California Air Resources Board

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

**Greenhouse Gas Reduction Fund
FY 2015-16**

December 1, 2015

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Section A. Introduction

The California Air Resources Board (ARB) is responsible for providing the quantification methodology to estimate greenhouse gas (GHG) emission reductions from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). For the California Department of Transportation's (Caltrans) Low Carbon Transit and Operations Program (LCTOP), ARB staff developed this quantification methodology and the accompanying calculator tool for agencies to use to estimate the GHG emission reductions from each proposed projects. ARB staff will 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.

This methodology uses calculations to estimate the reduction in vehicle miles traveled (VMT) and associated reduction in GHG emissions based on specific transportation characteristics of the proposed LCTOP projects. These calculations are 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) and ARB-developed GHG emission factors.

Methodology Development

ARB staff followed a set of principles to guide the development of the quantification methodology. These principles ensure that the methodology for LCTOP projects will:

- Apply at the project-level;
- Align with the project types proposed for funding;
- Provide uniform methodologies that can be applied statewide, and be accessible by all applicants;
- Support the analysis of GHG emission reductions from the proposed projects;
- Use existing and proven methods; and
- Use project-level data when available for estimated ridership increases and corresponding VMT reductions.

The methodology fits these objectives, and provides a uniform approach to quantify GHG emission reductions in metric tons of carbon dioxide equivalent (MTCO$_2$e).

ARB released a draft FY 2015-16 quantification methodology for public comment in November 2015.

Tools

The CMAQ Methods are a set of equations for evaluating the cost-effectiveness of certain types of transportation projects. 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.

GHG emission reductions used in this methodology are calculated based on well-to-wheels (WTW) emission factors, fuel energy density values, and fuel economy values. Emission factors were developed through ARB's Low Carbon Fuel Standard (LCFS) Program, fuel energy density values were developed through the California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (CA-GREET 2.0), and fuel economy values were developed from ARB's Mobile Source Emission Factor Model (EMFAC 2014). The WTW method accounts for the emissions produced from the production and distribution of the different fuel types, including hydrogen and electricity, as well as any associated exhaust emissions. The description of the derivation of the emission factors is included in the Appendix B.

Applicants must use this methodology, in conjunction with the accompanying calculator tool, to estimate the GHG emission reductions from their proposed LCTOP projects.

The calculator tool can be downloaded here:
http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/lctopcalctool.xlsm

LCTOP Projects

Per LCTOP Program Guidelines:

Eligible project types must:
- Support new or expanded bus or rail services, new or expanded water-borne transit, or expanded intermodal transit facilities;
- Increase mode share; and
- Reduce greenhouse gas emissions.

Additional project types:
- Must be in addition to one or more eligible project types;
- May result in quantifiable GHG reductions but do not meet all of the criteria of an eligible project type; and
- May include equipment acquisition, fueling, maintenance, and other costs to operate those services or facilities.

Note: Maintenance, operations, and/or installation of infrastructure to support cleaner vehicles or equipment (e.g., electric charging) are not included in the quantification methodology but are eligible expenses as component of an eligible project.

GHG Emission Reductions Quantification Approach

The metric used to assess the effectiveness of the project to reduce GHG emissions per dollar of GGRF funds will be reported by the applicant as:

$$\frac{Total\ Project\ GHG\ Reductions\ in\ Metric\ Tons\ of\ CO_2e}{Total\ GGRF\ Funds\ Requested\ (\$)}$$

GGRF Funds Requested is the dollar amount requested through LCTOP and any other GGRF programs to which the applicant has or may apply. Additional documentation and reporting requirements are provided in sections C and D. Section B describes the process for estimating the GHG emission reductions for proposed LCTOP projects in FY 2015-16.

Technical Assistance

ARB 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:
- Questions on this quantification 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 not related to this quantification document but pertaining to the LCTOP should be sent to LCTOPcomments@dot.ca.gov.

Section B. Quantification Methodology

This methodology estimates the GHG emission reductions of a proposed LCTOP project based on estimated ridership increases and corresponding passenger vehicle VMT reductions, as well as the use of cleaner vehicles and fuel savings. Applicants will use the calculator tool to estimate the total GHG emission reductions from the proposed project, as defined in the methodology.

