ENVIRON

MEMORANDUM

To: David Hitchcock, Director
Sustainable Transportation Programs, HARC

From: Lit Chan, John Grant, Amnon Bar-Ilan, Chris Lindhjem, and Alison Pollack

Date: December 20, 2006

Subject: Commercial Marine Vessel and Locomotive Emission Reductions from TERP in 2007, 2009 and 2012

INTRODUCTION

This memorandum presents results for a subtask of the HARC H72 AB study entitled "On-Road and Non-road Emissions Reductions from TERP in 2010" to document the emission inventories, emission reduction strategies, emission reduction scenarios for commercial marine vessels and locomotives. The outline for this memo is as follows:

- Introduction
- Background
- Commercial Marine and Locomotive Emissions
- Overview of Texas Emissions Reduction Plan
- Data Analysis of TERP Funded Projects for CMVs and Locomotives
- Potential Emission Reduction Strategies for CMVs and Locomotives
- Potential TERP Emission Reductions for CMVs and Locomotives

BACKGROUND

ENVIRON has been retained by the Houston Advanced Research Center (HARC) to conduct a study entitled "On-Road and Non-road Emission Reductions from TERP in 2007, 2009 and 2012" (H72 AB study) to project potential on-road and non-road NOx emission reductions for the TERP for the years 2007, 2009 and 2012 in the Houston-Galveston-Brazoria (HGB) and Dallas Fort-Worth (DFW) areas, and to update the TERP analysis to incorporate the CYs 2005 and 2006 TERP funded projects. The H72 AB study is an extension to the preceding HARC H42 study[1], which assessed the Texas Emissions Reduction Plan (TERP) and quantified the types and numbers of actions that would be necessary to achieve the required levels of NOx reductions from the TERP in the HGB and DFW areas in 2007, as well as to project potential on-road and non-road NOx emissions reductions for the TERP in 2010.

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[1] "On-Road and Non-Road Emission Reductions from TERP in 2007 and 2010 in the Houston, Galveston, and Dallas Fort-Worth Areas," Final Report to Houston Advanced Research Center; ENVIRON International, Novato, CA, January 31, 2005.

The H72 AB study consists of the following main tasks:

- Compile and/or develop 2007, 2009 and 2012 on-road and non-road emission inventories for HGB and DFW areas for TERP analysis;
- Project potential TERP NOx emission reductions for HGB and DFW areas in 2007, 2009 and 2012 based on analysis of the TERP funded projects as of FY 2005;
- Identify emission reduction strategies and develop potential emission reduction scenarios for on-road and non-road equipment for HGB and DFW areas in 2007, 2009, and 2012;
- Prepare a stand-alone report to document the emission inventories, emission reduction strategies, and emission reduction scenarios for commercial marine vessels and locomotives in response to HB 2481; and
- Prepare a report documenting the overall project results via updating Sections 2, 6, 7, and 8 of the H-42 report.

This memorandum presents the emission inventories, emission reduction strategies, and emission reduction scenarios for commercial marine vessels and locomotives in response to HB2481.

COMMERCIAL MARINE AND LOCOMOTIVE NOx EMISSIONS INVENTORIES

Commercial Marine

The 2009 emission inventory for commercial marine vessels in HGB was provided by TCEQ[2]. There are no commercial marine emissions in the DFW area. In order to project the 2012 emission inventory, ENVIRON resourced several relevant reports, including:

- “Improvements to the Commercial Marine Vessel Emission Inventory in the Vicinity of Houston, Texas” prepared by Eastern Research Group & Starcrest Consulting Group LLC for Houston Advanced Research Center. July 28, 2003 Final Draft;
- “Houston-Galveston Area Vessel Emissions Inventory” prepared by Starcrest Consulting Group LLC for Port of Houston Authority & TNRCC (TCEQ). November 2000; and
- “Evaluation of Mobile Source Control Strategies for the Houston-Galveston-Brazoria State Implementation Plan: Measure #88 - California Auxiliary Engine on Ocean-Going Vessels.” Draft Final Report to H-GAC, prepared by ENVIRON, May 2006.

After reviewing and extracting relevant data from these reports, ENVIRON estimated the 2012 Harbor Vessel, Tow boat, and Ocean Going Vessel (OGV) emissions based on a linear regression of the available 1997, 2007 and 2009 data. While existing TERP guidelines will only fund commercial harbor craft, such as tug boats, emission inventories for other commercial marine vessels were also estimated for potential hotelling (dwelling) and transit emission reduction potentials from these vessels. In order to produce the 2012 commercial marine vessel inventory that has a similar format as the TCEQ 2009 commercial marine vessel inventory, an assumption was made that the percentage of emissions by each vessel type within each boat class remained the same in 2007 and 2012 as in 2009. These percentages were then applied to 2007

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[2] "HGB Marine Emission Summary: DRAFT 1 -- FOR DISCUSSION PURPOSES ONLY." Fax received from TCEQ to ENVIRON, May 26, 2006.

and 2012 emissions by boat class in order to disaggregate emissions similar to the TCEQ 2009 commercial marine emission inventory.

The 2007, 2009 and 2012 emission inventories by different vessel types for HGB are provided in Table 1. As shown in this table, the major contributors to the commercial marine vessel emission inventories are oil chemical tankers (about 25-30%), tow boats (18-20%), ocean going vessels (11-14%), bulk cargo vessels (6-7%), and assist tugboats (5-6%) for all 2007, 2009 and 2012. Table 1 also shows that the commercial harbor craft contributes to about 30% of total commercial marine vessel emission inventories in 2007, 2009 and 2012.

In a commercial marine vessel emission inventory study for the HARC, the results presented in the HARC H8 final report indicated that dwelling emissions from large ocean going vessels contributed to about 60% of the in-port NOx emission inventory.[3] Table 2 shows the estimated dwelling (hotelling) emissions for large ocean going marine vessels. As shown in Table 2, dwelling NOx emissions from large ocean going marine vessels are estimated to be about 16 to 18 tpd in the HGB area, and dwelling emissions by individual vessel type to range from 0.6 tpd to more than 7 tpd.

Table 1. Commercial marine emission inventories by different vessel types for HGB in 2007, 2009 and 2012.

Vessel Types	NOx Emissions (tpd)		
	2007	2009	2012
Commercial Harbor Craft			
Assist Tugboats	1.8	2.3	2.3
Ferries	0.9	1.2	1.2
Dredges	0.5	0.6	0.6
Barge Pumps	1.0	1.3	1.3
Towboats	7.3	9.0	8.3
Commercial Harbor Craft Total	**11.5**	**14.4**	**13.8**
Large Ocean Going Vessels			
Ocean-going Vessels	4.6	5.0	5.3
Bulk Cargo Vessels	2.4	2.7	2.8
General Cargo Vessels	4.1	4.4	4.7
Container Ships	1.4	1.5	1.6
Liquified Gas Carriers	1.7	1.9	2.0
Oil Chemical Tankers	10.4	11.2	11.9
Other OGV	0.9	1.0	1.1
Cruise Ships	1.3	1.4	1.5
Large OGVs Total	**26.8**	**29.1**	**30.9**
CMV Total	**38.3**	**43.5**	**44.6**

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[3] "Improvements to the Commercial Marine Vessel Emission Inventory in the Vicinity of Houston, Texas" Draft Final Report to Houston Advanced Research Center, prepared by Eastern Research Group & Starcrest Consulting Group LLC, July 28, 2003.

Table 2. Dwelling or hotelling emissions estimated for large ocean going marine vessels by different vessel types for HGB in 2007, 2009 and 2012.

Vessel Types	NOx Emissions (tpd)		
	2007	**2009**	**2012**
Ocean-going Vessels	2.8	3.0	3.2
Bulk Cargo Vessels	1.5	1.6	1.7
General Cargo Vessels	2.4	2.7	2.8
Container Ships	0.8	0.9	0.9
Liquified Gas Carriers	1.0	1.1	1.2
Oil Chemical Tankers	6.2	6.7	7.2
Other OGV	0.6	0.6	0.6
Cruise Ships	0.8	0.8	0.9
Total	**16.1**	**17.5**	**18.5**

Locomotive

For the HARC H42 study, TCEQ provided the 2002, 2007, and 2010 locomotive emission inventories for locomotives in the HGB and DFW areas. ENVIRON interpolated between HARC H42 study's 2007 and 2010 emissions inventories to obtain the 2009 inventory. The 2012 emission inventory was projected by extending to 2012 the growth rate used to estimate the 2010 emissions inventory from the 2007 emissions inventory. The 2007 to 2010 growth rate provided by TCEQ was 1.070. Consistent with HARC H42 study's methodology[4], switching locomotive emissions were assumed to account for 17.3% of the total locomotive emissions in based on the national fraction of switching engines. Default by tier activity and emission factors from EPA, 1998[5] were used to estimate by tier line haul and switching locomotive NOx emissions.

In a 2006 locomotive emission inventory study for the HARC[6], the results presented in the HARC H18 final report indicated that switching locomotives contributed to about 30% and 25% of the 2003 locomotive emission inventories in the HGB and DFW areas, respectively. These percentages were also used in this H72 AB study to project line haul and switching locomotive emission inventories in HGB and DFW areas in 2007, 2009 and 2012.

