

# California Air Resources Board

## Greenhouse Gas Quantification Methodology for Air Resources Board Low Carbon Transportation Program On-Road Advanced Technology Demonstration Project

Greenhouse Gas Reduction Fund  
Fiscal Year 2016-17



**Note:**

Applicants must use the Fiscal Year 2016-2017 Low Carbon Transportation Investments Application for On-Road Advanced Technology Demonstration Project to calculate greenhouse gas reductions for application purposes. Solicitation materials can be found at: <https://www.arb.ca.gov/msprog/aqip/solicitations.htm>

**May 22, 2017**

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## Section A. Introduction

The goal of California Climate Investments (CCI) 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 (CARB) is responsible for providing the quantification methodology to estimate the GHG emission reductions from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). CARB 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>.

For the Fiscal Year (FY) 2016-17 CARB Low Carbon Transportation (LCT) On-Road Advanced Technology Demonstration Project, CARB staff developed this quantification methodology to estimate GHG emission reductions in metric tons (MT) of carbon dioxide equivalent (CO<sub>2</sub>e) from supported demonstration vehicle types (Sections 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).

### LCT On-Road Advanced Technology Demonstration Project

The LCT On-Road Advanced Technology Demonstration Project reduces GHG emissions by providing incentives for multiple types of zero-emission heavy-duty on-road vehicles and advanced technology used in freight transport. CARB has identified three On-Road Advanced Technology Demonstration Project categories:

- 1. Intelligent Transportation Systems (ITS) and Connected Trucks**  
Technologies in this category focus on increasing efficiencies by allowing communications between trucks and their environment, or between two or more trucks. These technologies have the potential to increase on-road truck efficiency, thereby reducing GHG emissions.
- 2. Advanced Engines and Powertrains**  
Advanced technologies employed in the generation of motive power have the potential to increase on-road truck efficiency, thereby reducing GHG emissions.
- 3. Zero-Emission or Near Zero-Emission Short and Regional Haul Trucks**  
Short and regional haul trucking services are characterized by shorter daily driving distances than line-haul trucking, but longer than some drayage trucks. These trucks tend to be domiciled in a central location nightly. Technologies to be demonstrated could include battery-electric, fuel-cell, electric drive with range extenders, or other advanced technologies that result in significant zero-emission miles.

## Methodology Development

CARB developed this quantification methodology consistent with the guiding implementation principles of CCI, including ensuring transparency and accountability.<sup>1</sup> The implementing principles ensure that the methodology will:

- Apply at the project-level;
- Provide uniform methods to be applied statewide;
- Use existing and proven methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emissions reduction estimates that are conservative and supported by empirical literature.

## Program Assistance

CARB staff will ensure that the quantification methods described in this document are properly applied to estimate the GHG emission reductions for the project types. Applicants should use the following resources for additional questions and comments:

- Questions on this quantification document should be sent to:  
[GGRFProgram@arb.ca.gov](mailto:GGRFProgram@arb.ca.gov)
- For more information on CARB's efforts to support implementation of GGRI investments, see: [www.arb.ca.gov/auctionproceeds](http://www.arb.ca.gov/auctionproceeds)
- Questions not related to this quantification document, but pertaining to the LCT On-Road Advanced Technology Demonstration Project should be sent to:

Earl Landberg  
[Earl.Landberg@arb.ca.gov](mailto:Earl.Landberg@arb.ca.gov)  
(916) 323-1384

**Note:** Questions will not be answered by CARB during the solicitation period. Please refer to the Fiscal Year 2016-17 Low Carbon Transportation Investments Application for On-Road Advanced Technology Demonstration Project for more information on how to submit questions during the solicitation period. Solicitation materials can be found at: <https://www.arb.ca.gov/msprog/aqip/solicitations.htm>

