

FRA Locomotive Emissions Comparison Tool (LECT) User Guide

LOCOMOTIVE EMISSIONS COMPARISON TOOL (LECT) USER GUIDE

The purpose of the Locomotive Emissions Comparison Tool (LECT) is to provide users with a standardized approach to estimating emission reductions from the implementation of FRA-funded projects, including locomotive replacement projects being considered for funding under the Consolidated Rail Infrastructure and Safety Improvements (CRISI) Grant Program and other discretionary grant programs. The LECT uses emission rates based on the U.S. Environmental Protection Agency's Locomotive Engine Standards¹, as well as other data sources. The tool can provide users with estimates of emission reductions for projects that replace diesel engines with newer versions or with alternative-fuel engines, including all-electric locomotives.²

This document is organized into three sections—**User Guide**, **Tool Methodology**, and **Examples**—to aid the user in understanding and interpreting results from the LECT:

- The [User Guide](#) provides directions for properly inputting values into the tool and definitions of both user inputs and tool outputs.
- The [Tool Methodology](#) section outlines the steps taken by the tool to calculate emission reductions, as well as any associated assumptions.
- The [Examples](#) section provides instructive scenarios that show how to use the tool in different types of project analysis.

Emission estimates from the LECT are not intended to meet specific requirements for State Implementation Plans (SIPs) or transportation conformity analyses. Information regarding the development of default emission rates and guidance on incorporating user-supplied emission rates can be found in the accompanying document, *Locomotive Emissions Comparison Tool (LECT): Emissions Data Documentation*.

¹ U.S. Environmental Protection Agency, *Emission Factors for Locomotives*, EPA-420-F-09-025 (April 2009). Available at: <https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockkey=P100500B.TXT>.

² The most current version of the LECT is dated December 2023.

Locomotive Emissions Comparison Tool User Guide

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USER GUIDE

This section describes each user input and tool output, as well as the emission reductions report, error messages, and other assumptions present in the tool.

Note about Excel version and macros: to ensure proper tool operation, please use the desktop app version of Excel, not the online version. Also confirm that macros are enabled: File > Options > Trust Center > Macro Settings (check Enable VBA Macros)

User Inputs

User-defined inputs are described in Table 1. Inputs are specific to locomotive engine type and (for electric locomotives) project location.

Table 1. User Inputs – Engine Repower or Replacement

Question	User Input	Units	Description
(1)	Project Year	-	Use the drop-down menu to select a year between 2019 and 2030.
(2)	Baseline equipment	-	Use the drop-down menu to select the baseline equipment associated with the project.
(3)	Emissions tier of baseline equipment	-	Use the drop-down menu to select the emissions standard to which the baseline equipment is held. Refer to <i>Table A1</i> for help in determining the correct emissions tier.
(4)	Engine type	-	Use the drop-down menu to select the engine type associated with the repowered/replacement equipment.
(4a)	eGrid Region*	-	Use the drop-down menu to select the eGrid region associated with the location of the replacement electric equipment. If the project operates in multiple regions, consider using the "U.S." national average (last item in drop-down).
4(b)	Manufacturer-supplied emission rates	g/bhp-hr	Enter manufacturer-supplied certification data in the table. Note this input is only required for locomotives that exceed the Tier 4 diesel standards.
(5)	Number of locomotives to be replaced	-	Enter the total number of locomotives that will be repowered or replaced.

Question	User Input	Units	Description
(6)	Emissions tier of replacement equipment	-	Use the drop-down menu to select the emissions standard to which the repowered/replacement equipment will be held.
(7)	Annual fuel use**	Gallons (per single locomotive)	Enter the annual fuel use for the baseline equipment and the replacement (if applicable) in gallons. Be sure to reflect any fuel efficiency improvements for the replacement equipment.
(8)	OPTIONAL – Save and Compare Scenarios	-	Use the buttons to Save, Compare, or Delete Existing Scenario(s). See below for further details on how to use this feature.

* For all-electric or equivalent replacement only.

** Please refer to the Fuel Use section below when estimating the annual fuel use for replacement equipment.

Baseline Equipment: Users may select two different types of equipment: Class II/III line-haul locomotive or switch locomotive.

