Texas Commission on Environmental Quality (TCEQ)

Texas Emissions Reduction Plan (TERP)

Emission Reduction Incentive Grants (ERIG) Program

Technical Supplement for Locomotives

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Summary

This supplement contains instructions and inputs to calculate nitrogen oxides (NO_x) reductions for qualifying activities under the Texas Commission on Environmental Quality (TCEQ) Texas Emissions Reduction Plan (TERP), Emissions Reduction Incentive Grants (ERIG) Program. The project categories may include replacement, repower, retrofit, and add-on activities. Please refer to the current Request for Grant Applications (RFGA) for a definitive list of eligible project categories.

Locomotives and engines equal to or greater than 25 horsepower (hp) are eligible for grants under this program. Most locomotive engines eligible under this program will be powered by diesel-fueled compression-ignition (CI) engines. If the activity being proposed involves a gasoline, liquified petroleum gas (LPG), liquified natural gas (LNG), or compressed natural gas (CNG) powered locomotives contact TCEQ for appropriate emission factors.

There is a worksheet provided at the end of this supplement that may be used to calculate the NO_x emissions reductions and the cost-effectiveness of the activities proposed in an application. The TCEQ also provides a web-based calculator that may be used for the calculations. The calculator and information about the grant application process will be available on the TERP website at www.terpgrants.org.

Before beginning the calculation steps, review the conversion information below to understand units of measurement that will be used in this technical supplement.

Energy Measurement and Conversion

> **Locomotive engine power can be measured in either horsepower (hp) or kilowatts (kW).** For consistency purposes, calculations for NO_x reductions use horsepower.
>
> To convert kW into horsepower, multiply the kW by 1.341.
>
> 1 kW = 1.341 hp
> 1 hp = 0.746 kW
>
> **Example**: Convert to hp an engine that has a maximum continuous rated (MRC) power of 450 kW.
>
> 450 kW x 1.341 hp/kW = 603.5 hp
>
> **Engine emission standards may also be converted by using these factors:**
>
> 1 g/kWh = 0.746 g/hp-hr
>
> 1 g/hp-hr = 1.341 g/kWh
>
> **Example:** Convert the emissions standard of an engine listed as 10.5 g/kW-hr to g/hp-hr.
>
> 10.5 g/kWh x 0.746 = 7.8 g/hp-hr

Instructions

Calculations are divided into three major steps.

Step 1: Determine that the activity meets the 25% NO_x emissions reduction requirement using baseline (old) and reduced (new) emissions standards.

Step 2: Calculating the NO_x Emissions Reductions

Step 3: Calculating the Cost Per Ton

These steps are explained in the following instructions. Applicants may use the worksheet found at the end of this technical supplement to compute the emissions reductions and cost per ton for their application. Applicants may instead use the available web-based calculator available at www.terpgrants.org which will also refer to this technical supplement.

Step 1: Determine that the activity meets the 25% NOX emissions reduction requirement using baseline (old) and reduced (new) emissions standards.

All activities must achieve at least a 25% reduction in NOx emissions when compared to a baseline emission rate.

Baseline NO_x Emission Rate

The baseline NO_x emission rate will normally be the federal NO_x emission standard for the model year and horsepower of the baseline engine. For locomotive engines, the type of locomotive is also needed to lookup the federal NO_x emission standard. These standards can be found in Appendix A. Please be aware that switcher locomotives, as defined by the EPA in 40 CFR 1033, are locomotives that are 2,300 horsepower or less.

For locomotives with engines that are model year 2003 or newer, the TCEQ will use the engine family code (EFC) of that engine to confirm the emission standard applicable to that engine. This is a 12-digit code that should be printed on the engine plate or be available via the engine manufacturer. Applicants may verify the emission standard of an engine by looking this code up on the EPA's website. Please be aware that some engines may have a Family Emission Limit (FEL) which may be different than the standard emission rate. If an engine has an FEL, the TCEQ will use that value as it is the emission standard applicable to that engine.

Reduced NO_x Emission Rate

The reduced NO_x emission standard will normally be the certified or verified emissions of the new reduced-emission engine.

