TEXAS EMISSIONS REDUCTION PLAN (TERP)
Emissions Reduction Incentive Grants Program

Technical Supplement No. 4
Locomotives

Revised – July 2014

Texas Commission on Environmental Quality (TCEQ)
Air Quality Division
Implementation Grants Section, MC-204
P.O. Box 13087
Austin, Texas 78711-3087
1-800-919-TERP (8377)

www.terpgrants.org

TECHNICAL SUPPLEMENT NO. 4

LOCOMOTIVES

Summary

This supplement contains the calculations for activities involving locomotives, including: new purchases and leases, replacement, repower, retrofit, and add-on activities.
Most of the engines eligible under this program will be powered by diesel-fueled compression-ignition engines. However, engines powered by other fuels may also be eligible, subject to decisions by the TCEQ for particular funding periods.
Use the worksheet provided at the end of this chapter to calculate the emission reductions and the cost-effectiveness of the activities proposed in your project.
This workbook is divided into three major steps.

a) Step 1: Does the activity meet the 25% NO_x emissions reduction requirement?

b) Step 2: Calculate the NO_x Emission Reductions.

c) Step 3: Calculate the Cost Per Ton.

These steps are explained in the following instructions. You should refer to the worksheet and use the instructions to complete each step of the calculations.

Step 1: Does the activity meet the 25% NO_x emissions reduction requirement?

All new purchase or lease, replacement, repower, retrofit, and add-on activities must meet requirements related to reductions in NO_x emission levels when compared to a baseline emission level. Use the worksheet to determine if your activity meets the minimum emission reduction requirements. Most of the calculations will require input of a NO_x emission standard applicable to the engine and/or locomotive.

Baseline NO_x Emission Standard

Criteria have been established to determine the eligibility of an activity, based on the NO_x federal certified emission standard for locomotive engines (see table 4.1). In situations where the model year of the locomotive and the model year of the existing engine are different, the model year of the engine must be used to determine the baseline emission standard for emission reduction calculations.

TABLE 4.1 DIESEL LOCOMOTIVES NOX EMISSION STANDARD BY MODEL YEAR

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

SLAC = Separate Loop Intake Air Cooling

Reduced NO_x Emission Standard

The reduced NO_x emission standard will normally be the certified or verified emissions of the reduced-emission locomotive or engine found in Table 4.1.

- **New Purchase or Lease.** Use the certified emission rate (g/bhp-hr) of the new locomotive. Certified means certified by the EPA or CARB, or otherwise accepted by the TCEQ.
- **Replacement.** Use the certified emission rate (g/bhp-hr) of the replacement locomotive and engine. Certified means certified by the EPA or CARB, or otherwise accepted by the TCEQ.
- **Repower.** Use the certified emission rate (g/bhp-hr) of the engine installed on the replacement locomotive. 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 verified or certified by the EPA or CARB, or otherwise accepted by the TCEQ.

  [(Baseline Engine - Reduced Engine) / Baseline Engine]
  x 100 = Baseline Emission Rate Reduction

EXAMPLE CALCULATIONS

Example calculation for determining 25% baseline emission rate reduction for new purchase/lease

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

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

Calculation of baseline emission rate reduction:
[(7.4 g/bhp-hr - 5.5 g/bhp-hr) / 7.4 g/bhp-hr] x 100 % = 25.68 % baseline emission rate reduction

Example calculation for determining 25% baseline emission rate reduction for repowers

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 g/bhp-hr – 8.1 g/bhp-hr) / 17.4 g/bhp-hr] x 100 % = 53.49% baseline emission rate reduction

Example calculation for determining 25% baseline emission rate reduction for replacements

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 g/bhp-hr - 7.4 g/bhp-hr) / 13.0 g/bhp-hr] x 100 % = 43.08 % baseline emission rate reduction

Example calculation for determining 25% baseline emission rate reduction for 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 NO_x emissions: 8.1 g/bhp-hr

Calculation of baseline emission rate reduction:
[(11.8 g/bhp-hr - 8.1 g/bhp-hr) / 11.8 g/bhp-hr] x 100 % = 31.36 % baseline emission rate reduction

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: Determine the NO_x emission factors
- Part C: Calculate the NO_x emission reductions

Points to remember when performing Emission Reduction Calculations

- Emission reduction represents the difference in the emission level of a baseline engine and a reduced-emission engine.
- The emission level is calculated by multiplying an emission factor, an activity level, and a conversion factor, if necessary.
- In situations where the model year of the locomotive chassis and the model year of the existing engine are different, the model year of the engine shall be used to determine the baseline emissions for benefit calculations.
- Because conversion 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 differences taken to determine emission reductions.
- Emission reduction calculations should be consistent with the type of records maintained over the life of each activity.
- If the equipment operates in a county or counties that is in the TxLED region the TxLED conversion factor must be determined

Part A: Texas Low Emission Diesel 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 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 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 locomotive activities in the applicable counties (not including El Paso County), a correction factor of **0.93** should be applied when calculating the baseline and/or reduced emissions for diesel engines.

