



**Texas Commission on Environmental Quality (TCEQ)
Texas Emissions Reduction Plan (TERP)**

**Emissions Reduction Incentive Grants Program
Technical Supplement No. 4
Locomotives**

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**Texas Commission on Environmental Quality (TCEQ)
Texas Emissions Reduction Plan (TERP)**

**Emissions Reduction Incentive Grants Program
Technical Supplement No. 2
Locomotives**

SUMMARY

This supplement contains the calculations for activities involving locomotives, including: new purchases and leases, replacement, repower, retrofit, and add-on device activities.

Most of the locomotive engines eligible under this program will be powered by diesel-fueled compression-ignition (CI) engines. However, engines powered by other fuels may also be eligible, subject to decisions by the TCEQ.

Use the Locomotives-1 (LO-1) worksheet provided in Section 3.0 of this supplement to calculate the emission reductions and the cost-effectiveness of the activities proposed for your project. You may also go to www.terpgrants.org and download the locomotive calculator for an estimate of your possible grant amounts.

Calculations are divided into three major steps:

Step 1: Determine if the new vehicle and/or engine is certified to emit 25% less NO_x

Step 2: Calculate the reductions in NO_x Emissions

Step 3: Calculate the Cost per Ton

Refer to the instructions included below, and use the LO-1 Worksheet to complete the calculations.

INSTRUCTIONS

STEP 1: DETERMINE IF THE NEW EQUIPMENT IS CERTIFIED TO EMIT 25% LESS NO_x.

All new purchase or lease, replacement, repower, retrofit, and add-on activities must achieve at least a **25% reduction in NO_x emissions** when compared to a baseline emission rate according to the following formula:

$$\text{Percent Baseline NO}_x \text{ Emission Rate Reduction} = \frac{[(\text{Baseline Emission Rate} - \text{Reduced Emission Rate}) / \text{Baseline Emission Rate}] \times 100\%}{}$$

Use Worksheet LO-1 in Section 3.0 below to determine if your activity meets the minimum emission reduction requirements.

a) Determine the 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. The federal NO_x emission standards for locomotive engines are presented in Appendix A. Emission factors for particulate matter (PM) are also provided in Appendix A, but are used for reference only and are not used in calculating grant amounts.

b) Determine the Reduced NO_x Emission Rate

The new NO_x emission rate will normally be the federal NO_x emission standard for the engine model year or a certified emission rate. Certified means certified by the EPA or CARB, or otherwise accepted by the TCEQ. See Appendix A for a list of federal NO_x emission standards by engine model year and horsepower.

Each activity type requires the calculation of an emissions reduction. The following list describes the emissions standard you should use for each project type:

- **New Purchase or Lease.** Use the certified emission standard (g/bhp-hr) of the new equipment.
- **Replacement.** Use the certified emission standard (g/bhp-hr) of the replacement equipment and engine.
- **Repower.** Use the certified emission standard (g/bhp-hr) of the engine installed on the replacement equipment.
- **Retrofit/Add-on.** Use the verified or certified emission standard (g/bhp-hr) or emission reduction percentage for the retrofit or add-on device. The emission reductions must be verified or certified by the EPA or CARB, or otherwise accepted by the TCEQ.

c) Calculate the difference in NO_x Emission Rates

See the example calculations below for determining if an Activity meets the 25% baseline emission rate reduction requirement by Project Category:

New Purchase/ Lease

Activity: Purchase of a line haul locomotive that has a certified NOx emission rate of 5.5 g/bhp-hr.

- **Engine emission** standard for current year model: 7.4 g/bhp-hr
- **New engine certified NOx emissions:** 5.5 g/bhp-hr

Calculation of baseline emission rate reduction:

$$[(7.4 \text{ g/bhp-hr} - 5.5 \text{ g/bhp-hr}) / 7.4 \text{ g/bhp-hr}] \times 100 \% = 25.68 \% \text{ baseline emission rate reduction}$$

Repower

Activity: Repowering of a 1970 switch locomotive with a rebuilt 2007 engine.

- **Original engine emission standard:** 17.4 g/bhp-hr
- **Replacement engine emission standard:** 8.1 g/bhp-hr

Calculation of baseline emission rate reduction:

$$[(17.4 \text{ g/bhp-hr} - 8.1 \text{ g/bhp-hr}) / 17.4 \text{ g/bhp-hr}] \times 100 \% = 53.49\% \text{ baseline emission rate reduction}$$

Replacement

Activity: Replacement of a 1970 Line Haul locomotive with a 2003 Locomotive.

