

California Air Resources Board

**Greenhouse Gas Quantification Methodology for the
Department of Transportation
Low Carbon Transit Operations Program**

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



January 31, 2017

Table of Contents

Section A. Introduction..... 1
 LCTOP Project Types..... 1
 Methodology Development 3
 Tools... 4
 Updates 4
 Program Assistance..... 5
Section B. GHG Quantification Methodology 6
 Overview..... 6
 Step 1. Define the Proposed Project Using the LCTOP Allocation Request..... 7
 Step 2. Identify the LCTOP Project Category 8
 Step 3. Determine the LCTOP Project Inputs Needed..... 9
 Step 4. Estimate GHG Emission Reduction Reductions for the Proposed Project
 Using the LCTOP GHG Calculator Tool..... 10
 Project Summary 11
Section C. Documentation 13
Section D. Reporting after Funding Award..... 14

Table 1. Eligible LCTOP Project Types 2
Table 2. Project Type by Category 8
Table 3. Required Fields by Project Category 9
Table 4. Quantification and Reporting By Project Phase..... 14

Figure 1. Steps to Estimating GHG Emission Reductions..... 6

Appendix A. Methods and Equations Supporting the LCTOP GHG Calculator 16
Appendix B. Example Project..... 20
Appendix C. Emission Factors 25

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 develops these methodologies based on the project types eligible for funding by each administering agency as reflected in the program Expenditure Records available at:

<https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/expenditurerecords.htm>. 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 Department of Transportation's (Caltrans) Low Carbon Transit Operations Program (LCTOP), ARB staff developed this quantification methodology and LCTOP GHG Calculator tool to provide methods for estimating net GHG emission reductions of each proposed project (Section B), provide instructions for documenting and supporting the estimate (Section C), and outline the process for tracking and reporting GHG emission reductions once a project is funded (Section D).

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"ⁱ (CMAQ Methods) to estimate the reduction in vehicle miles traveled (VMT) and associated GHG emission reductions based on transportation characteristics of the proposed project.

LCTOP Project Types

LCTOP funding shall be expended to provide transit operating or capital assistance that meets any of the following:

- Expenditures that directly enhance or expand transit service by supporting new or expanded bus or rail services, new or expanded water-borne transit, or expanded intermodal transit facilities, and may include equipment acquisition, fueling, and maintenance, and other costs to operate those services or facilities.;
- Operational expenditures that increase transit mode share.
- Expenditures related to the purchase of zero-emission buses, including electric buses, and the installation of the necessary equipment and infrastructure to operate and support these zero-emission buses.

Caltrans and ARB determined eligible project types that meet the objectives of LCTOP and achieve GHG emission reductions. Each project requesting GGRF funding must include at least one of the project types described in Table 1.

Table 1. Eligible LCTOP Project Types

Project Type	Description
Implement new transit service	Implement new transit service (new routes/lines).
Expand/Enhance transit service	Expand/Enhance transit service (extend transit routes, extend service hours, increase frequency of service, increase capacity [e.g., add more buses or rail cars to existing routes]).
Provide alternative transit options	Provide alternative transit options that use zero-emission or hybrid vehicles to improve mobility (e.g., vanpooling, shuttles, bikesharing).
Transit vouchers	Free or reduced-fare transit vouchers.
Network/fare integration	Network/fare integration (e.g., universal fare card that can be used for multiple transit systems).
Install new transit facilities	Install new transit facilities (stops/stations) for local bus, intercity rail, commuter bus or rail service or that connect to bike paths/pedestrian path.
Upgrade transit facilities	Upgrade transit stops/stations (e.g., bike-sharing facilities; bike racks/lockers; covered benches; energy efficient lighting) to support active transportation and encourages ridership.
Upgrade transit vehicle(s)	Upgrade transit vehicles (e.g., bicycle racks on buses; bicycle storage on rail cars) to support active transportation and encourage ridership.
Purchase zero-emission/hybrid vehicle(s)	Rolling stock acquisition. GHG emission reductions achieved by comparing each zero-emission or hybrid purchase against a conventional (diesel) vehicle as the baseline for each project.
Purchase replacement zero-emission/hybrid vehicle(s)	Rolling stock acquisition. Requires a vehicle to be replaced. GHG emission reductions achieved by comparing each zero-emission or hybrid purchase against the replaced (project specific) vehicle as the baseline for each project.

Methodology Development

ARB and Caltrans 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 *Cap-and-Trade Auction Proceeds: Funding Guidelines for Agencies that Administer California Climate Investments* (2015 Funding Guidelines).ⁱⁱ ARB and Caltrans developed this quantification methodology through a public process to estimate the outcomes of proposed projects and track the results of funded projects. The implementing principles ensure that the methodology will:

- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants;
- Use existing and proven tools and methods;
- Use project-level data, where available and appropriate; and
- Reflect relationships between mode shifts and corresponding VMT reductions and GHG emissions-reductions that are conservative and supported by empirical literature.

ARB reviewed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the LCTOP project types. ARB also consulted with Caltrans to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level.

ARB released a draft Fiscal Year (FY) 2016-17 quantification methodology and LCTOP GHG Calculator tool for public comment in October 2016. This FY 2016-17 quantification methodology and accompanying GHG emission reduction calculator have been updated to reflect public comments received.

In addition, Caltrans updated the Allocation Request form to be more user-friendly, clarify required information and streamline the application review process by integrating all of the required LCTOP application documents into one file with ARB's GHG Calculator tool.

Tools

The CMAQ Methods are used statewide, are publicly available, and are subject to regular updates to incorporate new information. 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 LCTOP project types. All of the equations and assumptions needed for this quantification method are included in this document and some assumptions have been modified, as necessary. The CMAQ Methods document can be downloaded from <https://www.arb.ca.gov/planning/tsaq/eval/eval.htm>.

The emission factors were developed using fuel consumption rates from ARB's Mobile Source Emission Factor Model (EMFAC 2014). EMFAC 2014 is a web-based tool developed by ARB used to determine vehicle emission factors based on region, calendar year, season, vehicle category, model year, speed, and fuel. The tool provides specified emission factor data in a comma separated values (CSV) output file that can be opened in most spreadsheet software. The tool is used statewide, publicly available, subject to regular updates to incorporate new information, is free of charge, and available to anyone with internet access. The tool can be accessed at: <https://www.arb.ca.gov/emfac/2014/>

Updates

ARB updated this quantification methodology from the previous version.ⁱⁱⁱ The changes include:

- Updates to the GHG emission factors used in calculating emission reductions;
- Reformat of the LCTOP GHG Calculator^{iv} tool to simplify the use of the quantification methodology and allow for additional project-specific input;
- Modification to allow for fuel-specific input supported by a carbon intensity score issued by ARB's Low Carbon Fuel Standard Program;
- Ability to calculate the operation of hybrid vehicles and the purchase of zero-emission buses; and
- Additional definitions and clarity to the text.