Replacement and Repower. Use the certified emission standard (g/bhp-hr) of the replacement engine. In most cases, an applicant should use the current NO_x emission standard for that model year and category of the locomotive. However, if the new engine is certain to be certified to a lower emissions standard (e.g., the engine will have an FEL), an applicant may use that rate, subject to approval by the TCEQ. Certified means certified by the EPA or CARB, or otherwise accepted by the TCEQ.

Retrofit/Add-on. Use the verified or certified emission rate (g/bhp-hr) or emission reduction percentage for the retrofit or add-on device. The emission reductions must be certified or verified by the EPA or CARB, or otherwise accepted by the TCEQ.

Calculate the Percentage NO$_x$ Emission Reductions

Utilizing the baseline NO$_x$ emission standard and the reduced NO$_x$ emission standard identified above, use the equation provided below to calculate the percentage reduction in NO$_x$ emissions. Remember, this value must be 25% or greater.

[(Baseline NO$_x$ emission standard - Reduced NO$_x$ emission standard) / Baseline NO$_x$ emission standard] x 100 = Percentage Reduction in NO$_x$ Emissions

Step 2: Calculate the NO$_x$ Emission Reductions

This step is divided into three main parts:

Part A: Determine the TxLED Correction Factor

Part B: Convert the emission rates to grams per hour (g/mile) and apply the TxLED correction factor (where appropriate)

Part C: Calculate the NO$_x$ emission reductions

Part A: Determine the TxLED Correction Factor

The TCEQ adopted rules (30 TAC 114.312 - 114.319) requiring that beginning on October 1, 2005, diesel fuel produced for use in compression-ignition engines in certain counties in Texas must meet new low emission diesel (TxLED) standards.

The counties affected by the new TxLED requirements currently include all of the counties eligible for TERP incentive funding, except for El Paso, Howard, and Hutchinson Counties.

The TxLED requirements set a maximum aromatic hydrocarbon content standard of 10 percent by volume per gallon. The requirements also set a minimum cetane number for TxLED of 48.

The TxLED requirements are intended to result in reductions in NO$_x$ emissions from diesel engines. Currently, a reduction factor of 5.7% (0.057) for on-road use and 7.0% (0.07) for non-road use and has been accepted as an estimate for use of TxLED. However, this reduction estimate is subject to change, based on the standards accepted by the EPA for use in the Texas State Implementation Plan (SIP).

For activities in the applicable counties, a correction factor of 0.93 will need to be applied when calculating the baseline and/or reduced emissions for diesel engines, regardless of when the grant-funded equipment began or will begin operation.

Part B: Convert the emission rates to grams per gallon (g/gal) and apply the TxLED correction factor (where appropriate)

The NO$_x$ emissions standards of heavy-duty engines are certified in grams per brake horsepower-hour (g/bhp-hr) or grams per kilowatt-hour (g/kW-hr). For performing these calculations, all emission standards must be in g/bhp-hr. Use the conversion factors provided in the Summary section of this document to convert emission standards that are in g/kW-hr to g/bhp-hr.

To perform the emissions reduction calculations, the emissions standards in g/bhp-hr must be converted to grams per hour (g/gal). Multiply the emission standard of an engine by its Energy Consumption Factor (ECF) to complete this conversion. Below is a table of Energy Consumption Factors for locomotive projects.

Table 1

Locomotive Type	ECF
Line Haul	20.8 bhp-hr/gal
Switcher	15.2 bhp-hr/gal
Short Haul/Regional*	18.2 bhp-hr/gal

*Depending on the type of service of these locomotives, a different ECF may be assigned. Please contact TCEQ if you're applying with one of these locomotive types.

Next, if an engine is determined to have a TxLED factor in Part A, apply that factor to the converted emission standard.

For each engine, new and old, the following equation should be completed to ensure that an emission rate has been calculated for each of them.

Emission Rate (g/bhp-hr) * ECF (bhp-hr/gal) * TxLED factor = Emission Rate (g/gal)

Part C: Calculate the NO_x Emission Reductions

Calculating the NO_x emissions reductions requires some of the information that has been calculated or gathered in the previous steps plus some additional information. The following is needed to calculate the NO_x emissions reductions.

- The emissions factors calculated in Part B for the new and old engines in g/gal.
- The default annual fuel usage for the old and new engines.
    - Use Appendix B to determine the default annual fuel usage for an engine.
- The percentage of time in area that the applicant will commit to use the locomotive in the eligible areas (e.g., 75%, 90%).
    - This value must not be less than 55% and may be increased in increments of 10% up to a maximum of 95%. See the RFGA for more details regarding usage commitments.
- The length of the activity life of the project.
    - See Table 2 for available activity life options.
- A conversion factor to convert grams to tons which is 907,200 grams in a U.S. standard ton.

