# SECTION 5.1

# FOOD & AGRICULTURE
# WINE FERMENTATION

*(Updated March 2005)*

**EMISSION INVENTORY SOURCE CATEGORY**
Industrial and Other Processes

**EMISSION INVENTORY CODES (CES CODES) AND DESCRIPTION**
**420-408-6090-0000 (47068)** Wine Fermentation

## METHODS AND SOURCES

This category is an inventory of the ethanol emissions resulting from the fermentation of grape juice at wineries to produce wine.

During the fermentation process, sugar in the grape juice reacts with yeast to form alcohol (ethanol) and carbon dioxide ($CO_2$) gas. Ethanol is emitted into the atmosphere through evaporation. According to Williams and Boulton[1], the only important mechanism for ethanol loss is equilibrium evaporation into the escaping $CO_2$ stream. The physical entrainment of ethanol droplets in the $CO_2$ gas is insignificant in modern enclosed fermentation vessels.

Wine fermentation in California was reported by the U.S. Alcohol and Tobacco Tax and Trade Bureau (TTB) to be 480,399,535 gallons in 2002. Monthly fermentation data was reported on a county basis for 2002 upon request from ARB staff.

The Department of Alcoholic Beverage Control[2] (DABC) permits the wine production activities at each winery in the State, limiting them to a maximum amount of wine produced each year. These data are aggregated and reported at the air basin and county level (Table I). The reported amount of wine annually fermented in each county by the TTB was disaggregated into county, air basin, and district (COABDIS) region using the DABC data according to the permitted maximum amount of wine each COABDIS region can produce.

The emission factors used in estimating ethanol emissions during wine fermentation are as follows: white wine - 2.5 lbs. ethanol/1000 gallons wine and red wine - 6.2 lbs. ethanol/1000 gallons wine produced. The Air Resources Board staff[3] derived the emission factors from a computer model developed by Williams and Boulton[1]. The model simulates the effects of fermentation temperature and the sugar concentration in the fermenting juice on the amount of evaporative ethanol loss during isothermal batch fermentation. Results show that the ethanol loss is proportional to the square of the sugar concentration in the juice and that as fermentation temperature increases, ethanol loss increases exponentially[1]. These researchers reported a good agreement between the estimates of ethanol loss using the model with available experimental measurements.

Using these emission factors and the activity data expressed as gallons of wine fermented, ethanol emissions were estimated for the two different types of wine: white and red. The relative proportion of the two types of wine fermented in California was based on California Agricultural Statistics Services report entitled "Grape Crush Final Report, 2001-2002 Crop[4]." The amount of wine grapes crushed for red wine and white wine was used to estimate the ratio of these wines fermented in the State. A composite emission factor of 4.7 lb/1000 gal of wine fermented was derived by using this ratio of wine grape types crushed (see sample calculations).

The statewide ethanol emissions for 2002 from wine fermentation are presented by air basin and county in Table II.

**ASSUMPTIONS**

1. Wine fermentation is proportional to the permitted wine production limit, which can be used to apportion the county wine production totals to the COABDIS regions.

2. The amount of grapes crushed for each type of wine is proportional to the amount of that type of wine fermented, which can be used to apportion the amount of total wine fermented into the amounts of red and white wine fermented.

3. The relative ratios of red and white wines produced in California are the same for all regions in the State.

4. The emission factors taken from the Williams and Boulton model run generated by the ARB are the best available to represent the amount of evaporative ethanol loss from the fermentation of wine.

**COMMENTS AND RECOMMENDATIONS**

The current procedure for estimating ethanol emissions from wine fermentation has the following limitations:

1. The estimated wine fermentation in each COABDIS region, calculated by disaggregating the county level wine fermentation data based on the permit limits for wine production, may not accurately reflect the actual wine

fermentation in each COABDIS region. This is because the permit limit is not a measure of actual fermentation but of maximum allowable production. Each winery will set this level based on business considerations. However, this is a reasonable surrogate and should not skew the breakout of wine fermentation by COABDIS region to any great degree.

2. The ratios of white to red wine are based on statewide crushed grape ratios. This leads to two possible errors. The first being the amount of wine fermented by crushing a given mass of white wine grapes may not be equal to the wine fermented by crushing the same mass of red wine grapes. The second is the assumption that all counties have the same ratio of fermentation of red to white wine, which is equal to the statewide crushed grape ratios.