Part B: Reduced Fuel Use for Locomotives

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.

Example calculation for reduced fuel usage

Example 1
Activity: Replacement of a 1965 switcher with a 2008 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 gal/yr x 1.43 = 57,200 gal/yr

Example 2
Activity: Replacement of a 1971 switcher with a 2008 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 gal/yr x 1.33 = 59,850 gal/yr

Part C. Determine 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 locomotive activities, the NO_x emission reduction factors should be based on annual hours of operation.

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 ECF factors are 20.8 and 15.2 bhp-hr/gal for line-haul locomotives and for switchers, respectively. Further, depending on the type of line-haul service, regional or short-haul locomotive 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 on the worksheet, 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 calculation for determining NO_x emission factor based on annual fuel use

Activity: Replacement of a 1965 switcher with a 2008 generation sets switcher.

Original engine emission standard: 17.4 g/bhp-hr
Energy conversion factor: 15.2 bhp-hr/gal
Replacement engine emission standard: 3.0 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

Baseline NOx Emission Factor (g/yr)
17.4 g/bhp-hr x 0.93 = 16.182 g/bhp-hr
16.182 g/bhp-hr x 15.2 bhp-hr/gal = 245.9664 g/gal
245.9664 g/gal x 57,200 gal/yr = **14,069,320 g/yr**

Reduced NOx Emission Factor (g/yr)
3.0 g/bhp-hr x 0.93 = 2.79 g/bhp-hr
2.79 g/bhp-hr x 15.2 bhp-hr/gal = 42.408 g/gal
42.408 g/gal x 40,000gal/yr = **1,696,320 g/yr**

Part D. Calculate the NO_x Emission Reductions

Use the factors determined in Part B to calculate the NO_x emission reductions for the activity.

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 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.

You must also enter the percentage of annual usage that will occur within the eligible counties. 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 an 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 on that use.

Activity life may not exceed the life of the locomotive. Table 4.2 lists the maximum activity life for locomotives. The minimum activity life is seven years, including leases. The applicant must also commit to using the locomotive in the eligible counties during the activity life of the locomotive.

TABLE 4.2 MAXIMUM CONTRACT ACTIVITY LIFE LOCOMOTIVE ACTIVITIES

	Minimum	Maximum*
New	5 years	20 years
Replacement	5 years	10 years
Repowers	5 years	20 years
Retrofit/Add-on	5 years	20 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 calculation for determining NO_x emission rate reduction based on annual fuel use

Activity: Replacement of a 1965 switcher with a 2008 generation sets switcher.

Baseline emission factor: 14,069,278 g/yr
Reduced emission factor: 1,696,320 g/yr
Percent time in affected counties: 100%

14,069,278 g/yr - 1,696,320 g/yr = 12,372,958 g/yr
12,372,958 g/yr x 1.00 = 12,372,958 g/yr
12,372,958 / 907,200 g/ton = **13.6386 ton/yr**

Step 3: Calculate the 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 = Cost Per Ton of NO_x Reduced

Worksheet LO-1

Annual Fuel Use

Please fill in the following information. This information will help you with your calculations

Base Information

Type of project ☐ New Purchase/Lease ☐ Repower ☐ Replacement ☐ 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) **[default is 20.8 for large line-haul, 18.2 for regional short-haul service, and 15.2 for switching locomotives]**	

Reduced Emission Engine Information

Model Year	
Fuel Type	
Locomotive Type	
Emission Standard (g/bhp-hr)	
Annual Fuel Consumption (gal/yr)	
Energy Consumption Factor (bhp-hr/gal) **[default is 20.8 for large line-haul, 18.2 for regional short-haul service, and 15.2 for switching locomotives]**	
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 COUNTY)

Non Road TxLED Correction Factor*1 - (0.07)*	0.93

PART B. DETERMINE THE NO_X EMISSION FACTOR

Determine Baseline NOx 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 NOx 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)	907200
= 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 COST PER TON?

Grant activity amount ($):	
/ NO_x emission reductions (ton):	
= cost per ton ($/ton)	