Program Assistance

ARB and Caltrans staff will review the quantification portions of the LCTOP 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:

- Applicants are encouraged to check the frequently asked questions (FAQ) page regularly during the application process, which is at: www.arb.ca.gov/cci-quantification
- Questions on this document should be sent to GGRFProgram@arb.ca.gov.
- For more information on ARB's efforts to support implementation of GGRF investments, see: www.arb.ca.gov/auctionproceeds.
- Questions pertaining to the LCTOP should be sent to LCTOPcomments@dot.ca.gov.

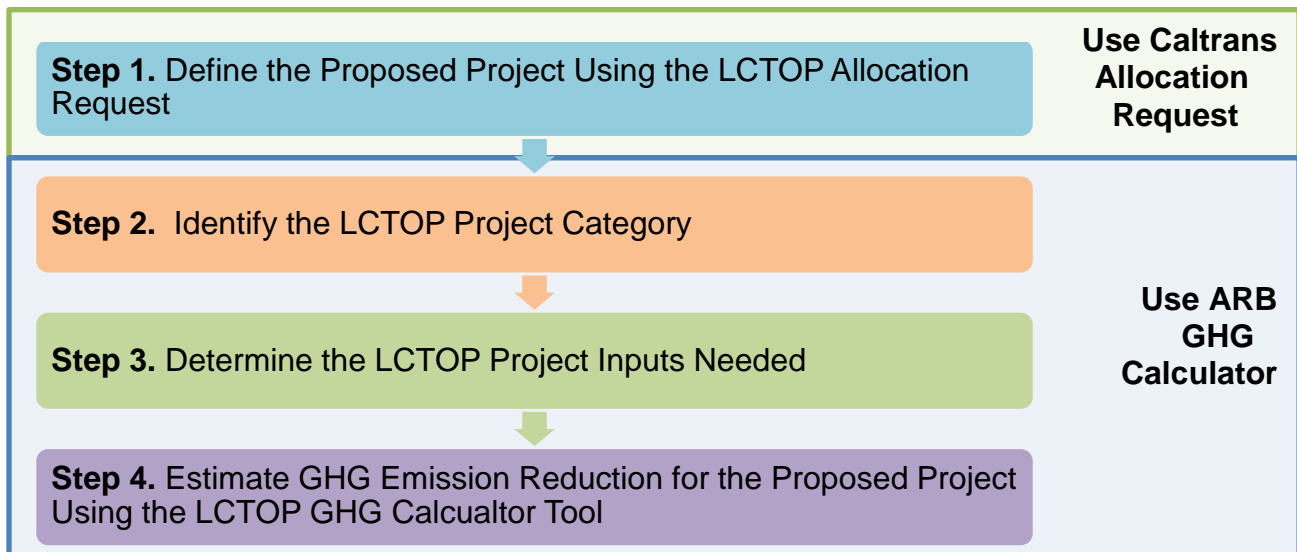
Section B. GHG Quantification Methodology

Overview

This quantification methodology accounts for GHG emission reductions based on estimated ridership increases and corresponding passenger auto VMT reductions. Applicants will use the Caltrans Allocation Request form and the ARB GHG Calculator tool to estimate the total GHG emission reductions from the proposed project, as defined in this methodology. Methods and equations used in the GHG Calculator tool for estimating the GHG emission reductions are provided in Appendix A.

Applicants will follow the steps outlined in Figure 1 to estimate the GHG emission reductions from the proposed project. Detailed instructions for each step are provided on subsequent pages. An example project showing how to use estimate GHG emission reductions from a New/Expanded Service project is included in Appendix B.

Figure 1. Steps to Estimating GHG Emission Reductions



Note: Applicants with more than one project type must use multiple LCTOP Allocation Requests and GHG Calculator tools to quantify the GHG emission reductions from each project.

Step 1. Define the Proposed Project Using the LCTOP Allocation Request

Applicants must complete the LCTOP **Allocation Request** tab in order to complete this step. The LCTOP Allocation Request form can be downloaded from <http://www.dot.ca.gov/drmt/splctop.html>.

Users should begin with the **AR-Read Me** tab, which contains instructions for users on entering project information. The Project Benefits section in the **Allocation Request** tab identifies inputs required by the user, generally requiring project-specific data or assumptions. Input and output fields are color coded:

- **Yellow** fields indicate a selection from a drop-down menu is available.
- **Blue** fields indicate auto populated fields.
- **Green** fields indicate calculation fields that are automatically populated based on user entries and the calculation methods.

Step 2. Identify the LCTOP Project Category

For GHG quantification purposes, eligible LCTOP projects fall into the four project categories shown in Table 2. The applicant will use the **Project Types by Category (QM-PTC)** tab to identify the LCTOP Project Category for the applicable project type as defined in the LCTOP Allocation Request form. Some projects may have additional GHG emission reductions, such as replacing existing transit vehicle(s) or from fuel reductions.

Table 2. Project Type by Category

Project Type	Project Category	Additional GHG Emission Reductions
Implement new transit service	New/Expanded Service	Optional: Fuel Reductions
Expand/Enhance transit service		Not Applicable
Provide alternative transit options		Not Applicable
Transit vouchers	Service Improvements	Not Applicable
Network/fare integration		Not Applicable
Install new transit facilities	Capital Improvements	Optional: Fuel Reductions
Upgrade transit facilities		Not Applicable
Upgrade transit vehicle(s)		Not Applicable
Purchase zero-emission/hybrid vehicle(s)	Cleaner Vehicles	Not Applicable
Purchase replacement zero-emission/hybrid vehicle(s)		Vehicle Replacement

Step 3. Determine the LCTOP Project Inputs Needed

The applicant will use the **Required Fields by Project Category (QM-RFC)** tab, presented as Table 3, to determine the required inputs needed. Input fields noted with an asterisk (*) in blue will be auto filled from the LCTOP **Allocation Request** tab.