## Section B. Greenhouse Gas Quantification Methodology

The purpose of this quantification methodology is to document the process used by CARB to estimate GHG emission reductions from the FY 2016-17 LCT On-Road Advanced Technology Demonstration Project. Applicants for funding must use the FY 2016-17 LCT Application for On-Road Advanced Technology Demonstration Project for application purposes as it includes methods for quantifying reductions in criteria pollutant emission in addition to reductions in GHG emissions. Project solicitation materials, including fuel energy densities, fuel carbon intensities, and fuel energy economy ratios to be used in calculations, can be found at: <https://www.arb.ca.gov/msprog/aqip/solicitations.htm>. Additionally, fuel energy densities, fuel carbon intensities, and fuel energy economy ratios to be used in calculations are included in Appendix B of this quantification methodology.

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

$$\text{GHG Emission Reductions} = \text{GHG Emissions}_{\text{Baseline Vehicle}} - \text{GHG Emissions}_{\text{Demonstration Vehicle}}$$

The GHG emissions are calculated based on the fuel type of the demonstration vehicle and a 2017 model year diesel fuel baseline vehicle. Example projects demonstrating how to use the methods are provided in Appendix A.

### Step 1. Calculate the Annual Fuel Usage of the Baseline Vehicle

The baseline vehicle's annual fuel usage is calculated using Equation 1.

#### Equation 1: Annual Fuel Usage of the Baseline Vehicle

$$FU_B = \frac{1}{FE} * M * D \quad (\text{Eq. 1})$$

Where,

$FU_B$  is the diesel fuel usage of the baseline vehicle (gallons/year)  
 $FE$  is the fuel efficiency of the baseline vehicle (miles/gallon);  
 $M$  is the daily miles the baseline vehicle is driven (miles/day); and  
 $D$  is the number of days the baseline vehicle is driven annually (days/year).

## Step 2. Calculate the GHG Emissions for the Baseline Vehicle

The GHG emissions for the baseline vehicle are calculated using Equation 2.

### Equation 2: GHG Emissions for the Baseline Vehicle

$$GHG_B = \frac{CI_D * ED_D * FU_B}{1,000,000} \quad (\text{Eq. 2})$$

Where,

GHG<sub>B</sub> is the GHG emissions of the baseline vehicle (MTCO<sub>2</sub>e/year);  
 CI<sub>D</sub> is the carbon intensity for diesel fuel (gCO<sub>2</sub>e/MJ);  
 ED<sub>D</sub> is the energy density for diesel fuel (MJ/gallon); and  
 FU<sub>B</sub> is the result from Step 1 (gallons/year).

## Step 3. Calculate the Fuel Usage of the Demonstration Vehicle

If the demonstration vehicle falls under project category 1, ITS and Connected Trucks, or project category 2, Advanced Engines and Powertrains, and provides a percent efficiency improvement, use Equation 3 to calculate the fuel usage. If the demonstration vehicle falls under project category 3, Zero-Emission or Near Zero-Emission Short and Regional Haul Trucks, use Equation 4 to calculate the fuel usage.

### Equation 3: Fuel Usage of the Demonstration Vehicle for Project Category 1 and 2

$$FU_{DV} = FU_B * \left(1 - \frac{(x * y\%)}{100\%}\right) \quad (\text{Eq. 3})$$

Where,

FU<sub>DV</sub> is the diesel fuel usage of the demonstration vehicle (gallons/year);  
 FU<sub>B</sub> is the result from Step 1 (gallons/year);  
 x is the fraction of time the ITS technology or advanced engine and powertrain system is enabled and providing emission reductions. If the advanced engine and powertrain technology is always engaged and providing emission reductions, assume that x is equal to 1; and  
 y is the percentage of fuel economy improvement that is gained by having the ITS technology enabled or advanced engine and powertrain system efficiency improvement over the baseline vehicle engine.

