Diesel Emissions Quantifier

User's Guide

United States
Environmental Protection
Agency

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User's Guide

Transportation and Regional Programs Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

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1. Introduction

The Diesel Emissions Quantifier ("the Quantifier") is a tool that enables users to estimate emissions from a fleet of diesel vehicles and/or equipment. The Quantifier can calculate emissions estimates of NO_x, PM, HC, CO, and CO_2 for highway and NonRoad vehicles, and marine vessels that utilize various emissions control technologies.

The Quantifier has been modeled after the National Mobile Inventory Model (NMIM) and the 2008 Locomotive Engines and Marine Diesel Engines Emission Standards Regulations. The NMIM is an application developed by the EPA to determine estimates of current and future emission inventories for on-road motor vehicles and NonRoad equipment. The Quantifier is a web-based interface that asks users intuitive questions to help estimate their emissions.

The Quantifier is capable of the following:

1. Calculating emissions from a single emissions reduction project;

2. Comparing fleet emissions using different retrofit control technologies; and

3. Assisting SmartWay carrier partners and grantees in developing proper data reports for submission to the EPA.

The Quantifier calculates the following quantities for the fleet's baseline emissions for one year, and for the lifetime of a fleet: emissions reduced by the use of control technologies, and the cost effectiveness of control technologies. The calculated results may then be downloaded.

The following SIP and conformity language appears as part of the Disclaimer on the Overview tab for the Quantifier:

> "The Diesel Emissions Quantifier is intended as a helpful tool to prepare estimates, but is not designed to meet requirements under other types of air or transportation submissions. Please do not continue using the Quantifier until you have read the important usage information below.
>
> - The Diesel Emission Quantifier should not be used for the calculation of any emission reductions to be incorporated in a State Implementation Plan (SIP) or conformity determination.
>
> - If you wish to calculate emission reductions for a SIP or conformity determination, you should review the appropriate SIP and conformity guidance document and consult with your EPA Regional Office.

- For long-duration idle reduction, the SIP and conformity guidance can be found in the document Guidance for Quantifying and Using Long Duration Truck Idling Emission Reductions in State Implementation Plans and Transportation Conformity (January, 2004, EPA420-B-04-001, PDF, 33 pages, 379K, About PDF).

- For retrofit projects, the SIP and conformity guidance can be found in the document Diesel Retrofits: Quantifying and Using Their Benefits in SIPs and Conformity (June, 2006, EPA420-B-06-005, PDF, 69 pages, 530K, About PDF).

- For emission reduction strategies not covered by those guidance documents, please consult with your EPA Regional Office."

2. Screen-Specific Instructions

2.1 Overview Tab

The Overview Tab provides users with a basic description of the ways in which the Quantifier can be used, and ways in which the Quantifier should not be used.

2.2 My Account Tab

On the My Account Tab (which is also accessible via the Use the Quantifier Tab) users have the option to log in by entering their email address and password. Logging in enables the user to store information on up to five fleets so that it can be retrieved at a later time.

To obtain a login and password, the user must click on the "Register New Account" link. This link takes the user to the registration screen, where contact information is entered. Required contact information includes the user's email address, chosen password, contact name, organization name, and phone number. The user can opt to enter additional contact information including their position and address. When the registration information is saved, the user is taken back to the Use the Quantifier Tab.

The "Forgot Password?" option takes the user to the My Account tab where they are prompted to enter their email address. An email will be sent to the user which contains an Internet link where the user can change their password. To log out at any time, the user can click on the "Log out" link at the top of each screen under the Use the Quantifier Tab.

2.3 Use the Quantifier Tab

2.3.1 Fleet Entry Section

On the Use the Quantifier Tab, either logged in as an authenticated user or not logged in as an unauthenticated user, users are then prompted to begin use of the Quantifier by defining basic Fleet Entry information. This includes information for the following fields:

Fleet Name: This is a user Defined Name for the Fleet.

Fleet Type: On Highway/NonRoad OR Marine. (Please note that the marine vessel component is separate from the On Highway and NonRoad component of the Quantifier.)

State: The user will select a state from the drop-down list. The user should select the state where the project is located. If the project spans across more than one state, select the state that will yield the majority of the emissions reduction benefits. The user does not need to select a state if they are returning to a saved scenario.

"Are you Quantifying Emissions for EPA?" Indicator: When the user selects this "preparing data" option, a contact information section will appear below the state drop-down list. All fields in the Required Contact Information section must be completed by all users who select the "preparing data" option. Users who want to download data to use in an EPA grant application only need to complete the Required Contact Information fields. In addition to the Required Contact Information section, existing SmartWay partners are required to complete the SmartWay Carrier Questionnaire which appears below the Optional Contact Information section when the "Click here if you are a SmartWay Carrier/Partner" hyperlink is clicked on. Users who are joining the SmartWay partnership for the first time are requested to complete the fields in the Required and Optional Contact Information sections, and the SmartWay Carrier questionnaire. The questionnaire contains the following information:

- Does the data represents the user's initial fleet baseline, action plan, or annual update?
- Average payload.
- The number of straight trucks, tractors, and trailers that are owned, leased, and subcontracted.
- The percentage of the fleet operating in each of the following modes:
  - -- Truckload;
  - -- Less than Truckload;
  - -- Pickup/Delivery;
  - -- Leasing; and
  - -- Other.
- The user's parent company and subsidiaries (if applicable).

The questionnaire can be hidden by clicking on the "Click here if you are not a SmartWay Carrier/Partner" hyperlink which appears at the top of the questionnaire. Once finished, the user can click Continue to move to the next screen to input specific information on the fleet.

"Are you entering project funding information to calculate total cost effectiveness?" Indicator: Entering funding data is optional, but if the user wants to view the Total Cost Effectiveness of a project, funding data are required. The user can select Yes for this indicator and a list of funding sources and fields for dollar amounts will appear. The user should enter funding amounts in the appropriate fields. Funding data includes all costs associated with a project, including retrofit capital costs, installation costs, administrative costs, etc.

Total Project Funding: This quantity is the sum of all funding source amounts entered by the user. The Quantifier automatically calculates this value. In order for the Quantifier to accurately calculate Total Cost Effectiveness, the user must ensure that the Total Project Funding amount only applies to the current vehicle group(s) entered. For example, if a user wishes to apply $100,000 of funding to two vehicle groups, entering $100,000 of funding for each vehicle group will result in a funding amount of $200,000 being used in the Total Cost Effectiveness calculation. Instead, the user should input all the funding information with the first vehicle group. If there are multiple vehicle groups then funding information for subsequent vehicle groups should be left at zero.

To Save Fleet Entry information, select Save Fleet, and the Enter Vehicle Group Section will be made available.

2.3.2 Enter New Vehicle Group Information Section

On this screen, the user will input information specific to each vehicle group in the fleet, as well as the vehicles to which one or more emission reduction strategies are applied. For fields specific to marine vessels, refer to Section 2.2.2.1. All other field definitions for marine vessels can be found in Section 2.2.2. This includes the types of vehicles in the fleet, the number, model year, and retrofit year of each vehicle group; fuel and usage information; the type(s) of technology applied; and cost information. This screen must be completed for each vehicle group separately. The user is encouraged to input fleet data with as much detail as possible; there is no limit to the number of vehicle groups that can be entered for a fleet. For example, a user has a fleet of 100 school buses with a range of model years from 1990 to 2005. The user may enter this fleet as one entry using an average model year. Alternatively, the user may enter vehicles of each model year separately. The more accurate the data entered is, the more accurate the results will be.

The Enter New Vehicle Group Information section of the Fleet Information screen is where the user enters information on each vehicle group in the fleet. After the required Fleet Information has been entered and saved, the user can begin entry for a Vehicle Group within the Fleet. The following fields appear in the order listed below, and must be completed or selected from drop-down lists. All of the drop-down list options are provided in Appendix A. Numeric values must be entered without commas.

State: The state selected on the Start Screen will appear as the Selected State.

Type: Select the vehicle type (either On Highway or NonRoad) for the vehicle group from the drop-down list.

Target Fleet: Select the vehicle group target fleet from the drop-down list. The list options will vary depending on the Type selected.

Class/Equipment: Select the Vehicle/Equipment category from the drop-down list. The list options vary depending on the Target Fleet selected.
Quantity: Enter the number of the vehicles of the fleet in a specific vehicle group.

Model Year: Enter the model year of the engine, not the vehicle.

Retrofit Year: Enter the year the emissions control retrofit will be installed.

Horsepower: If the user selects NonRoad as the Type, a field for Horsepower will appear below the Retrofit Year field. The user must select the vehicle's horsepower from the drop-down list. If the Horsepower drop-down list does not include an exact match for the user's vehicle, the user should select the nearest value.

