEFS) databases. Before an emission inventory is approved, a series of checks are performed to assure that the correct statewide emissions estimates are reported. Upon completion of the models, various scenarios are run to provide emissions by county, air basin, district, EIC code, pollutant, calendar year, and season. Queries are then run on these scenarios to provide the statewide emission totals by pollutant and year. Finally, as a check to ensure that what CEFS estimates as state totals match what EMFAC/OFFROAD estimates, the CEFS queries are matched against EMFAC/OFFROAD model output.

Inventory verification<sup>7</sup> is another important step to ensure the accuracy of the emission inventory. Since 1987 there have been a number of studies that have contributed to model development. In these tests, emissions from vehicle fleets are compared to output for similar fleets calculated from the EMFAC model. Comparisons have been made between EMFAC fuel consumption estimates and actual fuel sales for that fleet reported by the State Board of Equalization, and emissions derived from fuel sales and remote sensing data.

## **Specific Category Improvements**

### **Stationary**

Methods for estimating emissions from industrial point sources have continually improved as district staff work with facility owners to ensure that reported emissions are real as opposed to permitted (or potential) values. The California Clean Air Act Fee Regulation imposes fees on large permitted point sources thus encouraging facility owners to report the most accurate emissions possible. ARB audits the district emission inventory programs on a planned cycle to further ensure that emission inventory program requirements are met.

### **Area-wide**

New survey data for consumer products and architectural coatings improve the aggregated inventory estimates as well as a better characterization of emissions at the product type. Currently there are 152 consumer product categories and 56 architectural coatings categories - the 1994 SIP inventory only had three categories each. The same is true for degreasing categories - the 1994 SIP had only five categories and the current inventory now has 32 categories. Improvements have also been made to the agricultural industry categories as a result of a partnership between ARB and the agricultural community. ARB participates in an ad-hoc agricultural advisory committee to approve methods used for estimating base year emissions and future year growth and control assumptions for forecasting. The methodologies for the following categories have also been updated: auto refinishing, industrial coatings and solvents, livestock husbandry, pesticides, waste burning, wildland fire use, ammonia, and wineries. The most recent improvements to the area-wide emission inventory sectors are described below:

- *Ammonia*

A comprehensive 2002 ammonia inventory was developed for all area-wide sources (in addition to on-road, off-road, and natural sources). The emissions were calculated using data provided in reports by ENVIRON and the NASA Ames Research Center.

- *Architectural Coatings*

In response to the California Clean Air Act Fee Regulation, several architectural coating manufacturers submitted revisions to their 2001 survey data (calendar year 2000 sales). The changes in sales volume and emissions were applied uniformly across all categories.

- *Auto Refinishing*

This category was updated using data from a 2001 ARB survey and the emissions were grown to 2002.

- *Consumer Products*

Two sets of changes have been incorporated into the consumer products inventory. First, manufacturers submitted revisions to their 1997 survey data in response to the California Clean Air Act Fee Regulation and resulted in updates for 13 categories. Next,

results of the 2001 Consumer Products Survey have been incorporated. Some categories have been expanded and several new categories have been added.

- *Industrial Coatings and Solvents*

The emissions for several of these categories have been updated using the U.S. Census Bureau's 2002 Industrial Report for Paint and Allied Products. The nationwide consumption data were apportioned to California using manufacturing employment data for the industry sectors likely to use the specific types of industrial coatings.

- *Livestock Husbandry*

ARB published a new methodology in 2004 for estimating ROG emissions from livestock facilities including dairies, feedlots, poultry operations, and other confined animal facilities. The methodology also includes PM estimates for dairies and feedlots. The emission estimates are based on animal population data from the year 2000. ARB uses district-specific data where available and employs a generalized methodology where data are lacking. For permitting purposes and to more fully reflect the process-specific livestock emissions, the San Joaquin Valley Air District has adopted livestock emission factors that differ from the ARB default values.

- *Pesticides*

The pesticide inventory includes the emissions from agricultural and structural applications. Updated emissions for 2003 are calculated using information from the annual Pesticide Use Report (PUR) database and pesticide product emission potential (EP) data maintained by the California Department of Pesticide Regulation (DPR). The EPs that are assigned to the products are either measured by thermogravimetric analysis (TGA), calculated by DPR chemists, or assigned a default value equal to the median TGA-based EP in each formulation category. Prior to 2002, DPR assigned EP values to products with no measured values as the maximum TGA in that category. The use of median rather than maximum TGA values has resulted in a significant lowering of ROG emissions for pesticides with default emission values. The average 2003 TOG and ROG emissions from all agricultural and structural pesticides were 55 percent lower in 2003 than in 1995. The most significant reduction was in the structural methyl bromide category, likely due the Montreal Protocol, which mandates the phase-out of methyl bromide.

- *Waste Burning*

Emissions result from the waste burning of agricultural residues, weed abatement, range improvement, and other materials. Although this is a district-reported category, ARB has developed default 2002 emission estimates for several districts that have not provided updates in recent years. Updated emissions data have been developed for the following areas: South Coast Air Basin, Mojave Desert Air Basin, San Diego Air Basin, Salton Sea Air Basin, Amador County, and Western Nevada County. There have been no changes to the underlying methodology for calculating emissions. The emissions are based on district-reported burning activity. Emission factors and fuel loading values have been expanded to include more specific crop types.

- *Wildland Fire Use (WFU)*

A WFU is a naturally ignited lightning fire that is managed for resources benefit. The WFU emission inventory category was created in 2004, and inventory back-populated to 1994 where data were available. WFU emissions are calculated using the Geographic Information System (GIS) based Emission Estimating System model developed for ARB by UC Berkeley's Center for the Assessment and Monitoring of Forest and Environmental Resources laboratory.

- *Wineries*

This is a newly updated methodology for wine fermentation emissions. The emission factors for wine fermentation have not been updated from the older methodology, but the source of wine fermentation activity has been updated. The Tax and Trade Bureau (TTB) is now the source of estimates for amounts of wine fermented in the state. Temporal data gained from the TTB records allow us to give detailed monthly breakouts of wine fermentation in the state.

## **Mobile**

ARB is continually improving EMFAC and OFFROAD, and emission inventory elements as represented in each model. The following discussion includes evolution of EMFAC and OFFROAD, inventory verification, and improvements made for EMFAC2007 and the SIP.

### On-road

The following are modifications to the model and the inventory since the last SP. For a more thorough technical explanation please refer to the tech memos at <http://www.arb.ca.gov/msei/msei.htm>, and [http://www.arb.ca.gov/msei/onroad/previous\\_version.htm](http://www.arb.ca.gov/msei/onroad/previous_version.htm). The changes below are those changes reflected in EMFAC2007 that have occurred since EMFAC2002.

- *Revisions to the Methodology used to Characterize the On-road Vehicle Fleet*  
Vehicle population data by class, age and geographic area used in EMFAC are based on the Vehicle Registration Database maintained by the California Department of Motor Vehicles (DMV). EMFAC back-casts historic changes in vehicle population using the oldest DMV data available, and forecasts from the most recent. As new data are received, projections are replaced with actual data. EMFAC2007 population estimates were updated based on 2000-2005 data.

- *Modification of Mileage Accrual Rates*

Previous mileage accrual rates were based on Smog Check data acquired from 1991-1995. To more accurately model vehicle miles traveled, the new model incorporates data from Bureau of Automotive Repair (BAR) 2001-2003 for the following gasoline powered vehicle classes: passenger cars, light-duty trucks (Tiers 1 and 2), medium-duty trucks, light heavy-duty trucks (Tier 4 and 5), and motor homes.

- *Updating Vehicle Miles Traveled and Speed Distributions*

Vehicle miles traveled and speed distributions were submitted by transportation planning agencies for the South Coast, the San Francisco Bay Area, and San Diego and Santa Barbara Counties and used to update EMFAC.

- *Modifications to the Inspection Maintenance Programs*

Modifications were made to reflect the changes in inspection and maintenance (I&M) programs for areas that upgraded to the enhanced Accelerated Simulation Mode program and change-of-ownership exemptions.

- *Ethanol Permeation*

In the prior EMFAC, evaporative emissions were correlated to oxygen content. Evaporative emissions from methyl-tert-butyl ether (MTBE) and ethanol (EtOH) were assumed to be similar since both contained two percent oxygen. Because recently completed studies indicate that EtOH has much higher permeation rates through fuel tank walls, hoses and fittings, EMFAC was modified to reflect these findings.