Emissions Tier: Users may select the emissions tier that corresponds to the EPA emissions standard to which their equipment is held. If the emissions tier is unknown, the appendix provides guidance to help identify the appropriate tier. Table 2 below identifies how to select an appropriate tier from the appendix table given the type and condition of the baseline equipment. For locomotive technologies that exceed the current, highest tier for diesel locomotives (Tier 4), users should input emissions certification data from the manufacturer.

Table 2. Appendix Table Section Given Baseline Equipment

Baseline Equipment	Condition of Baseline Equipment	Appendix Table Section
Locomotive (line-haul or switch)	Not remanufactured or remanufactured pre-2008	use tiers <i>without</i> '+' symbol
Locomotive (line-haul)	Remanufactured in 2008+ and original year of manufacture was pre-2012	if Tier 0-2, use tier with '+' symbol*
Locomotive (switch)	Remanufactured in 2008+ and original year of manufacture was pre-2011	if Tier 0-2, use tier with '+' symbol*

*EPA holds remanufactured locomotives to a higher emissions standard.

Engine Type: Users may select one of five different engine types for the replacement equipment: diesel, diesel GenSet, all electric, battery or equivalent (e.g., batteries, hydrogen fuel cells, or grid power via overhead catenary lines), diesel-battery hybrid, or other technology.

Note that the diesel GenSet option in the tool is currently only available for switch locomotives. Diesel GenSets are a multi-engine configuration (typically 2 to 3 engines) that operate in series, with each

engine powering up as the load increases. The tool assumes that GenSets meet the EPA Tier 4 standards for switch locomotives. See the *Emissions Data Documentation* for further information.

Number of Locomotives: Users may input any value greater than 0 that corresponds to the total number of pieces of equipment being replaced. The tool assumes that all equipment included in each scenario run has the same characteristics (e.g., engine type, tier). If users wish to calculate emission reductions for more than one locomotive type, they should run the tool multiple times and sum the benefits from all scenarios to calculate total emission reductions for the entire fleet. See the [Scenario Comparison](#) section for details about how to save scenario and sum benefits.

Fuel Use: Users can input the annual diesel fuel use (in gallons) by a single locomotive or estimated annual diesel or diesel-equivalent fuel use for replacement equipment. For electric replacement locomotives, annual fuel use is zero. Newer locomotive engines may have lower fuel consumption. Expected fuel efficiency improvements differ depending on the engine type:

Diesel: Many technologies for reducing NO_x emissions cause decreases in the fuel efficiency of the engine. Without additional treatments, the fuel efficiency of diesel Tier 1 locomotives is between 5 and 15 percent less than that of Tier 0 engines.³ The EPA recognized a short-term trend of decreasing fuel efficiency as a result of implementing the older 1998 Locomotive Emission Standards; however, fuel efficiency was expected to remain constant or increase due to continual improvements in locomotive fuel economy in the long-term.⁴ Industry experts have estimated that diesel Tier 3 engines will show a 5 percent increase in fuel efficiency compared with Tier 2, and that Tier 4 engines will perform similarly.⁵

GenSet: For diesel GenSet switch locomotives, in the absence of specific fuel consumption data, users may assume a 25 percent reduction in fuel use compared with traditional diesel switchers. Please see the *Emissions Data Documentation* for additional information on GenSets.

Diesel-Battery Hybrid: Hybrid locomotives use a diesel engine in conjunction with a battery pack. Users should reflect anticipated fuel savings associated with the project. Please see the *Emissions Data Documentation* for further information about hybrid locomotive operational and charging modes and associated fuel savings.

Tool Outputs

Emission benefits are derived when replacing diesel locomotive engines with newer or cleaner-fuel versions. In the tool output, a positive change in emissions is equivalent to an emissions reduction

³ Argonne National Laboratory, *Railroad and Locomotive Technology Roadmap* (December 2002). Available at: <https://publications.anl.gov/anlpubs/2003/02/45512.pdf>.

Note that fleetwide averages for 2002 to 2009 are lower than the per-locomotive estimates, although the share of the fleet by each emission tier is not known. Some emissions reduction technologies, such as exhaust-gas recirculation (EGR), can further decrease fuel efficiency.

⁴ U.S. Environmental Protection Agency, *Retrospective Study of the Cost of EPA Regulations: A Report of Four Case Studies* (August 2014). Available at: https://www.epa.gov/sites/default/files/2017-09/documents/ee-0575_0.pdf.