In the following fields, the user must provide information on how the vehicles in a particular vehicle group are operated. This includes information on fuel usage, distance traveled, travel time, and idling time. There is a direct correlation between fuel usage and CO_2 emissions. Different fuels emit different amounts of CO_2 based on their chemical make-up.

Fuel Type: Select the fuel used by the vehicle group from the drop-down list. Table A-4 lists the options that appear in the Fuel Type drop-down list, their associated CO_2 factors, and the vehicle types and years for which each fuel type can be selected. The CO_2 factors are multiplied by the fuel volume to convert a non-diesel fuel volume into a diesel equivalent. The resulting value will be displayed in the "Calculated Fuel Volume" field.

Fuel Volume: Fuel Volume is the amount of fuel used (in gallons per year) by all vehicles in a group, including fuel consumed while idling. A Fuel Type must be selected before the user can enter Fuel Volume. Depending on which Fuel Type is selected, the user-entered Fuel Volume is converted into a diesel equivalent in the "Calculated Fuel Volume" field. This allows the CO_2 emissions to be compared on an equal basis across the entire fleet.

Vehicle Miles Traveled (VMT): This field will only appear if "On Highway" is selected as the Type. If "NonRoad" is selected as the Type, a Usage Rate field will appear instead. VMT is the average number of miles traveled per vehicle in the group per year. VMT can be calculated by averaging the miles traveled per year of all vehicles in a group. Alternatively, VMT can be calculated by dividing the total miles traveled in a year by the total number of vehicles in the group. The example below illustrates this calculation:

Example:

Vehicle	Miles/Year
1	10,000
2	20,000
3	30,000

VMT = (10,000 + 20,000 + 30,000 miles/year) / 3 vehicles = 20,000 miles/vehicle/year

Usage Rate: This field will only appear if "NonRoad" is selected as the Type. The Usage Rate is the average number of hours of use per vehicle per year. It is calculated by averaging the number of hours of use per year of all vehicles in a group. Alternatively, Usage Rate can be

calculated by dividing the total hours of use by all vehicles in a group in one year by the number of vehicles in the group. An example of this calculation is provided below:

Example:

Vehicle	Hours of Use/Year
1	500
2	1,000
3	1,200

Usage Rate = (500 + 1,000 + 1,200 hours/year) / 3 vehicles = 900 hours/vehicle/year

The Quantifier will automatically populate this field for Locomotive Passenger, Locomotive, Switch, and Locomotive Line Haul vehicles. The user can change these default values.

Idling Hours (including hours saved): The Idling Hours field only appears for On Highway vehicles. This is the average number of hours spent idling per vehicle per year including any hours diverted (saved) using an idling control strategy. The Quantifier calculates On Highway emissions based on two modes: drive and idle. In order to show proper savings, the user must input information based on the true number of hours diverted (saved) using the control strategy. Idling hours can be calculated by averaging the idling hours of each vehicle in a group, or by adding the idling hours of all vehicles in a group, and dividing this sum by the number of vehicles. This is to include hours that have been diverted through idling control measures.

2.3.2.1 Enter New Marine Vessel

Quantity: For marine vessels, only one vessel may be modeled at a time. This value is set to one.

Number of Engines: Enter the number of engines on the vessel (up to five), both propulsion and auxiliary engines.

Unique Engine Type 1: All fields under this and subsequent types are related to the specific engine.

Type: Select propulsion or auxiliary.

Quantity (Engines): Enter the number of engines unique to the characteristic defined in the following fields.

Displacement per cylinder: Select the range of displacement per cylinder per engine.

2.3.3 Apply a Technology to New Vehicle Group

In the Apply a Technology to New Vehicle Group section of the Fleet Information screen, the user enters information on the emission control technologies that are to be applied to the vehicle group. The user will have the option to add a new technology after saving the Vehicle Group. The following fields appear in the order listed below, and must be completed or selected from drop-down lists. All of the drop-down list options are provided in Appendix A.

Technology Type: The Technology Type is an emissions control category. The Technology Type is selected from the drop-down list.

Technology: Technology is a specific emissions control method that is selected from the drop-down list. When multiple technologies are applied to a single vehicle, the following rules and restrictions apply:

- **Engine Replacement/Repower** -- only one technology may be applied to a vehicle.
- **Hybrids** -- only one technology may be applied to a vehicle.
- **Emission Control Devices** -- only one technology may be applied to a vehicle**.**
- **Engine and Truck Upgrades** -- only one technology may be applied to a vehicle.
- **Trailer Strategies** -- only one technology may be applied to a vehicle.
- **Aerodynamic Devices** -- multiple selections may be applied to a vehicle.
- **Tire Technology** -- only one technology may be applied to a vehicle**.**
- **Weight Reduction** -- only one technology may be applied to a vehicle.
- **Fuel Options** -- only one technology may be applied to a vehicle.
- **Advanced Lubricant Technology Strategies** -- only one technology may be applied to a vehicle.
- **Speed Management Policies** -- only one technology may be applied to a vehicle.
- **Idling Control Strategies** -- multiple selections may be applied to a vehicle. Note that the idling hours reduced for all selections must not exceed the total idling hours which were inputted under the vehicle group section.

The following technology combinations are not allowed:

If This Is Selected…	Then This Is NOT an Option
Diesel Particulate Filter or any of the following combinations with a filter: • Lean NO_x Catalyst + Diesel Particulate Filter • Exhaust Gas Recirculation + Diesel Particulate Filter • Diesel Particulate Filter + ULSD • Hybrid Electric Replacement with Diesel Particulate Filter	Any Fuel Option.
Any of the following Diesel Oxidation Catalyst combinations with fuel: • Diesel Oxidation Catalyst + B10 • Diesel Oxidation Catalyst + B20 • Diesel Oxidation Catalyst + B100 • Diesel Oxidation Catalyst + ULSD • Diesel Oxidation Catalyst + emulsion • Diesel Oxidation Catalyst + Closed Crankcase Ventilation + B10 • Diesel Oxidation Catalyst + Closed Crankcase Ventilation + B20 • Diesel Oxidation Catalyst + Closed Crankcase Ventilation + B100 • Diesel Oxidation Catalyst + Closed Crankcase Ventilation + ULSD • Diesel Oxidation Catalyst + Closed Crankcase Ventilation + emulsion	Any Fuel Option.

New Model Year: This field will only appear if the Engine Replacement/Repower technology type is selected. This New Model Year is the model year of the new or retrofitted engine.

Idling Hours Reduced: If Idling Control Strategies are selected as the Technology Type, the Idling Hours Reduced field appears. The user should enter the number of idling hours reduced by implementing the selected Technology. The number of idling hours reduced cannot exceed the number of idling hours entered for the vehicle group.

Apply Technology To: Enter the number of vehicles to which this technology applies. This number can be all or a portion of the Quantity entered previously for the entire vehicle group. As the user adds technologies, this section will expand to list out each group of vehicles to which technologies have been applied. For example, if Technology 1 is applied to 20 out of 100 vehicles, the following two lines will appear:

- Apply to ___ vehicles (out of 20) that currently have Technology 1; and
- Apply to ___ vehicles (out of 80) that do not currently have a Technology.

Pollutants Table: Once the Technology Type and Technology are selected, the percent emissions reductions for NO_x, PM, HC, CO, and CO_2 will automatically populate the Pollutants table. The percent reductions are average values specific to the selected technology. Note that for Idling Control Strategies, the percent reductions are based on the engine being used in idling mode only. If the user knows the exact percent reductions for the specific technology they have selected, then they can manually change the values that appear in the table. The maximum percentage a user can enter is 100%. It is recommended that users only make changes if they have more accurate values from the manufacturer. The following disclaimer appears below the "Installation Cost" field and applies to the pollutants table:

> "Note that the percent reduction associated with a particular retrofit technology or cleaner fuel may vary by manufacturer and application and may change as more information becomes available. Please refer to EPA's verified technology web page for the latest detailed information on verified emission reductions from retrofit technologies. Some of the technologies listed here are not yet verified by EPA or the California Air Resources Board (CARB). Emissions reductions calculated by this model based on user-entered percent reductions not based on EPA or CARB's verified technology list should not be used for any official purposes or to meet any reporting requirements. Emission reductions calculated by this model based on user-entered percent reductions not based on EPA or CARB's verified technology list should not be used for any official purposes or to meet any reporting requirements."

EPA's verified technology web page is http://www.epa.gov/otaq/retrofit/verif-list.htm.

Unit Cost: The cost to purchase an emission control technology for one vehicle. The user must enter a non-negative numeric value. The Quantifier uses this value to calculate Capital Cost Effectiveness.

Installation Cost: The cost to install the selected emission control technology on one vehicle. The user must enter a non-negative numeric value. The Quantifier uses this value to calculate Capital Cost Effectiveness.

2.3.3.1 Apply a Technology to a Marine Vessel

Once a technology type and technology have been selected, the user must apply the technology to the Engine Type. The technology may be applied to one or more engine types.