- *Revision of Heavy Heavy-Duty Diesel Truck Emission Factors and Speed Correction Factors*

New chassis dynamometer testing data developed through the CRC E55-59 program were analyzed and integrated into EMFAC. Emission factors for this category reflect all available data from CRC as well as other data sets. These data were used to develop new emission factors and speed correction factors. New tampering, mal-maintenance and malfunction survey data were used to update deterioration rates, demonstrating that heavy heavy-duty diesel truck emissions are greater than previously estimated. Trucks were for the first time tested over an ARB-developed heavy-heavy-duty test cycle, generating idle emissions data covering a wide span of model years as well as emission data at several different speeds and idle. These new data have been adopted by ARB and used to generate new emission factors and new speed correction factors.

- *Redistribution of Heavy Heavy-Duty Diesel Truck Vehicle Miles Traveled in California*

Vehicle miles traveled estimates are provided by the transportation planning agencies, but ARB is responsible for the distribution of that VMT by vehicle class and region. Heavy duty diesel truck VMT in EMFAC2002 was allocated based on truck registration. This method is appropriate for light duty vehicles and heavy duty gasoline trucks, but heavy heavy-duty diesel trucks travel extensively outside their registration counties. VMT was redistributed in EMFAC2007 using survey information from the California Department of Transportation (CalTrans) and modeled from MVSTAFF, an annual report by CalTrans. The new distribution more accurately reflects actual truck travel patterns in California.

- *Revised Break Wear PM Emission Factors*

EMFAC has been modified to account for true brake counts. Previously a single emission factor for brake wear, based on a 1983 study,<sup>8</sup> was used to calculate the amount of airborne dust attributable to brake wear (12.8 mg/mile). This emission factor



assumed that all vehicles were equipped with four brakes, even if the vehicle had more than four brakes.

- *On-road Fuel Correction Factors*

Fuel correction factors are used to reflect the impact on emissions of commercial fuels compared to the fuel used during the certification process. Modifications to the fuel correction factors (FCFs) were incorporated into EMFAC2007 for both diesel and gasoline. For example, the FCFs for Phase II reformulated gasoline (RFG) were modified for the 1996-2003 calendar years to be cumulative to the Phase I (1992-1995 calendar years) values. Additionally, the impacts of ethanol on evaporative processes, changes in sulfur and aromatics composition in fuel, exhaust hydrocarbon benefits for clean diesel, and an out-of-state diesel fueling rate of 10 percent were incorporated.

- *Revised Planning Humidity Profiles*

Meteorological conditions impact the emissions process in vehicles, therefore, EMFAC2007 incorporates ambient relative humidity profiles to determine NO<sub>x</sub> conversion in exhaust as well as air conditioner usage by automobile drivers. Previously, EMFAC used annual average daily relative humidity profiles for each county or geographical area in the State. EMFAC2007 now incorporates hour-by-hour temperature, relative humidity, and ozone concentration data from 700 stations for the years 1996-2004.

- *Revised Planning Temperature Profiles*

EMFAC2007 contains daily ambient temperature profiles for use in evaluating evaporative emissions and other heating/cooling related processes. In the previous EMFAC, hourly temperature observations collected on high ozone days were spatially distributed by zip code and weighted by population. The resulting weighted profiles seemed rather cool. Weighting in EMFAC2007 is done by vehicle miles traveled (VMT) and provides more representative temperature profiles.

- *Corrections to Heavy-duty Gas Cap Benefits*

In reviewing the gas cap benefits staff noticed reductions on hydrocarbon emissions were negligible for heavy duty gasoline vehicles. Further review revealed the gas cap benefits were not fully implemented in EMFAC. In EMFAC2007, the gas cap algorithm has been implemented for heavy duty vehicles.

- *Coding Corrections*

Several coding errors have been corrected which results in a minor change to emissions estimates.

### Other Mobile

The following measures are reflected in OFFROAD2007 or the external modules. For a more thorough discussion on improvements to the other mobile inventory, please refer to the tech memos at <http://www.arb.ca.gov/msei/msei.htm>.

- *Addition of Tier 4 Emission Factors to Off-Road Large Compression Ignition Engines (>25 hp)*

The previous OFFROAD model only provided emission factors based on Tier 0, 1, 2 and 3 emission standards for compression-ignited engines greater than 25 horsepower (hp). In 2003, Tier 4 emission standards were adopted by ARB and the OFFROAD model has been updated to incorporate these new standards.

- *Off-road exhaust emissions inventory fuel correction factors*

Fuel correction factors have been modified to be consistent with EMFAC and to take into account current reformulated gasoline impacts. Carbon monoxide fuel correction factors for summertime and wintertime fuel which vary geographically, and the benefits of ultra low sulfur diesel (requirement commencing in 2007) were applied.

- *Addendum to Evaporative Emissions*

The current version of the OFFROAD model includes an updated estimate of the evaporative emissions from large spark-ignited engines, including those used in recreational marine applications.

- *Revisions to the Diesel Transport Refrigeration Units (TRU) Off-road Inventory*

TRU emissions are calculated in the OFFROAD model as a function of emission rate, population, activity, average horsepower, and load factor. With the exception of the emission rates, all other factors were based on the 1997 Power Systems Research (PSR) report. Since late 2002, ARB has obtained more up-to-date population and activity estimates from surveys of TRU manufacturers. These results have revised the input factors of population, activity, load factor, average horsepower, growth factors, survival rates, and useful lifetime estimates to the OFFROAD model.

- *Estimation of the Impact of Ethanol on Off-Road Evaporative Emissions*

Since the phase out of methyl-tert-butyl ether (MTBE) as a gasoline additive in 2004 ethanol (EtOH) has been used as an additive to meet the required two percent oxygen content in commercially dispensed gasoline. Because MTBE and EtOH both contained two percent oxygen, their evaporative emissions were assumed to be similar. However, recently completed studies indicate this is not a correct assumption. These tests indicate that EtOH has much higher permeation rates through fuel tank walls, hoses and fittings. OFFROAD2007 reflects these findings.

- *Recreational Marine*

Growth factors and engine-to-boat ratios were updated with more recent DMV and National Marine Manufacturers Association (NMMA) data. Additionally, evaporative emissions are separated into operating and storage emissions.

- *Agricultural*

Based on findings from the Agricultural Advisory Committee, growth factors for the San Joaquin Valley were updated.

- *Recreational Vehicles*

The OFFROAD model has been modified to account for updated population for MC, All Terrain Vehicles (ATVs) and snowmobiles using Department of Motor Vehicles (DMV) calendar year 1991-2005 totals. Human population data from Census 2000, personal income, and median household income data from Department of Finance were also applied to develop the growth rate for recreational vehicles. DMV 2005 registration data has been used to update county allocation factors. In addition, DMV registration also shows the inactive population for MC, ATV and snowmobile. Thus, the diurnal and resting emissions for inactive population for these three equipments are included in the OFFROAD2007. Also, the activity and load factor for snowmobile were updated to be the same as U.S. EPA's NONROAD model. Activity results from U.S. EPA's NONROAD model for specialty vehicles, benefits of golf carts and specialty vehicles subject to small off-road engine and large spark ignition (LSI) controls, benefits of snowmobiles subject to the U.S. EPA's capping standard, and the addition of OFMC and ATV evaporative emission factors as grams per mile were calculated in OFFROAD2007.

Although the overall statewide emissions from recreational vehicle are the same, the distribution of emissions to the specific county/air basin/air district has been changed relative the location where the equipment is stored or operated. The storage allocation is relevant to the diurnal and resting emissions from active and inactive recreational vehicles and is based on the county of DMV registration. The operational allocation applies to exhaust, hot soak and running loss emissions and represents where the off-road trails are located.

- *Construction and Ground Service Equipment (D > 25 horsepower)*

The OFFROAD model was updated with population, useful life, age distribution, annual activity, growth data and a deterioration rate cap introduced based on the 2003 McKay & Co. Study, ARB's 2005 Off-Road Diesel In-Use Equipment Survey, ARB's 2006 Off-Road Diesel In-Use Mini Survey, 2003 TIAX Survey of Public Fleets, and input from industry and stakeholders in public workgroup meetings and workshops.