The following is a summary of the steps LCTOP applicants will follow to estimate and report the GHG emission reductions for a proposed project. Detailed instructions for each step are provided on subsequent pages. An example for a New/Expanded Service is included in Appendix A.

Step 1	**Identify the LCTOP proposed project type(s)**: The applicant must select at least one eligible project type from Table 1. Applicant may select additional project types from Table 2.
Step 2	**Determine the inputs needed**: The applicant will use Tables 3 and 4 to determine the required project details needed for input into the calculator tool for the applicable project type selected in Step 1. Detailed instructions for obtaining the calculator tool are included.
Step 3	**Estimate GHG emission reductions (use calculator tool)**: The applicant will enter the project details into the calculator tool to calculate the total GHG emission reductions from the proposed project using the inputs identified in Step 2.

Step 1: Identify the LCTOP Proposed Project Type(s)

Caltrans and ARB have developed lists of the most common project types expected to be funded under LCTOP. The applicant must identify at least one project type from this list that defines the proposed project. Table 1 lists project types that meet all of the eligibility requirements. Table 2 lists project types that may be funded as a component of a project with an eligible project type but do not meet all of the eligibility requirements independently. The applicant should identify each project component by the respective identification number(s) for Eligible Project Types and letter(s) for Additional Project Types.

The applicant is **required to select at least one (1)** of the project types from Table 1 under " New/Expanded Service" or "Expanded Transit Facilities and Service Enhancements" below:

Table 1. Eligible Project Types

New/Expanded Service Project Types **(Expansion of services through new service or additional routes)**	
1.	Implement new routes or expansion of existing routes (e.g. local bus, long distance commuter, train, ferry).
2.	Provide alternative transit options that use zero-emission or hybrid vehicles to improve mobility (e.g., vanpooling, shuttles, bike sharing).
3.	Increase service (extend transit routes, increase frequency of service, extend service hours).
4.	Increase capacity on routes nearing capacity (e.g., add more buses or rail cars to existing routes).
Expanded Facilities and Service Enhancements Project Types	
5.	Install new stops/stations for local bus, intercity rail, ferry, commuter bus, rail transit or other multi-modal facilities.
6.	Install new transit stops/stations that connect to bike paths/pedestrian paths.
7.	Upgrade transit stops/stations to support active transportation and encourage ridership (e.g., bike sharing facilities, bicycle racks/lockers, covered benches, energy efficient lighting).
8.	Upgrade transit vehicles to support active transportation and encourage ridership (e.g., bicycle racks on buses, bicycle storage on rail cars).
9.	Network/fare integration (e.g., universal fare card that can be used for multiple transit systems).
10.	Free or reduced-fare transit passes/vouchers.

The applicant may select additional project type(s) listed in Table 2 under "Vehicle Improvement" or "Fuel Savings".

Table 2. Additional Project Types

Vehicle Improvement Project Types **(Use of cleaner vehicles or technologies that reduce GHG emissions)**	
A.	Purchase, operate, and maintain cleaner vehicles and equipment (e.g., zero-emission or hybrid buses, railcars, auxiliary electrical power units).
B.	Convert/retrofit diesel vehicles or equipment to zero-emission technology (e.g., zero-emission or hybrid buses, rail electrification, hybrid ferries).
Fuel Savings Project Types **(Reduction in fuel use from increased efficiency or fewer VMT)**	
C.	Replace/retrofit transit vehicles to improve fuel efficiency (e.g., anti-idling systems, regenerative braking for trains).
D.	Install renewable energy at transit facilities (e.g., solar panels).
E.	Relocate transit facility to reduce fuel consumption (e.g., to reduce deadhead mileage).

Step 2: Determine the Inputs Needed

The following section describes the data inputs needed to estimate the GHG emission reductions for proposed projects with the calculator tool per project type.