2.3.4 Save a New Vehicle Group and Technology

Once all the required vehicle group fields are complete, the user can save the information by clicking the "Save" button, or the "Add a New Vehicle Group" option to add additional vehicle groups. If the user would like to clear the data entered on the screen without saving it, the "Go Back to Start" hyperlink at the top of the screen must be clicked. From the Start Screen, the user can click "Continue" to return to the Fleet Information screen.

To save control technology information, the user must click the "Save Technology" button. Once at least one vehicle group is saved, the user can edit the group, add technologies, add additional vehicle groups, or proceed to the Results page.

2.3.5 Edit Data

The user can edit or delete any group, and delete any technology by clicking the "Edit" or "Delete" buttons.

2.3.5.1 Edit Vehicle Group Information

Once a vehicle group is saved, if the Vehicle Group Information is not immediately editable the user can edit vehicle group information by clicking on the Edit Group button. All Vehicle Group Information fields are editable.

To add an additional vehicle group, the user must click the "Add New Vehicle Group" header bar.

2.3.5.2 Edit Technology Information

To apply additional technologies to a vehicle group, the user must enter technology information and click the "Save Technology" Button. To edit a saved technology, the user must click the "Delete" button that corresponds to the technology and re-enter the data.

2.3.6 Calculate Results

Once the user has finished entering data for an entire fleet, the user can click the "Quantify Emissions" button at the bottom of the screen to calculate results.

2.3.6.1 Emissions Results Screen: Summary Results Tab

When the user clicks on the "Quantify Emissions" button on the Fleet Information screen, the user will be taken to the Results screen. The formulas used to generate the results are provided in Appendix B.

The data that appear in the Results table are an aggregation of the emissions from all vehicle groups and technologies that the user entered. The Results table has the following format:

Table 1:
Annual, Daily, and Lifetime Emission Results

Annual	NO_x (tons/ year)	PM (tons/ year)	HC (tons/ year)	CO (tons/ year)	CO_2 (tons/ year)	Diesel Equivalent (gallons/year)
Baseline of Entire Fleet						
Baseline of Vehicles Retrofitted						
Percent Reduced (%)						
Amount Reduced Per Year						
Daily	**NO_x (kg/ day)**	**PM (kg/ day)**	**HC (kg/ day)**	**CO (kg/ day)**	**CO_2 (kg/ day)**	**Fuel (g/day)**
Kilograms Reduced Per Day						----------
Lifetime	**NO_x (tons)**	**PM (tons)**	**HC (tons)**	**CO (tons)**	**CO_2 (tons)**	**Diesel Equivalent (gallons/year)**
Baseline of Entire Fleet						
Baseline of Vehicles Retrofitted						
Percent Reduced (%)						
Amount Reduced						
Amount Emitted after Retrofit, Entire Fleet						
Amount Emitted after Retrofit, Retrofitted Vehicles						
Capital Cost Effectiveness ($/ton), Retrofitted Vehicles						----------
Total Cost Effectiveness ($/ton), Retrofitted Vehicles						----------

2.3.6.1.1 Annual and Daily Results

The Annual and Daily sections of the Results table display annual baseline emissions information, and the emissions reduced daily and annually by applying the user-selected control technologies. The Baseline of Entire Fleet row displays annual emissions of NO_x, PM, HC, CO, and CO_2 without any emissions controls. The Baseline of Vehicles Retrofitted shows the uncontrolled emissions of each of the five pollutants from only the vehicles that will be retrofitted with a control technology. For example, if there are 100 vehicles in a fleet, and 50 vehicles are going to be retrofitted with emissions controls, then the Baseline of Entire Fleet will show the uncontrolled emissions from 100 vehicles, while the Baseline of Vehicles Retrofitted will show the uncontrolled emissions from 50 vehicles. Both quantities are shown in units of

tons/year. Percent Reduced values are the emission reduction percentages obtained after control technologies are applied to a fleet. Amount Reduced per Year values are the tons of pollutants reduced per year by applying controls. These values converted to kilograms per day are displayed in the Daily section of the table. The Diesel Equivalent of CO_2 emissions, in gallons per year, is displayed in the last column.

2.3.6.1.2 Lifetime Results

The Lifetime Emissions section of the Results table displays the emissions that are estimated to occur over the remaining lifetime of all vehicle groups in a fleet. The Baseline of Entire Fleet, Baseline of Vehicles Retrofitted, Percent Reduced, and Amount Reduced values are analogous to the values in the Annual and Daily results. The calculations used to derive these values are provided in Appendix B. Amount Emitted after Retrofit, Entire Fleet values are the lifetime emissions, in tons, of the entire fleet after the user-selected control technologies are applied. Amount Emitted after Retrofit, Retrofitted Vehicles values are the lifetime emissions, in tons, of only the retrofitted vehicles after the user-selected control technologies are applied. The Diesel Equivalent of CO_2 emissions, in gallons, is displayed in the last column.

Capital Cost Effectiveness is calculated by dividing the total unit and installation costs of all retrofits in the fleet by the Amount Reduced. These values are only calculated if the user enters unit and installation costs on the Fleet Information screen. Any technologies that increase emissions are excluded from the Capital Cost Effectiveness calculation. Total Cost Effectiveness is calculated by dividing the total cost of the retrofit project (capital costs, administrative costs, etc.) by the Amount Reduced. In this calculation, any emission increases from control technologies are not included in the Amount Reduced. Total Cost Effectiveness is only calculated if the user enters funding information on the Fleet Information screen. See Appendix B for details on how these calculations are performed. Total Cost Effectiveness results are displayed in the Emissions Results table, and not in the Detailed Results table.

The following note appears below the Lifetime emissions results:

> "The lifetime results are dependent on each vehicle group's remaining life. To determine the remaining life for each vehicle group, divide the lifetime results by the annual results using the Detailed Results tables below."

The funding data are displayed in a table below the Lifetime Emissions table.

2.3.6.1.3 Preview/Download Data: Detailed Results and Download Data Tabs

Before downloading data, the user can preview the data in the Detailed Results section, which appears as the second tab on the Results screen. This tab takes the user to the Detailed Results. These tables present results for each subgroup of vehicles that share the same control technologies. The first Detailed Results table presents annual data, and the second table presents lifetime data.

The following two download options appear on the Download Data:

View/Download Detailed Report: To download all the data entered in addition to the calculated data from the Results tables, the user must select the format by clicking either "as Microsoft Excel file" or "as CSV (comma separated values) file." The downloaded data file can be submitted to the EPA. This option is not available for Marine Vessels.

View/Download Summary Report: This option appears if the user selected "Preparing data for the EPA?" from the Select Scenario option on the Start screen. The user has the option to download the data in either Excel or CSV format. CSV files can be opened by many desktop spreadsheet and database applications.

This option allows the user to download a data file that is a condensed version of the Annual, Daily and Lifetime Results tables. This condensed data file may be selected by users applying for EPA grant funds as part of a grant application. This file contains the relevant information that EPA needs to review a grant application. If the user has already received grant funds, this file can be used to report required data to the EPA.

When the user clicks on "as Microsoft Excel file" or "as CSV (comma separated values) file," a dialog box will appear on the screen that lets the user open the file or save it to disk.

2.3.6.1.4 Benefits Module Tab

When the user clicks on the Health Benefits Tab on the Emission Results page, the user will be taken to the Benefits Module entry screen.

2.3.6.1.4.1 Entry Screen

The Entry Screen of the Benefits Module allows the user to enter up to five counties that will be affected by the emission reductions resulting from the retrofit technologies. The user also enters the percent reduction that is experienced in each county. The percent reductions must total to 100%. Once the user has properly defined the States, Counties, and Percent Reductions, they may click the "Calculate Health Benefits" button to take them to the results screen.

2.3.6.1.4.2 Results Screen

The Results Screen of the Benefits Module displays the Annual Diesel PM Reduction (tons) and the Annual Benefits ($) on a per county and total basis. The total Annualized Cost of the retrofit project is also displayed. Counties will appear with one asterisk if the benefits for that county are likely underestimated and two asterisks if the benefits are likely overestimated. Additionally, explanatory text will appear below the results table.

2.3.6.1.4.3 View/Download Benefits Module Results

To download the Results tables, the user must select the format by clicking either "as Microsoft Excel file" or "as CSV (comma separated values) file" at the bottom of the Results Screen. The user will then have the option to either view or download the results.

3. Quick Start Tab

This tab will provide the user with basic information that they will need before using the Quantifier (e.g., Necessary Inputs).

4. References Tab

On this tab the user can find links to References that users of the Quantifier might need.