The 2007, 2009 and 2012 line haul and switching locomotive emission inventories by engine type are provided in Table 3 and Table 4 for DFW and HGB, respectively. Figure 1 and Figure 2 depict graphically by tier locomotive emissions for the DFW and HGB, respectively, based on the line-haul and switching locomotive emission proportions as reported in the HARC H18 study. As shown in Figures 1 and 2, base engines are the greatest contributors to locomotive emissions in 2007 and 2009 in the DFW and HGB, accounting for 90% and 59% of NOx emissions from line haul and switching locomotives, respectively in 2007 and 63% and 48% of

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[4] "On-Road and Non-Road Emission Reductions from TERP in 2007 and 2010 in the Houston, Galveston, and Dallas Fort-Worth Areas," Final Report to Houston Advanced Research Center; ENVIRON International, Novato, CA, January 31, 2005.

[5] EPA 1998. Locomotive Emission Standards Regulatory Support Document. April, 1998.

[6] "Texas Railroad Emission Inventory Model (TREIM) and Results," Memorandum to TCEQ and HARC, prepared by ERG, March 9, 2006. http://files.harc.edu/Projects/AirQuality/Projects/H018A.2004.T1/H18A-2004-T1FinalReport.pdf

NOx emissions from line haul and switching locomotives, respectively in 2009. Also shown in Figures 1 and 2, Tier 0 engines are the greatest contributors to locomotive emissions in 2012 in the DFW and HGB, accounting for 69% and 62% of NOx emissions from line haul and switching locomotives, respectively.

Table 3. DFW locomotive NOx emission inventories in 2007, 2009 and 2012 with different line haul and switching locomotive fractions.

Calendar Year	Engine Type	NOx Emissions (tpd)					
		Line-Haul	Switching	Total	Line-Haul	Switching	Total
		National Line-Haul/Switching Emissions as Proportioned Based on 1997 EPA Study			National Line-Haul/Switching Emissions as Proportioned Based on HARC H18 Study		
2007	**Base**	19.21	2.65	21.86	16.34	5.52	21.86
	Tier 0	2.17	1.55	3.72	2.78	0.94	3.72
	Tier 1	0.00	0.10	0.10	0.07	0.03	0.10
	Tier 2	0.00	0.17	0.17	0.12	0.04	0.17
	TOTAL	**21.38**	**4.47**	**25.84**	**19.32**	**6.53**	**25.84**
2009	**Base**	14.04	2.22	16.27	12.16	4.11	16.27
	Tier 0	6.97	2.09	9.06	6.77	2.29	9.06
	Tier 1	1.35	0.11	1.46	1.09	0.37	1.46
	Tier 2	0.00	0.25	0.25	0.19	0.06	0.25
	TOTAL	**22.36**	**4.67**	**27.03**	**20.21**	**6.83**	**27.03**
2012	**Base**	2.66	1.36	4.01	3.00	1.01	4.01
	Tier 0	16.49	3.09	19.58	14.63	4.95	19.58
	Tier 1	2.53	0.13	2.66	1.98	0.67	2.66
	Tier 2	2.25	0.42	2.67	2.00	0.67	2.67
	TOTAL	**23.92**	**5.00**	**28.92**	**21.62**	**7.30**	**28.92**

Table 4. HGB locomotive NOx emission inventories in 2007, 2009 and 2012 with different line haul and switching locomotive fractions.

Calendar Year	Engine Type	NOx Emissions (tpd)					
		Line	Switching	Total	Line	Switching	Total
		National Line-Haul/Switching Emissions as Proportioned Based on 1997 EPA Study			National Line-Haul/Switching Emissions as Proportioned Based on HARC H18 Study		
2007	**Base**	15.15	2.09	17.23	12.12	5.12	17.23
	Tier 0	1.71	1.22	2.93	2.06	0.87	2.93
	Tier 1	0.00	0.08	0.08	0.06	0.02	0.08
	Tier 2	0.00	0.13	0.13	0.09	0.04	0.13
	TOTAL	**16.86**	**3.52**	**20.38**	**14.33**	**6.05**	**20.38**
2009	**Base**	11.07	1.75	12.83	9.02	3.81	12.83
	Tier 0	5.49	1.65	7.14	5.02	2.12	7.14
	Tier 1	1.06	0.09	1.15	0.81	0.34	1.15
	Tier 2	0.00	0.20	0.20	0.14	0.06	0.20
	TOTAL	**17.63**	**3.68**	**21.32**	**14.98**	**6.33**	**21.32**
2012	**Base**	2.10	1.07	3.17	2.22	0.94	3.17
	Tier 0	13.00	2.44	15.44	10.85	4.59	15.44
	Tier 1	1.99	0.10	2.09	1.47	0.62	2.09
	Tier 2	1.77	0.33	2.11	1.48	0.63	2.11
	TOTAL	**18.86**	**3.94**	**22.80**	**16.03**	**6.77**	**22.80**

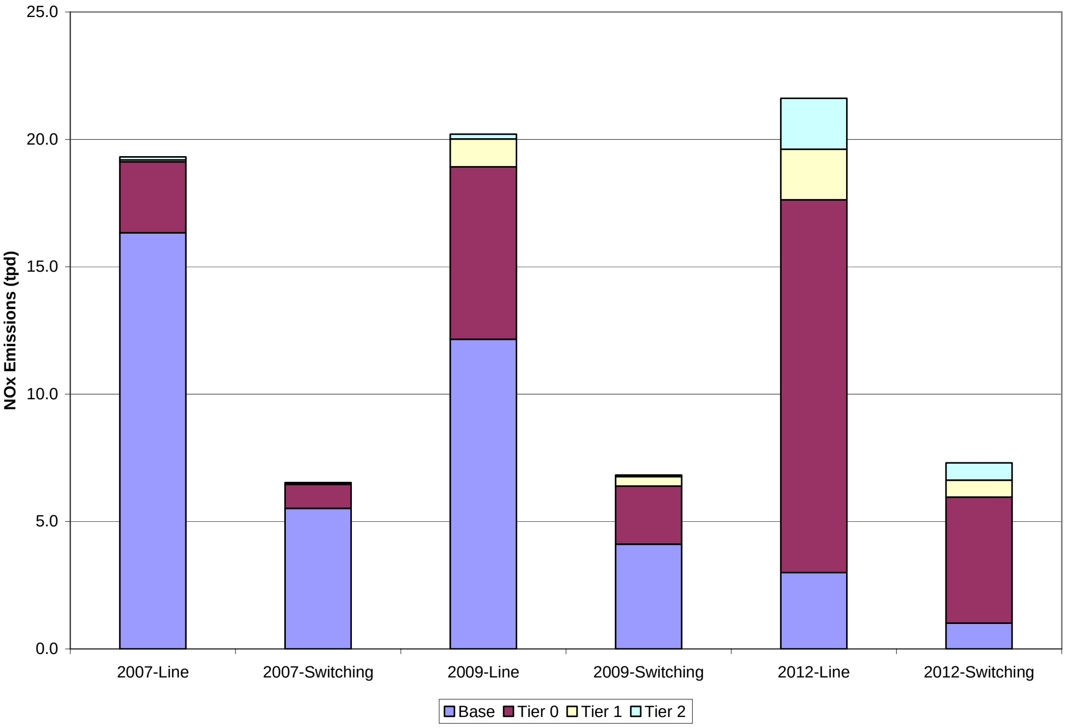

Figure 1. DFW Locomotive NOx emissions by engine type with the HARC H18 line-haul and switching locomotive fraction.

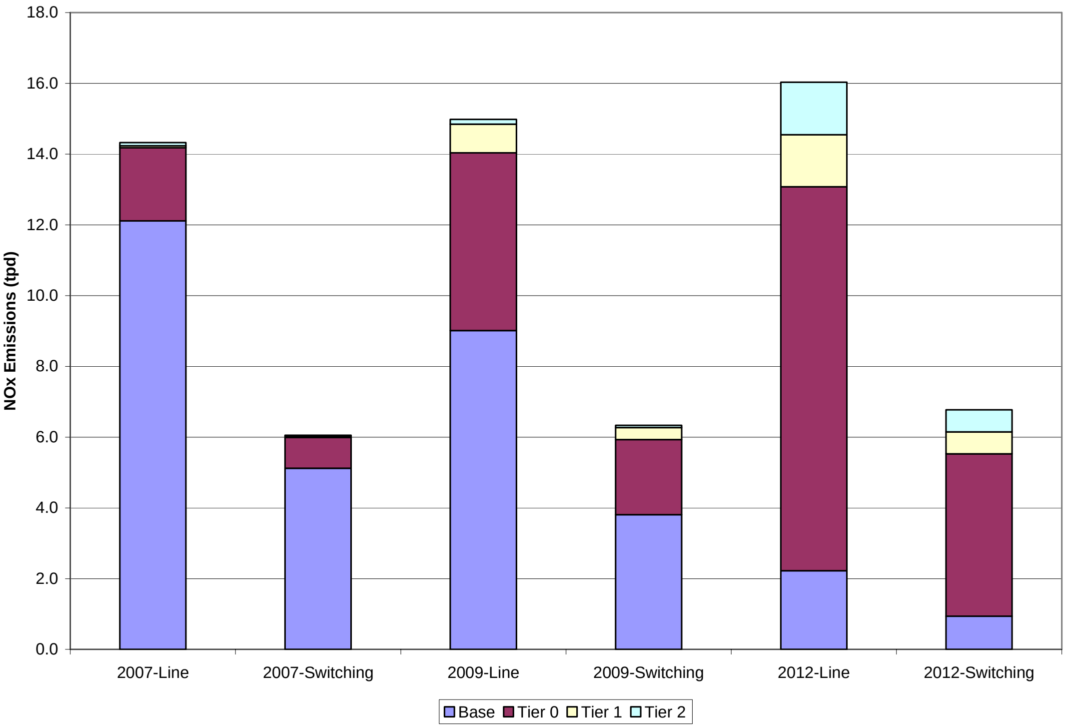

Figure 2. HGB Locomotive NOx emissions by engine type with the HARC H18 line-haul and switching locomotive fraction.