- *Small Off-Road Equipment (SORE)*

The OFFROAD model was updated with: new exhaust and evaporative standards; new population and activity estimates for residential lawn and garden equipment obtained from the Lawn and Garden Survey; new population estimates for commercial lawn and garden equipment from an ERG survey; and modified small off-road engine survival rate curves using information from the Outdoor Power Equipment Institute.

The following changes were made to external modules:

- *Changes to the Locomotive Inventory*

Locomotive growth factors were revised in the OFFROAD model based on new data that better reflected locomotive operations, including projected growth in intermodal freight traffic, both domestic and international, U.S. industrial production, and various railroad statistics available from the Association of American Railroads (AAR). Other

measures such as the 1998 South Coast and 2005 State memorandum of understanding were also reflected.

- *Cargo Handling Equipment*

A separate methodology for cargo handling equipment at the ports and inter-modal rail yards per the Cargo Handling Equipment Air Toxic Control Measure (December 2005) was incorporated.

- *Ocean Going Vessels*

The OGV inventory reflects updated population and activity data for ocean-going vessels statewide. The emission estimates were developed for main and auxiliary engines in eight vessel types (auto carrier, bulk cargo, container, general cargo, passenger, reefer, roll-on roll-off and tankers). In addition, methodology was developed to allocate statewide emissions to individual ports and districts. The ARB regulation requiring vessels with auxiliary engines to switch from heavy fuel oil to marine distillate within 24 nautical miles of California was incorporated into the inventory.

- *Commercial Harbor Craft*

The commercial harbor craft inventory was revised with a single statewide approach. OFFROAD emission factors were used to calculate emissions and adjusted to better reflect the "E3" test cycle which is more representative of marine engines.

- *Portable Fuel Containers/Gas Cans*

Emission estimates were developed from data such as percentage of household/businesses with cans, average cans per household/business, average volume of cans, and refill frequencies collected during two surveys in 1998 and 2004. Allocation factors and growth rates for residential gas cans are based on the Department of Finance's Census 2000 data and landscaping employment growth projected by EDD (California Employment Development Department).

## **Biogenic**

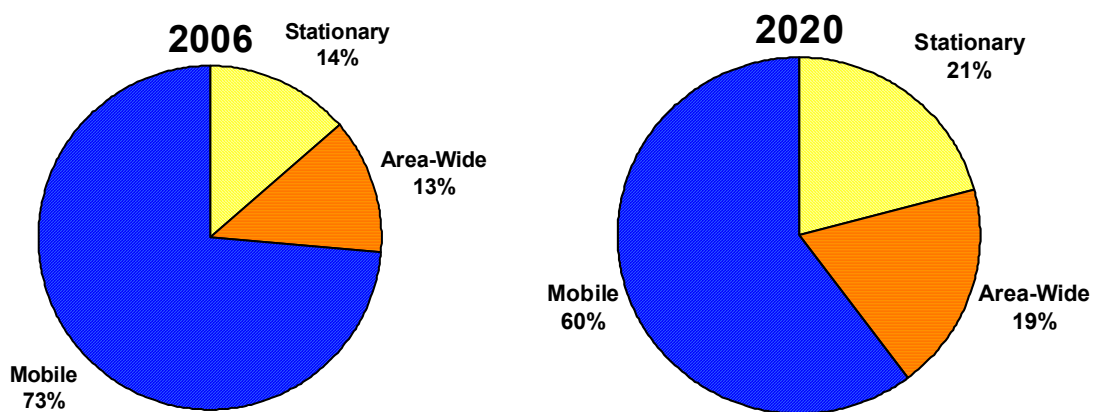
After its original application to the Southern California Ozone Study domain, the biogenic emission inventory GIS (BEIGIS) model was expanded to the Central California Ozone Study/California Regional Particulate Air Quality Study domain. In order to represent central and northern California conditions during summer and winter seasons, the BEIGIS model has incorporated further inputs, such as crop Geographic Information System (GIS) data for central and northern California developed by the California Department of Water Resources (DWR). Because it is a statewide land use/land cover database, the Gap Analysis Program (GAP) is still used to represent natural areas in the model. Urban vegetation survey data for Fresno, Oakland, and Sacramento were compiled from several studies and used to develop urban land use biogenic volatile organic compounds (BVOC) inputs for other urban areas in the central and northern California portion of the model. Crop BVOC and leaf mass factors for additional crops listed in DWR crop GIS databases were compiled from literature. Crop calendars developed by the University of California-Davis Department of Agricultural

and Resource Economics were consulted in order to develop growing season and dormant season crop BVOC inputs. In-leaf and off-leaf season BVOC profiles were also developed for natural and urban areas, in order to account for the presence of deciduous and evergreen species in landscapes. A 1 km<sup>2</sup> resolution winter Leaf Area Index (LAI) raster derived from Advanced Very High Resolution Radiometer (AVHRR) satellite data<sup>9</sup> was used in order to account for winter dormancy in natural areas and croplands.

### 3. Emissions Estimation Methods and Documentation

#### Major NOx/ROG Categories

Mobile sources account for about 75 percent of ozone precursor emissions (ROG and NOx) in the State in 2006 and will continue to dominate the inventory in 2020, however total emissions from all sources will drop 28 percent from 5,924 tons/day to 4,237 tons/day.



Emissions Inventory for ROG and NOx by Category Statewide 2005 and 2020

#### Emissions Estimation Methods

##### Stationary Emissions

Stationary emission sources identified on an individual basis or a single source are called point sources. Emissions from point sources are estimated from facilities that emit more than ten tons per year of any criteria pollutant. They are identified by name and location. A facility may have many individual, identifiable sources of emissions or (points) of emissions. For example, a coffee processing facility may have a boiler, roaster, grinder, and packing station as emission points. In addition, a point source may have one or more processes or operation. For example, a boiler burning natural gas part-time and oil part-time is considered to have two processes because emission rates are different for the two fuels.

The emissions for each point are computed as the product of use factor (an indicator of the extent of the activity per unit time) and an emission factor (the quantity of pollutant emitted per unit of the use factor). Point source use factors usually relate to a process rate, such as the amount of fuel oil consumed in a boiler or the amount of asphalt concrete produced at a batch plant. The general equation used to calculate the emissions is shown below:

$$\text{EMS} = \text{PR} \times \text{EF} \times \text{CONV}$$

Where: EMS = Emissions (tons/year)  
PR = Process Rate or activity data in (SCC unit/year)  
EF = Emission factor (mass/SCC unit)  
CONV = Unit conversion factor

Emission factors are derived from tests that relate emissions to the process causing the emissions. When adequate source test data are available for a source, these data are used to derive emission factors for the emission calculations. When adequate source test data for a source are not available, an alternative is to use average emission factors for similar emitting sources. These factors are usually derived by averaging the results of many tests of similar sources. Such factors are published by federal U.S. EPA in Compilation of Air Pollutant Emission Factors. The published emission factors in AP-42 are usually calculated for devices without control equipment. Because controls may vary among different facilities, it is therefore necessary to adjust the emissions factors to account for the specific control equipment being used.

In the base year emission inventory, controlled emissions are estimated by applying control efficiency factors to the “uncontrolled” emissions. These base year control factors take into account operational upsets and equipment malfunctions that lead to excess emissions. The resulting “controlled” inventory represents the actual emissions that have occurred over the 365 day calendar year. Due to the wide variation in how districts account for these operational fluctuations, rule effectiveness is not accounted for as an explicit reporting variable in CEIDARS, rather, rule effectiveness is treated as an implied variable maintained by the districts as part of the actual “controlled” emission estimates that are submitted to ARB.

In some cases, it is possible to determine emissions using a materials balance which reconciles the amounts of materials that enter and leave a process. This method is used for many sources, such as painting processes, where it is assumed that all the solvent used in the coating eventually evaporates.

The source information along with activity data and emission factors used to calculate emissions for all point sources are kept in district’s files and are reported to ARB on a regular basis (generally once a year).

## Data Acquisition

Information on emissions from stationary sources is obtained primarily from the districts which have primary responsibility under state law (Health and Safety Code section 40000) for regulation of stationary sources of air pollution.

In developing the emission inventory, there is considerable interaction between ARB and the districts. The planning process for an inventory development starts with the assessment of needs and requirements. Following the initial inventory planning, ARB collaborates with districts to prepare inventory development schedules and updates to the inventory.