Appendix A:
Drop-down List Options

Table A-1:
Vehicle Types and Associated Target Fleets

Vehicle Type	Target Fleet
On Highway	School Buses
	Transit Buses
	Refuse Hauler
	Short Haul
	Long Haul
	Delivery Truck
	Emergency Vehicle
	City/County Vehicle
NonRoad	Agriculture
	Port and Airports
	Rail
	Construction
	Stationary

Table A-2:
Target Fleets and Associated Class/Equipment

Target Fleet	Class/Equipment
Refuse Hauler, Short Haul, Long Haul, Delivery Truck, Emergency Vehicle, City/County Vehicle	Class 5 (16,001 – 19,500 lbs.) Class 6 (19,501 – 26,000 lbs.) Class 7 (26,001 – 33,000 lbs.) Class 8a (33,001 – 60,000 lbs.) Class 8b (60,001 and over)
School Buses	School Buses
Transit Buses	Transit Buses

(cont.)

Table A-2:
Target Fleets and Associated Class/Equipment (cont.)

Target Fleet	Class/Equipment
Agriculture	2-Wheel Tractors
	Agricultural Mowers
	Agricultural Tractors
	Balers
	Combines
	Irrigation Sets
	Logging Equip. Fell/Bunch/Skidders
	Logging Equipment Chain Saws > 6
	Logging Equipment Shredders > 6
	Off-Highway Tractors
	Off-Highway Trucks
	Other Agricultural Equipment
	Sprayers
	Swathers
	Tillers > 6 HP
Construction	Bore/Drill Rigs
	Cement & Mortar Mixers
	Concrete/Industrial Saws
	Cranes
	Crawler Tractors
	Crushing/Proc. Equipment
	Dumpers/Tenders
	Excavators
	Forklifts
	Graders
	Light Commercial Air Compressors
	Light Commercial Gas Compressors

(cont.)

Table A-2:
Target Fleets and Associated Class/Equipment (cont.)

Target Fleets	Class/Equipment
Construction (cont.)	Light Commercial Generator Sets
	Light Commercial Pressure Washer
	Light Commercial Pumps
	Light Commercial Welders
	Off-Highway Tractors
	Off-Highway Trucks
	Other Construction Equipment
	Pavers
	Paving Equipment
	Plate Compactors
	Rollers
	Rough Terrain Forklifts
	Rubber Tire Dozers
	Rubber Tire Loaders
	Scrapers
	Signal Boards
	Skid Steer Loaders
	Surfacing Equipment
	Sweepers/Scrubbers
	Tampers/Rammers (unused)
	Tillers > 6 HP
	Tractors/Loaders/Backhoes
	Trenchers
Port and Airports	AC Refrigeration
	Aerial Lifts
	Airport Support Equipment
	Cranes
	Forklifts

(cont.)

Table A-2:
Target Fleets and Associated Class/Equipment (cont.)

Target Fleet	Class/Equipment
Port and Airports (cont.)	Light Commercial Air Compressors
	Light Commercial Gas Compressors
	Light Commercial Generator Sets
	Light Commercial Pressure Washer
	Light Commercial Pumps
	Light Commercial Welders
	Off-Highway Tractors
	Off-Highway Trucks
	Other Construction Equipment
	Other General Industrial Equipment
	Other Material Handling Equipment
	Signal Boards
	Skid Steer Loaders
	Terminal Tractors
Rail	Aerial Lifts
	Cranes
	Forklifts
	Light Commercial Air Compressors
	Light Commercial Generator Sets
	Light Commercial Pressure Washer
	Line Haul Locomotive
	Off-Highway Tractors
	Off-Highway Trucks
	Other General Industrial Equipment
	Other Material Handling Equipment
	Passenger Locomotive
	Switch Locomotive
	Terminal Tractors
	Tractors/Loaders/Backhoes

(cont.)

Table A-2:
Target Fleets and Associated Class/Equipment (cont.)

Target Fleet	Class/Equipment
Stationary	Air Compressor
	Gas Compressor
	Irrigation
	Power Generation
	Pump
	Welding
Marine	Container
	Ferry/Excursion
	Tug Boat/Tow Boat
	Commercial Fishing
	Commercial Charter Fishing
	Crew and Supply
	Pilot
	Work Boat
	Other

Table A-3:
Horsepower Options

Horsepower
0
1
3
6
10
11
16
20
25
30
35
40
45
49
50
60
70
75
80
90
100
110
120
130
140
150
160
175
180
190

(cont.)

Table A-3:
Horsepower Options (cont.)

Horsepower
200
220
240
250
300
320
350
400
425
450
475
500
550
600
700
750
800
900
950
1000
1200
1300
1400
1500
1600
1700
1800
1900
2000
2250

(cont.)

Table A-3:
Horsepower Options (cont.)

Horsepower
2500
2750
3000
3250
3500
4000
4250
4500
5000
5500
6000
6500

Table A-4:
Displacement Options

Displacement
size < 0.9
0.9 < = size < 1.2
1.2 < = size < 2.5
2.5 < = size < 3.5
3.5 < = size < 5.0
5.0 < = size < 15.0
15.0 < = size < 20.0
20.0 < = size < 25.0
25.0 < = size < 30.0

Table A-5:
Fuel Types

Fuel Type	CO_2 Factor	Rules
LPG	0.65	Always available.
LNG	0.61	Always available.
CNG (lbs)	0.16	Always available.
CNG (ft3)	0.0074	Always available.
Biodiesel 100	0.92	Always available.
Biodiesel 20	0.985108	Always available.
Biodiesel 5	0.996277	Always available.
Biodiesel 2	0.998511	Not available to any vehicles or as a reduction technology.
E85	0.626126	Always available.
Regular Diesel, 3,400 ppm		Not available for On Highway, available for NonRoad for retrofit years up to and including 2006.
High Sulfur Non-Road Locomotive and Marine Diesel Fuel, 3,400 ppm	1	Available for Marine for model years up to and including 2010.
Ultra Low Sulfur Diesel (ULSD), 15 ppm	1	Not available for On Highway, available for NonRoad and Marine.
Emulsion	1	Always available.
Regular Diesel (LSD), 500 ppm	1	Not available for On Highway, available for NonRoad for retrofit years from 2007 – 2009.
Regular Diesel/Marine Diesel Fuel (LSD), 500 ppm	1	Available only for Marine Vessels for retrofit years from 2007 – 2012.
Low Sulfur Diesel (LSD), 500 ppm	1	Available for On Highway and NonRoad for retrofit years prior to 2007.
Regular Diesel (ULSD), 15 ppm	1	Available for On Highway, not available for NonRoad.

Table A-6:
Retrofit Technology Types and Associated Technologies

Retrofit Technology Type	Retrofit Technology
Emissions Control Devices	Diesel Oxidation Catalyst
	Diesel Oxidation Catalyst + B10
	Diesel Oxidation Catalyst + B20
	Diesel Oxidation Catalyst + B100
	Diesel Oxidation Catalyst + Closed Crankcase Ventilation + B10
	Diesel Oxidation Catalyst + Closed Crankcase Ventilation + B20
	Diesel Oxidation Catalyst + Closed Crankcase Ventilation + B100
	Diesel Oxidation Catalyst + Emulsion
	Diesel Oxidation Catalyst + Closed Crankcase Ventilation + Emulsion
	Diesel Particulate Filter
	Diesel Particulate Filter + ULSD (for NonRoad only)
	Diesel Oxidation Catalyst + Closed Crankcase Ventilation
	Diesel Particulate Filter + Closed Crankcase Ventilation
	Diesel Oxidation Catalyst + Closed Crankcase Ventilation + ULSD (for NonRoad only)
	Diesel Oxidation Catalyst + ULSD (for NonRoad only)
	Hybrid Electric Replacement with Diesel Particulate Filter
	Partial Flow Filter
	Compressed Natural Gas (CNG) Replacement
	Lean NO_x Catalyst/Diesel Particulate Filter
	Recalibration
	Selective Catalytic Reduction
	Exhaust Gas Recirculation + Diesel Particulate Filter
	Other

(cont.)

Table A-6:
Retrofit Technology Types and Associated Technologies (cont.)

Retrofit Technology Type	Retrofit Technology
Fuel Options	Ultra Low Sulfur Diesel (ULSD)
	Compressed Natural Gas
	Liquid Natural Gas
	Biodiesel (B20)
	Biodiesel (B100)
	Emulsion
Hybrid	Hybrid
Weight Reduction	100 lbs
	500 lbs
	1000 lbs
	5000 lbs
Trailer Strategies	45 Foot Trailer
	48 Foot Trailer
	53 Foot Trailer
	Double
	Rocky Mountain Double
	Turnpike Double
	Triple
Tire Technology	Single Wide Tires
	Automatic Tire Inflation
	Other Fuel Efficient Tire
Advanced Lubricant Technology Strategies	Low Friction Engine Lubricant
	Low Friction Drive Train Lubricant
	Other Advanced Lubricant Technology Strategies
Engine and Truck Upgrades	Direct Drive
	Single Axle vs. Double

(cont.)