⁵ California Air Resources Board (CARB), *Technology Assessment: Freight Locomotives* (November 2016). Available at: https://ww2.arb.ca.gov/sites/default/files/classic/msprog/tech/techreport/final_rail_tech_assessment_11282016.pdf.

(benefit), while a negative value can be interpreted as an emissions increase (disbenefit). Emission reductions (i.e., benefits) are calculated for five air pollutants—CO, NO_x, PM_{2.5}, PM₁₀, and VOC—reported in short tons per year, and three greenhouse gases (GHGs)—CO₂, CH₄, and N₂O—reported in metric tons per year. CO₂e is calculated based on the global warming potentials (GWP) of CO₂, CH₄, and N₂O, and provides an indication of the total impact of GHG emissions on global climate.⁶

Upstream GHG emissions are reported for baseline and replacement equipment in metric tons. Energy consumption (in kWh) is also provided for both upstream processes (i.e., energy to produce, transport, and store diesel, and energy usage for electricity production) and for locomotive operation. See below and the accompanying *Emissions Data Documentation* for details.

Note that users will need to click “Calculate or Update Results” again if any changes are made to the inputs after running the tool.⁷ The tool will not update the reported emission reductions automatically.

Export Results to PDF: Click this button to export results, including scenario comparisons (see below) to a PDF. The PDF will include user-supplied inputs and emission reductions.

Scenario Comparison (Optional)

The LECT includes a “Compare Scenarios” feature that allows users to compare and sum emissions benefits across different locomotive replacement scenarios. This feature is optional, and the tool will calculate results without saving each scenario run. The section below describes the Compare Scenario inputs and outputs:

Engine Repower or Replacement Tab

“Yes, Save Scenario”: click this button to save the current scenario. You will be prompted to enter a scenario name. You may save up to 10 scenarios.

“Compare Scenarios”: click this button to navigate to the Compare Scenarios tab where you can view emissions reduction results for all saved scenarios.

“Delete an Existing Scenario”: click this button to delete an existing scenario from the Compare Scenarios tab.

Compare Scenarios Tab

Features on this tab allow users to compare emissions benefits between scenarios (e.g., upgrading to a Tier 4 diesel vs. battery-electric locomotive) and sum emissions benefits across multiple locomotive replacement projects. As with the main tool interface described above, emission reductions are shown for all air pollutants and greenhouse gases.

⁶ GWP is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO₂). See the EPA’s Understanding Global Warming Potentials (web page) (April 18, 2023): <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>.

⁷ The tool does not automatically store user information, inputs, or outputs unless the user chooses to save scenarios.

In the Scenario Name column, use the drop-downs to switch between scenarios. Select whether to sum results across all selected scenarios. Click the “Export results to PDF” button to create a PDF of the scenario comparison results.

Error Messages

Error messages that users may encounter in this tool, the reason for the error messages, and the solutions are listed in Table 3.

Table 3. Error Messages

Error Message	Reason for Error	Solution
ERROR: Missing Project Year.	No input provided for Project Year.	Select a Project Year from the drop-down menu.
ERROR: No baseline equipment selected.	No input provided for baseline equipment type.	Select an equipment type from the pull-down menu.
ERROR: Missing emissions tier for [baseline or replacement] equipment.	No input provided for emissions tier.	Select an emissions tier from the pull-down menu. Refer to Table A1 for help determining an appropriate tier.
ERROR: Missing locomotive's eGrid region for upstream electricity emission calculations.	No input provided for equipment operations region	Select an eGrid region from the pull-down menu. Refer to Figure A2 for help determining the appropriate region.
ERROR: Missing number of locomotives to be replaced.	No input provided for the number of locomotives.	Input a whole number greater than 0.
ERROR: Missing engine type of the replacement equipment.	No input provided for the engine type of the replacement equipment.	Select an engine type from the pull-down menu.
ERROR: The Diesel GenSet option in this tool is currently only available for switch locomotives.	The diesel GenSet engine is not available for the equipment type selected.	Change the baseline equipment to “Switch Locomotive.”
ERROR: Missing annual fuel use for one locomotive.	No input provided for locomotive activity.	Input a number greater than 0 gal/yr.
ERROR: Name for the scenario cannot be blank.	The name entry was blank in the pop-up window after pressing the “Yes, Save Scenario” button or the “Delete an Existing Scenario” button.	Enter a non-empty name for the scenario when saving or deleting.