## **Area-wide Emissions**

Area source methodologies are used to calculate emissions from aggregated point sources and area-wide sources. Aggregated point sources are many small point sources, or facilities, that are not inventoried individually but are estimated as a group and reported as a single source category. Examples include gas stations and dry cleaners. Because many of these sources are already accounted for as facilities or point sources (see the previous section on Stationary Emissions), the area source emissions are reconciled with point emissions before being added to the emission inventory. For example, the area source methodology for dry cleaners is used to calculate the total emissions for a particular county. These area source emissions are then reconciled by subtracting the emissions for dry cleaners already accounted for in the point source inventory.

Area-wide sources include source categories associated with human activity and emissions take place over a wide geographic area. Consumer products and unpaved road dust are examples of area-wide sources.

Both ARB and districts share responsibility in updating the various area-wide source categories. Some categories are the responsibility of the district while other categories are ARB's responsibility. ARB methodologies and many of the districts methodologies can be accessed at <http://www.arb.ca.gov/ei/areasrc/index0.htm>.

## Data Acquisition

When ARB develops an area-wide source methodology, many possible sources of activity data and emission factors are considered. Often data are obtained during the development of regulations. For example, in developing consumer product regulations, ARB routinely conducts statewide surveys. Research studies, some of which are sponsored by ARB, are another source of emissions data. Finally, various state and federal agencies may have relevant data needed to estimate emissions.

If activity data are not available at the county level, then statewide emissions are apportioned to counties using a surrogate. In the case of consumer products, statewide emissions are apportioned to counties using population.

Once ARB has developed a draft methodology, it is submitted to Emission Inventory Technical Advisory Committee (EITAC) for review. EITAC is composed of emission inventory staff from the districts, ARB, and U.S. EPA. Following EITAC review and incorporation of recommended changes, the methodology becomes final and, where appropriate, emissions are reconciled with the point source inventory. Finally, process rate and emissions transaction format files are prepared and the CEIDARS database is updated.

The districts also provide updated emissions data to ARB. Process rate and emissions transaction format files provided by the districts are used to update the CEIDARS database. When they are provided, the methodologies developed by districts are reviewed by ARB.

### **CEFS Forecasting Algorithm (Used for Stationary, Area-wide, Aircraft, and Ships)**

The general forecasting equation for stationary sources is shown below. The CEFS processor calculates seasonal projections for planning and month/day specific projections for photochemical modeling inputs. CEFS employs a region and emission category selection hierarchy when selecting and applying growth and control factors. Consider, for example, a rule which applies to the entire universe of a particular process type (identified by source classification code (SCC)). If that rule is more stringent for a particular industry (identified by SIC), then a control profile specific to the SCC/SIC combination can be assigned. CEFS will cycle through the control data records applying the highest level of the selection hierarchy to that category (i.e. the growth and control data can be “layered” to target the source categories exactly as the rule calls for without double-counting (or overlaps). The same type of logic is used for the growth data.

$$E\_fy_{(r,s,p,y)} = E\_by_{(r,s,p,o)} \cdot TF_{(r,s)} \cdot FRAC_{(r,s,p,y)} \cdot GF_{(r,s)} \cdot [CF_{(r,m_1,s,p)} \cdot CF_{(r,m_2,s,p)} \cdot \dots \cdot CF_{(r,m_i,s,p)}]$$

where

Primary Variables:

E\_fy = Emissions in the future year (tons/day; annual average or seasonal)

E\_by = Emissions in the base year (tons/year)

TF = Temporal Factor (or “Seasonal Adjustment Factor”)

FRAC = ROG, VOC, PM<sub>10</sub>, or PM<sub>2.5</sub> fraction (if applicable)

GF = Growth Factor (is the ratio of two activity levels at the end-point years)

CF = Control Factor (is the ratio of two control levels at the end-point years)

Subscript Variables:

r = region (district, air basin, county)

s = the source category (SCC/SIC or EIC for the TREND algorithm; The GIS algorithm performs the projections at the facility level.)

p = the pollutant

m = the control measure (i = the i<sup>th</sup> control measure)

y = the year to be projected

o = the base year



## **Temporal Factors (Stationary and Area Sources Only)**

To better characterize emissions affected by seasons, seasonal adjustment factors (or “temporal factors”) are used to apportion emissions into the periods under consideration. The temporal algorithm used for calculating seasonal emission inventories was rewritten to better approximate the seasonal variation of emissions. In the prior algorithm used in the 1994 SIP, emission estimates for point sources represented an “average annual operating day”. The assessment of this algorithm showed that it did not accurately estimate seasonal emissions because the algorithm was driven by the number of operating days a point source process operates. For processes that operated intermittently, this resulted in exaggerated seasonal emission estimates because the algorithm assumed that all intermittent processes operated simultaneously. For area sources, the prior algorithm estimated emissions based on an “average seasonal operating day”.

### ROG, VOC, PM<sub>10</sub> and PM<sub>2.5</sub> Fractions

The reactive portion of the total organic gas (TOG) emissions (expressed as ROG) are calculated by applying reactive fractions which are maintained in CEIDARS. Districts may supply fractions at the facility/device/process level for point source processes. If these data are not provided at this level, default fractions maintained by ARB at the SCC level are invoked. In like manner, the portion of PM falling within the 10 micron and 2.5 micron size ranges (i.e. PM<sub>10</sub> and PM<sub>2.5</sub> respectively) are estimated from district-supplied fractions or by applying size fractions maintained by ARB in CEIDARS. As with the temporal factor, an emission-weighted fraction is developed for each SCC/SIC pair.

## **Growth Factors (Stationary and Area Sources Only)**

Growth factors are derived from county-specific economic activity profiles, population forecasts, and other socio/demographic activity. Growth profiles are typically associated with the type of industry and secondarily to the type of emission process. For point sources, economic output profiles by industrial sector are typically linked to the emission sources via SIC. For area sources, other growth parameters such as population, dwelling units, fuel usage etc. may be used. The growth factor is the ratio of the growth level in the future year to the growth level in the base year. These growth levels are also region and source category dependent.

### Data Acquisition

Growth factor data for use in CEFS are acquired from the districts, and where no data are available, growth activity projections are constructed from ARB contracts<sup>10</sup> with experts in the economic and demographic growth. ARB may also develop growth estimates in consultation with stakeholders. For example, ARB led an effort to revise growth assumptions in agricultural categories, under guidance of the State’s Agricultural Advisory Committee. Geographically speaking, much of the State relies on these constructed growth projections while other high emission regions, such as the South Coast and Bay Area, submit their own growth estimates based on data provided by

local councils of government (COGs). The varied sources of growth data are assembled into a comprehensive statewide growth data set that can be used for statewide emission projections.

## **Control Factors**

Control factors are derived from “adopted” ARB regulations, district rules, and “proposed” measures which impose emission reductions or a technological change on a particular emission process. Control factors comprise three components: Control Efficiency, Rule Effectiveness, and Rule Penetration. Control factors are closely linked to the type of emission process and secondarily to the type of industry. Control levels are assigned to emission categories which are targeted by the rules via emission inventory codes (SCC/SIC, EIC etc.) used in CEIDARS. The control factor is the ratio of the control level in the future year to the control level in the base year. These control levels are also region, control measure, source category, and pollutant dependent.

## Data Acquisition

The baseline emission projections require a full complement of control factor data that account for the “adopted” rules that are on the books by a predetermined cutoff date. A major component of the CEFS program is its ability to link rules to targeted emission categories and quantify the emission reductions associated with the rules. Implementation of CEFS requires districts to submit local control rule profiles (for all rules leading to emission reductions) that link the rules to the appropriate emission categories. The profiles must describe the behavior of the rule (i.e. whether the rule is phased in a linear fashion or abrupt implementation in the form of a step function). The rule profiles must be designed to be pollutant specific and must carry enough data points to adequately characterize the rule over the implementation period. The CEFS program interpolates the profile for intermediate years in either a step or linear mode depending on what the district has flagged for the rule. The construction of a comprehensive control rule data set for a large district is a sizeable undertaking. Some districts develop the control profiles in house, while others have opted to contract the work out. In either case, ARB staff work closely with the district staff and/or contractors to educate staff on the proper construction of the control profiles. In gearing up for the 8-Hour Ozone SIP, in Fall 2004, ARB conducted a special forecasting workshop to provide guidance to districts on all aspects of the emission forecasting program including presentations on forecasting logic and input data requirements. In most cases, districts responded by submitting rule-specific control profiles for their adopted rules as required.

