

**California Air Resources Board**

**Greenhouse Gas Quantification Methodology for the  
California Transportation Commission  
Active Transportation Program**

**Greenhouse Gas Reduction Fund  
Fiscal Year 2016-17**



October 28, 2016

**Note: This is a new Quantification Methodology specific to CTC ATP Projects that are eligible for GGRF funding. The SGC AHSC Quantification Methodology and Calculator Tool for FY 2015-16 may not be used for this program.**

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## Section A. Introduction

The goal of California Climate Investments is to reduce greenhouse gas (GHG) emissions and further the purposes of the Global Warming Solutions Act of 2006, known as Assembly Bill (AB) 32. The California Air Resources Board (ARB) is responsible for providing the quantification methodology to estimate the GHG emission reductions and other benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). ARB staff periodically review each quantification methodology to evaluate its effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified.

For the Fiscal Year (FY) 2016-17 California Transportation Commission (CTC) Active Transportation Program (ATP), ARB staff developed this GHG emission reduction quantification methodology and ATP GHG Emission Reduction Calculator Tool to provide methods for estimating GHG emission reductions of each proposed project applying for GGRF funds (Section B), provide instruction for documenting and supporting the estimate (Section C), and outline the process for tracking and reporting GHG reductions once a project is funded (Section D).

Although FY 2016-17 GGRF funds were appropriated to the California Department of Transportation (Caltrans), CTC is statutorily required to adopt the guidelines and selection criteria for and define the types of projects eligible to be funded through ATP GGRF monies. Caltrans is responsible for reporting expected and actual GHG emission reductions to ARB.

This methodology is based on the “Methods to Find the Cost-Effectiveness of Funding Air Quality Projects for Evaluating Motor Vehicle Registration Fee Projects and Congestion Mitigation and Air Quality Improvement Projects” (CMAQ Methods) to estimate the reduction in vehicle miles traveled (VMT) and associated GHG emission reductions based on transportation characteristics of the proposed project. Projects will report the total project GHG emission reductions estimated using this methodology as well as the total project GHG emission reductions per dollar of GGRF funds requested.

### ATP Project Types

The CTC ATP includes three project types that are eligible for GGRF funding, meet the objectives of ATP, and for which there are methods to quantify GHG emission reductions. ATP project types that are eligible to receive FY 2016-17 GGRF funding include:

- New pedestrian facilities,
- New bike paths or lanes (Class I, Class II, or Class IV); and
- New or expanded bike share.

Pedestrian and bike facility construction projects and bike share projects result in net GHG emission reductions by replacing auto trips with walking or bicycle trips, which reduce VMT. This quantification methodology includes methods for estimating GHG

emission reductions for the project types listed above.

Pedestrian facilities replace auto trips by providing or improving pedestrian access. An example is a pedestrian passageway over several lanes of heavy traffic providing safe walking access to adjacent activity centers.

GGRF eligible bike facilities include Class I, Class II, and Class IV bikeways, as defined below (from Assembly Bill 1193<sup>1</sup>).

- Class I bike paths or shared-use paths provide a completely separated right-of-way designated for the exclusive use of bicycles and pedestrians with crossflows by motorists minimized.
- Class II bike lanes provide a restricted right-of-way designated for the exclusive or semi-exclusive use of bicycles with through travel by motor vehicles or pedestrians prohibited, but with vehicle parking and crossflows by pedestrians and motorists permitted.
- Class IV separated bikeways provide a right-of-way designated exclusively for bicycle travel adjacent to a roadway and which are protected from vehicular traffic by features such as grade separation, physical barriers, or on-street parking.

Multi-use projects (i.e., Class I Bike Path) that will result in reduced VMT from bicycle and pedestrian uses may account for both uses. Contiguous projects are considered to be a single project for quantification of GHG emission reductions.

Note that Class III bike routes, which provide a right-of-way designated by signs or permanent markings and shared with pedestrians and motorists, are not currently quantified in this methodology.

New and expanded bike share projects reduce VMT by providing access to bicycles and therefore replacing auto trips with bike trips.

Section B details the methods to use based on the project type(s) proposed.

## **Methodology Development**

ARB developed this quantification methodology consistent with the guiding implementation principles of California Climate Investments, including ensuring transparency, accountability, and outreach and access for disadvantaged communities as described in ARB's Funding Guidelines for Agencies that Administer California

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<sup>1</sup> Assembly Bill 1193, available at:  
[https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill\\_id=201320140AB1193](https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201320140AB1193)

Climate Investments (Funding Guidelines).<sup>2</sup> ARB and CTC developed this quantification methodology through a public process to estimate GHG emission reductions from ATP projects that qualify for GGRF funding and to track the results of ATP projects funded with GGRF monies. The implementing principles ensure that the methodology would:

- Apply at the project-level.
- Align with the project types proposed for funding with GGRF monies.
- Provide uniform methods to be applied statewide, and be accessible by all applicants.
- Reflect relationships between the ATP project types listed above, and GHG emissions reductions that are conservative and supported by empirical literature; and
- Use project-level data, where available and appropriate.