Table 3. Required Fields by Project Category

Input Fields	New/Expanded Service	Service/Capital Improvements	Cleaner Vehicles
Project Category	*	*	*
Project Type	*	*	*
Service Type	✓	✓	✓
Region	✓	✓	✓
Subregion	✓	✓	✓
Year 1(Yr1)	*	*	*
Year F(YrF)	*	*	*
Project Yr1 Ridership	*	*	
Project YrF Ridership	*	*	
Adjustment Factor (A)	*	*	
Trip Length (L)	*	*	
Vehicle Type	✓		✓
Hybrid Vehicle	✓		✓
Fuel Type	✓		✓
Project Specific Emission Factor	Optional		Optional
Model Year	✓		✓
Annual VMT	✓		✓
Annual Fuel	Optional		Optional
Additional GHG Reductions	Optional: Fuel Reductions	Optional: Fuel Reductions	Optional: Vehicle Replacement
Fuel Type	✓	✓	✓
Model Year			✓
Annual VMT			✓
Annual Fuel	✓	✓	Optional
FY 2016-17 LCTOP GGRF Funds Requested	✓	✓	✓
Total LCTOP GGRF Funds Requested	✓	✓	✓
Total GGRF Funds Requested	✓	✓	✓

Step 4. Estimate GHG Emission Reductions for the Proposed Project Using the LCTOP GHG Calculator Tool

Applicants must use the LCTOP **GHG Calculator tool (QM-Tool)** tab to estimate GHG emission reductions associated with proposed LCTOP-funded projects.

Users should begin with the **QM-Read Me** tab, which contains instructions to estimate GHG emission reductions. The **QM-Tool** tab identifies inputs required by the user, generally requiring project-specific data or assumptions. Key terms are defined under the **Description** column and are described with respect to project category and project type. Input and output fields are color coded:

- **Purple** fields indicate a selection from a drop-down box or direct user input is required.
- **Blue** fields indicate inputs from user entries from the Allocation Request form, if applicable.
- **Pink** fields indicate an optional direct user input; additional documentation is required to support entry.
- **Green** fields indicate calculation fields that are automatically populated based on user entries and the calculation methods.

Helpful tips to provide clarification or suggested inputs may appear when input cells are selected.

Project Summary

The LCTOP **GHG Calculator Summary (QM SUM)** tab calculates and displays the annual and total auto VMT displaced and GHG emission reductions as well as the estimated GHG emission reductions per LCTOP GGRF dollar and per total GGRF dollar requested, as described below. Key terms are defined under the **Description** column.

- **Total Project GHG Emission Reductions** is equal to the sum total of each of the GHG emission reductions calculated in Section B and are automatically summed in the LCTOP GHG Calculator tool in the **Summary** tab.
- **LCTOP GHG Emission Reductions** is equal to the Total Project GHG Emission Reduction prorated as:

$$\text{LCTOP GHG Emission Reductions} = \text{Total Project GHG Emission Reductions} * \left(\frac{\text{Total LCTOP GGRF Funds Requested} (\$)}{\text{Total GGRF Funds Requested} (\$)} \right)$$

Applicants should enter the Total LCTOP GGRF Funds Requested (\$) and Total GGRF Funds Requested (\$) into the LCTOP GHG Calculator tool for all project features.

The Total LCTOP GGRF Funds Requested (\$) is equal to the amount of FY 2016-17 LCTOP dollars the applicant is requesting from Caltrans, plus all LCTOP dollars from Caltrans that have previously been awarded to the same project and any future LCTOP dollars that the project plans to apply for.

The Total GGRF Funds Requested (\$) is equal to the Total LCTOP Funds Requested (\$), plus all GGRF dollars that have previously been awarded to the same project and any other GGRF dollars that the project has or plans to apply for. For a list of GGRF funded programs, go to: www.arb.ca.gov/cci-events.

If no other GGRF funds have been requested, the Total GGRF Funds Requested (\$) will be the same amount as the Total LCTOP GGRF Funds Requested. The LCTOP GHG Calculator tool will provide the Total LCTOP GHG Emission Reductions.

- **LCTOP GHG Emission Reductions per Dollars of LCTOP GGRF Funds Requested** is calculated as:

$$\frac{\text{LCTOP GHG Emission Reductions (MTCO}_2\text{e)}}{\text{Total LCTOP GGRF Funds Requested} (\$)}$$

The LCTOP GHG Calculator will provide the LCTOP GHG Emission Reductions per LCTOP GGRF Funds Requested.

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

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

The LCTOP GHG Calculator will provide the Total Project GHG Emission Reductions per GGRF Funds Requested.

Section C. Documentation

In addition to LCTOP application requirements, applicants applying for LCTOP 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 Caltrans 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.

	Documentation Description	Completed
1.	Project description, including excerpts or specific references to the location in the LCTOP Allocation Request file (in .xlsm) of the project information necessary to complete the applicable portions of the quantification methodology	
2.	Populated LCTOP GHG Calculator tool (in .xlsm) with worksheets applicable to the project populated (ensure that the GHG emission reduction and GHG emission reduction/GGRF \$ requested fields in the summary worksheet contain calculated values). Please use the following file naming convention: “[Lead Agency]_[Project Name]” not to exceed 20 characters.	
3.	If the Total GGRF funds requested are different than the LCTOP GGRF funds requested, provide an explanation of the other GGRF program(s) where funding is sought, including the FY 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 California Climate Investment projects. As described in ARB's Funding Guidelines, each administering agency is required to track and report on the benefits of the California Climate Investments funded under their program(s). Each project funded by the GGRF is expected to provide a quantifiable GHG emission reduction. The previous sections of this document provides the methods and tools to estimate the GHG emission reductions of a proposed project based on project characteristics and assumptions of expected conditions and activity levels. This section explains the minimum reporting requirements for administering agencies and funding recipients during project implementation, termed Phase 1, and after a project is completed, termed Phase 2. Table 4 below shows the project phases and when reporting is required.

Table 4. Quantification and Reporting By Project Phase

	Timeframe	Quantification Methods
Project Selection	Period from solicitation to funding awards. Applicant submits application to Caltrans by due date in solicitation materials.	All applicants use methods in ARB's quantification methodology to estimate the GHG emission reductions of the project.
Phase 1	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 estimates of GHG emission reductions, as needed, based on project changes.
Phase 2	Starts after Phase 1 is complete and a project becomes operational.	GHG emission reductions achieved are quantified and reported for a subset of funded projects.

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 funding recipients, including the GHG emission reduction and information on benefits to disadvantaged communities.