Table 3. Required Calculator Inputs for Eligible Project Type(s)

New/Expanded Service Project Types
Project Details • Project Type: New/Expanded Service • Transit Service Type: bus (local bus), train, ferry, etc. • County: where the majority of the service occurs • Year 1(Yr1): first year of service • Year Final (YrF): final year that the service is funded **Displaced Auto Inputs** • Estimated Annual Ridership (Yr1 and YrF) • Adjustment factor for transit dependency (A)* • Length of average auto trip reduced (L)* • Adjustment for auto trips used to access transit (AA)* • Length of average trip for auto access to transit (LL)* **New/Expanded Service Vehicle Inputs** • Fuel Type (e.g., Electric/BEV or PHEV) • Engine Model Year (MY) • Annual VMT: annual VMT of the proposed transit services • Units of Fuel: for ferry service only (e.g., gallons of diesel) • Useful Life: use 10 years for advance technologies (i.e., electric, hydrogen fuel cell buses); for others, use Federal Transit Administration guidance available here www.**fta**.dot.gov/documents/**C_5010_1D**_Finalpub.pdf.
Expanded Transit Facilities and Service Enhancements Project Types
Project Details • Project Type: Expanded Transit Facilities and Service Enhancements • Transit Service Type: bus (local bus), train, ferry, etc. • County: where the majority of the service occurs • Year 1 (Yr1): first year of service or year the facility construction will be completed • Year Final (YrF): final year that the service is funded or of the facility useful life **Displaced Auto Inputs** • Estimated Annual Ridership (Yr1 and YrF) • Adjustment factor for transit dependency (A)* • Length of average auto trip reduced (L)* • Adjustment for auto trips used to access transit (AA)* • Length of average trip for auto access to transit (LL)*

* Refer to Appendix B for details.

Table 4. Required Calculator Inputs for Additional Project Types

Vehicle Improvement Project Types
Old Service Vehicle Inputs   • Additional Project Type: Vehicle Improvement   • Fuel Type (e.g., Diesel, Gasoline)   • Engine Model Year (MY): old service vehicle to be improved   • Annual VMT: old service vehicle Annual VMT now being serviced by new vehicle (e.g., 1,000 miles)   • Units of Fuel: for ferry service only (e.g., 1,500 gallons of diesel)
Fuel Savings Project Types
Displaced Fuel Inputs   • Additional Project Type: Fuel Savings   • Fuel Type (e.g., Diesel, Gasoline)   • Units of Fuel: annual fuel displaced (e.g., 12,000 gallons of diesel)

Step 3: Estimate GHG Emission Reductions Using The Calculator Tool

Once the applicant has compiled all of the required inputs from Step 2, the applicant should download the calculator tool and enter project specific data to estimate GHG emission reductions. An overview of the calculator tool is provided below.

Read Me Tab

- On the Read Me Tab, enter the Project Name, Project ID and the contact information for person who can answer project specific questions from staff reviewers on the quantification calculations. The Project ID is assigned by Caltrans. This file will be submitted with other required documents. Please use the following file naming convention: "[Project ID]_[Project Name]" not to exceed 20 characters. For example, if the application ID is "1-1C_001," the project name is "Transit BRT," and the file is the input file, the file name may be " 1-1C_001Transit BRT." Project names may be abbreviated.

Project Name:	1-1C_001
Project ID:	Transit BRT
Contact Name:	John Smith
Contact Phone Number:	916-555-1234
Contact Email:	john.smith@transit.org
Date Completed:	10/30/2015

Inputs Tab

- Headers in red indicate a field that requires input by the project applicant. For each row, applicants must work from left to right and enter all relevant data. Some cells may not be applicable to the project. These cells will turn black and will be locked based on inputs. Applicants should use as many rows as necessary to characterize all relevant features of the proposed project. Definitions are provided in the definitions tab, including how to determine Year 1, Year F, and adjustment factors. Inputs must be substantiated in the documentation provided to ARB.

All equations and calculations are included in the calculator tool developed by ARB staff as part of this quantification methodology; detailed documentation is included in Appendix B. In general, GHG emissions reductions are calculated using the following approaches:

New/Expanded Service Project Types
$GHG\ Emission\ Reductions =$ $GHG\ Emissions\ of\ Displaced\ Autos - GHG\ Emissions\ of\ New\ Service\ Vehicle$
Expanded Transit Facilities and Service Enhancements Project Types
$GHG\ Emission\ Reductions = GHG\ Emissions\ of\ Displaced\ Autos$

Vehicle Improvement Project Types
$GHG\ Emission\ Reductions =$ $GHG\ Emissions\ of\ Old\ Service\ Vehicle - GHG\ Emissions\ of\ New\ Service\ Vehicle$
Fuel Savings Project Types
$GHG\ Emission\ Reductions = GHG\ Emissions\ of\ Displaced\ Fuel$

Section C. Documentation

Applicants must report the Net GHG Benefits and provide documentation of the calculations and inputs used. The Net GHG Benefits are equal to the Total Project GHG Emission Reductions estimated in the calculator tool.