TEXAS EMISSIONS REDUCTION PLAN

Overview

The 77th Texas Legislature established the TERP in 2001 through enactment of Senate Bill (SB) 5. The TERP includes a number of voluntary financial incentive programs, as well as other assistance programs, to help improve Texas air quality. The primary purpose of the TERP program is to reduce NOx emissions through voluntary incentive programs, mainly from heavy-duty on and non-road vehicles and equipment in the HGB and DFW ozone nonattainment areas. The emission reductions from the TERP are intended to replace reductions that would have been achieved through two mandatory measures that SB5 directed the Texas Commission of Environmental Quality (TCEQ) to remove from the 2001 One-Hour Ozone SIP revisions for the HGB and DFW ozone nonattainment areas. The two repealed mandatory measures were the construction equipment restriction and the accelerated purchase of Tier 2/3 Diesel equipment, in which the NOx reduction expected from these measures totaled 18.9 tons per day (tpd) and 16.3 tpd for the HGB and DFW areas, respectively. In addition, the TERP incentives were also intended to achieve 14 to 20 tpd of NOx reduction out of the 56 tpd of remaining NOx reduction gap in the 2001 One-Hour Ozone SIP for the HGB area. Thus, the TERP was intended to reduce NOx emissions by 32.9 to 38.9 tons per day in the HGB area, and 16.3 tpd in the DFW area.

The 2004 SIP revision for HGB listed non-road and on-road TERP NOx emission benefits of 35.9 and 3 tpd, respectively, for a total TERP emission reduction of 38.9 tpd.[7] As for the DFW, the 2005 5 Percent Increment of Progress Demonstration (5% IOP) 8-Hour Ozone SIP for DFW listed a total TERP NOx emission benefit of 22.2 tpd in the DFW area in 2007[8]. Thus, the TERP goal of 38.9 tpd, as reported in the 2004 SIP for the HGB area, and the TERP goal of 22.2 tpd, as reported in the 2005 5% IOP SIP for the DFW area, are referred as the 2007 SIP goals for the TERP in this study.

The TERP is funded through revenues deposited in the Emission Reduction Plan Fund, which consists of fees and surcharges established by the SB5. Since then, the guidelines of the TERP have been amended in 2003 by HB 1365 and in 2005 by HB 2481 and HB 3469.

Notable TERP amendments in the HB 1365 included expanded affected TERP counties; inclusions of stationary engines and non-diesel vehicles or equipment; and revised funding allocation.

As for HB 2481, notable TERP amendments included the followings:

- Continuation and provisions of the TERP and the use of funding currently dedicated to TERP to after the then sunset period of September 1, 2008;
- Assessments of emission reduction potentials, strategies, and cost effectiveness of reducing emissions from locomotives and commercial marine vessels; and
- Recommendation to adopt a rebate grant program to streamline the approval of grant applications of standardized projects.

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[7] http://www.tceq.state.tx.us/implementation/air/sip/dec2004hgb_mcr.html
[8] http://www.tceq.state.tx.us/implementation/air/sip/apr2005dal_iop.html

The major TERP amendment in the HB 3469 was the establishment of a specific program to reduce emissions from diesel school buses via the TERP.

Through SB 5, the TERP was expected to receive approximately $130 million per fiscal year through September 1, 2008.[9] The HB 2481 extended the TERP funding to September 1, 2010. The TERP provides grants or financial incentives for cleaner on- and off-road engines, and for research and development of new technologies. The TCEQ administers the TERP grants and other TERP financial incentives.

As part of the TERP, the Emission Reduction Incentive Grant (ERIG) Program and the new Emission Reduction Rebate Grant (ERRG) Program each provide monetary grants to eligible projects in nonattainment areas and affected counties, including the HGB and DFW areas. The grants offset the incremental costs associated with reducing NOx emissions from high emitting internal combustion engines from on-road vehicles, non-road equipment, marine vessels, locomotives or stationary engines that are used at least 75% of the time within the eligible counties.

TERP General Guidelines

The guidelines for TERP were laid out in Senate Bill 5, and later amended by the HB 1365, HB 2481 and HB 3469. TCEQ published draft guidelines for the Emissions Reduction Incentive Grants Program in October 2003 and final guidelines in May 2004[10], as well as revised guidelines in HB 1365, HB 2481 and HB 3469.

According to these bills, TERP funds are to be distributed as follows:

- 87.5% (64% effective as of September 1, 2008) for diesel emission reduction incentive programs, of which not more than 10% may be used for on-road diesel purchase or lease incentives;
- 9.5% (33% effective as of September 1, 2008) for new technology and research; and
- 3% for administration costs.

In general, the guidelines specify that the TERP must meet the following conditions:

- On-road heavy-duty vehicles with gross vehicle weight ratings (GVWR) of 8,500 lbs or more;
- Non-road equipment with engine size of 25 hp or greater;
- Marine vessels with engine size of 25 hp or greater;
- Locomotives;

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[9] For the first year of the program (fiscal year 2002), the TERP received only $20.5 million as a result of a court's decision on the out-of-state vehicle inspection fee, as well as reduced revenue received for the construction equipment.

[10] "Texas Emissions Reduction Plan: Guidelines for Emissions Reduction Incentive Grants," RG-388, Texas Commission on Environmental Quality, Austin, TX, May 2004. http://www.tceq.state.tx.us/comm_exec/forms_pubs/pubs/rg/rg-388.html

- Stationary equipment with engine size of 25 hp or greater that are not covered by permit requirement[11];
- On-vehicle electrification and idle reduction infrastructure;
- On-site electrification and idle reduction infrastructure;
- Qualifying fuel infrastructure;
- 75% of the activity occurs within the eligible 41 counties, including those counties in the HGB and DFW areas;
- Cost effectiveness limit is $13,000 per ton of NOx reduced but recent solicitations specify grant request must not exceed $2,500 per ton of NOx reduced for locomotive and marine vessel applications, and $5,000 per ton of NOx reduced for other applications[12]; and
- For retrofits or add-ons, the system must be certified or verified to emit at least 25% less NOx than the engine prior to the retrofit or add-on (certification or verification means approved by the EPA, CARB, or otherwise accepted by the TCEQ).

The TERP funds eligible projects via new purchases, repowers, replacement cleaner equipment/engines, or retrofit with emission control systems. On a case-by-case basis, the TERP also funds demonstration programs for low-emission repower, retrofit or advanced technologies for on-road heavy-duty vehicles, and non-road equipment.

DATA ANALYSIS OF TERP FUNDED/RECOMMENDED PROJECTS

Since the establishment of TERP, TCEQ has completed grant application and selection processes for funding for FYs 2002 to 2006 via the Emission Reduction Incentive Grant (ERIG) Program and the new Emission Reduction Rebate Grant (ERRG) Program. In addition, TCEQ has also awarded 3rd party grants to the North Central Texas Council of Governments (NCTCOG) in FY 2005, and The Railroad Commission of Texas (RRC) in FYs 2004 to 2006.

As projects close and usage reports are received, TCEQ updates the TERP-funded/approved projects periodically to reflect revised emission reductions estimated as per TERP guidelines. The TERP data analysis and assessment results for this HARC H72 AB study were based on the FYs ’02 to ’05 data, and FY ‘06 Round 1 data provided to ENVIRON by TCEQ on August 28, 2006. FY ’06 Round 2 data were provided to ENVIRON by TCEQ on October 3, 2006, and the 3rd party grant data were provided to ENVIRON by TCEQ on September 11, 2006.

Information provided by TCEQ for the 3rd party grant awarded to NCTCOG was about $12.8 million for various projects, including truck stop electrification/idle reduction with IdleAire technologies for about $5.5 million and ShurePower technology for about $0.2 million; refuse hauler projects for about $1.6 million; and other open TERP-eligible projects for about $ 5.6 million. According to TCEQ, NCTCOG is working on technical and/or contractual issues with those two truck stop electrification/idling reduction projects, as well as actively conducting

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[11] According to the TERP Guidelines, RG-388, stationary engine is defined as an internal combustion engine used either in a fixed application or in a portable (transportable) application in which the engine will stay at a single site for at least a full year (12 consecutive months). The TCEQ will make the final determination of the type of engine.

[12] According to the TERP Guidelines RG388, cost-effectiveness is defined as the total dollar amount expended, adjusted using a discount rate of 3 percent per year, divided by the total number of tons of reductions in nitrogen oxide emissions attributable to that expenditure.

"open" call for projects on a weekly basis to solicit TERP-eligible projects. As of September 11, 2006, the funded projects data provided by TCEQ on the NCTCOG's 3rd party grants were for the refuse hauler project for about $1.6 million. Also, TCEQ indicated that the Railroad Commission of Texas has been awarded 3rd party grants of $1 million in FY '04, $3 million in FY '05, and $4 million in FY '06. TCEQ's data show that, as of September 11, 2006, RRC has funded a total of about $3 million worth of projects with about $1 million each in the HGB and DFW areas, and the remaining for other counties. Only the 3rd party grant funded projects provided by TCEQ were included in the TERP analysis.