ARB also develops control profiles for state rules and International Maritime Organizations (IMOs) such as for consumer products, pesticides, architectural coatings, and ships. For state rules, ARB deploys interdivisional teams to develop, refine, and finalize the control profiles to be used in SIP projections. Similar data requirements exist for the development of these control profiles as described above for district rules.

## Mobile Sources

Mobile sources include all non-stationary sources of air pollution such as cars, trucks, motorcycles, buses, airplanes, and locomotives. In general, emissions are calculated as the product of the number of sources (population/volume), activity and emission factor.

$$E = Pop * A * EF$$

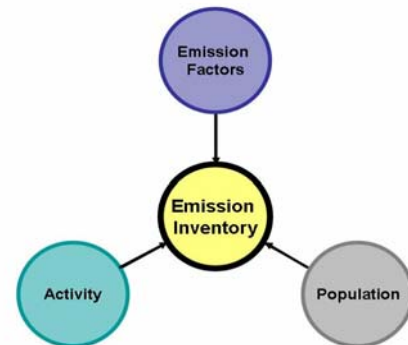
where,

E = pollutant specific emissions [mass emitted per unit time]

Pop = population of on-road mobile sources [-]

A = activity (travel data) [e.g. miles traveled per day, or hours operational]

EF = source specific emission factor [mass per unit activity]



In California, most mobile source inventories are estimated by two mathematical modeling tools: EMFAC for on-road sources and OFFROAD for off-road sources. Because many different types of data are necessary to develop an inventory, ARB must rely on other organizations to provide that data. The inventory has involved the efforts of the California Air Pollution Control Officers Association, CalTrans, the Southern California Council of Governments (SCAG), and the DMV. CalTrans provides SCAG with information regarding highway projects so that they can estimate and project vehicle miles traveled (VMT) from their Travel Demand Model (TDM). This activity data are then coupled with the emission factors generated from ARB's Emission Factor Model (EMFAC2007) and population data provided by the DMV to calculate the emission inventory. Finally, all statewide emission inventories are assembled and maintained by ARB in the CEIDARS and CEFS databases.

## On-Road Emission Inventory

EMFAC contains several different modules that account for different portions of the on-road inventory calculation process. EMFAC covers on-road mobile sources including gas and diesel cars, trucks, buses, and motorcycles. The subsequent sections illustrate the methods by which the on-road emission inventory is developed. For more detailed information please refer to the ARB website at <http://www.arb.ca.gov/msei/onroad/on-road.htm>. A guide to online documentation is also provided at the end of this section.

### Source Categories

On-road mobile sources are categorized into thirteen vehicle classes, two fuel types (gas and diesel), and three technology categories (catalyst, noncatalyst and diesel) as indicated in the table below.

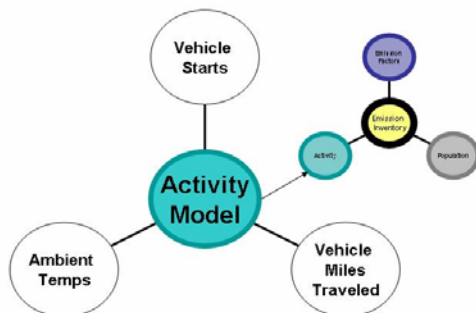
## EMFAC Vehicle Categories

Class	Description	Weight (GVW)	Abbreviation	Technology Group
PC	Light Duty Autos (Passenger Cars)	All	LDA	NCAT, CAT, DSL
T1	Light-Duty Trucks (LDT1)	0-3,750	LDT1	NCAT, CAT, DSL
T2	Light-Duty Trucks (LDT2)	3,751-5,750	LDT2	NCAT, CAT, DSL
T3	Medium-Duty Trucks	5,751-8,500	MDV	NCAT, CAT, DSL
T4	Light-Heavy Duty Trucks (LHDV1)	8,501-10,000	LHDT1	NCAT, CAT, DSL
T5	Light-Heavy Duty Trucks (LHDV2)	10,001-14,000	LHDT2	NCAT, CAT, DSL
T6	Medium-Heavy Duty Trucks (MHDV)	14,001-33,000	MHDT	NCAT, CAT, DSL
T7	Heavy-Heavy Duty Trucks (HHDV)	33,001+	HHDT	NCAT, CAT, DSL
UB	Urban Bus (UB)	All	UB	CAT, DSL
OB	Other Bus		OBUS	CAT, DSL
SB	School Buses	All	SBUS	CAT, DSL
MH	Motor Homes	All	MH	CAT, DSL
MC	Motorcycles	All	MCY	NCAT, CAT

### Population and Activity

In general, population data are obtained from vehicle registration data compiled by DMV and classified according to fuel, class, technology group, age (model year) and geographic area. Further calculations require data on population growth rates by calendar year, vehicle class, fuel type and geographic area. These estimates are coupled with activity data and emission factors, as indicated previously, to estimate total emissions.

On-road *activity* refers most commonly to vehicle miles traveled, speed, and number of trips for each vehicle type and model year.



### *Vehicle Miles Traveled*

Vehicle miles traveled (VMT) are the number of miles traveled by a given vehicle in a specified time period and is estimated from the inspection and maintenance program (I&M) where the model year and odometer reading is taken. The COG's provide VMT as estimated by their transportation demand models. EMFAC then matches VMT estimated in the model to those values provided by the COGs.

This analysis is completed for each county and helps to elucidate regional differences in travel. VMT is calculated based on the vehicle population and accrual rates by age, vehicle class, fuel type, by geographic and inspection and maintenance option. The model also contains hourly distributions of VMT by class.

### *Vehicle Starts or Trips*

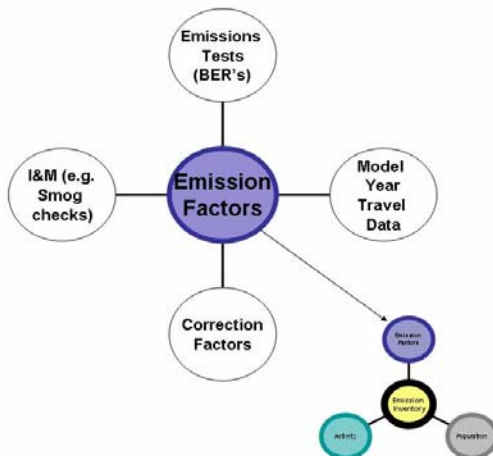
Vehicle starts are obtained for gasoline-powered vehicles except heavy-duty trucks and included as an input to the inventory. Starts are used to calculate trip emissions and calculated as the product of a per-vehicle start rate (starts per vehicle per day) and the fleet population. The estimates of trips per day are based on travel surveys and vehicle instrumented data for passenger cars, and light and medium duty trucks.

### *Ambient Temperatures*

Because motor vehicle emissions are dependent on temperature and humidity profiles, historical meteorological data are compiled. The emission inventory process includes data on averaged monthly, summer and winter episodic diurnal temperatures for each geographic area as well as averaged monthly relative humidity for each geographic area. The following table indicates the primary data sources for activity and population:

### Emission Factors

Emission factor used in EMFAC are based on emission tests with dynamometers coupled with certification data yield base emission rates (BERs) that are adjusted with correction factors, and vehicle inspection and maintenance (I&M) programs (e.g. smog check scenarios). Correction factors are applied for non-standard operating conditions such as what mode the vehicle is in (e.g. hot/cold/start/running), trip speed, environmental conditions, and inspection and maintenance programs within that geographic area. These correction factors include, but are not limited to, speed correction factors, temperature correction factors, fuel correction factors and driving cycle correction factors.



Emission factors are provided for different temperatures, operating speeds, emission modes, model types, model years, technology types, fuel, and relative humidity. These emission factors can be expressed as grams per vehicle, grams per mile, grams/hour and grams per start. Activity data are matched to the corresponding emission factor to estimate total emissions.

EMFAC includes tailpipe exhaust and evaporative emissions as part of the on-road inventory. Tailpipe exhaust emissions include running, idle and start exhausts. Running exhaust represents emissions released from the tailpipe under hot stabilized conditions, while idle and start exhaust, the other tailpipe emissions, include any emissions associated with idling and starting the vehicle. Evaporative emissions consist of hot

soaks, diurnals, resting losses and running losses all of which are generated by the evaporation of fuel from an engine. The inventory accounts for particulate matter (PM) associated with tire and break wear.