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 or ARB staff.

Documentation must include, at a minimum:

- Project application;
- Populated calculator tool file;
- Project description, including excerpts or specific references to the location in the main LCTOP application of the project information necessary to complete the applicable portions of the quantification methodology; and
- Project data support, including:
  - Calculator inputs determined in Step 2
  - Documentation of the project data used to estimate ridership, project VMT, adjustment factors (A, L, AA, LL), vehicle data (useful life, model year, etc.) and fuel savings;
  - References to public documents that are the source of the project data.

Section D. Reporting after Funding Award

Accountability and transparency are essential elements for all projects funded by the GGRF. Each administering agency is required to track and report on the benefits of the California Climate Investments funded under their program(s) and each funding recipient has the obligation to provide the necessary data or access to data for their project to support reporting on project outcomes.

In 2015, ARB developed Funding Guidelines for Agencies Administering California Climate Investments (Funding Guidelines).[1] These Funding Guidelines describe the reporting requirements and set the <u>minimum</u> project-level reporting requirements for projects funded by Caltrans. Volume III of the Funding Guidelines summarizes the major reporting components that Caltrans must report to ARB. Because much of this data comes directly from LCTOP projects, LCTOP funding recipients will need to provide project data to Caltrans to support these reporting requirements.
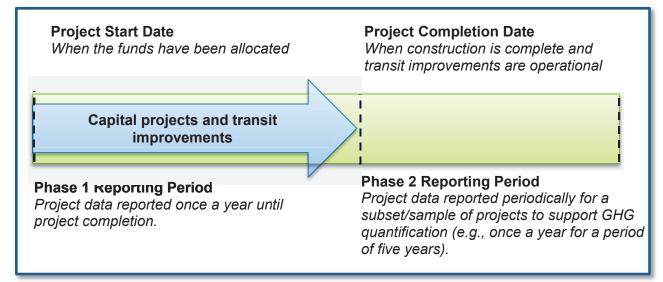
Table 5 and the figure below show the project phases and when reporting is required.

Project Start Date
When the funds have been allocated

Project Completion Date
When construction is complete and transit improvements are operational

Capital projects and transit improvements

Phase 1 Reporting Period
Project data reported once a year until project completion.

Phase 2 Reporting Period
Project data reported periodically for a subset/sample of projects to support GHG quantification (e.g., once a year for a period of five years).

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[1] California Air Resources Board. Funding Guidelines for Agencies Administering California Climate Investments. September 4, 2015. http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/funding_guidelines_public_proposed_draft_09-04-2015.pdf. After incorporating revisions to reflect the Board's direction, ARB will post the Final Funding Guidelines at: http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/fundingguidelines.htm

Table 5. Quantification and Reporting By Project Phase

	Timeframe	Quantification Methodology Section
Project Selection	Covers the period from solicitation to selection of projects and funding awards	All applicants use methods in this QM to **estimate** GHG reductions based on application data.
Phase 1	Covers the period from the beginning of the project until it becomes operational or the initial implementation is completed	Funded projects use methods in this QM, as needed, to update GHG **estimates** based on project changes.
Phase 2	Starts after Phase 1 is complete and a project becomes operational	GHG reductions **achieved** are quantified and reported for a subset of funded projects.

Phase 1 reporting is <u>required for all LCTOP funding recipients</u> during project implementation (e.g., initial construction). <u>This quantification methodology provides guidance on how to estimate project benefits to satisfy Phase 1 reporting requirements.</u> At a minimum, ARB expects that LCTOP funding recipients will report to Caltrans once a year during project construction (for projects with a capital component) or during implementation (for transit without a capital component) and once at the end of the project.

Phase 2 reporting is <u>required for only a subset of LCTOP projects</u> and is intended to <u>document actual project benefits achieved after the project becomes operational</u>. 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 field 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.   New/Expanded Service Example

Step 1. Identify the LCTOP Proposed Project Type(s)

The applicant first identifies an eligible project type under New/Expanded Service from Table 1. For this example, the selected project type number 1 from Table 1 is "Implement new routes or expansion of existing routes". In addition to the new service, the applicant also identifies an additional project type from Table 2 "Vehicle Improvement". The additional project type is "Purchase, operate, and maintain cleaner vehicles or equipment (e.g., zero-emission or hybrid buses, railcars, auxiliary electrical power units)" identified as project type 'A'.