- **Original engine emission standard:** 13 g/bhp-hr
- **Replacement engine emission standard:** 7.4g/bhp-hr

Calculation of baseline emission rate reduction:

$$[(13.0 \text{ g/bhp-hr} - 7.4 \text{ g/bhp-hr}) / 13.0 \text{ g/bhp-hr}] \times 100 \% = 43.08 \% \text{ baseline emission rate reduction}$$

Retrofit/ Add-On

Activity: Retrofitting a 1977 switcher with a device that has a certified emission of 8.1.

- **Engine emission standard for existing model year:** 11.8 g/bhp-hr
- **Retrofit certified NOx emissions:** 8.1 g/bhp-hr

Calculation of baseline emission rate reduction:

$$[(11.8 \text{ g/bhp-hr} - 8.1 \text{ g/bhp-hr}) / 11.8 \text{ g/bhp-hr}] \times 100 \% = 31.36 \% \text{ baseline emission rate reduction}$$

STEP 2: CALCULATE THE NO_x EMISSION FACTORS

Emissions reduction represents the difference in the emission level of a baseline (old) engine and a newer, reduced-emission engine. The emission level is calculated by multiplying the following:

- **Correction Factor**
 - If the equipment operates in a county or counties that is in the TxLED region the TxLED correction factor must be determined.
- **Activity Level (annual fuel consumption)**
 - For locomotive applications, the activity level should be established by the annual fuel consumption in gallons/year.
- **Emission Factor**
 - For most locomotive applications, the emission should be established by the fuel consumption in gallons/year.

Because correction factors and the activity levels may be expressed in different units for the existing and replacement engines, the emission levels for the baseline and reduced-emission engines should be calculated separately and then the differences taken to determine emission reductions. Usage amounts for the emission reduction calculations should be consistent with the anticipated grant life of each activity (number of years).

This step is divided into three main parts:

- Part A: Determine the TxLED Correction Factor
- Part B: Calculate the NO_x Emission Factors
- Part C: Calculate the NO_x Emission Reductions

Part A: Determine the TxLED Correction Factor

The TCEQ has 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, as listed in the *Guidelines*, **except for El Paso County**. The new requirements set a maximum aromatic hydrocarbon content standard of 10% 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 non-road activities in the applicable counties (does not include El Paso County), a correction factor of **0.93** should 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.

Calculate Reduced Fuel Use (if approved by the TCEQ)

For New Purchase or Lease, Replacement, or Repower Activities, the TCEQ may accept, at its discretion, fuel economy benefits of the new or repowered locomotive engine over the baseline unit when calculating emissions reductions. In general, fuel savings may occur as a result of idle reduction systems that come with the new or repowered locomotive and/or the enhanced fuel economy of the new engine.

The TCEQ may provide the option of using default usage rates for some types of projects in lieu of determining the usage specific to each particular vehicle or piece of equipment. Refer to the Request for Grant Applications (RFGA) for instructions and requirements on the default usage options.

Where a default usage rate option is used, the applicable default usage rates will include consideration of fuel economy benefits for certain types of replacement or repowered locomotives. If a default usage rate is not used, the TCEQ may allow the applicant to account for the fuel economy benefits in establishing the annual fuel use estimates. Refer to the RFGA for information on the allowed approach for determining the fuel use estimates.

In general, if this approach is allowed, the application must list the percentage reduction in fuel use expected through use of the reduced-emission locomotive when compared to the baseline. For Replacement and Repower Activities, the application should also list the historical average annual fuel use of the old locomotive (baseline) and an annual fuel use commitment for use of the new or repowered locomotive.

For “diesel-electric hybrid” and “genset” technology, the 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. The 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. The TCEQ will evaluate the documentation to determine the level of fuel savings that may be accepted.

Regardless of the baseline fuel use amount listed in the application, the TCEQ will apply a fuel economy factor to the fuel use commitment listed for the reduced-emission locomotive and engine. For instance, if the TCEQ agrees that the reduced-emission locomotive fuel use will be 30% less than the baseline locomotive fuel use for the same amount of work, then the baseline fuel use for the calculation will be determined by multiplying the fuel use commitment by a factor of 1.43 ($1/0.70 = 1.43$). If the historical annual fuel use listed in the application is less than the number derived by applying the fuel economy factor, then that lower baseline number will be used.