Error Message	Reason for Error	Solution
ERROR: The scenario name already exists. Please try again and enter a unique name.	This name already exists in the list of saved scenarios.	Enter a unique name instead of using a name that already exists as a saved scenario.
WARNING: No scenarios to delete	There are no saved scenarios so the “Delete an Existing Scenario” and “Clear All Scenarios” button won’t work.	Save a scenario for comparison before trying to delete a single scenario or clearing all scenarios.
ERROR: Missing emission factors for replacement equipment.	The emission rates table (manufacturer-supplied data) is blank or incomplete.	For locomotives that exceed Tier 4 standards, input emission rates in g/bhp-hr.

Click “Calculate or Update Results” to recalculate the results once errors are resolved.

TOOL METHODOLOGY

Emission reductions in the LECT are based on the comparison of emissions from the baseline and replacement equipment. The tool assumes all baseline equipment operates with diesel fuel. Users have the option to power their replacement locomotives with diesel or an alternative fuel, including liquefied natural gas and electricity.

Emission Rates Sources

Emission rates for locomotive applications can be found in Table A1 of the appendix as well as the Emissions Data document that accompanies this *User Guide*.

Diesel: Diesel engine emission rates for locomotive operation are based on EPA emission factors.⁸ Replacement equipment emissions are based on newer engines meeting the more stringent EPA standards. If the CRISI project involves engine technologies that exceed Tier 4 standards, users should provide manufacturer-supplied emissions certification data. Upstream emissions from diesel production, transport, and storage are also provided in the tool. Emissions are based on well-to-use emissions from the Department of Energy Argonne National Lab’s GREET model.⁹

All-electric, battery or equivalent: Operational emission rates for electric locomotives or the equivalent (e.g., battery- or hydrogen-fuel-cell-powered locomotives) are zero for all air pollutants and GHGs; however, the tool outputs upstream GHG emissions estimates for electric locomotives based on EPA’s eGRID data. eGRID provides emission rates (lb/MWh) for electricity generation based on the source mix of electricity generation by region. Please refer to Table A2

⁸ U.S. Environmental Protection Agency, *Emission Factors for Locomotives*, EPA-420-F-09-025 (April 2009). Available at: <https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100500B.TXT>.

⁹ Argonne National Laboratory. The Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (GREET) Tool (2022). Available at: <https://greet.anl.gov/net>.

and Figure A2 in the appendix for information on eGRID regions. To calculate upstream emissions, the tool assumes a diesel fuel-to-electricity ratio of 64.5 gallons per MWh for line-haul locomotives and 73.7 gallons per MWh for switcher locomotives (i.e., a replacement electric switcher will use 1 MWh of electricity for every 73.7 gallons of fuel consumed by the original diesel equipment).¹⁰

Additional information on the emission rates and tool calculations can be found in the Emissions Data documentation. The “Upstream” tab in the tool includes the underlying emission rates for upstream electricity generation and diesel fuel production, transport, and storage.

EXAMPLES

The three examples below highlight how the tool calculates emissions savings by applying user-provided operational data for completely replacing a locomotive. While users will likely have specific operational data available, these typical activity values may provide a helpful reference:

- Average annual fuel consumption for line-haul locomotive = 130,000 gallons diesel
- Average annual fuel consumption for switch locomotive = 30,000 gallons diesel

Example 1: Switch Locomotive Replaced with Fuel Cell–Powered Model

A state has implemented stricter air pollution regulations. To comply with the new rules, a rail yard decided to replace their three 1980s-era switch locomotives (that have not been remanufactured post 2007) with a new hydrogen fuel cell model¹¹ that has no regulated emissions (only water vapor). The rail yard currently consumes 100,000 gallons of diesel fuel annually across the three switchers. The project will be implemented in 2023.