## **Guide to Online Documentation**

“Understanding the On-Road Emissions Inventory Program” -  
<http://www.arb.ca.gov/msei/onroad/on-road.htm>

Mobile Source Emission Estimates -  
[http://www.arb.ca.gov/msei/onroad/emfac2002\\_output\\_table.htm](http://www.arb.ca.gov/msei/onroad/emfac2002_output_table.htm)

Previous Model Versions and Revisions -  
[http://www.arb.ca.gov/msei/onroad/previous\\_version.htm](http://www.arb.ca.gov/msei/onroad/previous_version.htm),  
[http://www.arb.ca.gov/msei/onroad/latest\\_revisions.htm](http://www.arb.ca.gov/msei/onroad/latest_revisions.htm)

EMFAC Technical Support Documentation -  
[http://www.arb.ca.gov/msei/onroad/doctable\\_test.htm](http://www.arb.ca.gov/msei/onroad/doctable_test.htm)

Tech Memos - <http://www.arb.ca.gov/msei/msei.htm>

## **Other Mobile Emission Inventory**

Off-road mobile sources include off-road vehicles such as boats, outdoor recreational vehicles (ORV's), industrial and construction equipment, farm equipment, lawn and garden equipment, ships, aircraft, and trains. OFFROAD is used to estimate emissions for most of these categories. Other sources such as ocean going vessels and commercial harbor craft are based on calculations in modules external to OFFROAD. Off-road emissions are calculated much in the same way as on-road emissions – the product of emission factor, activity, and population. The model also incorporates elements such as technology types, population, activity, horsepower, load factors, and control factors. For more detailed information please refer to the ARB website at <http://www.arb.ca.gov/msei/offroad/off-road.htm>. In addition, a guide to online documentation is provided at the end of this section.

### Source Categories

Off-road sources are divided up into eight major categories: aircraft, trains, ships and commercial boats, recreational boats, off-road recreational vehicles, off-road equipment, farm equipment, and fuel storage and handling. The categories are then subdivided by fuel type, engine type, horsepower group and preempted or non-preempted status to better characterize emissions, adopted and proposed control strategies, and use. Outlined below are a few categorical descriptions.

### *Commercial Marine Vessels*

Commercial marine vessels include ocean-going ships and harbor craft, but exclude recreational vessels. Ocean-going ships include international trade vessels such as container ships, bulk carriers, general cargo ships, tankers, and auto carriers. Passenger cruise ships, and some military and Coast Guard vessels, are also included in this category.

The diesel engines powering the majority of oceangoing ships are referred to by U.S. EPA as “Category 3” engines, meaning they have a displacement greater than 30 liters per cylinder. These engines are available in configurations with 4 to 14 cylinders, and power outputs ranging from roughly 5 to 100 megawatts.

Ocean-going ships generally run boilers and diesel generators in addition to propulsion engines, particularly while “hotelling” in port. Diesel generators provide electrical power for lights and equipment, and boilers provide steam for hot water and fuel heating.

Most ocean-going ships run their main propulsion engines (and many newer ships also run their auxiliary engines) on intermediate fuel oil (IFO 180 or IFO 380). This fuel is also referred to as “bunker fuel,” and requires heating to reduce its viscosity to a point where it can be properly atomized and combusted. Bunker fuel typically contains much higher levels of sulfur, nitrogen, ash, and other compounds which increase exhaust emissions. Diesel-powered gas turbine engines and auxiliary engines on many ocean-going ships use lighter “distillate” diesel fuel (also referred to as marine gas oil), which is much lower in sulfur and other contaminants.

Harbor craft (or the “captive fleet”) include tugboats, commercial fishing vessels, commercial passenger fishing vessels, work boats, crew boats, ferries, and some Coast Guard and military vessels. These vessels generally stay within California coastal waters and often leave and return to the same port. Most harbor craft use diesel-powered propulsion and auxiliary engines that generally run on distillate diesel fuel.

### *Locomotives and Rail-yards*

Railroads operate national locomotive fleets that travel between states daily, currently moving more than 40 percent of the total intercity revenue ton-miles of freight in the United States.

### *Compression-Ignition (diesel) Engines*

Off-road compression-ignition (CI) engines are diesel engines primarily used in farm, construction, and industrial equipment. Examples include tractors, excavators, dozers, scrapers, portable generators, transport refrigeration units (TRUs), irrigation pumps, welders, compressors, scrubbers, and sweepers. Locomotives, commercial marine vessels, marine engines over 37 kilowatts (kW), or recreational vehicles are excluded from this category.

### *Large Spark-Ignition Engines*

The large spark-ignition engine (LSI) category consists of off-road spark-ignition engines greater than 25 horsepower and typically fueled by gasoline or liquefied petroleum gas (LPG). A small number are fueled by compressed natural gas (CNG), and some have dual fuel capability. LSI engines are most commonly found in forklifts, specialty vehicles, portable generators, pumps, compressors, farm equipment, and construction equipment. This category excludes marine propulsion engines, engines used in equipment that operate on rails, recreational vehicles, snowmobiles, and gas turbines.

### *Recreational Vehicles*

This category consists of off-road motorcycles and all terrain vehicles (ATVs), both of which are designed for operation over rough terrain. U.S. EPA standards for exhaust and evaporative for off-road motorcycles and ATVs were established in 2006. Although the federal exhaust standards are not as stringent as California's, California will benefit from the evaporative standards which control fuel tank and fuel line permeability.

In 1994, ARB approved off-highway recreational vehicle regulations (including off-road motorcycles). These regulations established exhaust emission standards and test procedures that included off-road motorcycles and ATVs. The regulations also provided specific coding requirements of the vehicle identification number to distinguish an emission-compliant vehicle. In 1998, the regulations were amended to link vehicle registration and usage to compliance with California's exhaust emission standards. Those in compliance are eligible for off-highway vehicle (OHV) green sticker registration that allows year-round operation in designated off-road areas. Those not in compliance are eligible for OHV red sticker registration that allows operation only during designated months when ozone levels are low. These revisions affect engines built in 1997 greater than 90 cc. The same standards also apply to engines built in 1999 of 90 cc or less. Engines built pre-1997 and pre-1999, respectively, are not subject to this regulation.

### *Small Off-Road Engine (SORE)*

The small off-road engine (SORE or "small engine") category consists of off-road spark-ignition engines fueled typically by gasoline, liquid petroleum gas (LPG) or other alternative fuels and below 25 horsepower. The SORE category includes lawn, garden and other maintenance utility equipment. Within this category, engines are typically grouped by engine displacement measured in cubic centimeters (cc). Engines under 65 cc displacement are traditionally associated with handheld equipment such as weed trimmers, leaf blowers and chain saws. Engines greater than 65 cc displacement are collectively referred to as non-handheld small off-road engines. Non-handheld equipment is primarily lawn mowers, but also includes other equipment such as riding mowers and generator sets.

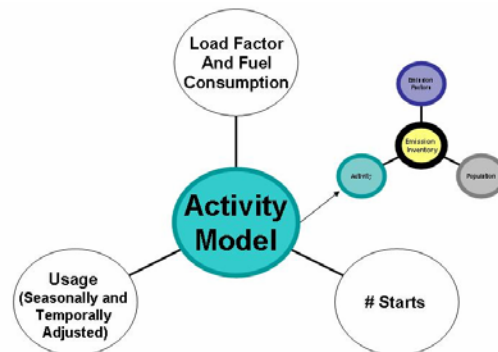
The sources of evaporative emissions from this category are from gasoline vapors vented from the carburetor and fuel cap and occur from diurnal (emissions due to daily temperature changes), hot soak (occur after shutdown of equipment), and running loss (occur during equipment operation) processes. Permeation (liquid gasoline migrating through the walls of plastic fuel tanks) is also another source of emissions.



## Activity and Population

As with the on-road inventory, emission factors must be coupled with population and activity data to estimate total emissions. The statewide equipment population of off-road mobile sources was collected from a variety of sources including industry and government agencies. Then growth factors based on socioeconomic indicators and scrappage factors were applied to determine future populations. Scrappage, or attrition, functions describe the relationship between equipment age and the proportion of equipment that has been removed from service. It is expressed as a fraction of the average lifetime of the equipment and is a function of the expected life of the engine, the annual hours of operation, and the average load factor.