Summarized results of the TERP funded projects for FYs '02 to '06 are provided in Table 5. As shown in Table 5, the NOx emission reductions to date were about 23.1 and 14.1 tpd for the HGB and DFW areas, respectively[13]. The TERP NOx emission reductions by years for the HGB and DFW areas are graphically shown in Figure 3. Table 5 shows that the total TERP funding to date for the HGB and DFW areas was about $211.4 and $119.5 million, respectively.

Figure 4 shows the TERP funding by years for the HGB and DFW areas. It should be noted that the actual TERP funding in FY '05 of $110.2 million and $52.2 million was higher than TCEQ's projected funding of $74.4 million and $37.6 million for HGB and DFW areas, respectively[14], and the FY 2005 Grants Allocation Concept.[15] However, TERP funding in FY '06 of $55.7 million and $31.1 million was lower than the projected funding of $71.6 million and $36.2 million for HGB and DFW areas, respectively[14]. Overall, the total FY 05 and 06 actual TERP funding of $165.9 million and $83.3 million was higher than the TCEQ's projected funding of $146.0 million and $73.8 million for HGB and DFW areas, respectively. Given that TCEQ projected NOx emission reductions with funding through FY 05 were 21.5 tpd and 13.5 tpd for HGB and DFW areas, respectively, indicating that TCEQ projected much higher emission reductions for less funding.

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[13] TCEQ estimated the emission reductions in tons per day based on a 250 working day per year basis.
[14] http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/sfr/079_04.pdf
[15] http://www.tceq.state.tx.us/assets/public/implementation/air/terp/erig/ws08_16_04spreadsheet.pdf

Table 5. Summary of TERP funded/recommended projects to date in the HGB and DFW areas (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

	HGB	DFW	HGB&DFW
NOx Emissions Reduction (tpd)			
FY 02	0.2	0.6	0.9
FY 03	1.0	0.3	1.3
FY 04	3.0	2.7	5.7
FY 05	11.8	4.8	16.7
FY 06	6.9	5.2	12.1
3rd Party	0.1	0.4	0.5
Total to Date	**23.1**	**14.1**	**37.1**
2007 SIP Goal	**38.9**	**22.2**	**61.1**
TERP Funding ($MM)			
FY 02	3.1	8.6	11.7
FY 03	12.3	1.5	13.8
FY 04	29.2	23.6	52.8
FY 05	110.2	52.2	162.4
FY 06	55.7	31.1	86.7
3rd Party	1.0	2.5	3.5
Total to Date	**211.4**	**119.5**	**330.9**
TERP Projects			
FY 02	25	9	34
FY 03	17	10	27
FY 04	57	75	132
FY 05	160	112	272
FY 06	300	141	441
3rd Party	48	20	68
Total to Date	**607**	**367**	**974**
TERP Activities			
FY 02	109	395	504
FY 03	252	21	273
FY 04	523	392	915
FY 05	927	746	1673
FY 06	909	415	1324
3rd Party	142	590	732
Total to Date	**2,862**	**2,559**	**5,421**
TERP Cost Effectiveness			
FY 02	$10,171	$7,019	$7,639
FY 03	$7,896	$2,836	$6,593
FY 04	$6,379	$5,124	$5,750
FY 05	$3,911	$3,626	$3,815
FY 06	$3,236	$2,949	$3,127
3rd Party	$4,858	$4,642	$4,700
Total to Date	**$4,064**	**$3,753**	**$3,946**
TERP Total NOx Emissions Reductions (tons)			
FY 02	300	1,226	1,526
FY 03	1,556	540	2,097
FY 04	4,583	4,604	9,186
FY 05	28,172	14,402	42,574
FY 06	17,200	10,538	27,738
3rd Party	197	544	742
Total to Date	**52,009**	**31,854**	**83,862**

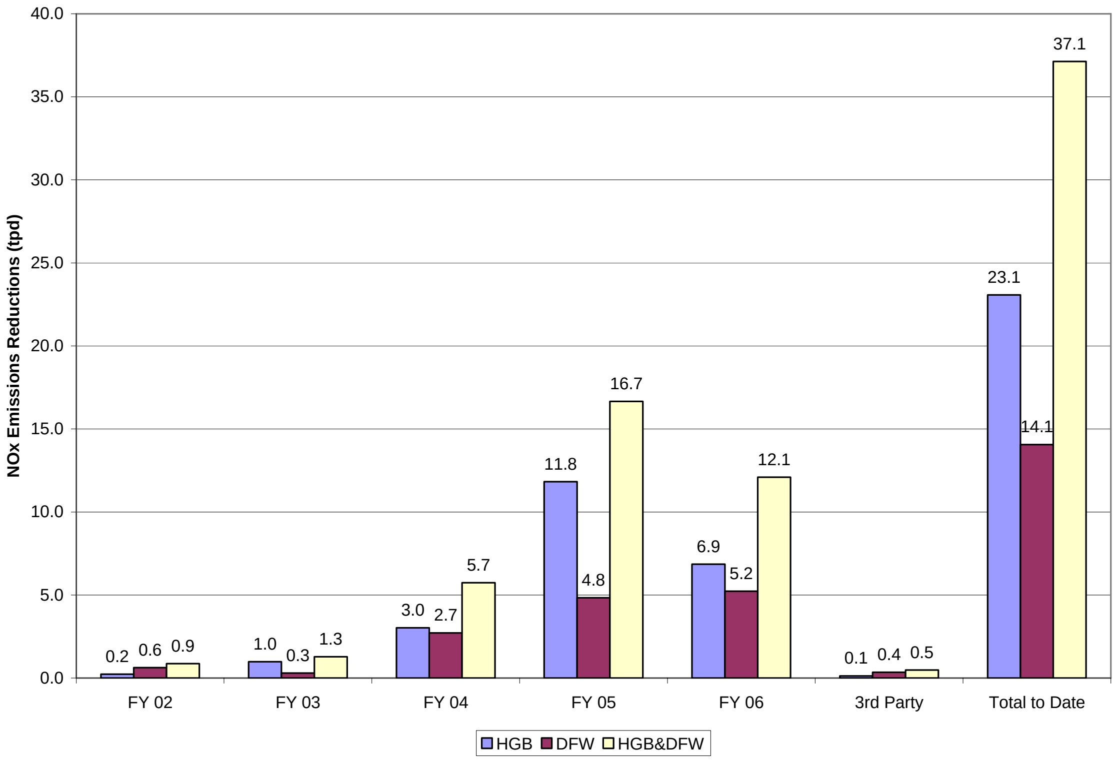

Figure 3. TERP NOx emission reductions for the HGB and DFW areas (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