Phase 1 reporting is required for all LCTOP funded projects. Caltrans will collect and submit data to ARB to satisfy Phase 1 reporting requirements. 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 LCTOP 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.

ⁱ <https://www.arb.ca.gov/planning/tsaq/eval/eval.htm>

ⁱⁱ [Cap-and-Trade Auction Proceeds: Funding Guidelines for Agencies that Administer California Climate Investments, December 2015.](#)

ⁱⁱⁱ [LCTOP Quantification Methodology for FY 2015-16, December 2015.](#)

^{iv} [LCTOP GHG Emission Reduction Calculator for FY 2015-16, December 2015.](#)

Appendix A. Methods and Equations Supporting the LCTOP GHG Calculator

In general, the GHG emission reductions are calculated using the following approaches:

Table A-1. GHG Quantification Approach by Category

New/Expanded Service
$GHG \text{ Emission Reductions} = GHG \text{ Emission Reductions of Displaced Autos} - GHG \text{ Emissions of New/Expanded Service}$
Service Improvements
$GHG \text{ Emission Reductions} = GHG \text{ Emission Reductions of Displaced Autos}$
Capital Improvements
$GHG \text{ Emission Reductions} = GHG \text{ Emission Reductions of Displaced Autos}$
Cleaner Vehicles
$GHG \text{ Emission Reductions} = GHG \text{ Emissions of Baseline Vehicle} - GHG \text{ Emissions of New Vehicle}$

Table A-2. Additional GHG Quantification Approach

Replacement
$GHG \text{ Emission Reductions} = GHG \text{ Emissions of Replacement Vehicle} - GHG \text{ Emissions of New Vehicle}$
Fuel Reductions
$GHG \text{ Emission Reductions} = GHG \text{ Emissions of Fuel Reductions}$

The GHG emission reductions from the project are quantified within the LCTOP GHG Calculator tool using the equations below. The GHG emission reductions are quantified using the equations below for Year 1 and Year F.

New/Expanded Service

The GHG emission reductions from New/Expanded Service projects are calculated as the difference between the GHG emission reductions from displaced autos and GHG emissions associated with the operation of the new/expanded service calculated using Equations 1 through 3. Equation 1 is used to calculate the annual VMT reductions from the proposed project and Equation 2 is used to calculate the GHG emission reductions associated with auto VMT reductions. Equation 3 is used to calculate the GHG emissions associated with the operation of the new/expanded service.

GHG Emission Reductions from New/Expanded Service

$$GHG \text{ Emission Reductions} = GHG \text{ Emission Reductions of Displaced Autos} - GHG \text{ Emissions of New/Expanded Service}$$

Equation 1: Annual Auto VMT Reduced in Miles per Year

$$AutoVMT = [(R) * (A) * (L)]$$

<i>Where,</i>		<u>Units</u>
<i>R</i>	= Annual increase in unlinked passenger trips directly associated with the proposed project	riders
<i>A</i>	= Adjustment factor to account for transit dependency Use: documented project specific data or system average developed from recent, statistically valid survey or default. Default: 0.5 for local service or 0.83 for long distance service, shuttle and vanpools.	unitless
<i>L</i>	= Estimated length of average unlinked passenger trip directly associated with the proposed project calculated as passenger-miles divided by unlinked trips. Applicants may use data reported to National Transit Database for similar service.	mile-rider

Equation 2: GHG Emission Reductions of Displaced Autos

$$GHG \text{ Emissions of Displaced Autos} = \frac{[(AutoVMT) * (AVEF)]}{1,000,000}$$

<i>Where,</i>		<u>Units</u>
<i>AutoVMT</i>	= Annual auto VMT reduced; calculated using Equation 1	miles
<i>AVEF</i>	= Auto Vehicle Emission Factor; see Table C-1	gCO ₂ e/mile
1,000,000	= Conversion factor	grams/MT

Equation 3: GHG Emissions of New/Expanded Service

$$GHG \text{ Emissions of New/Expanded Service} = \frac{[(NSVMT) * (NSEF)]}{1,000,000}$$

Or (for train/ferry service use only)

$$= \frac{[(NSFuel) * (FuelEF)]}{1,000,000}$$

<i>Where,</i>			<u>Units</u>
<i>NSVMT</i>	=	The estimated annual VMT attributed to the operation of the new/expanded service	miles
<i>NSEF</i>	=	Emission factor based on service type; see Table C-1	gCO2e/mile
<i>NSFuel</i>	=	The estimated annual fuel attributed to the operation of the new/expanded service - only available for train and ferry services	unit of fuel
<i>FuelEF</i>	=	Emission factor based on fuel type; see Table C-2	gCO2e/unit of fuel
1,000,000	=	Conversion factor	grams/MT

Service/Capital Improvements

The GHG emission reductions from Service/Capital Improvements that result in an increase in ridership are calculated as the GHG emission reductions from displaced autos, which can be calculated using Equation 1 and Equation 2.

GHG Emission Reductions from Service/Capital Improvements

$$GHG \text{ Emission Reductions} = GHG \text{ Emission Reductions of Displaced Autos}$$

Cleaner Vehicles

The GHG emission reductions from the acquisition of Cleaner Vehicles are calculated as the difference between the baseline or replaced vehicle and new vehicle. GHG emissions from the baseline, replaced and new vehicle are calculated using Equation 4.

For the acquisition of a new zero-emission vehicle, where there is not existing vehicle to be replaced, the GHG Calculator tool assumes a baseline vehicle with the model year equal the first year of operation to represent the newest available diesel-equivalent vehicle.

For the acquisition of a new vehicle, where there is an existing vehicle to be replaced, the GHG Calculator tool requires project specific inputs of the replacement vehicle to calculate the GHG emission reductions.

GHG Emission Reductions from Cleaner Vehicles

$$GHG \text{ Emission Reductions} = GHG \text{ Emission Reductions of Baseline/Repalced Vehicle} - GHG \text{ Emissions of New Vehicle}$$

Equation 4: GHG Emission Reductions from Cleaner Vehicles

$$GHG \text{ Emissions of Baseline/Replaced/New Vehicle} = \frac{[(AnnualVMT) * (VehicleEF)]}{1,000,000}$$

Or (for train or ferry only)

$$GHG \text{ Emissions of Baseline/Replaced/New Vehicle} = \frac{[(AnnualFuel) * (FuelEF)]}{1,000,000}$$

<i>Where,</i>		<u>Units</u>
<i>AnnualVMT</i>	= The estimated annual VMT of the vehicle to be acquired	miles
<i>VehicleEF</i>	= Emission factor based on vehicle type; see Table C-1	gCO2e/mile
<i>AnnualFuel</i>	= The estimated annual fuel of the vehicle to be acquired - only available for train and ferry services	unit of fuel
<i>FuelEF</i>	= Emission factor based on fuel type; see Table C-2	gCO2e/unit of fuel
1,000,000	= Conversion factor	grams/MT

Fuel Reductions

The GHG emission reductions from Fuel Reductions are calculated using Equation 5.