This is a new Quantification Methodology specific to CTC ATP Projects that are eligible for GGRF funding. The SGC AHSC Quantification Methodology and Calculator Tool for FY 2015-16 may not be used for this program.

ARB released a draft FY 2016-17 quantification methodology for public comment in October 2016. Public comments were considered with the development of this October 28, 2016 version of the quantification methodology, which now includes bike share as an additional project type.

## Tools

This quantification methodology and the ATP GHG Calculator Tool are based on CMAQ Methods and estimate the reduction in VMT and associated GHG emission reductions based on transportation characteristics of the proposed project.

The CMAQ Methods are used statewide, are publicly available, and are subject to regular updates to incorporate new information. The CMAQ Methods are a set of equations for evaluating the cost-effectiveness of certain types of transportation projects, including bicycle paths, vanpools, and new bus service. The CMAQ Methods were developed by ARB and Caltrans, and are used statewide by transportation agencies to evaluate criteria pollutant emission reductions from transportation projects competing for State motor vehicle fee and federal CMAQ funding. The CMAQ Methods were used as the basis for developing the GHG emission reduction estimates for the ATP GGRF project types. The CMAQ Methods document can be downloaded from <https://www.arb.ca.gov/>. However, all of the equations and assumptions needed for this quantification method are included in this document and some assumptions have been modified, as necessary.

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<sup>2</sup> Funding Guidelines for Agencies that Administer California Climate Investments, December 21, 2015 available at: <https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/arb-funding-guidelines-for-ca-climate-investments.pdf>

## Program Assistance

CTC, Caltrans, and/or ARB staff will review the quantification portions of the ATP GGRF supplemental project applications to ensure that the methods described in this document were properly applied to estimate the GHG emission reductions for the proposed project. Applicants should use the following resources for additional questions and comments:

- Questions on this document should be sent to [GGRFProgram@arb.ca.gov](mailto:GGRFProgram@arb.ca.gov).
- For more information on ARB's efforts to support implementation of GGRF investments, see: <https://www.arb.ca.gov/auctionproceeds>.
- For more information about ATP, contact Laurie Waters at [Laurie.Waters@dot.ca.gov](mailto:Laurie.Waters@dot.ca.gov) or 916-651-6145

## Section B. Greenhouse Gas Quantification Methodology

This quantification methodology is provided for new or expanded connectivity projects (i.e., bicycle or pedestrian facilities) and bike share projects that reduce VMT. Table 1 describes this method by project type.

**Table 1. Methods by ATP Project Type**

Project Type / Method	Description
Bicycle Paths or Lanes	Bicycle paths (Class I), bicycle lanes (Class II), or separated bikeways (Class IV) that are targeted to reduce commute VMT and other auto travel. Emissions are reduced by replacing auto trips with bicycle trips.
Pedestrian Facilities	Pedestrian facilities reduce VMT by providing pedestrian access and replacing auto trips with walking trips.
Bike Share	Bike share projects reduce VMT by providing access to bicycles and replacing auto trips with bike trips.

### ATP GHG Calculator Tool

Applicants must use the ATP GHG Calculator Tool to estimate GHG emission reductions associated with proposed GGRF-funded projects. An example project showing how to use the ATP GHG Calculator Tool is provided in Appendix A. The equations used to estimate VMT reductions are based on the CMAQ Methods and are provided in Appendix B. Information on the emission factors used to convert VMT reductions to GHG emission reductions is available in Appendix C. The ATP GHG calculator tool can be downloaded from:

<https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm>.

Users should begin with the **Read Me** tab, which contains instructions and prompts users to enter project information. Key terms are defined in the **Definitions** tab. The **New Bike-Ped Infrastructure** tab and the **Bike Share** tab identify inputs required by the user, generally requiring project-specific data or assumptions. Input and output fields are color coded:

- **Yellow** fields indicate a direct user input is required.
- **Green** fields indicate a selection from a drop-down box is required.
- **Gray** fields indicate output or calculation fields that are automatically populated based on user entries and the calculation methods.

Details of calculation methods are provided in Appendix B.

Table 2 indicates which factors in the **New Bike-Ped Infrastructure** tab and the **Bike Share** tab require input from the applicant (“✓”), which values are not applicable (shaded cells), and lists default values programmed into the ATP GHG calculator.

**Table 2. Input Requirements by Project Type**

Input	Description	Project-Level Data Required		
		Bike Infrastructure	Pedestrian Infrastructure	Bike Share
Year 1	First Year of Project	✓	✓	✓
Year F	Final Year of Useful Life	<b>Class I/IV:</b> 20 years <b>Class II:</b> 15 years	20 years	10 years
Days of operation per year of new service (D)	Days of use per year of new service	200	200	
Length of average auto trip reduced (L)	Length of bike or walk trip	1.8 miles	1.0 mile	1.8 miles
Average Daily Traffic (ADT)	Annual Average Daily Traffic (two-way traffic volume in trips/day on parallel road). Use applicable value from project data (Maximum = 30,000)	✓	✓	
Yr1 Trips	Total number of bike trips using bike share bikes expected in the first year of service			✓
Adjustment Factor (A)	<b>New Bike/Ped Infrastructure:</b> Adjustment factor to account for bike/pedestrian use. <b>Bike Share:</b> Discount factor applied to annual ridership to account induced demand and non-utilitarian or commuting use	Refer to Table B-1 in Appendix B	Refer to Table B-1 in Appendix B	0.5
Activity Center Credit (C)	Activity Center Credit near project	Refer to Table B-2 in Appendix B	Refer to Table B-2 in Appendix B	

The **GHG Summary** tab displays the total project GHG emission reductions as well as the estimated total project GHG emission reductions per ATP GGRF dollar, per total GGRF dollar requested, and per total project cost, as described below.