Activity includes information such as annual average usage hours, load factor, brake-specific fuel consumption, and starts per year for each equipment type by fuel, engine type, and horsepower group.



## Data Acquisition

The statewide equipment populations were obtained through various industry and government agency sources. Power Systems Research (PSR) is the source for many of the state population estimates for off-road categories. PSR's Power Systems Research/Compass International's 1996 Database contained engine data compiled over the last 7 years, and included engine sales records for every engine installed in North America, as well as imported engine-driven products. Engine data includes horsepower, model number and engine description (number of cylinders, turbocharged versus naturally-aspirated, displacement, etc). Some of the principal data sources, by category, are listed in the table below:

The Portable Equipment Database is maintained by ARB. Data are obtained through a voluntary registration program with the State as an alternate method of obtaining an operational permit for off-road non-propulsion engines. Equipment populations for dredging, oil drilling, lawn and garden, military tactical support and other portable equipment categories were obtained directly from the Portable Equipment Database. In order to avoid double counting, the population of generators, pumps and compressors found in the drilling, dredging, tactical support and other portable equipment, were subtracted from the industrial and light-commercial categories.

<b><u>Category</u></b>	<b><u>Data Source</u></b>
Agricultural	United States Department of Agriculture(USDA), Power Systems Research (PSR)
Construction and Mining	Mackay & Company, PSR, Portable Equipment Database, Energy & Environmental Analysis (EEA)
Light Commercial	PSR, Portable Equipment Database
Industrial	PSR, Booz Allen-Hamilton (BAH)
Logging	Power Systems Research
Lawn and Garden	Portable Equipment Database, BAH
Airport Ground Support	Air Transport Association (ATA), EEA
Transport Refrigeration Units	PSR, Department of Motor Vehicles (DMV)
Dredging	Portable Equipment Database
Oil Drilling	Portable Equipment Database
Military Tactical Support Equipment	Portable Equipment Database
Recreational Equipment	Department of Motor Vehicles (DMV)
Pleasure Craft	U.S. Coast Guard, DMV
Commercial and Government Vessels	BAH, US Coast Guard, CA Department of Fish and Game, ARB Survey
Locomotive and Rail Operations	Booz Allen-Hamilton
Aircraft (Commercial, Military and General)	Booz Allen-Hamilton
Agricultural Aircraft	Booz Allen-Hamilton
Ocean-Going Vessels	CA State Lands Commission, Port of Los Angeles EI, Survey, US Army Corp of Engineers, Entec
Agricultural Engines	District Permit Data, Carl Moyer Program, Sonoma Technology, CA Department of Water Resources Farmland Monitoring and Mapping Program

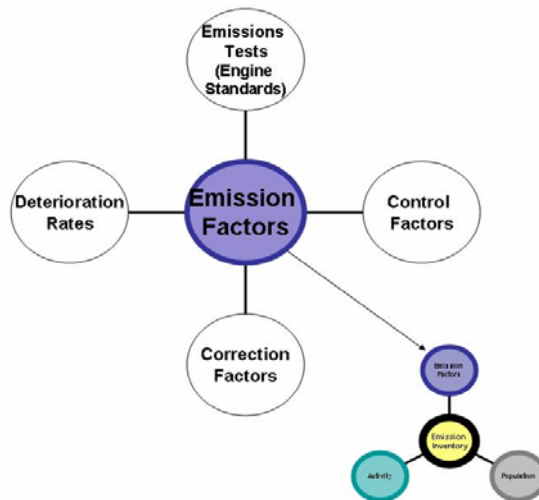
Mackay & Company conducted surveys in 1991, 1995, and 1999 to estimate nationwide construction equipment population and usage. This work was sponsored by Construction Equipment Magazine. Mackay & Company's 1999 Construction Equipment population analysis was used to obtain populations for those construction equipment contained in the analysis. Since data in Mackay's analysis are nationwide, staff used a factor of 10 percent in order to estimate California's statewide population. U.S. EPA staff estimated that 10 percent of the total nationwide dollar amount spent on construction-related activities occurs in California. For specific pieces of construction equipment not found in Mackay's analysis, 10 percent of PSR's nationwide data were used.

Finally, all statewide emission inventories are assembled and maintained by ARB in CEIDARS and CEFS databases.

## Emission Factors

ARB estimates all off-road mobile emissions with OFFROAD. OFFROAD integrates emission factors by model year for hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), oxides of nitrogen (NO<sub>x</sub>), particulate matter (PM), and oxides of sulfur (SO<sub>x</sub>). Hydrocarbon emissions are modeled for three types of engine processes: exhaust, evaporative and start emissions.

The emission factors for each engine are a function of new engine emissions expressed in grams per brake horsepower hour and deterioration rates. Deterioration is due primarily to tampering and mal-maintenance and wear on engine parts with use, and occurs at different rates for each pollutant. The OFFROAD methodology for estimating deterioration is based on the zero-hour emission rate (g/bhp-hr), the deterioration rate (increase in emissions per unit of activity, g/bhp-hr<sup>2</sup>), and the number of hours accumulated on the equipment. Equipment-specific emission factors are obtained by adjusting the appropriate engine emission rate by how the equipment is used (duty cycle). Finally, control factors can be applied to emissions or population to account for regulatory control scenarios.



## **Guide to Online Documentation**

“Understanding the Off-Road Emissions Inventory Program” - <http://www.arb.ca.gov/msei/offroad/off-road.htm>

Mobile Source Emission Estimates - [http://www.arb.ca.gov/msei/onroad/emfac2002\\_output\\_table.htm](http://www.arb.ca.gov/msei/onroad/emfac2002_output_table.htm)

Model Revisions - <http://www.arb.ca.gov/msei/offroad/updates.htm>

OFFROAD Technical Support Documentation - <http://www.arb.ca.gov/msei/offroad/pubs.htm>  
<http://www.arb.ca.gov/research/resnotes/notes/97-8.htm>

Tech Memos - <http://www.arb.ca.gov/msei/msei.htm>

## Biogenics (Overview of the BEIGIS Model)

Development of effective ozone and PM<sub>2.5</sub> control strategies in California requires accurate emission inventories of their precursor emissions, including biogenic volatile organic compounds (BVOCs) such as isoprene and monoterpenes. Due to the heterogeneity of vegetation land cover, species composition and leaf mass distribution in California, quantifying BVOC emissions in this domain requires an emission inventory model with region-specific input databases and a high degree of spatial and temporal resolution. In response to this need, ARB developed a GIS-based model for estimating BVOC emissions, called BEIGIS, which uses California-specific input databases with a minimum spatial resolution of 1 km<sup>2</sup> and an hourly temporal resolution.

The BEIGIS isoprene emission algorithm<sup>11</sup> is of the form  $I = IS \times CL \times CT$ , where  $I$  is the isoprene emission rate (grams isoprene per gram dry leaf mass per hour) at temperature  $T$  and photosynthetically active radiation flux  $PAR$ .  $IS$  is a reference emission factor (grams isoprene per gram dry leaf mass per hour) at a standard temperature of 30 °C and  $PAR$  flux of 1000  $\mu\text{mol m}^{-2} \text{s}^{-1}$ .  $CL$  and  $CT$  are environmental adjustment functions for  $PAR$  and temperature, respectively. The monoterpene emission algorithm adjusts a reference monoterpene emission factor by a temperature function<sup>11</sup>. Methylbutenol (MBO) emissions are modeled with an algorithm<sup>12</sup> similar to that for isoprene. Dry leaf mass/ leaf area ratios, and reference emission factors for isoprene, monoterpenes and MBO, are plant species-specific and assembled from the scientific literature. Modeled BVOC emissions for a given spatial domain therefore represent the contribution by various plant species (through their leaf mass and emission rates) to the total BVOC emissions.