**Equation 4: Fuel Usage of the Demonstration Vehicle for Project Category 3<sup>1</sup>**

$$FU_{DV} = FU_B * ED_D * \frac{1}{ED_F} * \frac{1}{EER_F} \quad (\text{Eq. 4})$$

Where,

$FU_{DV}$	is the fuel usage of the demonstration vehicle (unit <sup>1</sup> /year);
$FU_B$	is the result from Step 1 (gallons/year);
$ED_D$	is the energy density of diesel fuel (MJ/gallon);
$ED_F$	is the energy density for the fuel type of the demonstration vehicle (MJ/unit <sup>1</sup> ); and
$EER$	is the energy economy ratio value for the fuel type of the demonstration vehicle relative to diesel fuel (unitless).

**Step 4. Calculate the GHG Emissions for the Demonstration Vehicle**

The GHG emissions from the demonstration vehicle are calculated using Equation 5.

**Equation 5: GHG Emissions for the Demonstration Vehicle**

$$GHG_{DV} = \frac{CI_F * ED_F * FU_{DV}}{1,000,000} \quad (\text{Eq. 5})$$

Where,

$GHG_{DV}$	is the GHG emissions of the demonstration vehicle (MTCO <sub>2</sub> e/year);
$CI_F$	is the carbon intensity for the fuel type of the demonstration vehicle (gCO <sub>2</sub> e/MJ);
$ED_F$	is the energy density for the fuel type of the demonstration vehicle (MJ/unit <sup>1</sup> ); and
$FU_{DV}$	is the result from Step 3 (unit <sup>1</sup> /year).

For fuels that blend two of the same fuel types with different CIs for use in the proposed demonstration vehicle, use Equation 6 to calculate a composite CI value.

<sup>1</sup> Unit of fuel: gallons for CARBOB, CaRFG, diesel, FAME biodiesel, renewable diesel, liquefied natural gas, and denatured ethanol; standard cubic foot (scf) for compressed natural gas; kilograms (kg) for hydrogen; and kilowatt-hour (kWh) for electricity.

**Equation 6: Composite Carbon Intensity for Fuel Blends**

$$CI_{\text{composite}} = (TF_{F1} * CI_{F1}) + (TF_{F2} * CI_{F2}) \quad (\text{Eq. 6})$$

Where,

$CI_{\text{composite}}$  is the composite carbon intensity (gCO<sub>2</sub>e/MJ);  
 $TF_{F1/F2}$  is the fraction of total fuel for the corresponding fuel type 1 or 2 (unit less); and  
 $CI_{F1/F2}$  is the carbon intensity of the corresponding fuel type 1 or 2 (gCO<sub>2</sub>e/MJ).

**Step 5. Calculate the GHG Emission Reductions**

The GHG emission reductions attributable to the demonstration vehicle are calculated using Equation 7.

**Equation 7: GHG Emission Reductions<sup>ii</sup>**

$$GHG_{ER} = (GHG_B - GHG_{DV}) * PL \quad (\text{Eq. 7})$$

Where,

$GHG_{ER}$  is the GHG emission reductions attributed to the demonstration vehicle (MTCO<sub>2</sub>e);  
 $GHG_B$  is the emissions result from Step 2 (MTCO<sub>2</sub>e/year);  
 $GHG_{DV}$  is the result from Step 4 (MTCO<sub>2</sub>e/year); and  
 $PL$  is the project life for the demo (2 years).

## Section C. Documentation

CARB reports total project GHG emission reductions by project type. Total Project GHG Emission Reductions per dollar of GGRF funds can be calculated using Equation 8.

### Equation 8: Total Project GHG Emission Reductions per Dollar of GGRF Funds

$$\frac{\text{Total Project GHG Emission Reduction (MTCO}_2\text{e)}}{\text{Total GGRF Funds ($)}}$$
 (Eq. 8)

### Supporting Documentation

CARB is required to retain documentation that is sufficient to allow all quantification calculations to be reviewed and replicated.

Documentation collected includes:

- Contact information for the person who can answer project specific questions from staff reviewers on the quantification calculations;
- Project specific equipment specifications and certifications; and
- Summary page with, at a minimum, the following information:
  - Number of advanced vehicles by technology type;
  - GHG emission reduction estimates for the project;
  - GGRF funds requested for the project; and
  - Total Project GHG emission reductions per GGRF dollar.