GHG Emission Reductions from Fuel Reductions

$$GHG \text{ Emission Reductions} = GHG \text{ Emission Reductions of Fuel Reductions}$$

Equation 5: GHG Emission Reductions from Fuel Reductions

$$GHG \text{ Emission Reudcitions of Fuel Reductions} = \frac{[(AnnualFuel) * (FuelEF)]}{1,000,000}$$

<i>Where,</i>		<u>Units</u>
<i>AnnualFuel</i>	= The estimated annual fuel reductions to be realized as a result of the project	unit of fuel
<i>FuelEF</i>	= Emission factor based on fuel type; see Table C-2	gCO2e/unit of fuel
1,000,000	= Conversion factor	grams/MT

Appendix B. Example Project

Introduction

The following is a hypothetical project¹ to demonstrate how the FY 2016-17 LCTOP Quantification Methodology would be applied. This hypothetical project does not provide examples of the supporting documentation that is required of actual project applicants.

Overview of the Proposed Project

The lead agency plans to expand the existing weekday commuter express service by adding four round-trips per day. The proposed project is determined to be best represented by:

- New/Expanded Service, and
- Expand/Enhance transit service

The proposed project operates predominantly within the Sacramento Valley air basin with the following project features:

- First Year (Yr1) of service: 2017
- Final Year (YrF) of service: 2018
- Yr1 Ridership: 62,400
- YrF Ridership: 62,400
- Length of Average Trip (L): 16 miles
- Vehicle Type: 2015 hybrid-diesel Over-Road Coach
- Annual VMT: 37,440 miles are estimated to operate the expanded service
- FY 2016-17 LCTOP funds requested: \$93,860
- No additional LCTOP GGRF funds requested
- No additional GGRF funds requested
- Where project specific data is not available, ARB defaults were used.

¹ The hypothetical project has not undergone verification of any LCTOP Program requirements; all assumptions about location type and features are for quantification methodology demonstration purposes only.

Step 1: Define the Proposed Project Using the LCTOP Allocation Request

General Information (Allocation Request Tab)
<ul style="list-style-type: none"> • Project Name: Expanded Commuter Express Service • Lead Agency: Sacramento Transit • Date Completed: 1/15/2017 • Project ID, if applicable: N/A • Contact Name: John Smith • Contact Phone Number: (916) 555-1234 • Contact Email: john.smith@sactransit.org • Project Type: New/Expanded Service • Project Sub-Type: Expand/Enhance transit service
Project Specific Inputs (Allocation Request Tab)
<ul style="list-style-type: none"> • Year 1 (Yr1): 2017 • Year (YrF): 2018 • Yr1 Ridership: 62,400 • YrF Ridership: 62,400 • Adjustment Factor (A): 0.83 (default) • Length of Average Trip (L): 16

Step 2: Identify the LCTOP Project Category

Project Type	Project Category	Additional GHG Emission Reductions
Expand/Enhance transit service	New/Expanded Service	Not Applicable

The proposed project type is categorized as a New/Expanded Service and does not have any applicable additional GHG emission reductions components.

Step 3: Determine the LCTOP Project Inputs Needed

Greenhouse Gas Quantification Inputs (GHG Calculator Tab)
<ul style="list-style-type: none"> • Region: Air Basin • Subregion: Sacramento Valley • Service Type: Intercity/Express Bus (Long Distance) • Vehicle Type: Over-Road Coach • Hybrid Vehicle: Yes • Fuel Type: Diesel (gal) • Model year: 2015 • Annual VMT: 37,440 • Additional Benefits: Not Applicable • FY 16-17 LCTOP funds requested: \$93,860.00 • Total amount of LCTOP GGRF funds requested: \$93,860.00 • Total amount of GGRF funds requested: \$93,860.00

Step 4: Estimate GHG Emission Reduction for the Proposed Project Using the LCTOP GHG Calculator Tool

Inputs	Required	Description
This section is used to determine the GHG emission reduction method and emission factors to apply.		
Project Type	New/Expanded Service	Yes Enter the project category that best represents the proposed project type; see Required Fields by Category . If applying for more than one project type, then the agency must submit multiple Allocation Requests and GHG Calculator tools.
Project Sub-Type	Expand/Enhance transit service	Yes Expand/Enhance transit service (extend transit routes, extend service hours, increase frequency of service, increase capacity [e.g., add more buses or rail cars to existing routes]). GHG Emission Reductions = GHG Emissions of Displaced Autos – GHG Emissions of New Service
Region	Air Basin	Yes The region that best encompasses the geographic location for the proposed project type.
Sub region	Sacramento Valley	Yes The air basin where the majority of the service occurs.
Year 1 (Yr1)	2017	Yes The first year of service - funded by FY 2016-17 LCTOP funds.
Year F (YrF)	2018	Yes The final year of service - funded by FY 2016-17 LCTOP funds.
Useful Life	1	Calculated The number of years the service is funded by FY 2016-17 LCTOP funds.