- **Total Project GHG Emission Reductions** is equal to the sum of each of the GHG emissions reductions calculated in Section B and are automatically summed in the ATP GHG Calculator Tool in the **GHG Summary** tab.



- **Total Project GHG Emission Reductions per Dollars of ATP GGRF Funds** requested is calculated as:

$$\frac{\textit{Total Project GHG Emission Reductions (Metric Tons (MT) of CO}_2\textit{e)}}{\textit{ATP GGRF Funds Requested (\$)}}$$

Applicants should enter the ATP GGRF Funds Requested (\$) for all project features into the ATP GHG Calculator Tool. This amount is equal to the amount of GGRF dollars the applicant is requesting from CTC ATP. The ATP GHG Calculator Tool will provide the Total Project GHG Emissions per ATP GGRF Funds Requested.

- **Total Project GHG Emission Reductions per Dollars of GGRF Requested** is calculated as:

$$\frac{\textit{Total Project GHG Emission Reductions (MT CO}_2\textit{e)}}{\textit{Total GGRF Funds Requested (\$)}}$$

Applicants should enter the Total GGRF Funds Requested (\$) into the ATP GHG calculator for all project features. This amount is equal to the amount of GGRF dollars the applicant is requesting from CTC ATP, plus all GGRF dollars from other agencies that have previously been awarded to the same project and any GGRF dollars from agencies other than CTC that that project has or plans to apply for. For a list of GGRF funded programs, go to:

<https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/ggrfprogrampage.htm>.

If no other GGRF funds are requested, this will be the same amount as the ATP GGRF Funds Requested. The ATP GHG calculator will provide the Total Project GHG Emission Reductions per GGRF Funds Requested.

- **Total Project GHG Emission Reductions per Dollar (Total Project Cost)** is calculated as:

$$\frac{\textit{Total Project GHG Emission Reductions (MT CO}_2\textit{e)}}{\textit{Total Project Cost (\$)}}$$

Applicants should enter the total project cost. The ATP GHG Calculator Tool will provide the Total Project GHG Emissions per Dollar.

Once the Methods have been completed, go to **Section C. Documentation**.

## Section C. Documentation

In addition to ATP GGRF application requirements, applicants for GGRF funding are required to document results from the use of this quantification methodology, including supporting materials to verify the accuracy of project-specific inputs.

Applicants are required to provide electronic documentation that is complete and sufficient to allow the calculations to be reviewed and replicated. Paper copies of supporting materials must be available upon request by agency staff.

The following checklist is provided as a guide to applicants; additional data and/or information may be necessary to support project-specific input assumptions.

	<b>Documentation Description</b>	<b>Completed</b>
1.	Project description, including excerpts or specific references to the location in the main ATP application of the project information necessary to complete the applicable portions of the quantification methodology	
2.	Populated ATP GHG Calculator Tool file (in .xls or .xlsm) with worksheets applicable to the project populated (ensure that the GHG emission reductions and GHG emission reductions per GGRF funds requested fields in the summary worksheet contain calculated values)	
3.	If the Total GGRF Funds Requested are different than the ATP GGRF Funds Requested, identify the other GGRF program(s) where funding is sought, including the fiscal year of the application(s)	
4.	Any other information as necessary and appropriate to substantiate inputs	

## Section D. Reporting after Funding Award

Accountability and transparency are essential elements for all GGRF CCI projects. As described in ARB's Funding Guidelines<sup>2</sup>, each administering agency is required to track and report on the benefits of CCI funded under their program(s). Each project funded by the GGRF is expected to provide quantifiable GHG emission reductions. The previous sections of this document provide the methods and tools to estimate the GHG emission reductions of projects based on project characteristics and assumptions of expected conditions and activity levels. This section explains the minimum reporting requirements for Caltrans and ATP GGRF funding recipients as contracts are awarded and implemented, termed Phase 1, and after a project is completed, termed Phase 2. Table 2 shows the project phases and when reporting is required.

ATP GGRF funding recipients have the obligation to provide, or provide access to, data and information on project outcomes to Caltrans.

It is the responsibility of Caltrans to collect and compile project data from ATP GGRF funding recipients, including GHG emission reductions and information on benefits to disadvantaged communities.