The key for the application is to enter a realistic fuel use commitment for the expected work to be performed by the reduced-emission locomotive. If a grant is awarded, the grant recipient is obligated to use at least that amount of fuel annually in order to meet the grant usage requirements over the activity life. If the fuel use commitment is not met, the grant recipient may be obligated to return a share of the grant funds unless the grant recipient can provide documentation to show that the work performed by the locomotive was at the level expected and that the fuel use projections for performing that amount of work were too high.

Reduced Fuel Use

Example 1

Activity: Replacement of a 1995 switcher with a 2018 generation sets switcher.

- **Old locomotive fuel usage:** 80,000 gal/yr
- **New fuel usage commitment:** 40,000 gal/yr
- **Fuel Economy Factor based on an accepted 30% reduction in fuel use:**
 $1/(1 - 0.30)$ or $1/0.70 = 1.43$

Calculate the baseline fuel use for the emissions reduction calculations (gal/yr):
 $40,000 \text{ gal/yr} \times 1.43 = 57,200 \text{ gal/yr}$

Example 2

Activity: Replacement of a 1971 switcher with a 2018 generation sets switcher.

- **Old locomotive fuel usage:** 70,000 gal/yr
- **New fuel usage commitment:** 45,000 gal/yr
- **Fuel Economy Factor based on an accepted 25% reduction in fuel use:**
 $1/(1 - 0.25)$ or $1/0.75 = 1.33$

Calculate the baseline fuel use for the emissions reduction calculations (gal/yr):
 $45,000 \text{ gal/yr} \times 1.33 = 59,850 \text{ gal/yr}$

Part B: Calculate the NO_x Emission Factors

To complete the calculation of the NO_x emission reductions for the activity, you must convert the NO_x emission rates (g/bhp-hr) to a **NO_x emission factor**. For most types of equipment, the NO_x locomotive activities, the NO_x emission reduction factors should be based on annual fuel consumption. You should consult with the TCEQ to determine the factors to use for non-diesel engines, or if you wish to use a different conversion factor.

For calculations based on annual fuel use, the **energy consumption factor (ECF)** should be used to convert the NO_x emission rate (g/bhp-hr) to g/gal. The default ECFs are as follows:

- **switchers** - 15.2 bhp-hr/gal
- **line-haul locomotives** - 20.8 bhp-hr/gal
- **regional or short-haul locomotives** - depending on the type of line-haul service, these projects/activities may be assigned a lower EFC of 18.2 bhp-hr/gal. Consult the TCEQ regarding which EFC value to use for a particular line-haul service.

As shown below, because the estimated annual fuel use of the baseline locomotive/engine and the reduced emission locomotive/engine may differ, the g/gal factor is then multiplied by the number of gallons used per year, to determine the estimated g/year to be emitted by both the baseline and the reduced emission locomotive/engine. This factor is used to calculate the NO_x emission reductions.

Example NO_x Emission Factor Calculation

Activity: Replacement of a 1995 switcher with a 2018 generation sets switcher.

- **Original engine emission standard:** 11.8 g/bhp-hr
- **Energy conversion factor:** 15.2 bhp-hr/gal
- **Replacement engine emission standard:** 1.3 g/bhp-hr
- **Energy conversion factor:** 15.2 bhp-hr/gal
- **Annual fuel use (baseline engine):** 57,200 gal
- **Annual fuel use (reduced engine):** 40,000 gal
- **TxLED Correction factor:** 0.93

Calculate Baseline NO_x Emission Factor (g/yr)

$$\begin{aligned} 11.8 \text{ g/bhp-hr} \times 0.93 &= 10.974 \text{ g/bhp-hr} \\ 10.974 \text{ g/bhp-hr} \times 15.2 \text{ bhp-hr/gal} &= 166.805 \text{ g/gal} \\ &\downarrow \\ 166.805 \text{ g/gal} \times 57,200 \text{ gal/yr} &= \mathbf{9,541,256 \text{ g/yr}} \end{aligned}$$

Calculate Reduced NO_x Emission Factor (g/yr)

$$\begin{aligned} 1.3 \text{ g/bhp-hr} \times 0.93 &= 1.209 \text{ g/bhp-hr} \\ &\downarrow \\ 1.209 \text{ g/bhp-hr} \times 15.2 \text{ bhp-hr/gal} &= 18.377 \text{ g/gal} \\ &\downarrow \\ 18.377 \text{ g/gal} \times 40,000 \text{ gal/yr} &= \mathbf{735,080 \text{ g/yr}} \end{aligned}$$

Part C: Calculate the NO_x Emission Reductions

Use the factors determined in Step 2 (above) to calculate the NO_x emission reduction for the activity.