The main inputs to BEIGIS are land use land cover (LULC) GIS databases, gridded leaf area index (LAI) derived from AVHRR satellite data<sup>13</sup>, leaf area/dry leaf mass factors, reference emission factors, and gridded hourly ambient temperature and sunlight data (generated by the CALMET and/or MM5 models). For urban areas, LULC databases were developed from regional planning agency data and botanical surveys<sup>14</sup>. Natural areas are represented using GAP, a statewide LULC database developed by the University of California-Santa Barbara for the U.S.G.S. Biological Resources Division and the California Department of Fish and Game<sup>15</sup>. Agricultural areas are represented using crop GIS databases developed by the California Department of Water Resources (<http://www.landwateruse.water.ca.gov>). Ground surveys have been funded by ARB to validate vegetation land cover and LAI input databases used in BEIGIS<sup>16</sup>. Model validation using micrometeorological flux measurements is on-going. BEIGIS assimilates spatial and temporal inputs and executes BVOC emission algorithms within a GIS. Outputs from BEIGIS are gridded 1 km<sup>2</sup> hourly emissions of isoprene, monoterpenes and MBO, aggregated to 16 km<sup>2</sup> or 25 km<sup>2</sup> resolution, depending on photochemical modeling requirements. A fourth BVOC category called "other" biogenic VOC (OVOC) is comprised of compounds such as acetone, methanol, and other oxygenated BVOCs. OVOC is not modeled directly. Gridded hourly OVOC emissions are estimated as an added fraction, scaled to 30 percent of the sum of isoprene, monoterpene, and MBO within each grid cell. A speciation profile is applied to the

OVOC fraction based on OVOCs measured at Blodgett Experimental Forest<sup>17</sup>. The BEIGIS model was first applied in the Southern California Ozone Study<sup>18</sup> (SCOS97).

### **Emissions Inventory Systems Data (CEIDARS, CEFS)**

ARB redesigned its base year emission inventory system (known as the California Emissions Inventory Development and Reporting System (CEIDARS)) in 1995 and emission forecasting system (known as the California Emission Forecasting System (CEFS)). Technical papers describing these systems are available on request.

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## References

- <sup>1</sup> “FACT SHEET #1: Development of Organic Emission Estimates California's Emission Inventory and Air Quality Models” (2000) [Online] Air Resources Board. Available from [http://www.arb.ca.gov/ei/speciate/factsheets\\_model\\_ei\\_speciation\\_tog\\_8\\_00.pdf](http://www.arb.ca.gov/ei/speciate/factsheets_model_ei_speciation_tog_8_00.pdf) [Accessed March 2007]
- <sup>2</sup> *2002 Base Year Emission Inventory SIP Planning: 8-hr Ozone, PM<sub>2.5</sub> and Regional Haze Programs* (2002) [Online] Environmental Protection Agency. Available from [http://www.epa.gov/ttnchie1/eidocs/2002baseinven\\_102502new.pdf](http://www.epa.gov/ttnchie1/eidocs/2002baseinven_102502new.pdf) [Accessed February 2007]
- <sup>3</sup> ARB Project 05-6CCOS with Dr. Charles L. Blanchard. Understanding Relationships Between Changes in Ambient Ozone and Precursor Concentrations and Changes in VOC and NOx Emissions from 1990 to 2004 in Central California
- <sup>4</sup> STI - 05-3CCOS - *Comparison of Ambient Measurements to Emissions Representations for Modeling*
- <sup>5</sup> *National Emissions Inventories for the U.S. (2007)* [Online] Environmental Protection Agency. Available from <http://www.epa.gov/ttn/chie/net/index.html> [Accessed February 2007]
- <sup>6</sup> *The California Almanac of Emissions and Air Quality* (2006) [Online] California Air Resources Board. Available from <http://arb.ca.gov/aqd/almanac/almanac.htm> [Accessed February 2007]
- <sup>7</sup> *Triennial Review of the Emission Inventory SB 2174 Public Workshop November 2000* (2000) [Online] California Air Resources Board. Available from <http://www.arb.ca.gov/ei/sb2174slides/> [Accessed February 2007]
- <sup>8</sup> Cha, S.; Carter, P.; Bradow, R. *Simulation of Automobile Brake Wear Dynamics and Estimation of Emissions*, Society of Automotive Engineers, SAE Paper 831036, Warrendale, PA, 1983.
- <sup>9</sup> Nikolov, N; Zeller, K. *Efficient retrieval of vegetation leaf area index and canopy clumping factor from satellite data to support pollutant deposition assessments*. Environmental Pollution vol 141 (3) 539-549 (2006).
- <sup>10</sup> E. H. Pechan & Associates, *Development of Emission Growth Surrogates and Activity Projections Used in Forecasting Point and Area Source Emissions, Final Report*, February 26, 2001.
- <sup>11</sup> Guenther, A. B., P. R. Zimmerman, P. C. Harley, R. K. Monson and R. Fall. 1993. *Isoprene and monoterpene emission rate variability – model evaluations and sensitivity analyses*. Journal of Geophysical Research. 98(D7): 12609-12617.  
Guenther, A. B. R. K. Monson and R. Fall. 1991. *Isoprene and monoterpene emission rate variability: observations with eucalyptus and emission rate algorithm development*. Journal of Geophysical Research. 96: 10799-10808.
- <sup>12</sup> Harley, P., V. Fridd-Stroud, J. Greenberg, A. Guenther and P. Vasconcellos. 1996. *Emission of 2-methyl-3-buten-2-ol by pines: A potentially large natural source of reactive carbon to the atmosphere*. Journal of Geophysical Research. 103: 25479-25486.

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<sup>13</sup> Nikolov, N. and K. Zeller. 2006. *Efficient retrieval of vegetation leaf area index and canopy clumping factor from satellite data to support pollutant deposition assessments*. Environmental Pollution. Vol. 141 Issue 3: 539-549. DOI:10.1016/j.envpol.2005.08.059

<sup>14</sup> Benjamin, M., Sudol, M., Bloch, L. and A. Winer. 1996. *Low-emitting urban forests: ataxonomic methodology for assigning isoprene and monoterpene emission rates*. Atmospheric Environment. 30 (9): 1437-1452.

Horie, Y., Sidawi, S. and R. Ellefsen. 1990. *Inventory of leaf biomass and emission factors for vegetation in California's south coast air basin*. Final Technical Report III-C. South Coast Air Quality Management District. Diamond Bar, CA.

Nowak, D. J. 1991. *Urban forest development and structure: Analysis of Oakland, California*. PhD dissertation. University of California, Berkeley, CA.

Sidawi, S. and Y. Horie. 1992. *Leaf biomass density for urban, agricultural and natural vegetation in California's San Joaquin Valley*. Final Report. San Joaquin Valley Air Pollution Study Agency.

<sup>15</sup> Davis, F. W., D. M. Stoms, A. D. Hollander, K. A. Thomas, P. A. Stine, D. Odion, M. I. Borchert, J. H. Thorne, M. V. Gray, R. E. Walker, K. Warner, and J. Graae. 1995. *The California GAP Analysis Project—Final Report*. University of California, Santa Barbara, CA. [[http://www.biogeog.ucsb.edu/projects/gap/gap\\_rep.html](http://www.biogeog.ucsb.edu/projects/gap/gap_rep.html)]

<sup>16</sup> Karlik, J. and A. McKay. 1999. *Development of methodology and databases for estimating leaf masses in California airsheds*. Final Report. Contract No. 97-719. State of California Air Resources Board. Sacramento, CA.

Karlik, J. 2002. *Validation of databases for modeling biogenic volatile organic compound emissions in central California*. Final Report. Contract No. 00-16CCOS. San Joaquin Valleywide Air Pollution Study Agency and California Environmental Protection Agency – Air Resources Board.

Winer, A., Karlik, J. and J. Arey. 1998. *Biogenic hydrocarbon inventories for California: generation of essential databases*. Final Report. Contract No. 95-309. State of California Air Resources Board. Sacramento, CA.

Winer, A. and Karlik, J. 2001. *Development and validation of databases for modeling biogenic hydrocarbon emissions in California's airsheds*. Final Report. Contract No. 97-320. California Environmental Protection Agency – Air Resources Board. Sacramento, CA.

<sup>17</sup> Lamanna, M. and A. Goldstein. 1999. *In situ measurements of C2-C10 volatile organic compounds above a Sierra Nevada ponderosa pine plantation*. Journal of Geophysical Research. Vol. 104, No. D17: 21247-21262.

<sup>18</sup> Scott, K. and M. Benjamin. 2003. *Development of a biogenic volatile organic compounds emission inventory for the SCOS97-NARSTO domain*. Atmospheric Environment 37, Supplement No. 2: S39-S49.