This section is used to estimate the net GHG emission reductions from new/expanded service or from the purchase of new zero-emission/hybrid vehicle(s).			
Vehicle Type	Over-Road Coach	Yes	The vehicle type (e.g., Transit Bus, Streetcar, Ferry, etc.) that will operate the new service.
Hybrid Vehicle	Yes	Yes	Is the vehicle that will operate the new service a hybrid?
Fuel Type	Diesel (gal)	Yes	The fuel type (e.g. Electric, Diesel, etc.) of the vehicle that will operate the new service.
Project Specific Emission Factor		Optional	Applicant must be able to demonstrate an approved carbon intensity value under the Low Carbon Fuel Standard; must submit additional documentation.
Model Year	2015	Yes	The engine model year of the vehicle that will operate the new service.
Annual VMT	37,400	Yes	The estimated annual VMT required to operate the new service (e.g., 72,000). For rail and ferry vehicles, applicants may alternatively use Annual Fuel.
Annual Fuel		No	Not applicable for this vehicle type.
GHG Emissions	69.61	Calculated	The estimated GHG emissions (MTCO ₂ e) of the vehicle that will operate the new service.
Net GHG Reductions	357.47	Calculated	The estimated net GHG emission reductions (MTCO ₂ e) of the new service.
This section is used to estimate the GHG emissions from displaced auto vehicle miles traveled (VMT).			
Service Type	Intercity/Express Bus (Long Distance)	Yes	The transit service (e.g., Bus, Light Rail, Heavy Rail, etc.) directly associated with the the proposed project. For projects that serve multiple services, select Multi-modal.
Yr1 Ridership	62,400	Yes	The increase in unlinked passenger trips directly associated with the proposed project in the first year.
YrF Ridership	62,400	Yes	The increase in unlinked passenger trips directly associated with the proposed project in the final year. If the ridership is not expected to change, the same value should be input for Yr1 and YrF.
Adjustment Factor (A)	0.83	Yes	Discount factor applied to annual ridership to account for transit-dependent riders. Use: documented project specific data or system average developed from a recent, statistically valid survey or default.
Length of Average Trip (L)	16.00	Yes	Annual passenger miles over unlinked trips directly associated with the proposed project.
GHG Emission Reductions	427.08	Calculated	The estimated GHG emission reductions in metric ton (MT) of carbon dioxide equivalent (CO ₂ e) from displaced auto VMT from the proposed project.

This section is used to estimate the net GHG emission reductions from vehicle replacement or the GHG emission reductions from displaced fuel.			
Additional GHG Emission Reductions	Not Applicable	Yes	Not applicable for this project type.
Fuel Type		No	Not applicable for this project type.
Model Year		No	Not applicable for this project type.
Annual VMT		No	Not applicable for this project type.
Annual Fuel		No	Not applicable for this project type.
GHG Emissions		Calculated	Not applicable for this project type.
Net GHG Reductions		Calculated	Not applicable for this project type.
This section is used to gather the total Greenhouse Gas Reduction Fund (GGRF) funding requested or awarded.			
FY 2016-17 LCTOP GGRF Funds Requested	\$93,860.00	Yes	The amount of FY 2016-17 LCTOP dollars the applicant is requesting from Caltrans per State Controller's Office Eligible list for FY 2016-17.
Total LCTOP GGRF Funds Requested	\$93,860.00	Yes	The amount equal to FY 2016-17 LCTOP Funds Requested plus all LCTOP dollars from Caltrans that have previously been awarded to the same project and any future LCTOP dollars that the project plans to apply for. If no other LCTOP funds have been requested, the Total LCTOP GGRF Funds Requested will be the same amount as the FY 2016-17 LCTOP Funds Requested.
Total GGRF Funds Requested	\$93,860.00	Yes	The amount equal to the Total LCTOP Funds Requested plus all GGRF dollars that have previously been awarded to the same project and any other GGRF dollars that the project has or plans to apply for. If no other GGRF funds have been requested, the Total GGRF Funds Requested will be the same amount as the Total LCTOP GGRF Funds Requested.
This section calculates the greenhouse gas (GHG) emission reductions achieved by the proposed project.			
Total Project GHG Reductions	357.47	Calculated	Total GHG emission reductions (MTCO ₂ e) from the project during the useful life.
LCTOP Project GHG Reductions	357.47	Calculated	The prorated Total Project GHG Reductions based on the Total LCTOP GGRF funds over Total GGRF funds requested.

Appendix C. Emission Factors

Emission Factor Lookup Tables

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 and any associated exhaust emissions. LCTOP applicants 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 LCTOP GHG Calculator tool. Table C-1 provides links to the relevant Lookup tables used in the LCTOP GHG Calculator by vehicle type. Vehicle types are provided as drop-downs in the LCTOP GHG Calculator. A detailed methodology of how the emission factors were developed is provided below.

Table C-1. Emission Factor Look Up Tables

Vehicle Type	Link to Emission Factor Lookup Tables
Auto	www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_autos_draft.pdf
Cut-A-Way	www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_cutaway_draft.pdf
Over-Road Coach	www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_mc_draft.pdf
Train*	www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_train_draft.pdf
Transit Bus	www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_ubus_draft.pdf
Van	www.arb.ca.gov/cc/capandtrade/auctionproceeds/ef_van_draft.pdf

*Train lookup tables include Heavy Rail, Light Rail and Streetcar emission factors.

Ferry Emission Factors

Due to the high variability in ferries, standardized emission factors are not available for new ferry service. Emissions for ferries require project-specific information for the estimated quantity and type of fuel used annually, which are used with the appropriate carbon content factor from Table C-2 to convert fuel to GHG emissions. The same emission factor will be used for both Year 1 and Year F.

Train Emission Factors

Similar to Ferries, applicants may use project-specific information on the estimated quantity and type of fuel used annually. The same emission factor will be used for both Year 1 and Year F.

Table C-2. Fuel-Specific Factors⁶

Fuels (units)	Energy Density	Carbon Intensity	Carbon Content*
Biodiesel (gal)	126.13 (MJ/gal)	65.50 (gCO ₂ /MJ)	8,261.64 (gCO ₂ e/gal)
CNG (ft ³)	1.04 (MJ/ft ³)	78.37 (gCO ₂ /MJ)	81.28 (gCO ₂ e/ft ³)
Diesel (gal)	134.48 (MJ/gal)	102.01 (gCO ₂ /MJ)	13,718.04 (gCO ₂ e/gal)
Electric (KWh)	3.60 (MJ/KWh)	105.15 (gCO ₂ /MJ)	378.54 (gCO ₂ e/KWh)
Gas (gal)	115.83 (MJ/gal)	98.47 (gCO ₂ /MJ)	11,405.84 (gCO ₂ e/gal)
Hydrogen (kg)	119.99(MJ/kg)	88.33 (gCO ₂ /MJ)	10,598.43 (gCO ₂ e/kg)
LNG (gal)	78.83 (MJ/gal)	94.41 (gCO ₂ /MJ)	7,442.70 (gCO ₂ e/gal)
Renewable Diesel (gal)	129.65 (MJ/gal)	43.31 (gCO ₂ /MJ)	5,615.12 (gCO ₂ e/gal)
Renewable Natural Gas (ft ³)	1.04 (MJ/ft ³)	18.11 (gCO ₂ /MJ)	18.78 (gCO ₂ e/ft ³)

*Carbon Content Emission Factors are calculated using fuel type Energy Density (megajoule (MJ) per unit of fuel) and the fuel type Carbon Intensity (grams of CO₂e per MJ).^v

Table C-3. Energy Economy Ratios⁶

Fuels (units)	EER Values Relative to Diesel	EER Values Relative to Gas
Biodiesel (gal)	1.0	--
CNG (ft ³)	0.9	1.0
Diesel (gal)	1.0	--
Electric (KWh)	4.2 (Bus) 4.6 (Heavy Rail) 3.3 (Light Rail) 3.1 (Street Car)	3.4
Gas (gal)	0.9	1.0
Hydrogen (kg)	1.9	2.5
LNG (gal)	0.9	1.0
Renewable Diesel (gal)	1.0	--
Renewable Natural Gas (ft ³)	0.9	1.0

The emission factors were developed using fuel consumption rates from EMFAC 2014 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)^{vi} Program.