To complete the calculations, you will need to determine the usage rate for your equipment in gallons/year.

The TCEQ may provide the option of using default usage rates for some types of projects in lieu of determining the usage specific to each particular piece of equipment. Where a default usage rate option is used, the applicable default usage rates should be used for the emissions reduction calculations. Where a default usage rate is not used, refer to the instructions in the RFGA for determining the usage rate to enter in the application and use for the emissions reduction calculations.

Default usage rates for locomotives are listed in Appendix B. The list includes usage rates by type. You should select the default usage rate which applies to the locomotive type of the old/existing equipment.

You must also enter the **percentage of annual usage** that will occur within the eligible counties. To qualify, **at least 75%** of the annual usage must be projected to occur within those counties. A **primary area** will need to be identified in the project application form.

Activities to be operated in different primary areas will need to be submitted in separate applications.

Finally, to complete the calculations, you will need to designate a grant **Activity Life**. This will be the number of years used to calculate the emission reductions. If awarded the grant, you must commit to operating the equipment within the eligible counties for this time period, and to track and report the use to the TCEQ.

Activity life may not exceed the life of the piece of equipment. Refer to the following list for information on the maximum acceptable activity life for different types of activities. The minimum activity life must be five years, including leases.

Maximum Grant Activity Life Locomotive Activities

	Minimum	Maximum *
New	5 years	10 years
Replacement	5 years	10 years
Repowers	5 years	10 years
Retrofit/Add-on (maximum life for dual-fuel conversions is 7 years)	5 years	10 years

* If an applicant feels that a longer activity life is warranted, they should contact the TCEQ to discuss. Any request to use a longer activity life will need to be submitted in writing, and should include complete documentation and records of the historical use of similar equipment by the applicant.

Example NO_x Emission Rate Reduction Calculation Based on Annual Fuel Use

Activity: Replacement of a 1995 switcher with a 2018 generation sets switcher.

- **Baseline emission factor: 9,136,956 g/yr**
- **Reduced emission factor: 735,080 g/yr**
- **Percent time in affected counties: 100%**

NO_x emission rate reduction calculation

$$9,136,956 \text{ g/yr} - 735,080 \text{ g/yr} = 8,401,876 \text{ g/yr}$$

↓

$$8,401,876 \text{ g/yr} \times 1.00 = 8,401,876 \text{ g/yr}$$

↓

$$8,401,876 / 907,200 \text{ g/ton} = \mathbf{9.261 \text{ ton/yr}}$$

↓

$$9.261 \text{ ton/yr} \times 10 \text{ yrs} = \mathbf{92.61 \text{ total tons}}$$

STEP 3: CALCULATE THE COST PER TON

The cost per ton for an activity is 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.

$$\begin{aligned} & \text{Requested Grant Amount} / \text{Total NO}_x \text{ Emission Reductions} \\ & = \text{Cost Per Ton of NO}_x \text{ Reduced} \end{aligned}$$

Example Cost Per Ton of NO_x Reduced Calculation

Activity: Replacement of a 1995 switcher with a 2018 generation sets switcher.

- Requested Grant Amount: \$120,000.00
- Total NO_x Emission Reduction: 11.20 tons

$$\begin{aligned} & \text{Cost Per Ton of NO}_x \text{ Reduced Calculation} \\ & \$1,200,000.00 / 92.61 \text{ total tons} = \$12,957.56/\text{ton} \end{aligned}$$

WORKSHEET LO-1 ANNUAL FUEL CONSUMPTION

Please fill in the following information. This information will help you with your calculations. An interactive version of the purchase, replace, repower, and retrofit calculators is available on the TERP website at: www.terpgrants.org

Activity Information

Type of project <input type="checkbox"/> New Purchase/Lease <input type="checkbox"/> Repower <input type="checkbox"/> Replacement <input type="checkbox"/> Retrofit/Add-on	
What is the activity life of the project in years?	
What is the percent time the equipment is in the eligible counties?	
What is the requested grant amount for the activity?	