**Table 3. Quantification and Reporting by Project Phase**

	<b>Timeframe</b>	<b>Quantification Methods</b>
<b>Funding Allocation</b>	Period from solicitation to selection of projects and funding awards. Applicant submits ATP GGRF supplemental project application to CTC by due date in solicitation materials.	All applicants use methods in ARB's quantification methodology to estimate the GHG emission reductions of the project.
<b>Phase 1</b>	Period from project award date through project completion date. Caltrans reports to ARB on an annual basis.	All funded projects use methods in ARB's quantification methodology to update initial estimate of GHG emission reductions, as needed, based on project changes.
<b>Phase 2</b>	Begins after Phase 1 is complete.	GHG reductions achieved are quantified and reported for a subset of funded projects.

Phase 1 reporting is required for all ATP GRRF funded projects. Caltrans will collect and submit data to ARB to satisfy Phase 1 reporting requirements. ATP GGRF funding recipients must report any changes that impact GHG emission reduction estimates (i.e., assumptions or quantities) to Caltrans prior to project completion.

Phase 2 reporting is required for only a subset of ATP GGRF funded projects and is intended to document actual project benefits achieved after the project becomes operational.

Phase 2 data collection and reporting will not be required for every project. Caltrans will be responsible for identifying the subset of individual projects that must complete Phase 2 reporting, identifying who will be responsible for collecting Phase 2 data, and for reporting the required information to ARB. ARB will work with Caltrans to address Phase 2 procedures, including but not limited to:

- The timelines for Phase 2 reporting, i.e., when does Phase 2 reporting begin, how long will Phase 2 reporting be needed.
- As applicable, approaches for determining the subset of projects that need Phase 2 reporting (i.e., how many X projects out of Y total projects are required to have Phase 2 reporting).
- Methods for monitoring or measuring the necessary data to quantify and document achieved GHG reductions and other select project benefits.
- Data to be collected, including data fields needed to support quantification of GHG emission benefits.
- Reporting requirements for transmitting the data to ARB or Caltrans for program transparency and use in reports.

Once the Phase 2 quantification method and data needs are determined, ARB will develop and post the final ARB approved Phase 2 methodology for use in Phase 2 reporting.

# Appendix A. Example Project

## Introduction

The following is a hypothetical project<sup>3</sup> to demonstrate how the FY 2016-17 ATP GGRF Program Quantification Methodology would be applied. This example does not provide examples of the supporting documentation that is required of actual project applicants.

## Overview of the proposed project

The proposed project is a new bike infrastructure project proposing the construction of 1 mile of Class II bike lane. The proposed project is located in Los Angeles and will be constructed in 2017. The project will cost \$700,000 to construct and the applicant does not have leverage funds. The road adjacent to the project has an ADT of 17,500 and there is a post office, a bank, a grocery store, and a church within ½ mile of the project site.

## Methods to apply

The Bicycle Paths or Lanes, and Pedestrian Facilities quantification methodology, through the use of the **New Bike-Ped Infrastructure** tab of the ATP GHG Emission Reduction Calculator Tool, should be utilized to estimate the GHG emission reductions for this project.

To begin, project identification information should be entered into the user input cells on the **Read Me** tab of the tool.

### Read Me Tab

Enter the Project Name and the contact information for person who can answer project specific questions on the quantification calculations.

Project Name:	Example Project
Contact Name:	John Smith
Contact Phone Number:	(555) 555-5555
Contact Email:	<a href="mailto:JohnSmith@exampleproject.com">JohnSmith@exampleproject.com</a>
Date Completed:	10/28/2016

Next, utilizing Table 2 above, the project specific inputs for a Class II bike lane are compiled. The required inputs are as follows:

- The project is located within Los Angeles County
- The first year of project (Yr 1) is 2017
- Based on a useful life of 15 years, the final year of useful life (Yr F) is 2032
- Annual Days of Operation (D) is the default of 200 days
- Average Daily Traffic (ADT) is 17,500

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<sup>3</sup> The hypothetical project has not undergone verification of any ATP or ATP GGRF Program requirements; all assumptions about location type and features are for quantification methodology demonstration purposes only.



# Appendix B. Equations Supporting the LCTOP GHG Calculator Tool

ARB developed the ATP GHG calculator tool to automate calculations described in this quantification methodology. This appendix provides the equations used in the ATP GHG calculator tool.

## Emission Factor Lookup Table

GGRF programs estimate transportation-related emissions using a “Well-to-Wheels” approach, which consists of emissions resulting from the production and distribution of different fuel types, including hydrogen and electricity, and any associated exhaust emissions. ATP Program applicants receiving GGRF funds use project-specific data to calculate new or avoided VMT, and VMT is converted to GHG emissions using Well-to-Wheels emission factors embedded in the ATP GHG calculator tool. The Lookup table used in the ATP GHG Calculator tool is attached as Appendix C. A detailed methodology of how the emission factors were developed is provided in Appendix C.

## Bicycle Paths or Lanes, and Pedestrian Facilities

Annual VMT Reductions of Displaced Autos from Bicycle Paths/Lanes and Pedestrian Facilities

$$Auto\ VMT\ Reduced = (D) * (ADT) * (A + C) * (L) \tag{Eq. 1}$$

Where,

- D** is the days of use per year (default is 200 days);
- ADT** is the annual average daily traffic (two-way traffic volume in trips/day on parallel road). Use applicable value from project data (Maximum is 30,000);
- A** is the adjustment factor to account for bike/ped use (use applicable value from Table A-1);
- C** is the activity center credit (use applicable value from Table A-2); and
- L** is the bike trip length (1.8 miles per trip in one direction) or walking trip length (1.0 miles per trip in one direction).