The following sections provide details on how the emission factors were developed. Some emission factors were developed using similar approaches for more than one vehicle type, therefore are included together under the same section. For example, Transit Bus and Over-Road Coach were developed using a diesel baseline and Cut-away and Van emission factors were developed using a gasoline baseline.

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. The auto fuel consumption rate (**AFCR**, in gallons of gasoline per mile) was calculated using the total gallons of gasoline used by each vehicle category divided by the total mileage by vehicle category by county and year, using Equation 6.

Equation 6: Auto Fuel Consumption Rate

$$AFCR = \frac{(Fuel_Consumption_{LDA} + Fuel_Consumption_{LDT1} + Fuel_Consumption_{LDT2} + Fuel_Consumption_{MDV}) * 1,000}{VMT_{LDA} + VMT_{LDT1} + VMT_{LDT2} + VMT_{MDV}}$$

<p>Where,</p> <p><i>Fuel Consumption</i></p> <p><i>VMT</i></p>	<p>= the total fuel consumption for the vehicle type, in 1,000 gallons per day, from EMFAC 2014</p> <p>= is the total VMT for the vehicle type, in miles per day, from EMFAC 2014.</p>	<p><u>Units</u></p> <p>gasoline gallons</p> <p>miles</p>
--	--	--

3. The auto vehicle emission factors (**AVEF**, in grams of CO₂e per mile) were calculated for each year and county by multiplying the auto fuel consumption rate by the Well-to-Wheels carbon content factor for gasoline, which is 11,405.84 g CO₂e per gallon (Table C-2), using Equation 7.

Equation 7: Auto Vehicle Emission Factor

$$AVEF = 11,405.84 * AFCR$$

<i>Where,</i>		<u>Units</u>
11,405.84	= Well-to-Wheels carbon content factor for gasoline	gCO ₂ e/ gallon
<i>AFCR</i>	= Auto Fuel Consumption calculated in Equation 6	gallons/mile

Transit Bus and Over-Road Coach Emission Factors

The transit bus/over-road coach (bus) emission factors (**BEF**) were derived using a similar method, as follows.

1. The statewide emissions each calendar year from 2017 through 2050 were downloaded from EMFAC 2014 with the following parameters:
 - a. Annual Average
 - b. EMFAC2011 vehicle categories UBUS for Transit Bus and Motor Coach (MC) for Over-Road Coach
 - c. All model years
 - d. Aggregated speed
 - e. Diesel fuel

2. The bus fuel consumption rate (**BCR**, in gallons of diesel per mile) was calculated using the total gallons of diesel fuel used by each vehicle category and model year divided by the total mileage by vehicle category and model year, using Equation 8.

Equation 8: Bus Fuel Consumption Rate

$$BCR_{diesel} = \frac{Fuel_Consumption_{(UBUS \ OR \ MC)} * 1,000}{VMT_{(UBUS \ OR \ MC)}}$$

<i>Where,</i>		<u>Units</u>
<i>Fuel Consumption</i>	= the total fuel consumption for the vehicle type, in 1,000 gallons per day, from EMFAC 2014	gasoline gallons
<i>VMT</i>	= is the total VMT for the vehicle type, in miles per day, from EMFAC 2014.	miles

3. Diesel emission factors were developed using data as described in (a) below. Emission factors for other fuel types convert the diesel bus fuel consumption rate to the appropriate fuel type as described in (b).

- a. Diesel: the bus emission factor (**BEF**, in grams of CO₂e per mile) for each calendar year and model year were obtained by multiplying the bus fuel consumption rate (**BCR**, in gallons per mile) by the Well-to-Wheels carbon content factor for diesel (13,718.04 g CO₂e per gallon) using Equation 9.

Equation 9: Diesel Bus Emission Factor

$$BEF = 13,718.04 * BCR$$

<i>Where,</i>		<u>Units</u>
13,718.04	= Well-to-Wheels carbon content factor for diesel	gCO ₂ e/ gallon
<i>BCR</i>	= Bus Fuel Consumption Rate calculated in Equation 8	gallons/mile

- b. Non-Diesel: For fuel types other than diesel, staff converted the diesel fuel consumption rate (**BCR**) from Step 1 to the equivalent bus emission factor (**BEF**, in grams of CO₂e per mile) using Equation 10.

Equation 10: Non-Diesel Bus Emission Factor

$$BEF_{new_fuel} = BCR_{diesel} * ED_{diesel} * \left(\frac{1}{ED_{new_fuel}}\right) * \left(\frac{1}{EER}\right) * CC_{new_fuel}$$

<i>Where,</i>		<u>Units</u>
<i>BCR_{diesel}</i>	= Bus Consumption Rate calculated in Equation 8	gallons/mile
<i>ED_{diesel}</i>	= 134.48 MJ per gallon, from Table C-2	MJ/gallon
<i>ED_{new_fuel}</i>	= Energy density of the new fuel type, from Table C-2	MJ/unit of new fuel
<i>EER</i>	= Energy Economy Ratio, from Table C-3	unitless
<i>CC_{new_fuel}</i>	= Carbon Content of the new fuel type, from Table C-2	gCO ₂ e/ unit of new fuel

Cut-A-Way and Van Emission Factors

The alternative transit vehicle emission factors (**ATEF**) were derived using a similar method, as follows.

1. The statewide emissions each calendar year from 2017 through 2050 were downloaded from EMFAC 2014 with the following parameters:
 - a. Annual Average
 - b. EMFAC2011 vehicle categories LDH1 for Van and LHD2 for Cut-A-Way
 - c. All model years
 - d. Aggregated speed

e. Gasoline fuel

2. The alternative transit vehicle fuel consumption rate (**ATCR**, in gallons of gasoline per mile) was calculated using the total gallons of gasoline fuel used by each vehicle category and model year divided by the total mileage by vehicle category and model year, using Equation 11.