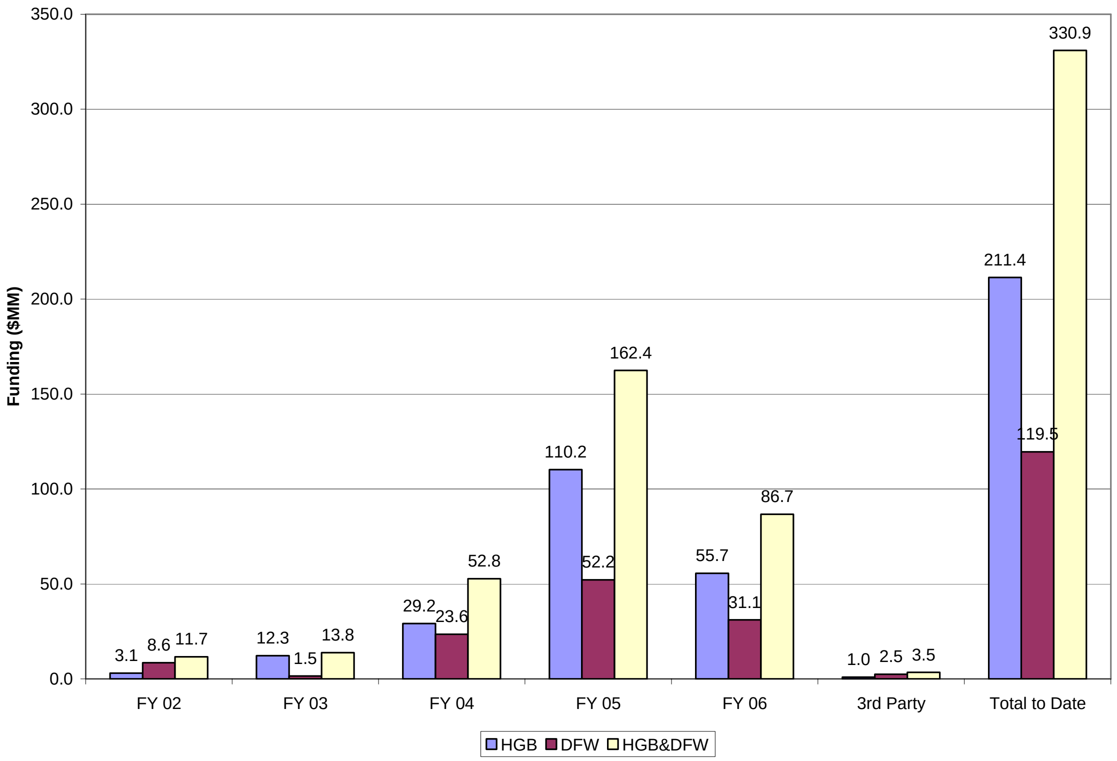

Figure 4. TERP funding for the HGB and DFW areas (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Table 6. Summary of TERP funded/approved projects to date in the HGB and DFW areas by emission sources (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Types of Projects	Funding ($MM)	NOx Reduction (tpd)	Avg. Cost Effectiveness ($/Ton)
FY 02 to 06 & 3rd Party Projects by Type - HGB and DFW			
Railroad Projects	$141.8	12.25	$3,753
Commercial Marine Vessels	$28.7	4.61	$3,185
Non-road Vehicles and Equipment	$61.4	7.65	$5,180
On-road Vehicles	$94.6	11.29	$4,138
Stationary Sources	$4.4	1.33	$1,868
Total	**$330.9**	**37.13**	**$3,946**
FY 06 (1st & 2nd round only) Projects by Type - HGB & DFW			
Railroad Projects	$30.0	3.91	$2,472
Commercial Marine Vessels	$7.3	1.22	$2,135
Non-road Vehicles and Equipment	$14.6	2.21	$3,769
On-road Vehicles	$31.2	3.48	$5,117
Stationary Sources	$3.7	1.27	$1,653
Total	**$86.7**	**12.09**	**$3,127**
FY 05 Projects by Type - HGB & DFW			
Railroad Projects	$93.2	6.47	$4,300
Commercial Marine Vessels	$16.6	2.87	$3,541
Non-road Vehicles and Equipment	$15.0	1.91	$5,030
On-road Vehicles	$37.0	5.35	$2,815
Stationary Sources	$0.7	0.06	$6,790
Total	**$162.4**	**16.66**	**$3,815**
FY 04 Projects by Type - HGB & DFW			
Railroad Projects	$18.4	1.86	$4,600
Commercial Marine Vessels	$4.5	0.49	$5,223
Non-road Vehicles and Equipment	$25.6	2.77	$6,751
On-road Vehicles	$4.4	0.61	$8,090
Stationary Sources	$0.0	0.00	$2,849
Total	**$52.8**	**5.74**	**$5,750**
FY 03 Projects by Type - HGB & DFW			
Non-road Vehicles and Equipment	$2.0	0.26	$3,444
On-road Vehicles	$11.9	1.02	$7,773
Total	**$13.8**	**1.28**	**$6,593**
FY 02 Projects by Type - HGB & DFW			
Railroad Projects	$0.3	0.00	-
Commercial Marine Vessels	$0.3	0.02	$6,183
Non-road Vehicles and Equipment	$2.4	0.21	$9,401
On-road Vehicles	$8.7	0.63	$7,104
Total	**$11.7**	**0.87**	**$7,639**
3rd Party Projects by Type - HGB & DFW			
Non-road Vehicles and Equipment	$1.9	0.28	$4,877
On-road Vehicles	$1.6	0.20	$4,498
Total	**$3.5**	**0.48**	**$4,700**

Table 7. Summary of TERP funded/approved projects to date in the HGB area by emission sources (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Types of Projects	**Funding ($MM)**	**NOx Reduction (tpd)**	**Avg. Cost Effectiveness ($/Ton)**
FY 02 to 06 & 3rd Party Projects by Type – HGB			
Railroad Projects	$83.2	6.38	$3,870
Commercial Marine Vessels	$28.7	4.61	$3,185
Non-road Vehicles and Equipment	$38.2	4.59	$5,469
On-road Vehicles	$61.2	7.47	$4,222
Stationary Sources	$0.1	0.01	$4,241
Total	**$211.4**	**23.07**	**$4,064**
FY 06 (1st & 2nd round only) Projects by Type - HGB			
Railroad Projects	$18.4	2.06	$2,456
Commercial Marine Vessels	$7.3	1.22	$2,135
Non-road Vehicles and Equipment	$9.9	1.33	$4,267
On-road Vehicles	$20.0	2.27	$5,054
Stationary Sources	$0.0	0.00	NA
Total	**$55.7**	**6.86**	**$3,236**
FY 05 Projects by Type - HGB			
Railroad Projects	$55.4	3.67	$4,429
Commercial Marine Vessels	$16.6	2.87	$3,541
Non-road Vehicles and Equipment	$11.4	1.40	$5,128
On-road Vehicles	$26.7	3.86	$3,057
Stationary Sources	$0.1	0.01	$4,621
Total	**$110.2**	**11.82**	**$3,911**
FY 04 Projects by Type - HGB			
Railroad Projects	$9.0	0.65	$6,135
Commercial Marine Vessels	$4.5	0.49	$5,223
Non-road Vehicles and Equipment	$14.0	1.56	$6,795
On-road Vehicles	$1.8	0.32	$8,958
Stationary Sources	$0.0	0.00	$2,849
Total	**$29.2**	**3.02**	**$6,379**
FY 03 Projects by Type - HGB			
Non-road Vehicles and Equipment	$0.7	0.04	$13,224
On-road Vehicles	$11.6	0.95	$7,714
Total	**$12.3**	**0.99**	**$7,896**
FY 02 Projects by Type - HGB			
Railroad Projects	$0.3	0.00	NA
Commercial Marine Vessels	$0.3	0.02	$6,183
Non-road Vehicles and Equipment	$1.3	0.13	$9,321
On-road Vehicles	$1.1	0.09	$10,663
Total	**$3.1**	**0.24**	**$10,171**
3rd Party Projects by Type - HGB			
Non-road Vehicles and Equipment	$1.0	0.13	$4,858
On-road Vehicles	$0.0	0.00	NA
Total	**$1.0**	**0.13**	**$4,858**

Table 8. Summary of TERP funded/approved projects to date in the DFW area by emission sources (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Types of Projects	Funding ($MM)	NOx Reduction (tpd)	Avg. Cost Effectiveness ($/Ton)
FY 02 to 06 & 3rd Party Projects by Type - DFW			
Railroad Projects	$58.6	5.87	$3,598
Commercial Marine Vessels	$0.0	0.00	NA
Non-road Vehicles and Equipment	$23.2	3.06	$4,766
On-road Vehicles	$33.4	3.82	$3,994
Stationary Sources	$4.3	1.31	$1,848
Total	**$119.5**	**14.06**	**$3,753**
FY 06 (1st & 2nd round only) Projects by Type - DFW			
Railroad Projects	$11.5	1.86	$2,498
Commercial Marine Vessels	$0.0	0.00	NA
Non-road Vehicles and Equipment	$4.7	0.89	$3,024
On-road Vehicles	$11.1	1.21	$5,235
Stationary Sources	$3.7	1.27	$1,653
Total	**$31.1**	**5.23**	**$2,949**
FY 05 Projects by Type - DFW			
Railroad Projects	$37.7	2.80	$4,123
Commercial Marine Vessels	$0.0	0.00	NA
Non-road Vehicles and Equipment	$3.6	0.50	$4,740
On-road Vehicles	$10.3	1.49	$2,338
Stationary Sources	$0.6	0.04	$7,203
Total	**$52.2**	**4.84**	**$3,626**
FY 04 Projects by Type - DFW			
Railroad Projects	$9.4	1.21	$3,708
Commercial Marine Vessels	$0.0	0.00	NA
Non-road Vehicles and Equipment	$11.6	1.21	$6,698
On-road Vehicles	$2.6	0.29	$7,594
Stationary Sources	$0.0	0.00	NA
Total	**$23.6**	**2.72**	**$5,124**
FY 03 Projects by Type - DFW			
Non-road Vehicles and Equipment	$1.3	0.22	$2,474
On-road Vehicles	$0.2	0.08	$12,189
Total	**$1.5**	**0.30**	**$2,836**
FY 02 Projects by Type - DFW			
Railroad Projects	$0.0	0.00	NA
Commercial Marine Vessels	$0.0	0.00	NA
Non-road Vehicles and Equipment	$1.1	0.08	$9,498
On-road Vehicles	$7.5	0.55	$6,765
Total	**$8.6**	**0.63**	**$7,019**
3rd Party Projects by Type - DFW			
Non-road Vehicles and Equipment	$1.0	0.15	$4,897
On-road Vehicles	$1.6	0.20	$4,498
Total	**$2.5**	**0.35**	**$4,642**