Steps 2 & 3. Determine the Inputs Needed and Estimate GHG Emission Reductions

The applicant determines all of the required inputs from Table 3 for the calculator to estimate GHG emission reductions. The applicant enters the project information on the 'Read Me Tab'.

Read Me Tab (this page):
Enter the Project Name, Project ID and the contact information for person who can answer project specific questions from staff reviewers on the quantification calculations. The Project ID is assigned by Caltrans. This file will be submitted with other documentation requirements. Please use the following file naming convention: "[Project ID]_[Project Name]" not to exceed 20 characters. For example, if the application ID is "1-1C_001," the project name is " Transit BRT," and the file is the input file, the file name may be " 1-1C_001Transit BRT." Project names may be abbreviated.

Project Name:	1-1C_001
Project ID:	Transit BRT
Contact Name:	John Smith
Contact Phone Number:	916-555-1234
Contact Email:	john.smith@transit.org
Date Completed:	10/30/2015

For this example, the applicant enters applicable information for **Project Type 1 from Table 1** into the inputs tab as indicated by red headers.

The applicant proposes to provide three years of funding from their LCTOP allocations to establish the implementation of a new electric bus rapid transit (BRT) project in Sacramento from 2017 (Yr1) and ending in 2020 (YrF).

Project Details
- x Project Type: New/Expanded Service
- • Transit Service Type: Bus (local bus)
- • County: Sacramento
- x Year 1: 2017
- • Year F: 2020

Project Details				
Eligible Project Type	Transit Service Type	County	Year 1 (Yr1)	Year F (YrF)
New/Expanded Service	Bus (local bus)	Sacramento	2017	2020

The applicant estimates the proposed project to have an average of 200 daily riders for 260 days per year and a 2% annual ridership increase. The projected annual ridership is estimated to be 52,000 (200 riders/day * 260 days/year) for Yr1 and 55,000 for YrF. The applicant used the ARB developed recommended default values for this service type.

Displaced Auto Inputs
- Yr1 Annual Ridership: 52,000
- YrF Annual Ridership: 55,000
- Adjustment (A): 0.50
- Length (L): 9
- Adjustment (AA): 0.10
- Length (LL): 2

Displaced Autos Details						
Yr1 Annual Ridership	YrF Annual Ridership	Adjustment (A)	Length (L)	Adjustment (AA)	Length (LL)	Annual Average VMT Displaced
52,000	55,000	0.50	9.00	0.10	2.00	235,400.00

The applicant estimates the proposed project BRT route to be 40 miles roundtrip, and service 4 roundtrips a day for 260 days a year. The projected annual VMT is estimated to be 41,600 (40 miles/trip * 4 trips/day * 260 days/year). The useful life of an electric bus is assumed to be 10 years.

New/Expanded Vehicle Inputs
- Fuel Type: Electric/BEV or PHEV
- Engine MY: 2017
- Annual VMT/Units of Fuel: 41,600
- Useful life: 10

New/Expanded Vehicle Details			
Fuel Type	Engine MY	Annual VMT or Units of Fuel	Useful Life
Electric/BEV or PHEV	2017	41,600	10

In addition, the applicant proposes to use the electric bus to replace an existing diesel bus with a 2010 engine model year that was operating for 20,000 miles a year. The applicant enters applicable information for **Project Type A from Table 2** into the inputs tab as indicated by red headers.

Old Service Vehicle Inputs
- Additional Project Type: Vehicle Improvement
- Fuel Type: Diesel
- Engine MY: 2010
- Annual VMT: 20,000

Old Service Vehicle or Displaced Fuel Details			
Additional Project Type	**Fuel Type**	**Engine MY**	**Annual VMT or Units of Fuel**
Vehicle Improvement	Diesel	2010	20,000

Funds Requested

The LCTOP Funds Requested ($) is equal to the funds requested per State Controller's Office Eligible list for FY 2015-16: $250,000. Since the applicant intends to provide three allocations towards the project as identified in Step 2, the Total LCTOP Funds Requested is estimated to be three allocations of $250,000, or $750,000. There are no additional GGRF Funds requested from any other GGRF Program, therefore the Total GGRF Funds Requested is equal to the Total LCTOP Funds Requested, or $750,000. Use the State Controller's Office Eligible list for FY 2015-16 allocation funding amount to estimate the subsequent funding allocations.