A survey of the wine fermentation districts could be conducted to obtain COABDIS region specific data on the relative ratios of the different types (red and white) of wine fermented, rather than relying on a Statewide grape crush ratio.

## CHANGES IN METHODOLOGY

The current methodology has changed the method and surrogate used to determine wine fermentation by COABDIS region from those used in the previous 1992 update. The method for determining the temporal distribution of wine fermentation emissions has also changed, but the emission factors have remained the same, with the only difference being that all wines are now grouped into only two categories, red or white, whereas the previous methodology included a third category: rose wines.

Previously, amounts of grapes crushed by wine district and amount of grapes produced by county were used to disaggregate the statewide wine fermentation to the counties, but this has a greater potential for error than the current method. Grapes crushed are only recorded at the wine district level, and had to be further disaggregated itself to the county level using the amount of grapes produced by county. Unfortunately, grapes produced in a county may not be used by that county, but rather shipped to another place for fermentation of wine, for example. Nor will all the grapes produced even be used for wine. Some are used for table grapes, making raisins, and making grape juice. This introduced error in dividing up the wine to the counties. Furthermore, grapes crushed in a district may not be used in that district, being shipped to another place for the actual fermentation process. The new method uses directly reported wine fermentation at the county level from the TTB, disaggregating this to the COABDIS region level using the DABC’s wine production permit limit which is more directly related to each winery’s ability to ferment wine.

The temporal factor changes reflect the use of a new data source from the TTB, which breaks out wine fermentation by month on a county level basis.

## TEMPORAL ACTIVITY

Ethanol emissions are distributed monthly based on the 2002 reported wine fermentation at the county level for that month as shown in Table II. During each month, it is assumed that emissions occur 24 hours per day and seven days a week. Below is a summarized temporal distribution using a statewide average of all county specific distributions to give some idea of how wine fermentation emissions are distributed by month.

***2002 Statewide Wine Fermentation Emissions Distribution***

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.6 | 1.4 | 0.8 | 0.5 | 0.7 | 0.7 | 0.6 | 4.8 | 28.5 | 32.1 | 12.3 | 14.0 |

## SAMPLE CALCULATIONS

A. Calculate statewide ratios of white and red wine production.

Determine the tons of grapes crushed for each type of wine compared to the total tons of grapes crushed for both types in 2002.

CA red wine fermentation ratio = 1,816,715.6 tons red wine grapes crushed/ 3,104,580.9 tons of both wine grapes crushed
= 0.585 (58.5%)

CA white wine fermentation ratio = 1,287,865.3 tons white wine grapes crushed/ 3,104,580.9 tons of both wine grapes crushed
= 0.415 (41.5%)

B. Calculate composite emission factor.

Red wine TOG emission factor (6.2 lb/1000 gallons) x 0.585 +
White wine TOG emission factor (2.5 lb/1000 gallons) x 0.415 = 4.7 lb/1000 gallons

## REFERENCES


1. L.A. Williams & R. Boulton, Modeling and Prediction of Evaporative Ethanol Loss during Wine Fermentation, American Journal of Enology and Viticulture, 32:234-242, (1983).

2. California Department of Alcoholic Beverage Control, David Kurano (916) 419-2548.

3. Air Resources Board, A Suggested Control Measure for Control of Ethanol Emissions from Winery Fermentation Tanks, a Technical Support Document Prepared by the Energy Section, Stationary Source Division, ARB, California, (October 1991).

4. California Agricultural Statistics Services, Grape Crush Final Report, 2001-2002 Crop, http://www.nass.usda.gov/ca/bul/crush/Final/2002/200203gcbtb01.htm