Table B- 1. Adjustment Factor (A) Lookup Table for Eq. 1

Average Daily Traffic (ADT)	Length of Bike/Ped Project (one direction)	A (for cities >250,000 and non-university towns <250,000)	A (for university towns with population <250,000)
ADT ≤ 12,000 vehicles per day	≤ 1 mile	.0019	.0104
	> 1 & ≤ 2 miles	.0029	.0155
	> 2 miles	.0038	.0207

12,000 < ADT ≤ 24,000 vehicles per day	≤ 1 mile	.0014	.0073
	> 1 & ≤ 2 miles	.0020	.0109
	> 2 miles	.0027	.0145
24,000 < ADT ≤ 30,000 vehicles per day Maximum is 30,000	≤ 1 mile	.0010	.0052
	> 1 & ≤ 2 miles	.0014	.0078
	> 2 miles	.0019	.0104

**Table B- 2. Activity Center Credit (C) Lookup Table for Eq. 1**

Count your Activity Centers. If there are...	Within 1/2 mile of Project Area	Within 1/4 mile of Project Area
3	.0005	.001
More than 3 but fewer than 7	.0010	.002
7 or more	.0015	.003

**Activity Center examples:** Bank, church, hospital or HMO, light rail station (park & ride), office park, post office, public library, shopping area or grocery store, university, junior college, primary school, or secondary school. These metrics should be evaluated for the project location site and surrounding area which can extend a distance from the housing development not to exceed one-half (½) mile.

Auto GHG Reductions for Year 1 and Year F of the bike or pedestrian facility

$$Auto\ Reductions_{Yr1} = \frac{Auto\ VMT\ Reduced * AVEF_{Yr\ 1}}{1,000,000} \quad (Eq. 2)$$

$$Auto\ Reductions_{YrF} = \frac{Auto\ VMT\ Reduced * AVEF_{Yr\ F}}{1,000,000} \quad (Eq. 3)$$

Where,

**AVEF** is the auto vehicle emission factor, see Appendix C.

GHG Emission Reductions over the useful life of the project

$$GHG\ Emission\ Reductions = \frac{Auto\ Reductions_{Yr1} + Auto\ Reductions_{YrF}}{2} * UL \quad (Eq. 4)$$

Where,

**UL** is the useful life, which is 20 years for Class I, 15 years for Class II and Class IV bicycle lanes, and 20 years for pedestrian facilities.

## Bike Share

The GHG emission reductions from Bike Share projects that result in an increase in bike trips are calculated as the GHG emission reductions from displaced autos.



$$\text{Auto VMT Reduced} = (T) * (A) * (L) \quad \text{(Eq. 5)}$$

Where,

- T** is the total number of bike trips using bike share bikes expected in the first year of service;
- A** is the adjustment factor to account for induced demand and non-utilitarian and/or non-commute use (default is 0.5); and
- L** is the bike trip length (1.8 miles per trip in one direction).

Auto GHG Reductions for Year 1 and Year F of the bike share project

$$\text{Auto Reductions}_{Yr1} = \frac{\text{Auto VMT Reduced} * \text{AVEF}_{Yr1}}{1,000,000} \quad \text{(Eq. 6)}$$

$$\text{Auto Reductions}_{YrF} = \frac{\text{Auto VMT Reduced} * \text{AVEF}_{YrF}}{1,000,000} \quad \text{(Eq. 7)}$$

Where,

**AVEF** is the auto vehicle emission factor, see Appendix C.

GHG Emission Reductions over the useful life of the project

$$\text{GHG Emission Reductions} = \frac{\text{Auto Reductions}_{Yr1} + \text{Auto Reductions}_{YrF}}{2} * UL \quad \text{(Eq. 8)}$$

Where,

**UL** is the useful life, which is 10 years for a bike share project.

## Appendix C. Emission Factors

The emission factors were developed using fuel consumption rates from ARB's Mobile Source Emission Factor Model (EMFAC 2014)<sup>4</sup> and carbon intensity values for different fuel types from ARB's Low Carbon Fuel Standard (LCFS) Program. This approach provides consistency amongst transportation-related GGRF programs and ARB's Low Carbon Fuel Standard (LCFS)<sup>5</sup> Program.

The following sections provide details on how the emission factors were developed.

### Auto Vehicle Emission Factors

Passenger (auto) vehicle emission factors (AVEF) were derived using the following steps.