## Section D. Reporting after Funding Award

Accountability and transparency are essential elements for all GGRF CCI projects. As described in CARB’s Funding Guidelines, each administering agency is required to track and report on the benefits of the 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 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. Table 2 below shows the project phases and when reporting is required.

Funding recipients have the obligation to provide, or provide access to, data and information on project outcomes to CARB.

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

**Table 1. Quantification and Reporting By Project Phase**

	Timeframe	Quantification Methods
<b>Project Selection</b>	Period from solicitation to funding awards. Applicant submits application to CARB by due date in solicitation materials.	All applicants must use the Fiscal Year 2016-2017 Low Carbon Transportation Investments Application for On-Road Advanced Technology Demonstration Project to calculate greenhouse gas reductions for application purposes.
<b>Phase 1</b>	Period from project award date through project completion date.	All funded projects use methods in CARB’s quantification methodology to update initial estimates of GHG emission reductions, as needed, based on project changes.

Phase 1 reporting is required for all On-Road Advanced Technology Demonstration Projects. CARB will collect and submit data to satisfy Phase 1 reporting requirements. Funding recipients must report any changes that impact GHG emission reduction estimates (i.e. assumptions or quantities) to CARB prior to project completion.

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<sup>i</sup> California Air Resources Board. Funding Guidelines for Agencies Administering California Climate Investments. December 21, 2015.

[www.arb.ca.gov/ccifundingguidelines](http://www.arb.ca.gov/ccifundingguidelines).

<sup>ii</sup> Based on required minimum life, as designated in the Funding Plan. California Air Resources Board. Proposed Fiscal Year 2016-17 Funding Plan for Low Carbon Transportation and Fuels Investments and The Air Quality Improvement Program. May 20, 2016. [https://www.arb.ca.gov/msprog/aqip/fundplan/proposed\\_fy16-17\\_fundingplan\\_full.pdf](https://www.arb.ca.gov/msprog/aqip/fundplan/proposed_fy16-17_fundingplan_full.pdf)

## Appendix A. Example Projects

The following examples are hypothetical projects to demonstrate how the FY 2016-17 LCT On-Road Advanced Technology Demonstration Project Quantification Methodology would be applied. The hypothetical projects have not undergone verification of any LCT or LCT GGRF Program requirements; all assumptions about project features are for quantification methodology illustration purposes only. These hypothetical projects do not provide examples of the supporting documentation that is required of actual project applicants. Results from each step are rounded to two significant figures before proceeding to the next calculation.

### ITS and Connected Trucks

The proposed demonstration project includes the installation of an ITS on a 2017 model year Class-8 diesel truck with a 2017 on-road diesel engine. The truck has a fuel efficiency of 5 miles per gallon and is driven 275 miles a day, 210 days per year. The truck is at freeway speeds for 75 percent of the miles driven. The ITS system provides a 7 percent increase in fuel economy for 50 percent of the freeway speed driving only. The cost of the demonstration on-road truck with ITS is \$115,000.

#### Example Calculations using the Method in Section B

##### Step 1. Calculate the Baseline Vehicle's Annual Fuel Usage

$$FU_B = \frac{1}{FE} * M * D = \frac{1}{5 \frac{\text{miles}}{\text{gallon}}} * 275 \frac{\text{miles}}{\text{day}} * 210 \frac{\text{days}}{\text{year}} = 11,550 \frac{\text{gallons diesel}}{\text{year}}$$

##### Step 2. Calculate the GHG Emissions for the Baseline Vehicle

$$\begin{aligned} GHG_B &= \frac{CI_D * ED_D * FU_B}{1,000,000} = \frac{102.01 \frac{\text{gCO}_2\text{e}}{\text{MJ}} * 134.47 \frac{\text{MJ}}{\text{gallon}} * 11,550 \frac{\text{gallons}}{\text{year}}}{1,000,000} \\ &= 158.43 \frac{\text{MTCO}_2\text{e}}{\text{year}} \end{aligned}$$