## UPDATED BY

Larry Hunsaker
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**Table I**

**Wine Production Permit Limits in California by County and Air basin (1000 Gallons)**

| County | AB | Maximum Allowed Wine Production |
|---|---|---|
| ALAMEDA | SF | 7,560 |
| AMADOR | MC | 2,905 |
| BUTTE | SV | 65 |
| CALAVERAS | MC | 1,315 |
| CONTRA COSTA | SF | 105 |
| EL DORADO | MC | 1,275 |
| FRESNO | SJV | 113,190 |
| HUMBOLDT | NC | 70 |
| KERN | SJV | 21,205 |
| LAKE | LC | 4,375 |
| LASSEN | NEP | 5 |
| LOS ANGELES | SC | 1,175 |
| LOS ANGELES | MD | 10 |
| MADERA | SJV | 19,370 |
| MARIN | SF | 95 |
| MARIPOSA | MC | 45 |
| MENDOCINO | NC | 15,285 |
| MERCED | SJV | 59,005 |
| MODOC | NEP | 5 |
| MONTEREY | NCC | 23,430 |
| NAPA | SF | 84,415 |
| NEVADA | MC | 150 |
| ORANGE | SC | 20 |
| PLACER | SV | 45 |
| PLACER | MC | 5 |
| RIVERSIDE | SC | 2,085 |
| RIVERSIDE | SS | 20 |
| SACRAMENTO | SV | 1,055 |
| SAN BENITO | NCC | 13,465 |
| SAN BERNARDINO | SC | 30 |
| SAN DIEGO | SD | 330 |
| SAN FRANCISCO | SF | 25 |
| SAN JOAQUIN | SJV | 120,500 |
| SAN LUIS OBISPO | SCC | 30,865 |
| SAN MATEO | SF | 160 |
| SANTA BARBARA | SCC | 10,145 |
| SANTA CLARA | SF | 5,700 |
| SANTA CRUZ | NCC | 2,955 |
| SHASTA | SV | 10 |
| SISKIYOU | NEP | 15 |
| SOLANO | SV | 15 |
| SOLANO | SF | 225 |
| SONOMA | NC | 47,660 |
| SONOMA | SF | 26,985 |
| STANISLAUS | SJV | 63,055 |
| TEHAMA | SV | 5 |
| TRINITY | NC | 40 |
| TULARE | SJV | 16,020 |
| TUOLUMNE | MC | 30 |
| VENTURA | SCC | 145 |
| YOLO | SV | 5,240 |
| YUBA | SV | 105 |
| **TOTAL** | | **702,010** |

**Table II**

**2002 Area Source Emissions (CES: 47068)**
**Activity: Wines & Brandy**
**Process: Food & Agricultural**
**Entrainment: Process Loss**
**Dimn: Fermentation (Wine) Wine**
**Process Rate Unit: 1000 Gallons Fermented Per Year**