In the Engine Replacement module, the user would select the following inputs:

- Question 1: Project Year: **2023**
- Question 2: Baseline Equipment: **Switch Locomotive**
- Question 3: Emission tier of baseline equipment: **Tier 0**

If the emissions tier of the baseline equipment is unknown, the user could refer to *Table A1– Locomotive Emission Standards* in the Appendix of this document. Switch locomotives built in the 1980s that have not been remanufactured post 2007 fall under the Tier 0 EPA standards.

¹⁰ California Air Resources Board. *Appendix F: Technology Feasibility Assessment for the Proposed In-Use Locomotive Regulation*. Available at: <https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/locomotive22/appf.pdf> (see Table 8). Accessed December 2023.

¹¹ K. Hess et al. (Fuelcell Propulsion Institute), “Demonstration of a Hydrogen Fuel-Cell Locomotive” (2010). Available at: <https://pdfs.semanticscholar.org/bc5b/8df3251a993d608295aad4ae795678c046cf.pdf>.

	Pre-1973	Uncontrolled
	1973-2001	Tier 0
	1973-2001	Tier 0+
	2002-2004	Tier 1
Diesel (Switch)	2002-2004	Tier 1+
	2005-2010	Tier 2
	2005-2010	Tier 2+
	2011-2014	Tier 3
	2015+	Tier 4

Question 4: Engine type of repowered/replacement equipment: **All-Electric, Battery or Equivalent**

Since hydrogen fuel cells do not generate regulated emissions (only water vapor), the user can select the “All-Electric, Battery or Equivalent” option for this question as the fuel cell is equivalent to all-electric. Since an Electric or Equivalent engine has been selected for the replacement, a project region (eGRID) has to be selected. Additionally, once the “All-Electric, Battery or Equivalent” option is selected, the Question 6 input cell will be grayed out.

Question 4a: Region project is located in: **RFCE**

If the project location is unknown, the user can enter the region as “U.S.” for a more general estimate. The different regions across the United States are in Figure A1 of the Appendix.

Question 5: Number of Locomotives to be replaced: **3**

Question 6: Emission tier of repowered/replacement equipment: **(leave grayed out)**

Since the replacement locomotive is not powered by diesel fuel and therefore not held to EPA’s diesel locomotive tiers, the user should leave this question blank. If a value is input for Question 6 by mistake, the tool will still run correctly.

Question 7: Input annual fuel use in gallons of diesel: **33,333**

Note: The input activity is for one locomotive, not the entire rail yard operation. 100,000 gallons of diesel divided by 3 locomotives gives an annual average of 33,333 gallons per switcher.

Once the inputs are entered, click the “Calculate or Update Results” button to estimate emission reductions for the project. The estimated operational emission reductions are:

EMISSION REDUCTIONS (LOCOMOTIVE OPERATION)

Reductions in Air Pollutants (short tons/year)	
Carbon Monoxide (CO)	3.066
Nitrogen Oxides (NO _x)	21.111
Particulate Matter ≤2.5 μm (PM _{2.5})	0.715
Particulate Matter ≤10 μm (PM ₁₀)	0.737
Volatile Organic Compounds (VOC)	1.782
Reductions in Greenhouse Gases (metric tons/year)	
Carbon Dioxide (CO ₂)	319.997
Carbon Dioxide Equivalents (CO ₂ e)	329.745
Methane (CH ₄)	0.080
Nitrous Oxide (N ₂ O)	0.026

Example 2: Switch Locomotive Replaced with GenSet Model

A county is working with a busy railyard to replace old diesel switchers with GenSet models to save fuel and reduce local emissions impacts on neighboring communities. Each switch locomotive uses approximately 30,000 gallons of fuel annually and pre-dates the EPA's first locomotive emissions standards (uncontrolled).

In the tool, the user would select the following inputs:

Question 1: Project Year: **2026**

Question 2: Baseline Equipment: **Switch Locomotive**

Question 3: Emission tier of baseline equipment: **Uncontrolled**

Question 4: Engine type of repowered/replacement equipment: **Diesel GenSet**

Question 5: Number of Locomotives to be replaced: **4**

Question 6: Emission tier of repowered/replacement equipment: **Tier 4**

Question 7: Input annual fuel use for baseline equipment in gallons of diesel: **30,000**

Question 7(a): Input annual fuel use for replacement equipment in gallons of diesel: **22,500**¹²

Once the inputs are entered, click the "Calculate or Update Results" button to estimate emission reductions for the project. The estimated operational emission reductions are:

¹² Assuming 25% fuel savings for the replacement GenSet model (30,000 * 0.75)

EMISSION REDUCTIONS (LOCOMOTIVE OPERATION)

Reductions in Air Pollutants (short tons/year)	
Carbon Monoxide (CO)	0.920
Nitrogen Oxides (NO _x)	33.477
Particulate Matter ≤2.5 μm (PM _{2.5})	0.215
Particulate Matter ≤10 μm (PM ₁₀)	0.862
Volatile Organic Compounds (VOC)	2.011
Reductions in Greenhouse Gases (metric tons/year)	
Carbon Dioxide (CO ₂)	96.000
Carbon Dioxide Equivalents (CO ₂ e)	98.924
Methane (CH ₄)	0.024
Nitrous Oxide (N ₂ O)	0.008

Example 3: Large Line-Haul Locomotive Replaced with Diesel Tier 4

A state is working with a Class II railroad to replace one of its oldest diesel locomotives with a newer engine that meets Tier 4 emissions standards. The current engine meets Tier 1 standards and uses approximately 130,000 gallons of fuel each year. Fuel efficiency savings of 10 percent are expected with the newer engine.

In the tool, the user would select the following inputs:

Question 1: Project Year: **2024**

Question 2: Baseline Equipment: **Line-Haul Locomotive (Class II/III)**

Question 3: Emission tier of baseline equipment: **Tier 1**

Question 4: Engine type of repowered/replacement equipment: **Diesel**

Question 5: Number of Locomotives to be replaced: **1**

Question 6: Emission tier of repowered/replacement equipment: **Tier 4**

Question 7: Input annual fuel use for baseline equipment in gallons of diesel: **130,000**

Question 7(a): Input annual fuel use for replacement equipment in gallons of diesel: **117,000**

Once the inputs are entered, click the “Calculate or Update Results” button to estimate emission reductions for the project. The estimated emission reductions are:

EMISSION REDUCTIONS (LOCOMOTIVE OPERATION)

Reductions in Air Pollutants (short tons/year)	
Carbon Monoxide (CO)	0.334
Nitrogen Oxides (NO _x)	15.127
Particulate Matter ≤2.5 μm (PM _{2.5})	0.775
Particulate Matter ≤10 μm (PM ₁₀)	0.799
Volatile Organic Compounds (VOC)	1.192
Reductions in Greenhouse Gases (metric tons/year)	
Carbon Dioxide (CO ₂)	41.600
Carbon Dioxide Equivalents (CO ₂ e)	42.867
Methane (CH ₄)	0.010
Nitrous Oxide (N ₂ O)	0.003

Example 4: Small Line-Haul Locomotive Replaced with Diesel Exceeding Tier 4

A state is working with a Class II railroad to replace one of its oldest diesel locomotives with newer engines that exceed Tier 4 emissions standards and have manufacturer-supplied emission factors data. The current engines meet Tier 1 standards and each use approximately 130,000 gallons of fuel each year. Fuel efficiency savings of 10 percent are expected with the newer engines.

In the tool, the user would select the following inputs:

Question 1: Project Year: **2026**

Question 2: Baseline Equipment: **Line-Haul Locomotive (Class II/Class III)**

Question 3: Emission tier of baseline equipment: **Tier 1**

Question 4: Engine type of repowered/replacement equipment: **Diesel**

Question 5: Number of Locomotives to be replaced: **2**

Question 6: Emission tier of repowered/replacement equipment: **Exceeds Tier 4**

Question 6(a): Manufacturer-provided emission factors data:

NO_x: **0.85**

PM₁₀: **0.01**

PM_{2.5}: **0.025**

HC: **1.28**

CO: **0.01**

Question 7: Input annual fuel use for baseline equipment in gallons of diesel: **130,000**

Question 7(a): Input annual fuel use for replacement equipment in gallons of diesel: **117,000**

Once the inputs are entered, click the “Calculate or Update Results” button to estimate emission reductions for the project. The estimated emission reductions are:

EMISSION REDUCTIONS (LOCOMOTIVE OPERATION)