Table 2 – Activity Life for Locomotives

Minimum Activity Life	Maximum Activity Life
5 years	10 years

NO_x emissions reductions are calculated in tons and should be rounded to 4 decimal places at the end of the calculation, should rounding be needed. The formula for the NO_x emissions reduction calculation is shown below.

ERIG is a competitive grant round and one of the factors utilized in the grant selection process is total NO_x emissions reductions. The higher the NO_x emissions reductions of the project, the more competitive the grant application may be.

Old engine emissions factor (g/gal) * default old fuel usage (gal/yr) = old reduced emission factor (g/yr)

New engine emissions factor (g/gal) * default new fuel usage (gal/yr) = new reduced emissions factor (g/yr)

Old reduced emission factor (g/yr) – new reduced emission factor (g/yr) = reduced emissions per year (g/yr)

Reduced emissions per year (g/yr) * usage in area (%) = reduced area emissions per year (g/yr)

Reduced area emissions per year (g/yr) ÷ grams to tons factor (g/ton) = reduced area emissions (tons/yr)

Reduced area emissions (tons/yr) * activity life (yr) = Total NO_x emissions reductions (tons)

Step 3. Calculate Cost Per Ton

The cost per ton for an activity is then determined by dividing the requested grant amount for that activity by the total NO_x emission reductions for that activity.

For multi-activity projects, the cost per ton of the complete project is determined by dividing the requested grant amount for the entire project by the total NO_x emission reductions for all of the activities included in that project.

Requested Grant Amount ($) / Total NO_x Emission Reductions (tons)

= Cost Per Ton of NO_x Reduced ($/tons)

Locomotive Calculation Worksheet

This worksheet is provided to assist applicants in estimating the NO_x emissions reductions and cost per ton of NO_x reduced for each activity. See the Project Cost Per Ton and NO_x Emissions Reductions Worksheet to calculate these values for the entire project.

Activity Information

What is the default hours of usage for your engine/vessel (Table 7)?	
What is the percent of usage in the eligible counties (Part C)?	
What is the incremental cost of the activity?	
What is the requested grant amount for the activity?	
Old Engine Information	
Model Year:	
Engine Power (hp):	
Emission Rate (g/bhp·hr) (Step 1):	
Energy Consumption Factor (Part B):	
TxLED Factor (Part A): Note: Only if applicable	
New Engine Information	
Model Year:	
Engine Power (hp):	
Emission Rate (g/bhp·hr) (Step 1):	
Energy Consumption Factor (Part B):	
TxLED Factor (Part A): Note: Only if applicable	
Check the Emissions Rate Reduction	
Old Engine Emission Standard (g/bhp·hr):	
- New Engine Emission Standard (g/bhp·hr):	
= Difference (g/bhp·hr):	
÷ Old Engine Emission Standard (g/bhp·hr):	
x:	100
= Emission Rate Reduction (%): Note: Must be 25% or more	

Determine Old Engine NO$_x$ Emission Rate (g/mile)	
Old Engine NO$_x$ Emission Rate (g/bhp·hr):	
x TxLED Correction Factor:	
= Corrected NO$_x$ Emission Rate (g/bhp·hr):	
x Energy Consumption Factor (bhp-hr/gal):	
= Converted Old Engine NO$_x$ Emission Rate (g/gal):	
Determine New Engine NO$_x$ Emission Rate (g/mile)	
New Engine NO$_x$ Emission Rate (g/bhp·hr):	
x TxLED Correction Factor:	
= Corrected NO$_x$ Emission Rate (g/bhp·hr):	
x Energy Consumption Factor (bhp-hr/gal):	
= Converted New Engine NO$_x$ Emission Factor (g/gal):	
Calculate the NO$_x$ Emissions Reductions	
(A) Converted Old Engine NO$_x$ Emission Factor (g/gal) x Old Fuel Usage (gal/yr):	
(B) Converted New Engine NO$_x$ Emission Factor (g/gal) x New Fuel Usage (gal/yr):	
A-B (g):	
x Percent within Eligible Counties (%):	
= Grams per Year Reduced (g/yr):	
÷ 907,200 Grams per Ton	907200
= Estimated Annual NO$_x$ Emission Reduction (tons/yr):	
x Activity Life (years):	
= Estimated Activity Life NO$_x$ Emission Reductions (tons):	
Requested Grant Amount ($) ÷ NO$_x$ Emission Reductions (tons) = Cost Per Ton ($):	
Eligibility Checks	
Is the requested grant amount less than or equal to 80% of the incremental cost?	
Does the new engine reduce emissions by at least 25%?	