1. Emissions by county for each calendar year from 2017 through 2050 were downloaded from EMFAC 2014 with the following parameters:
  - a. Annual Average
  - b. EMFAC2011 vehicle categories LDA, LDT1, LDT2, and MDV
  - c. Aggregated model year
  - d. Aggregated speed
  - e. Gasoline fuel
2. Calculate the auto fuel consumption rate (AFCR, in gallons of gasoline per mile) using the following equation:

$$AFCR = \frac{(FC_{LDA} + FC_{LDT1} + FC_{LDT2} + FC_{MDV}) * 1000}{VMT_{LDA} + VMT_{LDT1} + VMT_{LDT2} + VMT_{MDV}} \quad (\text{Eq. 9})$$

Where,

- FC** is the total fuel consumption for the vehicle type, in 1,000 gallons per day, from EMFAC 2014; and
- VMT** is the total vehicle miles traveled for the vehicle type, in miles per day, from EMFAC 2014.

3. Calculate the auto vehicle emission factors (AVEF, in grams of CO<sub>2</sub>e per mile), using the following equation:

$$AVEF = 11,405.84 * AFCR \quad (\text{Eq. 10})$$

Note: 11,405.84 is the Well-to-wheels Carbon content factor for gasoline in g CO<sub>2</sub>e per gallon of gasoline.

<sup>4</sup> <https://www.arb.ca.gov/emfac/2014/>

<sup>5</sup> <https://www.arb.ca.gov/fuels/lcfs/lcfs.htm>

FY 2016-17 Auto Vehicle Emission Factors (AVEF)  
in grams of CO<sub>2</sub>e per mile

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	
County	Alameda	507	493	480	466	452	438	424	409	395	383
	Alpine	487	473	459	445	431	417	404	390	377	365
	Amador	483	469	455	441	427	413	399	385	372	360
	Butte	540	523	506	489	473	456	439	423	408	394
	Calaveras	531	516	500	485	470	454	439	424	410	397
	Colusa	517	501	485	469	453	438	423	408	393	381
	Contra Costa	509	494	480	465	450	435	420	406	391	379
	Del Norte	568	553	538	524	509	493	478	464	449	436
	El Dorado	535	519	499	484	468	453	438	424	409	397
	Fresno	518	504	488	473	457	441	426	411	396	385
	Glenn	536	519	501	485	468	452	436	420	405	392
	Humboldt	529	516	503	490	477	463	450	436	423	410
	Imperial	515	499	483	468	453	438	423	411	397	384
	Inyo	542	526	510	495	479	463	448	433	418	405
	Kern	560	541	524	508	491	474	458	443	427	412
	Kings	518	496	480	465	451	436	421	407	392	382
	Lake	542	528	514	500	485	470	455	441	426	413
	Lassen	584	567	550	533	517	500	484	468	452	438
	Los Angeles	553	538	522	508	494	479	464	452	438	425
	Madera	546	540	522	505	481	464	447	440	424	420
	Marin	508	493	479	466	451	437	423	409	395	383
	Mariposa	565	548	531	514	497	480	463	447	432	418
	Mendocino	523	510	497	484	470	457	443	430	416	404
	Merced	535	523	507	490	476	460	443	429	413	402
	Modoc	645	626	607	589	570	552	533	515	498	482
	Mono	531	515	499	484	468	453	438	423	408	395
	Monterey	564	549	534	518	503	487	471	456	440	424
	Napa	499	484	468	454	438	423	408	394	380	367
	Nevada	530	516	502	489	474	460	446	431	418	405
	Orange	516	501	488	474	459	444	430	415	401	388
	Placer	512	496	482	467	451	436	421	407	392	380
	Plumas	624	606	588	571	554	536	519	502	486	471
	Riverside	503	489	474	460	446	431	417	404	390	378
	Sacramento	517	503	486	472	457	442	428	413	399	386
	San Benito	496	481	466	452	440	425	411	397	383	370
	San Bernardino	513	499	482	467	454	439	425	413	399	386
	San Diego	524	509	493	478	463	447	432	418	403	390
	San Francisco	530	516	502	488	474	460	446	432	418	405
	San Joaquin	523	506	491	476	459	443	428	412	397	384
	San Luis Obispo	498	483	469	455	440	426	412	399	385	373
	San Mateo	487	476	466	455	443	431	418	406	393	383
	Santa Barbara	483	469	456	443	430	416	403	390	377	363
	Santa Clara	489	475	462	449	435	421	408	394	381	369
	Santa Cruz	536	522	508	493	481	467	452	437	423	410
	Shasta	541	523	506	489	472	456	440	424	409	396
	Sierra	608	591	574	558	540	523	506	489	473	458
	Siskiyou	584	567	550	534	517	501	484	468	452	438
	Solano	525	509	494	479	463	448	433	418	403	391
	Sonoma	525	509	493	477	461	445	430	415	400	387
	Stanislaus	545	536	519	502	486	469	452	436	420	406
	Sutter	498	482	465	449	433	418	402	388	373	361
	Tehama	530	513	496	480	463	447	432	417	402	389
Trinity	664	646	627	609	591	572	554	535	517	501	
Tulare	524	505	489	473	458	442	426	410	395	379	
Tuolumne	575	559	542	526	509	493	476	460	444	429	
Ventura	505	490	476	461	448	433	418	405	391	378	
Yolo	522	507	490	476	461	446	431	416	401	388	
Yuba	508	491	470	454	438	422	407	393	379	366	