Reductions in Air Pollutants (short tons/year)	
Carbon Monoxide (CO)	6.630
Nitrogen Oxides (NO_x)	30.958
Particulate Matter ≤2.5 μm (PM_{2.5})	1.574
Particulate Matter ≤10 μm (PM₁₀)	1.622
Volatile Organic Compounds (VOC)	-3.746
Reductions in Greenhouse Gases (metric tons/year)	
Carbon Dioxide (CO₂)	83.200
Carbon Dioxide Equivalents (CO₂e)	85.734
Methane (CH₄)	0.021
Nitrous Oxide (N₂O)	0.007

Appendix: Emissions Tables & Load Factors

Table A1. Locomotive Emission Factors¹³

Fuel Type	Year of Manufacture	Tier ¹⁴	Emission Factors (g/bhp-hr)			
			NO _x	PM	HC ¹⁵	CO
Diesel (Line-haul)	Pre-1973	Uncontrolled	13.00	0.32	0.48	1.28
	1973-1992	Tier 0	8.60	0.32	0.48	1.28
	1973-1992	Tier 0+	7.20	0.20	0.30	1.28
	1993-2004	Tier 1	6.70	0.32	0.47	1.28
	1993-2004	Tier 1+	6.70	0.20	0.29	1.28
	2005-2011	Tier 2	4.95	0.18	0.26	1.28
	2005-2011	Tier 2+	4.95	0.08	0.13	1.28
	2012-2014	Tier 3	4.95	0.08	0.13	1.28
	2015+	Tier 4	1.00	0.015	0.04	1.28
Diesel (Switch)	Pre-1973	Uncontrolled	17.40	0.44	1.01	1.83
	1973-2001	Tier 0	12.60	0.44	1.01	1.83
	1973-2001	Tier 0+	10.60	0.23	0.57	1.83
	2002-2004	Tier 1	9.90	0.43	1.01	1.83
	2002-2004	Tier 1+	9.90	0.23	0.57	1.83
	2005-2010	Tier 2	7.30	0.19	0.51	1.83
	2005-2010	Tier 2+	7.30	0.11	0.26	1.83
	2011-2014	Tier 3	4.50	0.08	0.26	1.83
	2015+	Tier 4	1.00	0.015	0.08	1.83
GenSet*	2015+	Tier 4	1.00	0.015	0.08	1.83
Electric (or equivalent) ^o	All	N/A	0.0	0.0	0.0	0.0

Tiers with “+” are applicable only to locomotives that were originally manufactured in the corresponding Year of Manufacture range and remanufactured in 2008 or later; EPA holds these remanufactured locomotives to a higher emissions standard.

*Emission rates are estimated at the Tier 4 switch locomotive emission rates (refer to *Emissions Data Documentation* for details).

^oOperational emissions only. See Figure A2 and Table A2 for emission rates used to quantify emissions from upstream electricity generation.

¹³ U.S. Environmental Protection Agency, *Emission Factors for Locomotives*, EPA-420-F-09-025 (April 2009). Available at <https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100500B.TXT>.

¹⁴ The EPA tiers may also be applied to diesel-battery hybrids (diesel engine emissions) and other technologies and fuels, such as biodiesel. These locomotives should be certified to meet or exceed Tier 3/4 standards.