Baseline Engine Information

Model Year	
Fuel Type	
Locomotive Type	
Emission Standard (g/bhp-hr)	
Annual Fuel Consumption in Gallons (gal/yr)	
Energy Consumption Factor (bhp-hr/gal): The default is 15.2 for switcher locomotives, 20.8 for large line-haul, and 18.2 for regional short-haul service.	

Reduced Engine Emission Information

Model Year	
Fuel Type	
Locomotive Type	
Emission Standard (g/bhp-hr)	
Annual Fuel Consumption (gal/yr)	
Energy Consumption Factor (bhp-hr/gal) The default is 15.2 for switcher locomotives, 20.8 for large line-haul, and 18.2 for regional short-haul service.	
If the activity is a retrofit/add-on, is there a verified percentage NO _x emission reduction?	%

STEP 1: DOES THIS PROJECT MEET THE 25% NO_x BASELINE EMISSION RATE REDUCTION REQUIREMENTS?

Baseline Engine Emission Standard (g/bhp-hr)	
- Reduced Engine Emission Standard (g/bhp-hr)	
= Difference (g/bhp-hr)	
/ Baseline Engine Emission Standard (g/bhp-hr)	
x	100
= Emission Rate Reduction	

STEP 2: WHAT ARE YOUR NO_x EMISSION REDUCTIONS?

PART A. CALCULATE THE TXLED CORRECTION FACTOR (all areas except for El Paso)

Non-Road TxLED Correction Factor 1 - (0.07)	0.93
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PART B. DETERMINE THE NO_x EMISSION FACTOR

Determine Baseline (Original) NO_x Emission Factor (g/year)	
baseline engine NO _x emission standard (g/bhp-hr)	
x TxLED correction factor (diesel engines only)	
= corrected NO _x emission factor (g/bhp-hr)	
x energy consumption factor (bhp-hr/gal)	
x annual fuel consumption (gal/yr)	
= baseline NO _x emission factor (g/yr)	

Determine Reduced NO_x Emission Factor (g/year)	
Option A. Reduced-emission engine certified to a specific emissions standard (g/bhp-hr)	
reduced engine NO _x emission standard (g/bhp-hr)	
x TxLED correction factor (diesel engines only)	
= corrected NO _x emission factor (g/bhp-hr)	
x energy consumption factor (bhp-hr/gal)	
x annual fuel consumption (gal/yr)	
= reduced NO _x emission factor (g/yr)	

Option B. Reduced-emission technology certified/verified to achieve a percentage reduction from the baseline.

baseline NO _x emission factor (g/yr)	
x certified/verified percentage reduction from baseline	
= reduced NO _x emission factor (g/yr)	

PART C. CALCULATE THE NO_x EMISSION REDUCTION USING ANNUAL FUEL USE

baseline NO _x emission factor (g/yr)	
- reduced NO _x emission factor (g/yr)	
= grams reduced (g/yr)	
x percent within affected counties (%)	
= grams per year reduced (g/yr)	
/ 907,200 (g/ton)	907,200
= estimated annual NO _x emission reduction (tons/yr)	
x activity life (yr)	
= estimated activity life NO _x emission reduction (ton)	

STEP 3: WHAT IS THE ACTIVITY COST PER TON?

Grant activity amount (\$):	
/ NO _x emission reductions (ton):	
= cost per ton (\$/ton)	

APPENDIX A: LOCOMOTIVE ENGINE EMISSION STANDARDS

Duty Cycle	Tier Level	Model Year	NO_x Emission g/bhp-hr
Line Haul	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	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, the 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.

You 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%).

Baseline (old/existing) Locomotive Usage

Equipment Type	Annual Gallons
Rail Yard and similar operations (start-stop system not installed)	50,000
Regional Short-Haul and Passenger Rail (start-stop system not installed)	50,000
Industrial Rail (start-stop system not installed)	35,000
For locomotive that already have an automatic start stop system installed, the standard baseline usage is reduced by 15% (you must note in the application whether a start stop system is installed)	
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