FY 2016-17 Auto Vehicle Emission Factors (AVEF)  
in grams of CO<sub>2</sub>e per mile (continued)

		2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
County	Alameda	372	362	353	345	339	333	327	323	319	316
	Alpine	355	345	337	330	323	318	313	308	305	302
	Amador	349	338	329	321	314	308	302	297	293	289
	Butte	381	370	360	351	343	336	330	324	320	316
	Calaveras	385	374	364	355	348	341	334	329	324	320
	Colusa	369	359	350	342	335	329	323	319	315	311
	Contra Costa	368	358	349	341	334	329	324	319	316	313
	Del Norte	423	412	401	392	383	375	368	361	356	351
	El Dorado	385	374	365	357	350	343	338	333	329	325
	Fresno	373	363	353	345	338	331	326	321	317	313
	Glenn	380	369	360	351	344	338	332	327	323	319
	Humboldt	399	388	378	369	361	353	346	340	335	330
	Imperial	373	363	354	346	340	334	329	324	320	317
	Inyo	394	383	374	365	358	352	346	341	337	333
	Kern	400	389	379	371	364	357	352	347	343	339
	Kings	370	360	351	343	335	329	324	319	315	311
	Lake	401	390	379	370	361	354	347	341	336	331
	Lassen	425	413	402	392	384	376	369	363	358	353
	Los Angeles	413	403	393	385	379	372	366	361	357	353
	Madera	407	395	385	375	367	360	354	349	345	341
	Marin	372	362	354	346	340	334	329	325	321	318
	Mariposa	405	393	383	373	365	358	351	345	340	336
	Mendocino	393	382	372	363	355	348	341	336	330	326
	Merced	389	378	367	358	350	344	338	332	328	324
	Modoc	468	455	443	433	423	415	408	401	395	390
	Mono	383	373	364	355	348	342	336	331	327	323
	Monterey	412	400	390	381	372	365	358	353	348	343
	Napa	356	346	337	330	323	317	312	307	303	300
	Nevada	393	382	372	363	355	348	342	336	331	327
	Orange	377	368	359	352	345	339	334	330	327	324
	Placer	368	358	349	342	335	329	324	319	315	312
	Plumas	457	444	433	422	413	404	396	390	384	378
	Riverside	367	357	349	341	336	331	326	322	318	315
	Sacramento	375	364	355	347	340	334	328	324	320	316
	San Benito	359	349	340	332	325	320	314	310	306	303
	San Bernardino	375	365	356	349	342	336	331	327	323	320
	San Diego	379	369	361	353	347	341	336	332	328	325
	San Francisco	395	385	377	369	363	357	352	348	345	342
	San Joaquin	372	362	353	344	337	331	325	320	316	313
	San Luis Obispo	362	352	344	336	329	323	317	313	309	305
	San Mateo	373	365	357	351	345	340	335	331	328	325
	Santa Barbara	353	343	335	327	321	315	309	305	301	297
	Santa Clara	359	350	341	334	328	322	317	313	310	307
	Santa Cruz	398	387	377	369	361	354	347	342	337	333
	Shasta	384	373	363	355	348	341	336	331	327	323
	Sierra	445	433	422	412	404	396	390	384	378	374
	Siskiyou	425	414	403	394	386	378	372	366	361	357
	Solano	380	370	361	353	346	340	335	330	327	324
	Sonoma	375	364	355	347	340	333	328	323	319	316
	Stanislaus	393	381	371	362	354	347	341	335	331	327
	Sutter	349	339	330	322	315	309	304	300	296	293
	Tehama	377	367	357	349	342	336	330	325	321	318
Trinity	487	473	461	449	439	430	421	414	408	402	
Tulare	367	356	346	338	330	324	318	313	309	305	
Tuolumne	416	404	392	382	373	365	358	352	347	342	
Ventura	367	358	349	342	336	331	326	322	318	315	
Yolo	376	366	356	348	341	335	329	324	320	317	
Yuba	355	345	336	328	321	315	310	306	302	311	

FY 2016-17 Auto Vehicle Emission Factors (AVEF)  
in grams of CO<sub>2</sub>e per mile (continued)