| County | AB | Process Rate | TOG (Tons/Year) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ALAMEDA | SF | 2,657 | 6.198 | 0.2 | 0.0 | 0.1 | 0.1 | 0.6 | 0.0 | 0.0 | 0.0 | 10.0 | 42.7 | 31.7 | 14.4 |
| AMADOR | MC | 955 | 2.227 | 1.8 | 0.5 | 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.7 | 28.9 | 21.4 | 42.8 |
| BUTTE | SV | 24 | 0.057 | 15.0 | 0.7 | 1.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.9 | 8.4 | 12.9 | 1.0 | 59.6 |
| CALAVERAS | MC | 488 | 1.139 | 15.1 | 0.0 | 5.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.6 | 13.9 | 15.3 | 44.3 |
| CONTRA COSTA | SF | 16 | 0.037 | 37.3 | 1.6 | 2.5 | 0.5 | 0.6 | 0.0 | 0.0 | 2.2 | 20.8 | 32.1 | 2.6 | 0.0 |
| EL DORADO | MC | 343 | 0.800 | 1.4 | 0.0 | 3.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.2 | 32.4 | 14.3 | 40.9 |
| FRESNO | SJV | 103,726 | 241.948 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 8.2 | 49.7 | 30.5 | 10.3 | 0.5 |
| HUMBOLDT | NC | 40 | 0.094 | 6.5 | 0.0 | 9.2 | 0.1 | 9.9 | 8.2 | 1.8 | 0.0 | 8.8 | 16.8 | 11.1 | 27.5 |
| KERN | SJV | 10,393 | 24.243 | 0.0 | 0.7 | 0.0 | 1.3 | 0.0 | 0.0 | 0.0 | 10.5 | 40.0 | 30.4 | 12.9 | 4.2 |
| LAKE | LC | 2,017 | 4.705 | 12.3 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9 | 4.2 | 1.9 | 4.7 | 75.4 |
| LASSEN | NEP | 1 | 0.003 | 24.5 | 1.1 | 1.6 | 0.3 | 0.4 | 0.0 | 0.0 | 1.4 | 13.7 | 21.1 | 1.7 | 34.3 |
| LOS ANGELES | MD | 1 | 0.003 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 5.1 | 0.0 | 0.0 | 20.7 | 10.3 | 0.9 | 62.8 |
| LOS ANGELES | SC | 129 | 0.301 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 5.1 | 0.0 | 0.0 | 20.7 | 10.3 | 0.9 | 62.8 |
| MADERA | SJV | 29,483 | 68.770 | 2.3 | 0.6 | 1.2 | 0.8 | 0.8 | 0.9 | 2.6 | 4.9 | 26.4 | 33.6 | 11.5 | 14.2 |
| MARIN | SF | 36 | 0.084 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.5 | 0.0 | 22.4 | 8.1 | 14.4 | 17.2 | 35.3 |
| MARIPOSA | MC | 8 | 0.019 | 31.6 | 1.4 | 2.1 | 0.4 | 0.5 | 0.0 | 0.0 | 1.8 | 17.6 | 27.2 | 2.2 | 15.1 |
| MENDOCINO | NC | 9,084 | 21.190 | 2.0 | 0.5 | 0.7 | 2.5 | 1.6 | 0.7 | 0.0 | 0.0 | 1.6 | 9.4 | 14.7 | 66.4 |
| MERCED | SJV | 67,423 | 157.269 | 0.8 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 33.4 | 49.5 | 8.3 | 6.2 |
| MODOC | NEP | 1 | 0.003 | 24.5 | 1.1 | 1.6 | 0.3 | 0.4 | 0.0 | 0.0 | 1.4 | 13.7 | 21.1 | 1.7 | 34.3 |
| MONTEREY | NCC | 11,025 | 25.717 | 45.3 | 9.2 | 3.1 | 0.2 | 1.2 | 3.8 | 0.0 | 0.0 | 0.8 | 4.7 | 9.5 | 22.1 |
| NAPA | SF | 43,191 | 100.746 | 3.9 | 1.6 | 2.6 | 1.5 | 0.9 | 0.7 | 0.8 | 1.5 | 15.8 | 23.5 | 19.2 | 28.0 |
| NEVADA | MC | 56 | 0.131 | 15.0 | 0.6 | 1.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.9 | 6.9 | 32.2 | 1.0 | 42.0 |
| ORANGE | SC | 7.19 | 0.017 | 15.6 | 0.7 | 1.0 | 0.2 | 0.2 | 0.0 | 0.0 | 0.9 | 8.7 | 13.4 | 1.1 | 58.1 |
| PLACER | MC | 1.7 | 0.004 | 16.9 | 0.7 | 1.1 | 0.2 | 0.3 | 0.0 | 0.0 | 1.0 | 9.4 | 14.5 | 7.6 | 48.2 |
| PLACER | SV | 15 | 0.035 | 16.9 | 0.7 | 1.1 | 0.2 | 0.3 | 0.0 | 0.0 | 1.0 | 9.4 | 14.5 | 7.6 | 48.2 |
| RIVERSIDE | SC | 367 | 0.857 | 0.0 | 0.0 | 1.9 | 0.5 | 1.7 | 3.2 | 0.0 | 0.0 | 1.2 | 44.6 | 26.6 | 20.3 |