Project Cost Per Ton and NO$_x$ Emissions Reductions Worksheet

This worksheet is provided to assist applicants in calculating their project NO$_x$ emissions reductions and cost per ton.

Activity	NO$_x$ Reductions	Requested Grant Amount
Activity 1		
Activity 2		
Activity 3		
Activity 4		
Activity 5		
Activity 6		
Activity 7		
Activity 8		
Activity 9		
Activity 10		
Total		

Total Requested Grant Amount	Math Function	Total NO$_x$ Reductions	Math Function	Project Cost Per Ton
	÷		=	

Appendix A: Locomotive Engine Emission Standards

Line Haul Duty Cycle

Tier Level	Model Year	NO$_x$ Emission g/bhp-hr
Uncontrolled	N/A	13
Tier 0	1973-2001	7.4 (8.0 if no SLAC)
Tier 1	2002-2004	7.4
Tier 2	2005-2011	5.5
Tier 3	2012-2014	5.5
Tier 4	2015+	1.3

Switchers Duty Cycle

Tier Level	Model Year	NO$_x$ Emission g/bhp-hr
Uncontrolled	N/A	17.4
Tier 0	1973-2001	11.8
Tier 1	2002-2004	11.0
Tier 2	2005-2010	8.1
Tier 3	2011-2014	5.0
Tier 4	2015+	1.3

Appendix B: Default Usage Rates for Locomotives

The default usage rates for locomotives vary depending on the type of work they do and whether the old/existing locomotive has a start-stop system installed. A distinction is made between 1) Rail Yard and similar operations, 2) Regional Short-Haul and Passenger Rail, and 3) Industrial Rail. The industrial rail category includes locomotives owned or leased by or otherwise contracted to serve an individual industrial, commercial, or military entity/operation. This may include locomotives operating within a single facility or a locomotive used to move a limited number of rail cars among several facilities operated by that entity. Rail operations providing service to multiple industrial or commercial entities would not normally fall under this category. However, TCEQ retains the discretion to classify a rail operation as industrial for purposes of assigning a default usage rate if it is determined that the locomotive will only be used on a limited basis.

Applicants must note in the application the type of work the locomotive performs and whether a start-stop system is installed on the old/existing locomotive. For locomotives that already have an automatic start-stop system installed, the standard baseline usage is reduced by 15%.

For "diesel-electric hybrid" and "genset" technology, TCEQ has accepted up to a 30 percent fuel economy benefit as a result of idle reduction systems and efficiency of the engines when compared to a baseline locomotive. TCEQ may consider a greater fuel economy benefit based on independent studies and test data. Documentation must be submitted with the application to justify the reduced fuel amount. TCEQ will evaluate the documentation to determine the level of fuel savings that may be accepted.

Baseline (old/existing) Locomotive Usage

Start-stop system not installed.

Equipment Type	Annual Gallons
Rail Yard and similar operations	50,000
Regional Short-Haul and Passenger Rail	50,000
Industrial Rail	35,000

Baseline (old/existing) Locomotive Usage

Start-stop system installed. The standard baseline usage is reduced by 15%. Must be noted in the application whether a start-stop system is installed.

Equipment Type	Annual Gallons
Rail Yard and similar operations (start-stop system installed)	42,500
Regional Short-Haul and Passenger Rail (start-stop system installed)	42,500
Industrial Rail (start-stop system installed)	29,750

New or Upgraded Locomotive Usage
(All new or upgraded locomotives should have a start-stop system installed)

Equipment Type	Annual Gallons
New or upgraded locomotive	42,500
New or upgraded locomotive – small industrial facility operations	29,750
Genset and Hybrid switcher locomotive	35,000
Genset and Hybrid switcher locomotive – small industrial facility operations	24,500