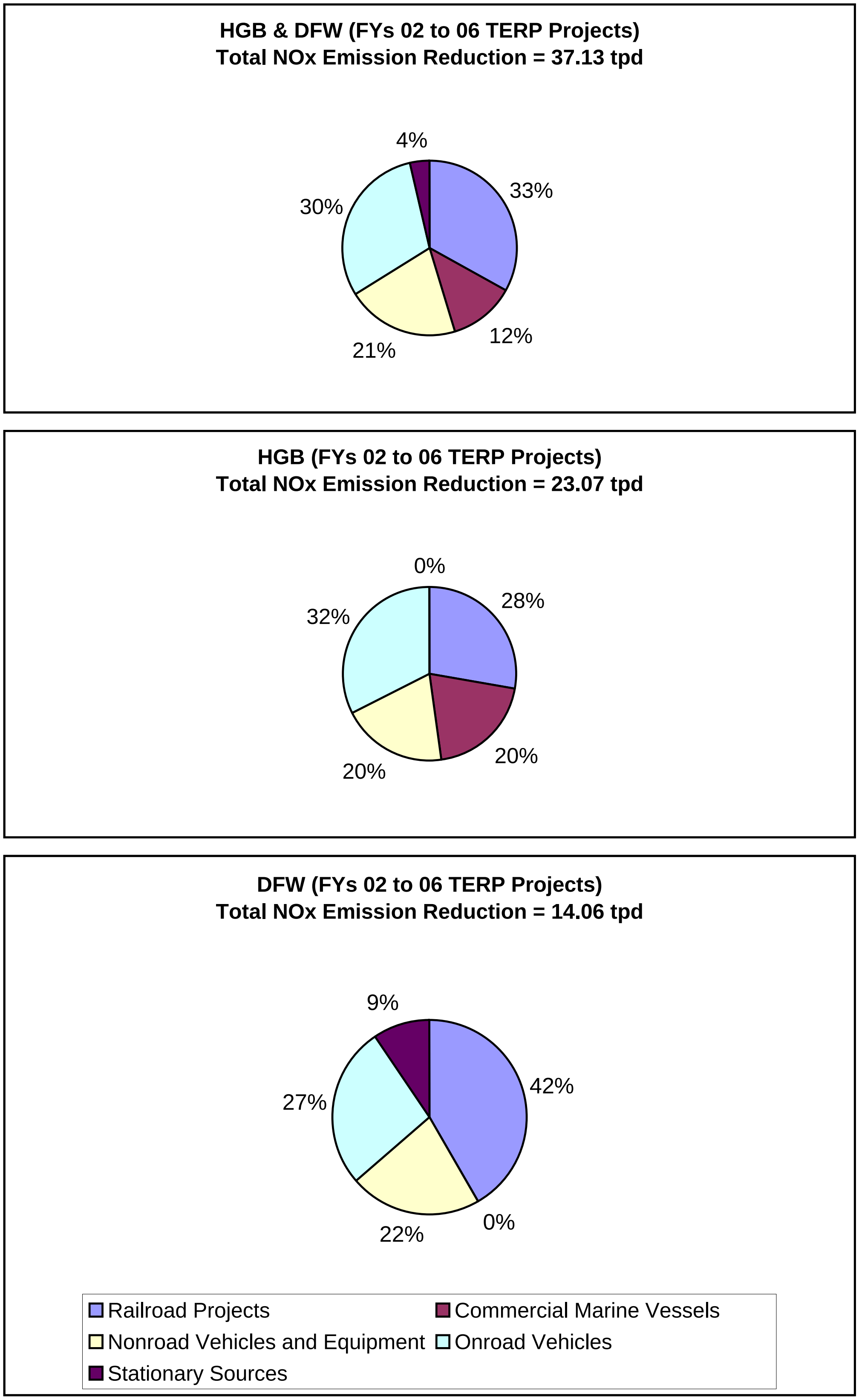

Figure 5. TERP emission reductions by sources for the HGB and DFW areas (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Tables 6 to 8 show the TERP funded/approved projects to date by emission sources in the combined HGB and DFW areas, HGB and DFW areas, respectively. As shown in Figure 5, about 33% of the TERP emission reductions through FY '06 in combined HGB and DFW areas were from locomotive projects. Marine vessel projects contributed to about 12%, on-road and non-road equipment projects contributed to about 30 to 21%, respectively, and the remaining of about 4% reductions were from stationary engine projects.

Table 6 shows that the overall average cost-effective value for the funded projects for the combined HGB and DFW areas was less than $ 4,000 per ton of NOx reduced. The most cost-effective projects were those for stationary engine projects at an average of about $1,900 per ton of NOx reduced, following by commercial marine vessel projects at an average of about $3,200 per ton, locomotive projects at an average of about $3,800 per ton, on-road projects at an average of about $4,100 per ton, and non-road projects at an average of about $5,200 per ton of NOx reduced.

For the HGB area, Figure 5 shows that about 32% of the TERP emission reductions through FY '06 were from on-road projects, following by 28% from locomotive projects, 20% each from non-road and marine vessel projects, and less than 0.1% from stationary engine projects. As shown in Table 7, the overall average cost-effective value for the funded projects for the HGB area was about $4,100 per ton of NOx reduced. The most cost-effective projects were from the marine vessels at an average of about $3,200 per ton of NOx reduced, following by about $3,900 per ton for locomotive projects, about $4,200 per ton for on-road and stationary engine projects, and about $5,500 per ton of NOx reduced for non-road projects.

Figure 5 also shows that about 42% of the TERP emission reductions through FY '06 in the DFW area were from railroad projects, following by about 27% from on-road projects, 22% from the non-road projects, and 9% from the stationary engine projects. Table 8 shows that the overall average cost-effective value for the funded projects for the DFW area was about $3,800 per ton of NOx reduced. The most cost-effective projects in the DFW area were from stationary engine projects at an average of about $1,900 per ton of NOx reduced, following by about $3,600 per ton for locomotive projects, $4,000 per ton for on-road projects, and $4,800 for non-road projects.

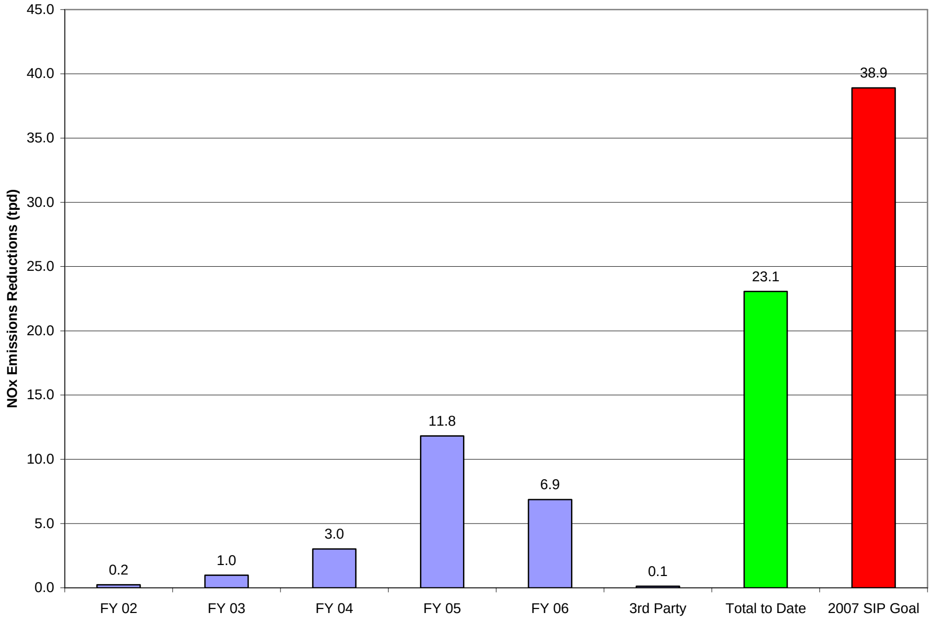

Figure 6. TERP NOx emission reductions to date vs. the 2007 SIP TERP goal in the HGB area (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

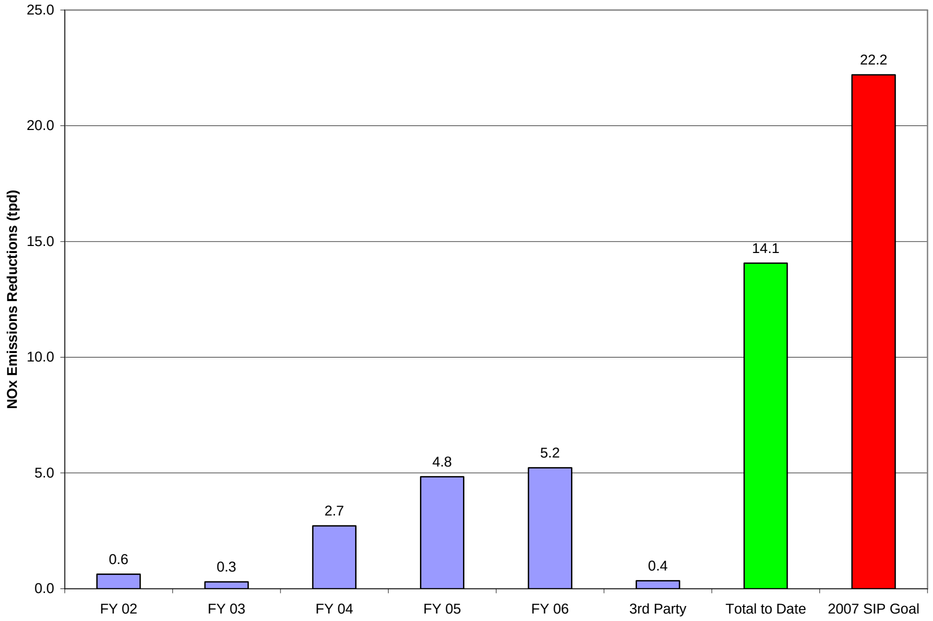

Figure 7. TERP NOx emission reductions to date vs. the 2007 SIP TERP goal in the DFW area (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Figures 6 and 7 compare the NOx emission reductions to date to the 2007 SIP TERP goals in the HGB and DFW areas, respectively. As shown in these figures, the total NOx emission reductions to date were about 60% and 63%, respectively, of the SIP goals for HGB of 38.9 tpd and DFW of 22.2 tpd. Commercial marine vessel and locomotive projects contributed to about 48% of the total emission reductions for the HGB area, and locomotive projects contributed to about 42% of the total emission reductions for the DFW area.