| RIVERSIDE | SS | 4 | 0.008 | 0.0 | 0.0 | 1.9 | 0.5 | 1.7 | 3.2 | 0.0 | 0.0 | 1.2 | 44.6 | 26.6 | 20.3 |
| SACRAMENTO | SV | 105 | 0.246 | 0.8 | 2.4 | 3.8 | 0.7 | 0.9 | 0.0 | 0.0 | 3.3 | 31.4 | 48.4 | 3.9 | 4.5 |
| SAN BENITO | NCC | 3,227 | 7.528 | 0.4 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 3.6 | 21.3 | 10.2 | 63.9 |
| SAN BERNARDINO | SC | 7 | 0.017 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 1.3 | 12.6 | 72.9 | 0.0 | 12.9 |
| SAN DIEGO | SD | 51 | 0.118 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 7.2 | 4.4 | 87.7 |
| SAN FRANCISCO | SF | 6 | 0.013 | 24.5 | 1.1 | 1.6 | 0.3 | 0.4 | 0.0 | 0.0 | 1.4 | 13.7 | 21.1 | 1.7 | 34.3 |
| SAN JOAQUIN | SJV | 63,324 | 147.707 | 0.1 | 0.4 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 1.4 | 27.3 | 50.1 | 11.9 | 8.6 |
| SAN LUIS OBISPO | SCC | 17,316 | 40.391 | 24.9 | 2.2 | 1.7 | 0.3 | 0.1 | 0.3 | 0.2 | 0.2 | 4.2 | 20.2 | 28.4 | 17.3 |
| SAN MATEO | SF | 35 | 0.082 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.1 | 7.0 | 55.8 | 32.2 |
| SANTA BARBARA | SCC | 4,448 | 10.375 | 15.5 | 1.1 | 0.7 | 1.1 | 3.5 | 0.8 | 0.2 | 0.8 | 1.6 | 7.2 | 5.0 | 62.6 |
| SANTA CLARA | SF | 2,740 | 6.391 | 5.2 | 0.7 | 3.3 | 0.1 | 2.1 | 6.1 | 7.6 | 2.5 | 2.6 | 6.8 | 5.7 | 57.3 |
| SANTA CRUZ | NCC | 689 | 1.606 | 28.1 | 8.6 | 1.9 | 0.3 | 0.1 | 5.3 | 1.6 | 1.4 | 18.4 | 12.1 | 8.2 | 14.1 |
| SHASTA | SV | 2 | 0.005 | 24.5 | 1.1 | 1.6 | 0.3 | 0.4 | 0.0 | 0.0 | 1.4 | 13.7 | 21.1 | 1.7 | 34.3 |
| SISKIYOU | NEP | 3 | 0.008 | 24.5 | 1.1 | 1.6 | 0.3 | 0.4 | 0.0 | 0.0 | 1.4 | 13.7 | 21.1 | 1.7 | 34.3 |
| SOLANO | SF | 110 | 0.255 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.7 | 59.2 | 6.0 |
| SOLANO | SV | 7 | 0.017 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 34.7 | 59.2 | 6.0 |
| SONOMA | NC | 25,805 | 60.191 | 7.5 | 5.9 | 2.2 | 1.8 | 1.9 | 1.1 | 1.4 | 0.9 | 6.0 | 19.1 | 17.3 | 35.0 |
| SONOMA | SF | 14,611 | 34.080 | 7.5 | 5.9 | 2.2 | 1.8 | 1.9 | 1.1 | 1.4 | 0.9 | 6.0 | 19.1 | 17.3 | 35.0 |
| STANISLAUS | SJV | 51,752 | 120.715 | 0.3 | 2.1 | 0.5 | 0.3 | 2.8 | 2.5 | 1.6 | 12.7 | 29.0 | 28.5 | 10.3 | 9.3 |
| TEHAMA | SV | 1 | 0.003 | 24.5 | 1.1 | 1.6 | 0.3 | 0.4 | 0.0 | 0.0 | 1.4 | 13.7 | 21.1 | 1.7 | 34.3 |
| TRINITY | NC | 9 | 0.021 | 24.5 | 1.1 | 1.6 | 0.3 | 0.4 | 0.0 | 0.0 | 1.4 | 13.7 | 21.1 | 1.7 | 34.3 |
| TULARE | SJV | 11,868 | 27.683 | 0.0 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.7 | 58.3 | 18.0 | 0.1 | 0.7 |
| TUOLUMNE | MC | 18 | 0.043 | 9.1 | 0.4 | 0.6 | 0.1 | 0.1 | 0.0 | 0.0 | 0.5 | 5.1 | 7.8 | 0.6 | 75.5 |
| VENTURA | SCC | 35 | 0.081 | 24.5 | 0.9 | 8.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.7 | 0.9 | 56.6 |
| YOLO | SV | 2,713 | 6.328 | 3.6 | 0.0 | 0.7 | 0.1 | 0.3 | 0.0 | 0.0 | 0.0 | 12.3 | 61.9 | 9.6 | 11.4 |
| YUBA | SV | 24 | 0.056 | 24.5 | 1.1 | 1.6 | 0.3 | 0.4 | 0.0 | 0.0 | 1.4 | 13.7 | 21.1 | 1.7 | 34.3 |
| **STATEWIDE** | | **480,400** | **1,120.565** | **3.6** | **1.4** | **0.8** | **0.5** | **0.7** | **0.7** | **0.6** | **4.8** | **28.5** | **32.1** | **12.3** | **14.0** |

Fraction of Reactive Organic Gases (FROG): 1.0000
(Reactive Organic Gases (ROG) Emissions = TOG X FROG)