##### Step 3. Calculate the Fuel Usage of the Demonstration Vehicle

$$\begin{aligned} FU_{DV} &= FU_B * \left( 1 - \frac{(x * y\%)}{100\%} \right) = 11,550 \frac{\text{gallons}}{\text{year}} * \left( 1 - \frac{(0.75 * .5) * 7\%}{100\%} \right) \\ &= 11,246.81 \frac{\text{gallons diesel}}{\text{year}} \end{aligned}$$

**Step 4. Calculate the GHG Emissions for the Demonstration Vehicle**

$$GHG_{DV} = \frac{CI_F * ED_F * FU_{DV}}{1,000,000} = \frac{102.01 \frac{gCO_2e}{MJ} * 134.47 \frac{MJ}{gallon} * 11,246.81 \frac{gallon}{year}}{1,000,000}$$

$$= 154.28 \frac{MTCO_2e}{year}$$

**Step 5. Calculate the GHG Emission Reductions**

$$GHG_{ER} = (GHG_B - GHG_{DV}) * PL = \left( 158.43 \frac{MTCO_2e}{year} - 154.28 \frac{MTCO_2e}{year} \right) * 2 \text{ years}$$

$$= 8.30 MTCO_2e$$

The total Project GHG Emission Reductions per dollar of GGRF funds can be calculated using Equation 8.

$$\frac{\text{Total Project GHG Emission Reduction (MTCO}_2e\text{)}}{\text{Total GGRF Funds (\$)}} = \frac{8.30 MTCO_2e}{\$115,000}$$

$$= 0.000072 \frac{MTCO_2e}{GGRF \text{ Dollar}}$$

## Advanced Engine and Powertrains

The proposed demonstration project includes the installation of an advanced engine on a Class-8 truck chassis. The advanced engine is 20 percent more efficient than a 2017 conventional diesel engine and is certified to the optional Low NO<sub>x</sub> engine standard of 0.02 g/bhp-hr. The truck has a fuel efficiency of 6 miles per gallon and is driven 400 miles a day, 300 days per year. The cost of the demonstration advanced engine on-road truck is \$1,000,000.

### Example Calculations using the Method in Section B

#### Step 1. Calculate the Baseline Vehicle's Annual Fuel Usage

$$FU_B = \frac{1}{FE} * M * D = \frac{1}{6 \frac{\text{miles}}{\text{gallon}}} * 400 \frac{\text{miles}}{\text{day}} * 300 \frac{\text{days}}{\text{year}} = 20,000 \frac{\text{gallons diesel}}{\text{year}}$$

#### Step 2. Calculate the GHG Emissions for the Baseline Vehicle

$$\begin{aligned} GHG_B &= \frac{CI_D * ED_D * FU_B}{1,000,000} = \frac{102.01 \frac{\text{gCO}_2\text{e}}{\text{MJ}} * 134.47 \frac{\text{MJ}}{\text{gallon}} * 20,000 \frac{\text{gallons}}{\text{year}}}{1,000,000} \\ &= 274.35 \frac{\text{MTCO}_2\text{e}}{\text{year}} \end{aligned}$$

#### Step 3. Calculate the Fuel Usage of the Demonstration Vehicle

$$\begin{aligned} FU_{DV} &= FU_B * \left( 1 - \frac{(x * y\%)}{100\%} \right) = 20,000 \frac{\text{gallons}}{\text{year}} * \left( 1 - \frac{1 * 20\%}{100\%} \right) \\ &= 16,000 \frac{\text{gallons diesel}}{\text{year}} \end{aligned}$$