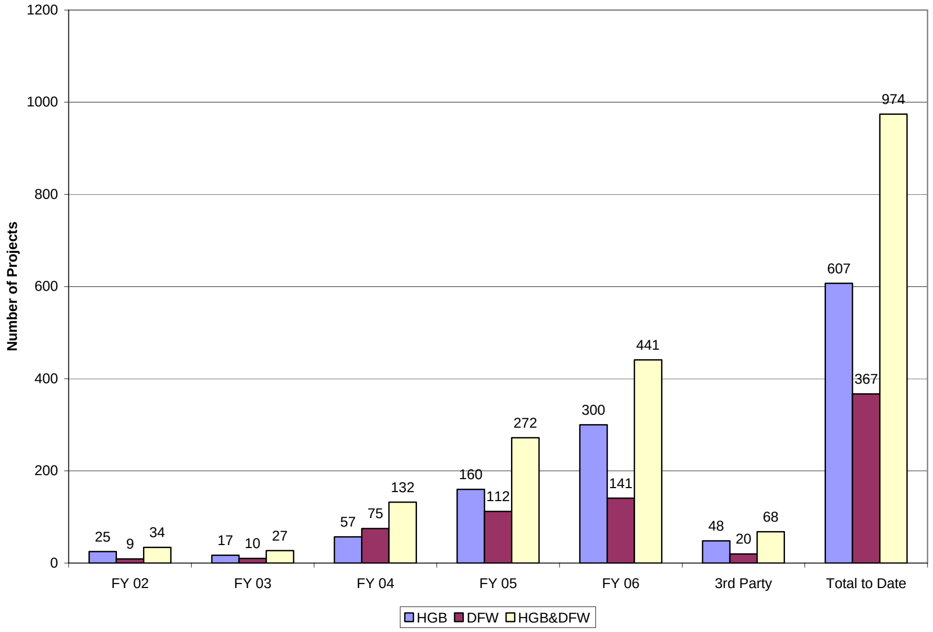

Figure 8. TERP number of projects to date for HGB and DFW areas (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

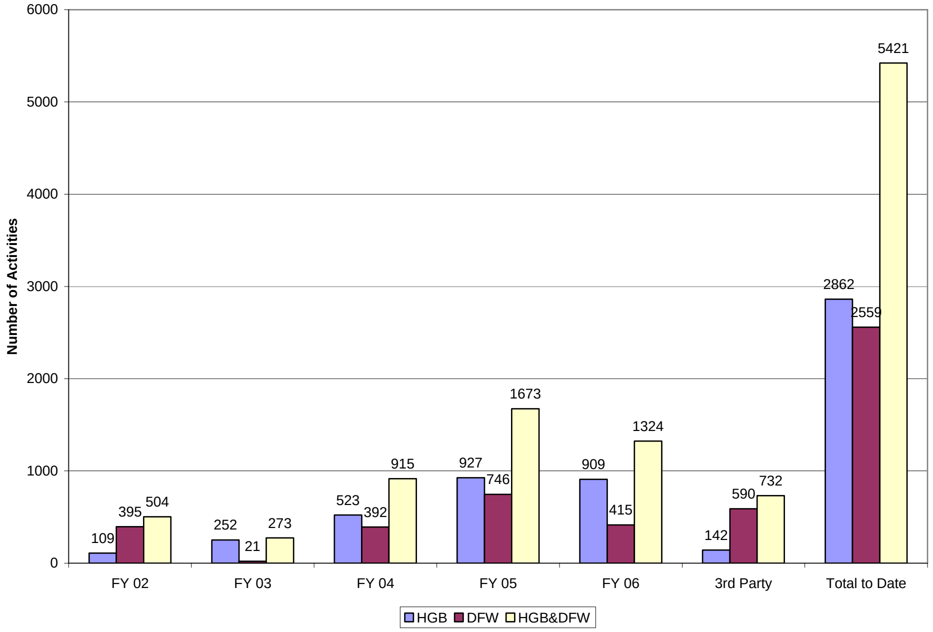

Figure 9. TERP number of activities to date for HGB and DFW areas (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Figure 8 shows that there were 607 and 367 funded or recommended projects to date for HGB and DFW areas, respectively. Among those projects, there were 11 locomotive projects and 49 CMV projects in the HGB area, and 8 locomotive projects in the DFW area. Figure 9 shows the number of activities (i.e. number of vehicles/equipment) for these projects were 2,862 and 2,559 for HGB and DFW areas, respectively. Among those activities, there were 136 locomotive activities and 389 CMV activities in the HGB area, and 122 locomotive activities in the DFW area.

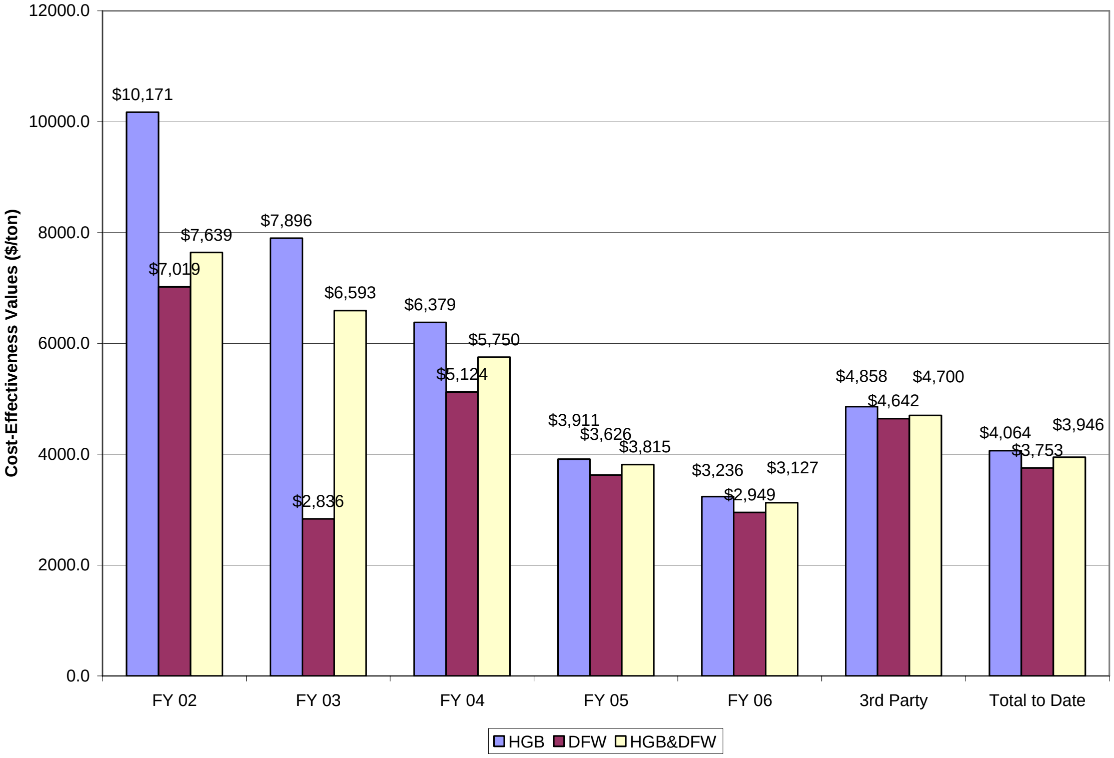

Figure 10. TERP average cost effectiveness values to date for HGB and DFW areas (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Figure 10 shows that the average cost-effectiveness values for the TERP funded or recommended projects through FY ’06 were about $4,100, $3,800, and $4,000 per ton of NOx reduced for HGB, DFW, and HGB/DFW combined, respectively. The average cost-effectiveness value for the DFW TERP funded projects was slightly lower than that for HGB mainly due to the fact that DFW funded more cost-effective projects during FYs 02 to 04.

In addition, these results show that the cost-effectiveness values have been steadily reduced since the inception of the TERP program in 2001, indicating that the TERP program has been funding more cost effectiveness projects. Comparing to the cost effectiveness values for the FY ‘05 to ‘06 ERIG/ERRG funded projects, these data shows that the average cost effectiveness values for the 3rd party grants funded projects in both HGB and DFW areas were slightly higher at about $5,000 per ton of NOx reduced.

For comparison, the average cost-effectiveness values for locomotive projects in the HGB, DFW, and combined HGB and DFW areas were about $3,900, $3,600, and $3,800 per ton of NOx reduced, respectively. As for CMV projects, the average cost-effectiveness value was $3,200 in the HGB area. While these overall average cost-effectiveness values were higher than the $2,500 per ton of NOx reduced TERP guideline for locomotive and CMV projects, the average cost-effectiveness values for locomotive and CMV projects funded in FY 06 were lower than the $2,500 per ton of NOx reduced.