Table A-6:
Retrofit Technology Types and Associated Technologies (cont.)

Retrofit Technology Type	Retrofit Technology
Speed Management Policy	65 mph
	64 mph
	63 mph
	62 mph
	61 mph
	60 mph
	59 mph
	58 mph
	57 mph
	56 mph
	55 mph
Aerodynamic Devices	Aero Profile Tractor
	Cab Over Engine Tractor
	Integrated Cab Roof Fairing
	Cab Roof Fairing
	Cab Roof Deflector
	Cab Side Fairing
	Cab Front Air Dam Front Bumper
	Cab Aerodynamic Mirrors
	Nose Cone
	Trailer Tails
	Trailer Gap 44" – 36"
	Trailer Gap 35" or less
	Trailer Side Skirts
	Flatbed Trailer Tarps

(cont.)

Table A-6:
Retrofit Technology Types and Associated Technologies (cont.)

Retrofit Technology Type	Retrofit Technology
Engine Replacement/Repower	Engine Repower
	Engine Replacement
Idling Control Strategies	Direct Fired Heater
	Auxiliary Power Unit
	Truck Stop Electrification
	Driver Tag Teams
	Double Drivers
	Engine Shutdown
	Other

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Appendix B:
Quantifier Calculations

1. Overview

This document provides a brief overview of the calculations used in computing the emissions results produced by the Diesel Emissions Quantifier.

Equations and inputs are presented in two columns. The parentheses following each entry denote the units of the result of computing the expression on the left. For inputs, brackets following each entry denote whether the input is taken from the database ("[d]"), user input ("[u]"), a database default or a user input value ("[d/u]"), or embedded into business logic ("[e]").

Textual references (e.g., "total number of vehicles in the fleet") have been replaced by symbolic equivalents (e.g., n_{Σ}) as defined below.

2. Symbols

These symbols take on different meanings depending on their parameters, or if they are constrained to a particular set of values.

t	Vehicle type (one of "NonRoad" (t_{nr}) or "On Highway" (t_{hw})) [d]
p	Pollutant type (one of "CO," "CO_2," "HC," "PM," "NO_x") [d]
$k_{s,t}$	Conversion factor from units s to units t [e]
M_n	Results calculation n [e]

3. Inputs

Calculations require several inputs, as noted below.

n_{Σ}	Number of vehicles (veh) [u]
n	Number of vehicles retrofitted with a given technology (veh) [u]
n_{engine}	Number of a given unique engine type (Marine Vessels Only) [u]
HP	Horsepower [u]
VMT	Vehicle miles traveled (mi/veh/yr) [u]
u_d	Default usage rate (hr/veh/yr) [d]

u	Actual usage rate (hr/veh/yr) [u]
u_{fd}	Default fuel usage rate (Rail only) (gal/veh/yr) [d]
u_f	Actual fuel usage rate (Rail only) (gal/veh/yr) [d]
I	Total idling hours per year (hr/veh/yr) [u]
I_R	Idling hours reduced per year (hr/veh/yr). Used only with idling control strategies [u]
$m_{p,t}$	Emissions for pollutant p of vehicle type t (tons/mi/mo/veh for On Highway, tons/hr/yr/veh for NonRoad [d]
$m^I_{p,t}$	Idling emissions for pollutant p of vehicle type t (ton/hr/veh | ton/hr/veh) [d]
r_p	Emissions reduction for pollutant p of a given technology (dimensionless) [d/u]
s	Scrappage rate sum for a given vehicle's age and retrofit year. A table of scrappage rate sums is provided in Table C-1 of Appendix C [d]
f	Total fuel usage (gallons) [u]
f_i	Fuel usage during idling (gallons) [u]
C_u	Unit cost for a particular emissions technology ($) [d]
C_i	Installation cost for a particular emissions technology ($) [d]
C_T	Total project funding ($) [u]

4. Conversion Factors and Constants

Numeric literals have been replaced by their appropriate conversion factor or constant below.

$k_{mo,yr} = 12$	Months in a year (months/year)
$k_{kg,ton} = 907.18474$	Kilograms in a ton (kg/ton)
$k_{yr,d} = 1/365 \approx 2.7397 \times 10^{-3}$	Years in a day (years/day)
$k_{p,ton}$	Diesel-equivalent fuel emissions of pollutant p (gallons/ton) [d]

CO_2 fuel factor	The following factors are used to convert non-diesel fuels into diesel equivalent gallons: • LPG: 0.65; • LNG: 0.61; • CNG (lbs): 0.16; • CNG (ft^3): 0.0074; • Biodiesel 100: 0.92; • Biodiesel 20: 0.985108; • Biodiesel 5: 0.996277; • Biodiesel 2: 0.998511; and • E85: 0.626126.
U_i	Idling fuel usage factor (gallons/hour) [d]
$m^I{}_{PM,t_{hw}} = 4.29901411\,x\,10^{-6}$	On Highway idling emissions factor for PM (g/hr/yr/veh)
$m^I{}_{NOx,t_{hw}} = 1.58732829\,x\,10^{-4}$	On Highway idling emissions factor for NO_x (g/hr/yr/veh)
$m^I_{HC,t_{hw}} = 0$	On Highway idling emissions factor for HC (g/hr/yr/veh)
$m^I_{CO,t_{hw}} = 0$	On Highway idling emissions factor for CO (g/hr/yr/veh)

5. Results Calculations

5.1 Daily/Annual Emissions Results Calculations

- $M_{1t_{hw}}$ - On Highway fleet baseline emissions (tons/year):

  -- Non-CO_2:

  $$M_{1t_{hw}oper} = k_{mo,yr} \cdot m_{p,t_{hw}} \cdot n_{\Sigma} VMT$$
  $$M_{1t_{hw}idle} = m^I{}_{p,t_{hw}} \cdot n_{\Sigma} I$$
  $$M_{1t\,hw} = M_{1t_{hw}oper} + M_{1t_{hw}idle}$$

  -- Total CO_2 (running + idling) baseline emissions:

  $$M_{1t_{hw}} = f \cdot CO_2 \;\; fuel \;\; factor \cdot 0.0111$$

  -- CO_2 from idling if user enters non-zero idling hours (*I*):

  The following equation results in gallons per year. This quantity can be used to determine idling emissions as follows:

$$f_i = Idling\ Fuel\ Usage\ Factor \cdot I \cdot n_\Sigma$$

$$M_{1t_{hw}} = f_i \cdot CO_2\ \ fuel\ \ factor \cdot 0.0111$$

- M_{1tnr} - NonRoad fleet baseline emissions (tons/year):

  -- Non-CO_2 (non-Rail):

  $$M_{1t_{nr}oper} = m_{p,t_{nr}} \cdot n_\Sigma \cdot \frac{u}{u_d}$$

  $$M_{1t_{nr}idle} = m^I{}_{p,t_{nr}} \cdot n_\Sigma \cdot I$$

  $$M_{1t\,nr} = M_{1t_{nr}oper} + M_{1t_{nr}idle}$$

  -- Non-CO_2 (Rail):

  $$M_{1t_{nr}oper} = m_{p,t_{nr}} \cdot n_\Sigma \cdot \frac{u_f}{u_{fd}}$$

  $$M_{1t_{nr}idle} = m^I{}_{p,t_{nr}} \cdot n_\Sigma \cdot I$$

  $$M_{1t\,nr} = M_{1t_{nr}oper} + M_{1t_{nr}idle}$$

  -- Non-CO_2 (Rail - Line-Haul, Passenger and Switch Locomotives):

  $$M_{ltnr} = n_\Sigma \cdot Locomotive\ Emission\ Factor \cdot HP \cdot Activity\ Hours \cdot \frac{1\,ton}{907184.74\,g}$$

  Locomotive Emission Factors are pulled from the database, and default Activity Hours are listed in Table D-1. The year in use used to look up the Activity Hours is determined by the following: (calendar year - model year) + 1. The Quantifier automatically enters this value into the Usage Rate field, but the user can change it.

  -- Non-CO_2 (Marine Vessels):

  $$M_{ltnr} = n_{engines} \cdot Marine\ Emission\ Factor \cdot HP \cdot Load\ \ Factor \cdot Activity\ Hours \cdot \frac{1\,ton}{907184.74\,g}$$

  Marine Emission Factors and Load Factors are pulled from the database. The Activity Hours are input by the user and cannot exceed the number of hours in a year (8760).