		2037	2038	2039	2040	2041	2042	2043	2044	2045	2046
County	Alameda	313	311	309	308	306	305	304	304	303	303
	Alpine	299	297	295	293	292	291	291	290	289	289
	Amador	286	283	281	279	277	276	275	274	273	272
	Butte	312	310	307	305	304	303	301	301	300	299
	Calaveras	317	314	311	309	307	305	304	302	301	300
	Colusa	309	306	304	303	301	300	299	299	298	297
	Contra Costa	310	308	306	305	303	302	302	301	300	300
	Del Norte	346	342	339	336	333	331	329	327	325	324
	El Dorado	322	320	318	316	314	313	312	311	310	309
	Fresno	311	308	306	304	303	302	301	300	300	299
	Glenn	316	314	312	310	309	308	307	306	305	305
	Humboldt	326	322	319	316	313	311	309	307	306	304
	Imperial	314	312	310	308	307	306	305	304	304	303
	Inyo	330	328	325	324	322	321	320	319	318	317
	Kern	336	334	332	330	329	328	327	326	326	325
	Kings	309	306	304	303	301	300	299	299	298	297
	Lake	327	323	320	318	315	313	312	310	309	307
	Lassen	349	346	343	340	338	336	335	333	332	331
	Los Angeles	350	348	346	344	342	341	340	339	339	338
	Madera	338	335	333	331	330	329	328	327	326	326
	Marin	315	313	311	310	309	308	307	306	306	305
	Mariposa	332	329	326	323	321	319	318	317	315	314
	Mendocino	322	318	315	312	310	308	306	304	303	301
	Merced	321	318	316	314	313	311	310	309	309	308
	Modoc	386	382	379	376	374	372	370	369	368	366
	Mono	320	317	315	313	312	311	309	308	308	307
	Monterey	340	336	334	331	329	328	326	325	324	323
	Napa	298	295	294	292	291	290	289	288	288	287
	Nevada	323	320	317	314	312	310	308	307	305	304
	Orange	321	319	318	316	315	314	314	313	313	312
	Placer	310	308	306	304	303	302	301	301	300	299
	Plumas	374	370	366	363	361	358	356	354	352	351
	Riverside	312	310	308	307	306	305	304	303	303	302
	Sacramento	314	311	309	308	306	305	304	304	303	302
	San Benito	300	298	296	294	293	292	291	290	289	289
	San Bernardino	317	315	313	311	310	309	308	307	306	306
	San Diego	323	321	319	318	317	316	315	315	314	314
	San Francisco	339	338	336	335	334	333	332	332	331	331
	San Joaquin	310	307	305	304	302	301	300	299	299	298
	San Luis Obispo	302	300	298	296	295	293	292	291	291	290
	San Mateo	323	321	319	318	317	316	315	315	314	314
	Santa Barbara	294	292	290	288	286	285	284	283	282	281
	Santa Clara	304	302	300	299	298	297	296	295	295	294
	Santa Cruz	329	326	323	321	319	318	316	315	314	313
	Shasta	320	318	316	314	313	312	311	310	309	309
	Sierra	370	367	364	362	360	358	357	356	355	354
	Siskiyou	354	351	348	346	344	342	341	340	339	338
Solano	321	319	317	316	314	313	313	312	311	311	
Sonoma	313	310	308	307	305	304	303	303	302	301	
Stanislaus	324	321	319	317	316	314	313	313	312	311	
Sutter	290	288	286	285	283	282	282	281	280	280	
Tehama	315	312	310	309	307	306	305	304	304	303	
Trinity	397	393	389	385	383	380	378	376	374	373	
Tulare	302	299	297	295	294	293	292	291	290	290	
Tuolumne	336	334	331	328	326	324	322	320	319	317	
Ventura	312	310	309	307	306	305	305	304	303	303	
Yolo	314	312	310	308	307	306	305	304	304	303	
Yuba	308	306	304	302	301	300	299	298	297	297	

FY 2016-17 Auto Vehicle Emission Factors (AVEF)  
in grams of CO<sub>2</sub>e per mile (continued)

	2047	2048	2049	2050
Alameda	302	302	301	301
Alpine	289	288	288	288
Amador	271	270	270	269
Butte	299	298	298	297
Calaveras	299	299	298	298
Colusa	297	297	296	296
Contra Costa	300	299	299	299
Del Norte	322	321	320	319
El Dorado	309	308	308	308
Fresno	299	299	298	298
Glenn	304	304	303	303
Humboldt	303	302	300	299
Imperial	303	302	302	301
Inyo	317	316	316	315
Kern	325	324	324	324
Kings	297	297	296	296
Lake	306	305	304	304
Lassen	330	329	328	328
Los Angeles	338	337	337	336
Madera	325	325	324	324
Marin	305	305	305	304
Mariposa	313	313	312	311
Mendocino	300	299	298	297
Merced	307	307	307	306
Modoc	365	364	364	363
Mono	306	306	305	305
Monterey	322	321	320	320
Napa	287	286	286	286
Nevada	302	301	300	299
Orange	312	311	311	311
Placer	299	299	298	298
Plumas	349	348	346	345
Riverside	302	302	301	301
Sacramento	302	301	301	301
San Benito	288	288	287	287
San Bernardino	305	305	304	304
San Diego	314	313	313	313
San Francisco	331	331	330	330
San Joaquin	298	297	297	297
San Luis Obispo	289	289	288	288
San Mateo	314	313	313	313
Santa Barbara	280	280	279	279
Santa Clara	294	294	293	293
Santa Cruz	312	311	310	310
Shasta	308	308	308	307
Sierra	353	352	351	350
Siskiyou	337	336	336	335
Solano	311	310	310	310
Sonoma	301	301	300	300
Stanislaus	311	310	310	310
Sutter	280	279	279	279
Tehama	303	302	302	301
Trinity	371	370	369	368
Tulare	289	289	289	288
Tuolumne	316	315	314	314
Ventura	303	302	302	302
Yolo	303	302	302	301
Yuba	296	296	295	295