Funds Requested		
FY 2015-16 LCTOP Funds Requested ($)	**Total LCTOP Funds Requested ($)**	**Total GGRF Funds Requested ($)**
$ 250,000.00	$ 750,000.00	$ 750,000.00

Submit Documentation

To complete the quantification process, the applicant must submit an electronic copy of the calculator (in .xlsm) and all of the required documentation as noted in Section C.

For this example New/Expanded Service project type, the Total GHG Emission Reductions (MTCO2e) is equal to the sum of GHGs of Displaced Autos minus the GHGs of New Service Vehicle plus any Additional Project GHG Emission Reductions. The applicant would report the Net GHG Benefits as **835.36 MTCO2e.**

Results	GHG Emissions (MTCO2e)	Description
Net GHG Benefits	835.36	Total GHG Emission Reductions (MTCO2e)
LCTOP Funds Requested ($)	250,000.00	Funds requested per State Controller's Office Eligible list for FY 2015-16
Total LCTOP Funds Requested ($)	750,000.00	Includes all LCTOP allocations the applicant intends to utilize (up to three FY allocations including FY 2015-16) for the proposed project. Use the State Controller's Office Eligible list for FY 2015-16 allocation funding amounts to estimate the subsequent funding allocations.
Total GGRF Funds Requested ($)	750,000.00	Includes the Total LCTOP fund requested and any other GGRF Program monies
Total GHG Emission Reductions /Total GGRF Funds Requested ($)	0.0011	The metric to be reported in the application.

Appendix B.   GHG Emission Reduction Calculations

$$AutoVMT = Annual\ Auto\ VMT\ Reduced\ in\ miles\ per\ year$$
$$= [(D) * (R) * (A)] * [(L) - (AA) * (LL)]$$

Where:

D   = Days of operation per year
R   = Average daily ridership increase
A   = Adjustment factor to account for transit dependency
L   = Length (miles) of average auto trip reduced.
AA   = Adjustment factor to account for auto trips used to access transit service.
LL   = Length (miles) of average trip for auto access to transit.

Where:

A =   Adjustment factor to account for transit dependency
          Use: documented project specific data or system average developed from a recent, statistically valid survey or default
          Default: 0.5 for local bus service or 0.83 for long distance commuter service
L =   Length (miles) of average auto trip reduced
          Use: value based on specific project or system average reported to the National Transit Database (consult Caltrans for assistance)
AA =   Adjustment factor to account for auto trips used to access transit service.
          Use: value based on project specific data or system average developed from a recent, statistically valid survey or default
          Default: 0.1 for local bus service or 0.8 for long distance commuter service
LL =   Length (miles) of average trip for auto access to transit
          Use: value based on specific project data or default
          Default: 2 miles for local bus or 5 miles for long distance commuter service.

Note: Applicant must provide detailed supporting documentation for variables used in Step 2. ARB has developed recommended default values[2] for certain service types that may be used if project specific data does not exist.

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[2] "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"

GHGs of Displaced Autos $= \dfrac{[(AutoVMT)*(AVEF)]}{1{,}000{,}000}$

GHGs of Old or New/Expanded Service Vehicle $= \dfrac{[(SVMT)*(SVEF)]}{1{,}000{,}000}$

GHGs of Displaced Fuel $= \dfrac{[(Fuel)*(FuelEF)]}{1{,}000{,}000}$

Where:
AutoVMT = Annual Auto VMT Reduced calculated using ridership
AVEF = Auto Vehicle Emission Factor (in gCO2e/mile)
SVMT = Annual VMT of the vehicle in service based on project data
SVEF = Service Vehicle Emission Factor (in gCO2e/mile)
Fuel = Annual fuel consumption of the service vehicle based on project data
Fuel EF = Fuel-Specific Carbon Content (in gCO2e/unit of fuel) from Table B-1