  -- CO_2:

  $$M_{1t_{hw}} = f \cdot CO_2\ \ fuel\ \ factor \cdot 0.0111$$

- M_{2thw} - On Highway retrofitted baseline emissions (tons/year):

  -- Non-CO_2:

  $$M_{2t_{hw}oper} = k_{mo,yr} \cdot m_{p,t_{hw}} \cdot n \cdot VMT$$
  $$M_{2t_{hw}idle} = m^{I}{}_{p,t_{hw}} \cdot n \cdot I$$
  $$M_{2t_{hw}} = M_{2t_{hw}oper} + M_{2t_{hw}idle}$$

  -- CO_2:

  $$M_{2t_{hw}} = (n / n_{\Sigma}) \cdot f \cdot CO_2 \ \ fuel \ \ factor \cdot 0.0111$$

- M_{2tnr} - NonRoad retrofitted baseline emissions (tons/year):

  -- Non-CO_2 (non-Rail):

  $$M_{2t_{nr}oper} = m_{p,t_{nr}} \cdot n \cdot \frac{u}{u_d}$$
  $$M_{2t_{nr}idle} = m^{I}{}_{p,t_{nr}} \cdot n \cdot I$$
  $$M_{2t_{nr}} = M_{2t_{nr}oper} + M_{2t_{nr}idle}$$

  -- Non-CO_2 (Rail):

  $$M_{2t_{nr}oper} = m_{p,t_{nr}} \cdot n \cdot \frac{u_f}{u_{fd}}$$
  $$M_{2t_{nr}idle} = m^{I}{}_{p,t_{nr}} \cdot n \cdot I$$
  $$M_{2tnr} = M_{2t_{nr}oper} + M_{2t_{nr}idle}$$

  -- Non-CO_2 (Rail - Line-Haul, Passenger and Switch Locomotives):

  $$M_{2tnr} = n \cdot Locomotive\ Emission\ Factor \cdot HP \cdot Activity\ Hours \cdot \frac{1\,ton}{907184.74\,g}$$

  Locomotive Emission Factors are pulled from the database, and default Activity Hours are in Table D-1.

  -- Non-CO_2 (Marine Vessels):

  $$M_{2tnr} = M_{ltnr}$$

-- CO_2:

$$M_{2t_{nr}} = (n / n_{\Sigma}) \cdot f \cdot CO_2 \ \ fuel \ \ factor \cdot 0.0111$$

-- CO_2 (Marine Vessels):

$$M_{2tnr} = M_{ltnr}$$

- M_{d3} - Emissions percent reduction (dimensionless):

$$M_{d3} = r_p$$

- M_{d3thw}, M_{d3tnr} - Emissions reduction, tons per year (tons/year):

-- For NonRoad, and On Highway:

$$M_{d3t_{oper}} = M_{2t} \cdot r_p$$

If more than one technology is applied to a set of vehicles, each technology after the first is applied to a reduced retrofitted baseline. That is, the first technology reduces the original retrofitted baseline, the second technology is applied to the reduced retrofitted baseline that remains after the first technology is applied, the third technology is applied to the retrofitted baseline that remains after two technologies are applied, etc.

-- For Non-CO_2 emissions of On Highway vehicles using idling control strategies, the idling reduction is the lesser of:

1. The total emissions of retrofit vehicles; and

2. $M_{d3t_{idle}} = m^I{}_{p,t} \cdot I_R \cdot nr_p$
   $M_{d3t} = M_{d3t_{oper}} + M_{2t_{idle}}$

-- For CO_2 emissions of On Highway vehicles using idling control strategies, the emission reduction is:

$$M_{d3t_{idle}} = U_i \cdot n \cdot I_R \cdot CO_2 \ \ Fuel \ Factor \cdot 0.0111 \cdot r_p$$

- M_{d4t} - On Highway/NonRoad emissions reduction, kilograms per day (kg/day):

$$M_{d4t} = M_{d3t} \cdot k_{yr.d} \cdot k_{kg,ton}$$

- Diesel Equivalent, gallons per year:

Diesel Equivalent = CO_2 tons/0.0111

- Diesel Equivalent, gallons per day:

  *Diesel Equivalent = Diesel Equivalent (gal/year) * $k_{yr,d}$*

5.2 Lifetime Emissions Results Calculations

- M_{l3t} - Lifetime fleet baseline emissions (tons):

  -- On Highway: $M_{l3t_{hw}} = M_{lt_{hw}} \cdot s$

  -- NonRoad:

  Median Life (M) is pulled from the database. A table of Median Life values is provided in Table C-2 in Appendix C.

  Iteration Limit (L): the lesser of (2 x M) and 30

  Age from New (Y): (Calendar Year - Model Year) + 1
  Age Ratio (A) = Y/M

  The value for A is used to determine the Cumulative Percent Scrapped (CPS) for a given year. The Cumulative Percent Scrapped is determined using the values in Table C-3 in Appendix C and linear interpolation.

  Survival Rate (for a given year) = 1 - CPS

  Number of iterations of Age Ratio required to calculate total Survival Rate = (L – Y) + 1.

  For each iteration, Y = Y + 1 and the Age Ratio is calculated until Y = L. For each Age Ratio, the Survival Rate is calculated. The Survival Rates from all of these iterations are then summed.

  $$M_{l3t_{nr}} = Survival\ Rate\ Sum \cdot M_{1t_{nr}}$$

  -- Non-CO_2 for Rail (Line-Haul and Passenger Locomotive)

  $$M_{l3t_{nr}} = n_{\Sigma} \cdot Locomotive\ Emission\ Factor \cdot HP \cdot \sum_{\text{Retrofit Year}}^{40th\ Year} Activity\ Hours \cdot \frac{1\,ton}{907184.74\,g}$$

  The retrofit year is determined by: (Calendar Year - Model Year) + 1

If the user changes the activity hours, and the user-defined value is smaller than the default value of the retrofit year, the user-defined value is used in the sum for each year until the user-defined value exceeds the default value.

-- Non-CO_2 for Rail (Switch Locomotive)

$$M_{l3t_{nr}} = n_{\Sigma} \cdot Locomotive\ Emission\ Factor \cdot HP \cdot \sum_{\text{Retrofit Year}}^{70th\ Year} Activity\ Hours \cdot \frac{1\,ton}{907184.74\,g}$$

The retrofit year is determined by: (Calendar Year - Model Year) + 1
If the user changes the activity hours, and the user-defined value is smaller than the default value of the retrofit year, the user-defined value is used in the sum for each year until the user-defined value exceeds the default value.

-- CO_2 for Rail (Line-Haul, Passenger, Switch Locomotive)

$$M_{l3t_{nr}} = Survival\ Rate\ Sum \cdot M_{1t_{nr}}$$

- M_{l4t} - Lifetime retrofitted baseline emissions (tons):

-- On Highway: $M_{l4t_{hw}} = M_{2t_{hw}} \cdot s$

-- NonRoad: $M_{l4t_{nr}} = M_{2t_{nr}} \cdot Survival\ Rate\ Sum$

-- Non-CO_2 for Rail (Line-Haul or Passenger Locomotive):

$$M_{l4t_{nr}} = n \cdot Locomotive\ Emission\ Factor \cdot HP \cdot \sum_{\text{Retrofit Year}}^{40th\ Year} Activity\ Hours \cdot \frac{1\,ton}{907184.74\,g}$$

-- Non-CO_2 for Rail (Switch Locomotive):

$$M_{l4t_{nr}} = n \cdot Locomotive\ Emission\ Factor \cdot HP \cdot \sum_{\text{Retrofit Year}}^{70th\ Year} Activity\ Hours \cdot \frac{1\,ton}{907184.74\,g}$$

-- CO_2 for Rail (Line-Haul, Passenger, Switch Locomotive)

$$M_{l4t_{nr}} = M_{2t_{nr}} \cdot Survival\ Rate\ Sum$$

- M_{l3} - Lifetime emissions percent reduction (percent):

$$M_{l3} = r_p$$

- M_{l5t} - Lifetime emissions reduction (tons):

$$M_{l5t} = M_{l4t} \cdot r_p$$

- M_{l6t} - Post-retrofit lifetime emissions for fleet (tons):

  $$M_{l6t} = M_{l3t} - M_{l5t}$$

- M_{l7t} - Post-retrofit lifetime emissions for retrofitted vehicles (tons):

  $$M_{l7t} = M_{l4t} - M_{l5t}$$

- M_{l8t} - Capital cost effectiveness for retrofitted vehicles ($/ton):

  $$M_{l8t} = \sum \frac{n(C_u + C_i)}{M_{l5t}}$$

  The summed quantity is calculated for each technology that is applied to a vehicle subgroup. Any technologies that increase emissions should be excluded from these calculations (i.e., the number of vehicles retrofitted, installation cost, unit cost, and emissions increases should not be included in the sum).

- M_{l9t} - Total cost effectiveness for retrofitted vehicles ($/ton):

  $$M_{l9t} = \frac{C_T}{M_{l5t}}$$

  If any technology causes an increase in emissions, that emissions increase is excluded from the Lifetime Emissions Reduction amount (M_{l5t}).