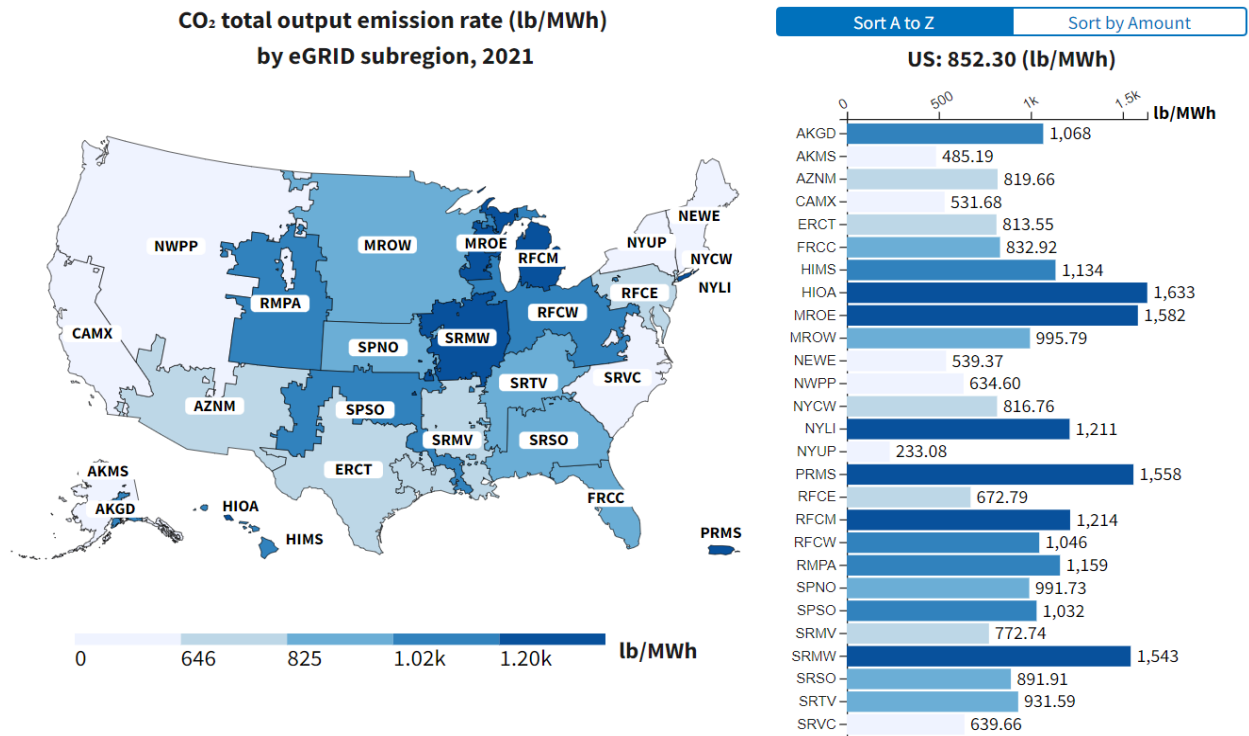
¹⁵ Hydrocarbon (HC) emission factors were converted to volatile organic compounds (VOC) emission factors using conversion factors developed by EPA. Please see the *Emissions Data Documentation* for further detail.

Table A2. eGRID Subregion Total Output Emission Rates (lb/MWh)¹⁶

eGRID Subregion	CO ₂	CH ₄	N ₂ O	CO ₂ e
AKGD	1067.7	0.091	0.012	1073.7
AKMS	485.2	0.025	0.004	487.1
AZNM	819.7	0.052	0.007	823.1
CAMX	531.7	0.031	0.004	533.6
ERCT	813.6	0.054	0.008	817.2
FRCC	832.9	0.053	0.007	836.3
HIMS	1134.4	0.135	0.021	1143.9
HIOA	1633.1	0.176	0.027	1645.5
MROE	1582.1	0.148	0.022	1592.3
MROW	995.8	0.107	0.015	1003.1
NEWE	539.4	0.072	0.009	544
NWPP	634.6	0.058	0.008	638.5
NYCW	816.8	0.019	0.002	817.9
NYLI	1210.9	0.126	0.016	1218.9
NYUP	233.1	0.015	0.002	234
PRMS	1558	0.081	0.013	1563.9
RFCE	672.8	0.049	0.007	676
RFCM	1214.1	0.115	0.016	1221.8
RFCW	1046.1	0.095	0.014	1052.5
RMPA	1158.9	0.109	0.016	1166.2
SPNO	991.7	0.108	0.016	999.1
SPSO	1031.6	0.08	0.012	1037
SRMV	772.7	0.04	0.006	775.4
SRMW	1543	0.171	0.025	1554.7
SRSO	891.9	0.067	0.01	896.4
SRTV	931.6	0.087	0.013	937.5
SRVC	639.7	0.052	0.007	642.9
U.S.	852.3	0.071	0.01	857

¹⁶ U.S. Environmental Protection Agency, Summary Data eGRID with 2021 Data (web page) (January 30, 2023). Available at <https://www.epa.gov/egrid/summary-data>.

Figure A1. eGrid Regions¹⁷



¹⁷ U.S. Environmental Protection Agency, eGrid Data Explorer 2021 (web page) (September 26, 2023). Available at: <https://www.epa.gov/egrid/data-explorer>.