#### Step 4. Calculate the GHG Emissions for the Demonstration Vehicle

$$\begin{aligned} GHG_{DV} &= \frac{CI_F * ED_F * FU_{DV}}{1,000,000} = \frac{102.01 \frac{\text{gCO}_2\text{e}}{\text{MJ}} * 134.47 \frac{\text{MJ}}{\text{gallon}} * 16,000 \frac{\text{gallon}}{\text{year}}}{1,000,000} \\ &= 219.48 \frac{\text{MTCO}_2\text{e}}{\text{year}} \end{aligned}$$

**Step 5. Calculate the GHG Emission Reductions**

$$GHG_{ER} = (GHG_B - GHG_{DV}) * PL = \left( 274.35 \frac{MTCO_2e}{year} - 219.48 \frac{MTCO_2e}{year} \right) * 2 \text{ years}$$

$$= 109.74 MTCO_2e$$

The total Project GHG Emission Reductions per dollar of GGRF funds can be calculated using Equation 8.

$$\frac{\text{Total Project GHG Emission Reduction (MTCO}_2e\text{)}}{\text{Total GGRF Funds (\$)}} = \frac{109.74 MTCO_2e}{\$1,000,000}$$

$$= 0.00011 \frac{MTCO_2e}{GGRF \text{ Dollar}}$$

## Zero-Emission or Near Zero-Emission Short and Regional Haul Trucks

The proposed demonstration project includes a fuel cell on-road regional haul truck. The calculations below assume that the demonstration truck will have the same energy requirements as the baseline 2017 diesel counterpart and will be used the same number of miles. The proposed truck will not be plugged into the electrical grid to charge the on-board battery packs, but will use the onboard fuel cell. Hydrogen that is produced from natural gas and then compressed will be used for the demonstration project. The baseline truck has a fuel efficiency of 5 miles per gallon and is driven 175 miles a day, 210 days per year. The cost of the demonstration fuel cell on-road regional haul truck is \$750,000.

### Example Calculations using the Method in Section B

#### Step 1. Calculate the Baseline Vehicle's Annual Fuel Usage

$$FU_B = \frac{1}{FE} * M * D = \frac{1}{5 \frac{\text{miles}}{\text{gallon}}} * 175 \frac{\text{miles}}{\text{day}} * 210 \frac{\text{days}}{\text{year}} = 7,350 \frac{\text{gallons diesel}}{\text{year}}$$

#### Step 2. Calculate the GHG Emissions for the Baseline Vehicle

$$\begin{aligned} GHG_B &= \frac{CI_D * ED_D * FU_B}{1,000,000} = \frac{102.01 \frac{\text{gCO}_2\text{e}}{\text{MJ}} * 134.47 \frac{\text{MJ}}{\text{gallon}} * 7,350 \frac{\text{gallons}}{\text{year}}}{1,000,000} \\ &= 100.82 \frac{\text{MTCO}_2\text{e}}{\text{year}} \end{aligned}$$

#### Step 3. Calculate the Fuel Usage of the Demonstration Vehicle

$$\begin{aligned} FU_{DV} &= FU_B * ED_D * \frac{1}{ED_F} * \frac{1}{EER_F} = 7,350 \frac{\text{gallons}}{\text{year}} * 134.47 \frac{\text{MJ}}{\text{gallon}} * \frac{1}{120.00 \frac{\text{MJ}}{\text{kg H}_2}} * \frac{1}{1.9} \\ &= 4,334.89 \frac{\text{kg H}_2}{\text{year}} \end{aligned}$$

#### Step 4. Calculate the GHG Emissions for the Demonstration Vehicle

$$\begin{aligned} GHG_{DV} &= \frac{CI_F * ED_F * FU_{DV}}{1,000,000} = \frac{88.33 \frac{\text{gCO}_2\text{e}}{\text{MJ}} * 120.00 \frac{\text{MJ}}{\text{kg H}_2} * 4,334.89 \frac{\text{kg H}_2}{\text{year}}}{1,000,000} \\ &= 45.95 \frac{\text{MTCO}_2\text{e}}{\text{year}} \end{aligned}$$