- Diesel Equivalent, gallons:

  Diesel Equivalent = CO_2 tons/0.0111

6. Special Cases

When certain types of emissions reductions technologies are selected, the results calculations change, depending on the technology selected.

6.1 Vehicle and Engine Replacement/Repower Strategies

In these strategies, an aging vehicle's engine is replaced with a new one of a different model year. If selected, the user supplies the new engine's model year *y* as an additional input parameter for the technology. The default percent reduction r_p for a particular pollutant *p* is then computed by comparing the old vehicle's emissions $m_{p,t}$ against the new vehicle's emissions, $m^y_{p,t}$ rather than pulled from the database.

The computed percent reduction becomes:

$$r_p' = \frac{m_{p,t} - m^{y}_{p,t}}{m_{p,t}}$$

and this value should be used in place of r_p for all calculations in Section V.

6.2 Trailer Strategies

When trailer strategies are selected as a control technology, only the calculation of the CO_2 baseline of retrofitted vehicles is affected. $M_{2t_{hw}}$ is calculated as follows:

$$M_{2t_{hw}} = (n / n_{\Sigma}) \cdot f \cdot CO_2 \;\; fuel \;\; factor \cdot 0.0111 \cdot \frac{r_p}{1 - r_p}$$

6.3 Aerodynamic Devices

Aerodynamic devices reduce fuel consumption during operation, so the percent reduction should only be applied to running emissions. The equation for CO_2 emissions reduced when aerodynamic devices are employed is as follows:

$$M_{d3t} = r_p \cdot (f - f_i) \cdot CO_2 \;\; fuel \;\; factor \cdot 0.0111$$

7. Benefits Module

The Benefits Module will perform health benefits calculations using the following methodology:

- On Highway Tons reduced per county:

$$On\ Highway\ Tons\ reduced_{county} = (\Sigma\ Tons\ reduced_{OnHighway,\,i}) \cdot \%Allocated_{county}$$

- NonRoad Tons reduced per county:

$$NonRoad\ Tons\ reduced_{county} = (\Sigma\ Tons\ reduced_{NonRoad,\,i}) \cdot \%Allocated_{county}$$

- Total Tons reduced per county:

$$Total\ Tons\ reduced_{county} = On\ Highway\ Tons\ reduced_{county} + NonRoad\ Tons\ reduced_{county}$$

- Total Tons Reduced:

$$Total\ Tons\ reduced_{total} = \Sigma\ Total\ Tons\ reduced_{county}$$

- On Highway Benefit per county:

$$On\ Highway\ Benefit_{county} = On\ Highway\ Tons\ reduced_{county} \cdot Benefit\ \ per\ Ton\ On\ Highway_{county}$$

- NonRoad Benefit per county:

$$NonRoad\ \ Benefit_{county} = NonRoad\ Tons\ reduced_{county} \cdot Benefit\ \ per\ Ton\ NonRoad_{county}$$

- Annual Benefit per county:

$$Annual\ \ Benefit_{county} = NonRoad\ \ Benefit_{county} + On\ Highway\ \ Benefit_{county}$$

- Annual Benefit:

$$Annual\ \ Benefit_{total} = \Sigma\ Annual\ \ Benefit_{county}$$

- Annualized Cost per scenario:

$$Annual\ Cost_{scenario} = \frac{(Capital\ Cost \cdot 0.03)}{(1-(1+0.03)^{-number\ of\ \ years\ remaining})}$$

- Total Annual Cost:

$$Total\ \ Annual\ Cost = \Sigma\ Annual\ Cost_{scenario}$$

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Appendix C:
Scrappage Rate Tables

Table C-1:
On Highway Scrappage Table:
Scrappage Table Survival Fraction (Based on 1980 Vehicles)

- Discount rate: 3%
- Scrappage rates are adjusted based on the year of retrofit.

Vehicle Age From New (Years)	Age at Retrofit																											
	New	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	Survival %																												
1	100%	0%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	100%	100%	0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	100%	100%	100%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	98.5%	98.5%	98.5%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	96.7%	96.7%	96.7%	98.2%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	94.5%	94.5%	94.5%	96.0%	97.8%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	92.0%	92.0%	92.0%	93.5%	95.3%	97.5%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	89.1%	89.1%	89.1%	90.6%	92.4%	94.6%	97.1%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	86.0%	86.0%	86.0%	87.5%	89.3%	91.5%	94.0%	96.9%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	82.7%	82.7%	82.7%	84.2%	86.0%	88.2%	90.7%	93.6%	96.7%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	79.1%	79.1%	79.1%	80.6%	82.4%	84.6%	87.1%	90.0%	93.1%	96.4%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	75.4%	75.4%	75.4%	76.9%	78.7%	80.9%	83.4%	86.3%	89.4%	92.7%	96.3%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	71.6%	71.6%	71.6%	73.1%	74.9%	77.1%	79.6%	82.5%	85.6%	88.9%	92.5%	96.2%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	67.7%	67.7%	67.7%	69.2%	71.0%	73.2%	75.7%	78.6%	81.7%	85.0%	88.6%	92.3%	96.1%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	63.7%	63.7%	63.7%	65.2%	67.0%	69.2%	71.7%	74.6%	77.7%	81.0%	84.6%	88.3%	92.1%	96.0%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	59.7%	59.7%	59.7%	61.2%	63.0%	65.2%	67.7%	70.6%	73.7%	77.0%	80.6%	84.3%	88.1%	92.0%	96.0%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0	0
17	55.7%	55.7%	55.7%	57.2%	59.0%	61.2%	63.7%	66.6%	69.7%	73.0%	76.6%	80.3%	84.1%	88.0%	92.0%	96.0%	100.0%	0	0	0	0	0	0	0	0	0	0	0	0
18	51.8%	51.8%	51.8%	53.3%	55.1%	57.3%	59.8%	62.7%	65.8%	69.1%	72.7%	76.4%	80.2%	84.1%	88.1%	92.1%	96.1%	100.0%	0	0	0	0	0	0	0	0	0	0	0

(cont.)

Table C-1:
On Highway Scrappage Table:
Scrappage Table Survival Fraction (Based on 1980 Vehicles) (cont.)

Vehicle Age From New (Years)	Age at Retrofit																											
	New	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	Survival %																												
19	47.9%	47.9%	47.9%	49.4%	51.2%	53.4%	55.9%	58.8%	61.9%	65.2%	68.8%	72.5%	76.3%	80.2%	84.2%	88.2%	92.2%	96.1%	100.0%	0	0	0	0	0	0	0	0	0	0
20	44.2%	44.2%	44.2%	45.7%	47.5%	49.7%	52.2%	55.1%	58.2%	61.5%	65.1%	68.8%	72.6%	76.5%	80.5%	84.5%	88.5%	92.4%	96.3%	100.0%	0	0	0	0	0	0	0	0	0
21	40.6%	40.6%	40.6%	42.1%	43.9%	46.1%	48.6%	51.5%	54.6%	57.9%	61.5%	65.2%	69.0%	72.9%	76.9%	80.9%	84.9%	88.8%	92.7%	96.4%	100.0%	0	0	0	0	0	0	0	0
22	37.1%	37.1%	37.1%	38.6%	40.4%	42.6%	45.1%	48.0%	51.1%	54.4%	58.0%	61.7%	65.5%	69.4%	73.4%	77.4%	81.4%	85.3%	89.2%	92.9%	96.5%	100.0%	0	0	0	0	0	0	0
23	33.7%	33.7%	33.7%	35.2%	37.0%	39.2%	41.7%	44.6%	47.7%	51.0%	54.6%	58.3%	62.1%	66.0%	70.0%	74.0%	78.0%	81.9%	85.8%	89.5%	93.1%	96.6%	100.0%	0	0	0	0	0	0
24	30.6%	30.6%	30.6%	32.1%	33.9%	36.1%	38.6%	41.5%	44.6%	47.9%	51.5%	55.2%	59.0%	62.9%	66.9%	70.9%	74.9%	78.8%	82.7%	86.4%	90.0%	93.5%	96.9%	100.0%	0	0	0	0	0
25	27.6%	27.6%	27.6%	29.1%	30.9%	33.1%	35.6%	38.5%	41.6%	44.9%	48.5%	52.2%	56.0%	59.9%	63.9%	67.9%	71.9%	75.8%	79.7%	83.4%	87.0%	90.5%	93.9%	97.0%	100.0%	0	0	0	0
26	24.8%	24.8%	24.8%	26.3%	28.1%	30.3%	32.8%	35.7%	38.8%	42.1%	45.7%	49.4%	53.2%	57.1%	61.1%	65.1%	69.1%	73.0%	76.9%	80.6%	84.2%	87.7%	91.1%	94.2%	97.2%	100.0%	0	0	0
27	22.2%	22.2%	22.2%	23.7%	25.5%	27.7%	30.2%	33.1%	36.2%	39.5%	43.1%	46.8%	50.6%	54.5%	58.5%	62.5%	66.5%	70.4%	74.3%	78.0%	81.6%	85.1%	88.5%	91.6%	94.6%	97.4%	100.0%	0	0
28	19.8%	19.8%	19.8%	21.3%	23.1%	25.3%	27.8%	30.7%	33.8%	37.1%	40.7%	44.4%	48.2%	52.1%	56.1%	60.1%	64.1%	68.0%	71.9%	75.6%	79.2%	82.7%	86.1%	89.2%	92.2%	95.0%	97.6%	100.0%	0
29	17.6%	17.6%	17.6%	19.1%	20.9%	23.1%	25.6%	28.5%	31.6%	34.9%	38.5%	42.2%	46.0%	49.9%	53.9%	57.9%	61.9%	65.8%	69.7%	73.4%	77.0%	80.5%	83.9%	87.0%	90.0%	92.8%	95.4%	97.8%	100.0%
30	15.5%	15.5%	15.5%	17.0%	18.8%	21.0%	23.5%	26.4%	29.5%	32.8%	36.4%	40.1%	43.9%	47.8%	51.8%	55.8%	59.8%	63.7%	67.6%	71.3%	74.9%	78.4%	81.8%	84.9%	87.9%	90.7%	93.3%	95.7%	97.9%
SUM	1826%	1726%	1626%	1566%	1513%	1468%	1428%	1395%	1363%	1332%	1304%	1275%	1243%	1209%	1173%	1133%	1089%	1040%	987%	928%	864%	795%	722%	644%	562%	476%	386%	294%	198%