Equation 11: Alternative Transit Fuel Consumption Rate

$$ATCR_{gas} = \frac{Fuel_Consumption_{(LDH1 \ OR \ LDH2)} * 1,000}{VMT_{(LDH1 \ OR \ LDH2)}}$$

<i>Where,</i>		<u>Units</u>
<i>Fuel Consumption</i>	= the total fuel consumption for the vehicle type, in 1,000 gallons per day, from EMFAC 2014	gasoline gallons
<i>VMT</i>	= is the total VMT for the vehicle type, in miles per day, from EMFAC 2014.	miles

3. Gasoline emission factors were developed using data as described in (a) below. Emission factors for other fuel types convert the gasoline alternative transit vehicle fuel consumption rate to the appropriate fuel type as described in (b or c).
 - a. Gasoline: the alternative transit vehicle emission factor (**ATEF**, in grams of CO₂e per mile) for each calendar year and model year were obtained by multiplying the alternative transit vehicle fuel consumption rate (**ATCR**, in gallons per mile) by the Well-to-Wheels carbon content factor for gasoline (11,405.84 g CO₂e per gallon) using Equation 12.

Equation 12: Gasoline Alternative Transit Emission Factor

$$ATEF_{gas} = 11,405.84 * ATCR$$

<i>Where,</i>		<u>Units</u>
11,405.84	= Well-to-Wheels carbon content factor for gasoline	gCO ₂ e/ gallon
<i>ATCR</i>	= Alternative Transit Fuel Consumption calculated in Equation 11	gallons/mile

- b. Non-Gasoline (non-diesel): For non-gasoline fuel types other than diesel, staff converted the gasoline fuel consumption rate (**ATCR**) from Step 2 to the equivalent alternative transit vehicle emission factor (**ATEF**, in grams of CO₂e per mile) using Equation 13.

Equation 13: Alternative Transit Emission Factor

$$ATEF_{new_fuel} = ATCR_{gas} * ED_{gas} * \left(\frac{1}{ED_{new_fuel}} \right) * \left(\frac{1}{EER} \right) * CC_{new_fuel}$$

<i>Where,</i>		<u>Units</u>
$ATCR_{gas}$	= Alternative Transit Vehicle Consumption Rate for gasoline, from Equation 11	gallons/mile
ED_{gas}	= 115.83 MJ per gallon, from Table C-2	MJ/gallon
ED_{new_fuel}	= Energy density of the new fuel type, from Table C-2	MJ/unit of new fuel
EER	= Energy Economy Ratio, from Table C-3	unitless
CC_{new_fuel}	= Carbon Content of the new fuel type, from Table C-2	gCO ₂ e/ unit of new fuel

- c. Non-Gasoline (diesel): For diesel, staff converted the gasoline fuel consumption rate (**ATCR**) from Step 2 to the equivalent alternative transit vehicle emission factor (**ATEF**, in grams of CO₂e per mile) using Equation 14.

Equation 14: Diesel Alternative Transit Emission Factor

$$ATEF_{diesel} = ATCR_{gas} * EER * ED_{gas} * \left(\frac{1}{ED_{diesel}} \right) * CC_{diesel}$$

<i>Where,</i>		<u>Units</u>
$ATCR_{gas}$	= Alternative Transit Vehicle Consumption Rate for gasoline calculated in Equation 11	gallons/mile
EER	= Energy Economy Ratio, from Table C-3	unitless
ED_{gas}	= 115.83 MJ per gallon, from Table C-2	MJ/gallon
ED_{diesel}	= 134.47 MJ per gallon, from Table C-2	MJ/gallon
CC_{new_fuel}	= Carbon Content of the new fuel type, from Table C-2	gCO ₂ e/ unit of new fuel

Train Emission Factors

Train emission factors were derived using the following process.

1. A Train Consumption Rate (**TCR**, in gallons of diesel per mile) was calculated using the total gallons of diesel fuel used by 130 trains across the State in 2010 divided by the total mileage of those trains using Equation 15.

Equation 15: Train Consumption Rate

$$TCR = \frac{\text{Fuel Consumption}}{VMT}$$

Where,

<i>Fuel Consumption</i>	=	The total fuel consumption for 130 trains	<u>Units</u> gallon
<i>VMT</i>	=	Total mileage from 130 trains	miles

2. The diesel emission factor was developed using data as described in (a) below. Emission factors for other fuel types convert the diesel new service fuel consumption rate to the appropriate fuel type as described in (b).
 - a. Diesel: the train emission factor (**TEF**, in grams of CO₂e per mile) was obtained by multiplying the train fuel consumption rate (**TCR**, in gallons per mile) by the Well-to-Wheels carbon content factor for diesel (13,718.04 g CO₂e per gallon) using Equation 16.

Equation 16: Diesel Train Emission Factor

$$TDEF = 13,718.04 * TCR$$

Where,

13,718.04	=	Well-to-Wheels carbon content factor for diesel	<u>Units</u> gCO ₂ e/ gallon
<i>TCR</i>	=	Train Fuel Consumption calculated in Equation 15	gallons/mile

- b. Non-Diesel: For fuel types other than diesel, staff converted the diesel fuel consumption rate (**TCR**) from Step 2 to the equivalent new service emission factor (**TEF**, in grams of CO₂e per mile) using Equation 17.

Equation 17: Non-Diesel Train Emission Factor

$$TEF_{new_fuel} = TCR_{diesel} * ED_{diesel} * \left(\frac{1}{ED_{new_fuel}}\right) * \left(\frac{1}{EER}\right) * CC_{new_fuel}$$

Where,

<i>TCR_{diesel}</i>	=	Train Consumption Rate calculated in Equation 15	<u>Units</u> gallons/mile
<i>ED_{diesel}</i>	=	134.48 MJ per gallon, from Table C-2	MJ/gallon
<i>ED_{new_fuel}</i>	=	Energy density of the new fuel type, from Table C-2	MJ/unit of new fuel
<i>EER</i>	=	Energy Economy Ratio, from Table C-3	unitless
<i>CC_{new_fuel}</i>	=	Carbon Content of the new fuel type, from Table C-2	gCO ₂ e/ unit of new fuel

^v Low Carbon Fuel Standard Program Regulation

<https://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf>

^{vi} <https://www.arb.ca.gov/fuels/lcfs/lcfs.htm>