**Step 5. Calculate the GHG Emission Reductions**

$$GHG_{ER} = (GHG_B - GHG_{DV}) * PL = \left(100.82 \frac{MTCO_2e}{year} - 45.95 \frac{MTCO_2e}{year}\right) * 2 \text{ years}$$

$$= 109.74 MTCO_2e$$

The total Project GHG Emission Reductions per dollar of GGRF funds can be calculated using Equation 8.

$$\frac{\text{Total Project GHG Emission Reduction (MTCO}_2\text{e)}}{\text{Total GGRF Funds (\$)}} = \frac{109.74 MTCO_2e}{\$750,000}$$

$$= 0.00015 \frac{MTCO_2e}{GGRF \text{ Dollar}}$$

## Appendix B. Fuel Specific Factors

Tables B-1, B-2, and B-3 provide fuel specific factors required for the methods in Section B of this quantification methodology. These factors include energy density (Table B-1), carbon intensity (Table B-2), and energy efficiency ratio for various fuel types (Table B-3). If project specific carbon intensities are available, the applicant should use those instead. A full list of carbon intensities approved by ARB can be found at: <https://www.arb.ca.gov/fuels/lscf/fuelpathways/pathwaytable.htm>.

**Table B-1. Fuel-Specific Energy Densities<sup>2</sup>**

Fuels (units)	Energy Density
CARBOB (gal)	119.53 (MJ/gal)
CaRFG (gal)	115.83 (MJ/gal)
Diesel (gal)	134.47 (MJ/gal)
CNG (scf)	1.04 (MJ/scf)
LNG (gal)	78.83 (MJ/gal)
Electric (KWh)	3.60 (MJ/KWh)
Hydrogen (kg)	120.00(MJ/kg)
Denatured Ethanol (gal)	81.51 (MJ/gal)
FAME Biodiesel (gal)	126.13 (MJ/gal)
Renewable Diesel (gal)	129.65 (MJ/gal)

<sup>2</sup> Low Carbon Fuel Standard Program Regulation.  
<https://www.arb.ca.gov/regact/2015/lscf2015/lscffinalregorder.pdf>

**Table B-2. Fuel-Specific Carbon Intensities<sup>2</sup>**

Fuels	Pathway Identifier	Carbon Intensity (gCO <sub>2</sub> /MJ)
ULSD – based on the average crude oil supplied to California refineries and average California refinery efficiencies	ULSD001	102.01
CaRFG (calculated)	--	98.47
Fossil CNG	CNG400T	78.37
Fossil LNG	LNG401T	94.42
Biomethane CNG	CNG500T	46.42
Biomethane LNG	LNG501T	64.63
Biodiesel – any feedstock	BIOD202T	102.01
Renewable Diesel – any feedstock	RNWD302T	102.01
Ethanol – corn	ETH100T	75.97
Ethanol – any starch or sugar feedstock	ETH103T	98.47
Hydrogen – all sources	HYGN005	88.33
Electricity – California average	ELC001	105.16

**Table B-3. Fuel/Vehicle Combination-Specific Energy Economy Ratio Values<sup>2</sup>**

Fuel/Vehicle Combinations	EER Value Relative to Diesel
Diesel Fuel or Biomass Based Diesel Blends	1.0
CNG or LNG/Any Vehicles (Spark-Ignition Engines)	0.9
CNG/LNG /Any Vehicle (Compression-Ignition Engines)	1.0
Electricity / Battery Electric or Plug-in Hybrid Electric Truck	2.7
Electricity / Battery Electric or Plug-in Hybrid Electric Bus	4.2
Electricity / Fixed Guideway, Heavy Rail	4.6
Electricity / Fixed Guideway, Light Rail	3.3
Electricity / Trolley Bus, Cable Car, Street Car	3.1
Electricity/Forklifts or Equipment	3.8
H <sub>2</sub> / Fuel Cell Vehicle	1.9
H <sub>2</sub> / Fuel Cell Forklifts	2.1