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 2016 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 the following equation:

$$AFCR = \frac{\begin{array}{c}(Fuel\_Consumption_{LDA} + Fuel\_Consumption_{LDT1}\\ + Fuel\_Consumption_{LDT2} + Fuel\_Consumption_{MDV}) * 1{,}000\end{array}}{VMT_{LDA} + VMT_{LDT1} + VMT_{LDT2} + VMT_{MDV}}$$

Where:
Fuel_Consumption: 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. The auto vehicle emission factors (**AVEF**, in grams of CO_2e 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 11,460.09 g CO_2e per gallon (Table B-1), using the following equation:

$$AVEF = 11,460 * AFCR$$

Service Vehicle Emission Factors (SVEF)

The bus and van/shuttle service vehicle emission factors were derived using a similar method, as follows.

1. The statewide emissions each calendar year from 2016 through 2050 were downloaded from EMFAC 2014 with the following parameters:
   a. Annual Average
   b. EMFAC2011 vehicle categories UBUS for bus and LHD1 for Van/Shuttle
   c. All model years
   d. Aggregated speed
   e. Diesel fuel

2. The new service fuel consumption rate (**NSCR**, 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 the following equation:

$$NSCR_{diesel} = \frac{Fuel\_Consumption_{(UBUS\ OR\ LDH1)} * 1,000}{VMT_{(UBUS\ OR\ LDH1)}}$$

3. Diesel emission factors were 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 service vehicle emission factor (**SVEF**, in grams of CO_2e per mile) for each calendar year and model year were obtained by multiplying the new service fuel consumption rate (**NSCR**, in gallons per mile) by the Well-to-Wheels carbon content factor for diesel (13,818.14 g CO_2e per gallon) using the following equation:

   $$NSEF = 13,818 * NSCR$$
   b. Non-Diesel: For fuel types other than diesel, staff converted the diesel fuel consumption rate (**NSCR**) from Step 2 to the equivalent service vehicle emission factor (**SVEF**, in grams of CO_2e per mile) using the following equation:

   $$SVEF_{new\_fuel} = NSCR_{diesel} * ED_{diesel} * \left(\frac{1}{ED_{new\ fuel}}\right) * \left(\frac{1}{EER}\right) * CC_{new\_fuel}$$

Where:

NSCR$_{diesel}$ = New Service Consumption Rate for diesel, from Step 2 (gallons per mile)

ED$_{diesel}$ = 134.47 MJ per gallon, from Table B-1

ED$_{new fuel}$ = Energy density of the new fuel type (MJ per unit of new fuel), from Table B-1

EER = Energy Economy Ratio (unitless), from Table B-1

CC$_{new\_fuel}$ = Carbon Content of the new fuel type (grams of CO_2e per unit of new fuel), from Table B-1

Table B-1. Fuel-Specific Factors

Fuels (units)	Energy Density	Carbon Content gCO$_2$e/unit*	EER Values Relative to Diesel
Diesel (gal)	134.47 (MJ/gal)	13,818.14 (gCO$_2$e/gal)	1.0
Renewable Diesel (gal)	129.65 (MJ/gal)	4,509.75 (gCO$_2$e/gal)	1.0
Gas (gal)	115.63 (MJ/gal)	11,460.09 (gCO$_2$e/gal)	0.9
CNG (scf)	0.98 (MJ/scf)	77.88 (gCO$_2$e/scf)	0.9
LNG (gal)	78.83 (MJ/gal)	6,824.31 (gCO$_2$e/gal)	0.9
Hydrogen (kg)	120.00 (MJ/kg)	12,678.00 (gCO$_2$e/kg)	1.9
Hydrogen SB 1505 compliant (kg)		10,466.4 (gCO$_2$e/kg)	
Electric (KWh)	3.6 (MJ/KWh)	378.58 (gCO$_2$e/KWh)	4.2 (Bus) 2.7 (Shuttle/Van)

*Calculated using fuel type megajoule (MJ) per unit of fuel from Table III-2. Energy Densities of LCFS Fuels and Blendstocks[3] and the fuel type grams of CO_2e per MJ from CA-GREET 1.8b versus 2.0 CI Comparison Table. [4]

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[3] Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Proposed Re-Adoption of the Low Carbon Fuel Standard, December 2014
[4] Direct values (without energy efficiency ratio adjustments). Source: California Air Resources Board, CA-GREET 1.8b versus 2.0 CI Comparison Table, April 1, 2015