Table C-2:
NonRoad Median Life Table

Target Fleet*	Equipment	Median Life		
		HP 0 – 50	HP 51 – 300	HP 301 – 99999
c	Pavers	5.16	9.63	14.45
c	Tampers/Rammers	12.64	23.59	35.39
c	Plate Compactors	12.01	22.42	33.63
c	Rollers	5.58	10.41	15.61
c	Scrapers	4.64	8.65	12.98
c	Paving Equipment	6.81	12.72	19.07
c	Surfacing Equipment	7.55	14.10	21.15
c	Signal Boards	10.87	20.29	30.43
c, p	Trenchers	7.15	13.34	20.01
c	Bore/Drill Rigs	12.48	23.29	34.93
c	Excavators	3.88	7.24	10.86
c	Concrete/Industrial Saws	7.31	13.64	20.46
c	Cement & Mortar Mixers	21.14	39.47	59.20
c, p, r	Cranes	5.87	10.96	16.44
c	Graders	4.40	8.22	12.33
c, a, p, r	Off-Highway Trucks	2.58	4.82	7.23
c	Crushing/Proc. Equipment	6.09	11.36	17.05
c	Rough Terrain Forklifts	6.40	11.95	17.92
c	Rubber Tire Loaders	5.57	10.39	15.59
c	Rubber Tire Dozers	4.71	8.80	13.20
c, r	Tractors/Loaders/Backhoes	10.49	19.58	29.37
c	Crawler Tractors	4.53	8.45	12.68
c, p	Skid Steer Loaders	14.55	27.17	40.75
c, a, p, r	Off-Highway Tractors	4.96	9.25	13.88
c	Dumpers/Tenders	21.03	39.26	58.89
c, p	Other Construction Equipment	6.99	13.05	19.58

(cont.)

Table C-2:
NonRoad Median Life Table (cont.)

Target Fleet*	Equipment	Median Life		
		HP 0 – 50	HP 51 – 300	HP 301 – 99999
p, r	Aerial Lifts	31.00	57.87	86.81
c, p, r	Forklifts	2.49	4.65	6.98
c	Sweepers/Scrubbers	4.77	8.90	13.34
p, r	Other General Industrial Equipment	6.62	12.36	18.54
p, r	Other Material Handling Equipment	28.28	52.79	79.18
p	AC Refrigeration	4.34	8.09	12.14
c	Terminal Tractors	3.37	6.29	9.44
a	Two-Wheel Tractors	7.79	14.54	21.81
a	Agricultural Tractors	8.92	16.65	24.98
a	Combines	28.25	52.73	79.10
a	Balers	44.60	83.26	124.89
a	Agricultural Mowers	11.67	21.79	32.68
a	Sprayers	47.08	87.89	131.83
a	Tillers > Six HP	24.64	45.99	68.98
a	Swathers	38.52	71.91	107.86
a	Hydro Power Units	7.36	13.74	20.61
a	Other Agricultural Equipment	11.12	20.76	31.14
a	Irrigation Sets	7.76	14.49	21.73
c, p	Light Commercial Generator Sets	17.20	32.11	48.16
c, p	Light Commercial Pumps	14.43	26.93	40.39
c, p, r	Light Commercial Air Compressors	7.13	13.32	19.97
c, p, r	Light Commercial Gas Compressors	0.68	1.28	1.92
c, p, r	Light Commercial Welders	18.51	34.56	51.84
c, p, r	Light Commercial Pressure Washer	40.10	74.85	112.27
a	Logging Equipment Chain Saws > 6	60.53	113.00	169.49
a	Logging Equipment Shredders > 6	35.31	65.92	98.87

(cont.)

Table C-2:
NonRoad Median Life Table (cont.)

Target Fleet*	Equipment	Median Life		
		HP 0 – 50	HP 51 – 300	HP 301 – 99999
a	Logging Equip Fell/Bunch/Skidders	3.32	6.20	9.30
p	Airport Support Equipment	5.79	10.81	16.21
m	Other Underground Mining Equipment	7.77	14.50	21.74
r	Switch	26.51	49.49	74.23
r	Passenger	10.17	18.98	28.46
r	Line-Haul	10.17	18.98	28.46

* c = construction; a = agriculture; p = port-related; r = rail.

Table C-3:
NonRoad Default Scrappage Curve

Age Ratio	Cumulative Percent Scrapped
0.0000	0.00
0.0588	0.01
0.1694	0.03
0.2710	0.05
0.3639	0.07
0.4486	0.09
0.5254	0.11
0.5948	0.13
0.6570	0.15
0.7125	0.17
0.7617	0.19
0.8049	0.21
0.8425	0.23
0.8750	0.25
0.9027	0.27
0.9259	0.29
0.9451	0.31

(cont.)

Table C-3:
NonRoad Default Scrappage Curve (cont.)

Age Ratio	Cumulative Percent Scrapped
0.9607	0.33
0.9730	0.35
0.9824	0.37
0.9894	0.39
0.9942	0.41
0.9973	0.43
0.9990	0.45
1.0000	0.50
1.0010	0.55
1.0027	0.57
1.0058	0.59
1.0106	0.61
1.0176	0.63
1.0270	0.65
1.0393	0.67
1.0549	0.69
1.0741	0.71
1.0973	0.73
1.1250	0.75
1.1575	0.77
1.1951	0.79
1.2383	0.81
1.2875	0.83
1.3430	0.85
1.4052	0.87
1.4746	0.89
1.5514	0.91
1.6361	0.93
1.7290	0.95
1.8306	0.97
1.9412	0.99
2.0000	1.00

Appendix D:
Locomotive Default Usage

Table D-1:
Annual Activity Hours (Default Usage) for Line-Haul, Passenger, and Switch Locomotive

Year in Usage	Line-Haul or Passenger	Switch
1	4350	4450
2	4350	4450
3	4350	4450
4	4350	4450
5	4350	4450
6	4350	4450
7	4350	4450
8	4350	4450
9	4268	4450
10	4187	4450
11	4105	4450
12	4024	4450
13	3942	4450
14	3861	4450
15	3779	4450
16	3698	4450
17	3616	4450
18	3534	4450
19	3453	4450
20	3371	4450
21	3290	4450
22	3208	4450
23	3127	4450
24	3045	4450
25	2963	4450

(cont.)

Table D-1:
Annual Activity Hours (Default Usage) for Line-Haul, Passenger, and Switch Locomotive (cont.)

Year in Usage	Line-Haul or Passenger	Switch
26	2882	4450
27	2800	4450
28	2719	4450
29	2637	4450
30	2556	4450
31	2474	4450
32	2393	4450
33	2311	4450
34	2229	4450
35	2148	4450
36	2066	4450
37	1985	4450
38	1903	4450
39	1822	4450
40	1740	4450
41		4450
42		4450
43		4450
44		4450
45		4450
46		4450
47		4450
48		4450
49		4450
50		4450
51		4383
52		4317
53		4250
54		4183

(cont.)

Table D-1:
Annual Activity Hours (Default Usage) for Line-Haul, Passenger, and Switch Locomotive (cont.)

Year in Usage	Line-Haul or Passenger	Switch
55		4116
56		4050
57		3983
58		3916
59		3849
60		3783
61		3716
62		3649
63		3582
64		3516
65		3449
66		3382
67		3315
68		3249
69		3182
70		3115

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