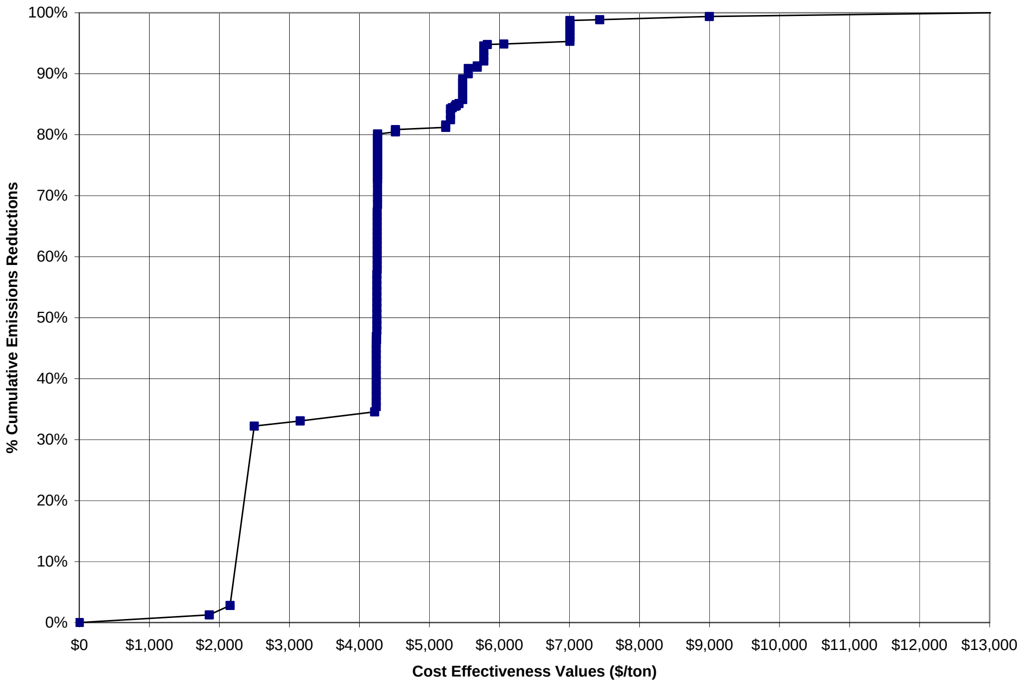

Figure 11. Cumulative distribution of NOx emission reductions as a function of cost-effectiveness values for TERP funded and recommended **locomotive** projects in the **HGB area** (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

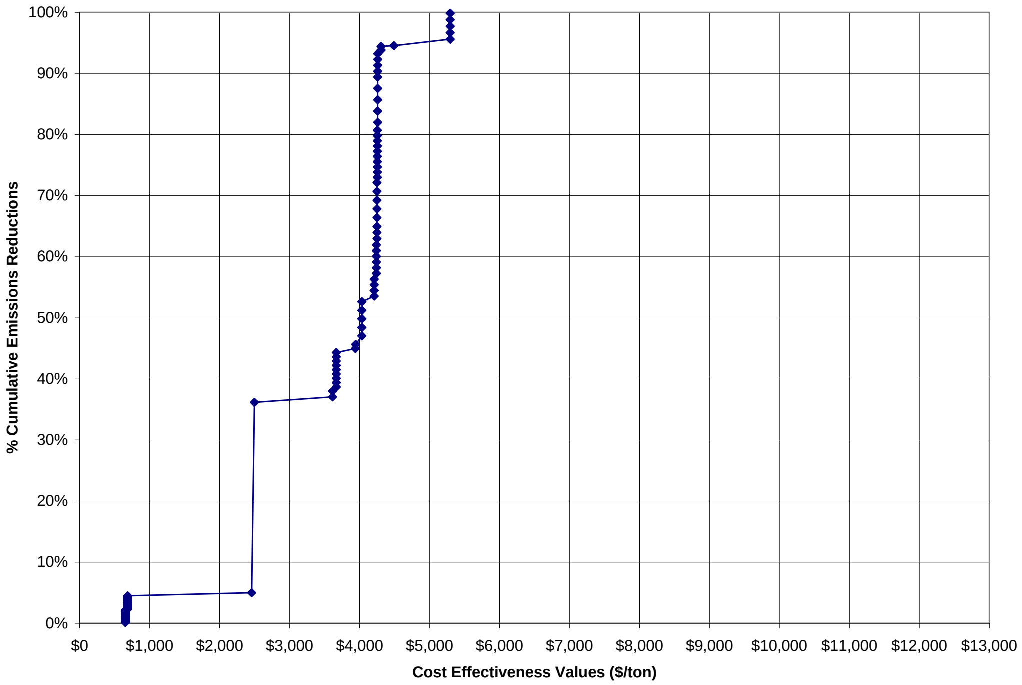

Figure 12. Cumulative distribution of NOx emission reductions as a function of cost-effectiveness values for TERP funded and recommended **locomotive projects** in the **DFW area** (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

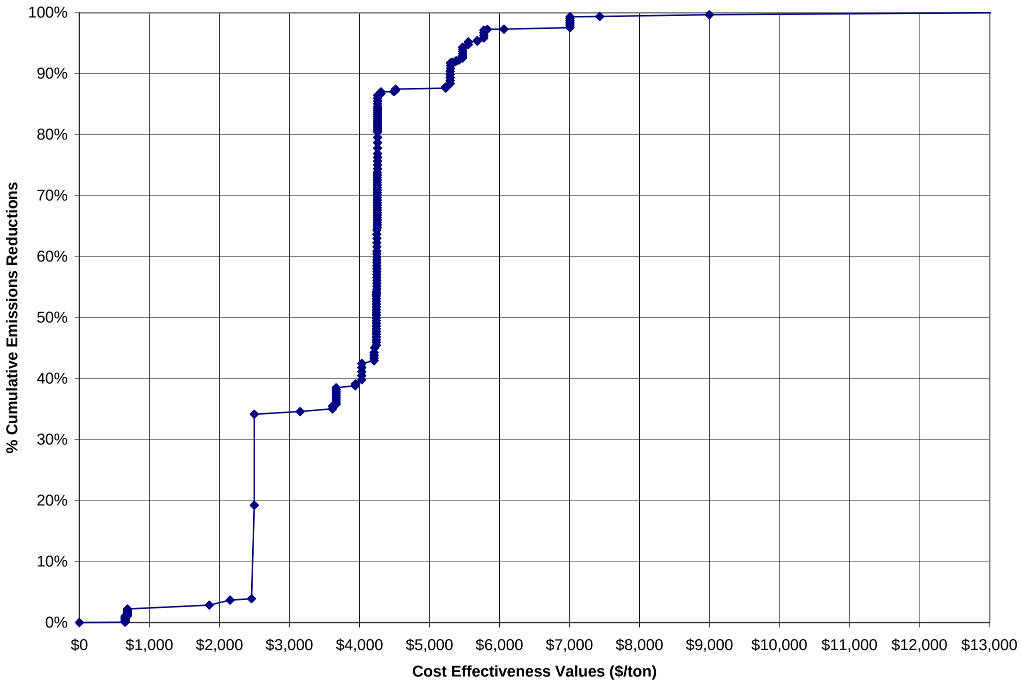

Figure 13. Cumulative distribution of NOx emission reductions as a function of cost-effectiveness values for TERP funded and recommended **locomotive projects** in the **HGB and DFW areas** (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

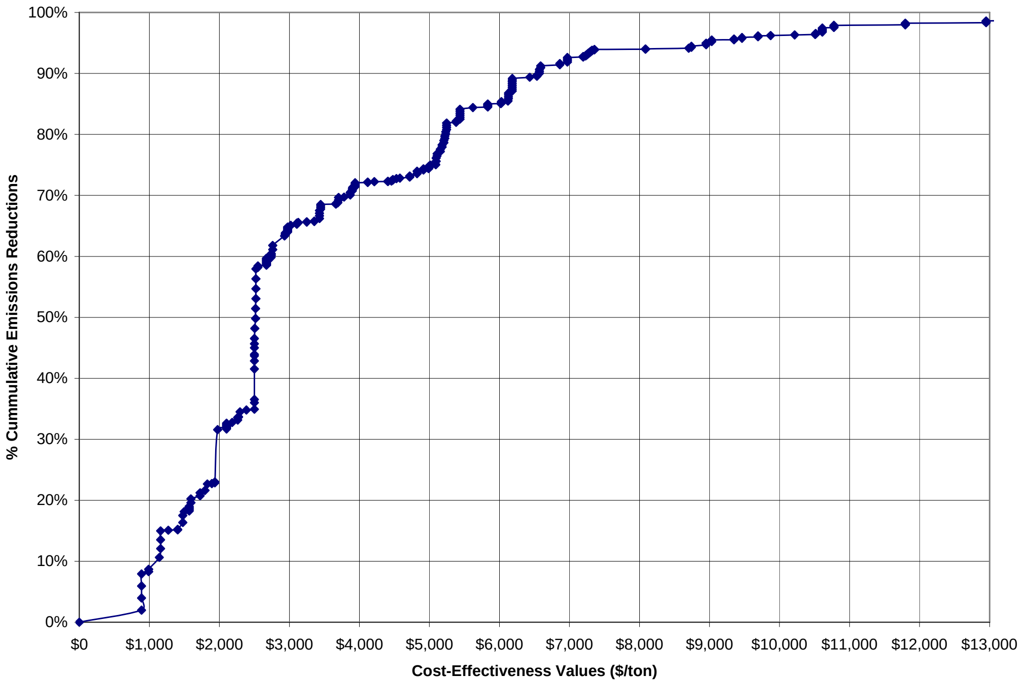

Figure 14. Cumulative distribution of NOx emission reductions as a function of cost-effectiveness values for TERP funded and recommended **CMV projects** in the **HGB area** (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Figures 11 to 13 show the cumulative distributions of emission reductions as a function of cost-effectiveness values of funded and recommended locomotive projects to date for HGB, DFW, and HGB/DFW combined, respectively. As shown in these figures, only about 35% of the emission reductions were from projects with a cost-effectiveness value of $2,500 or less per ton of NOx reduced in the HGB and DFW areas, and combined HGB and DFW areas. However, these figures show that more than 80% of the emission reductions were from projects with a cost-effective value of $5,000 per ton of NOx reduced in the HGB and DFW areas, or combined HGB and DFW areas.

Figure 14 shows the cumulative distribution of emission reductions as a function of cost-effectiveness values of funded and recommended CMV projects to date for the HGB area. As shown in this figure, about 60% of the CMV projects were below the $2,500 per ton of NOx reduced TERP guideline for locomotives and CMVs, and about 75% of the CMV projects were below $5,000 per ton of NOx reduced.

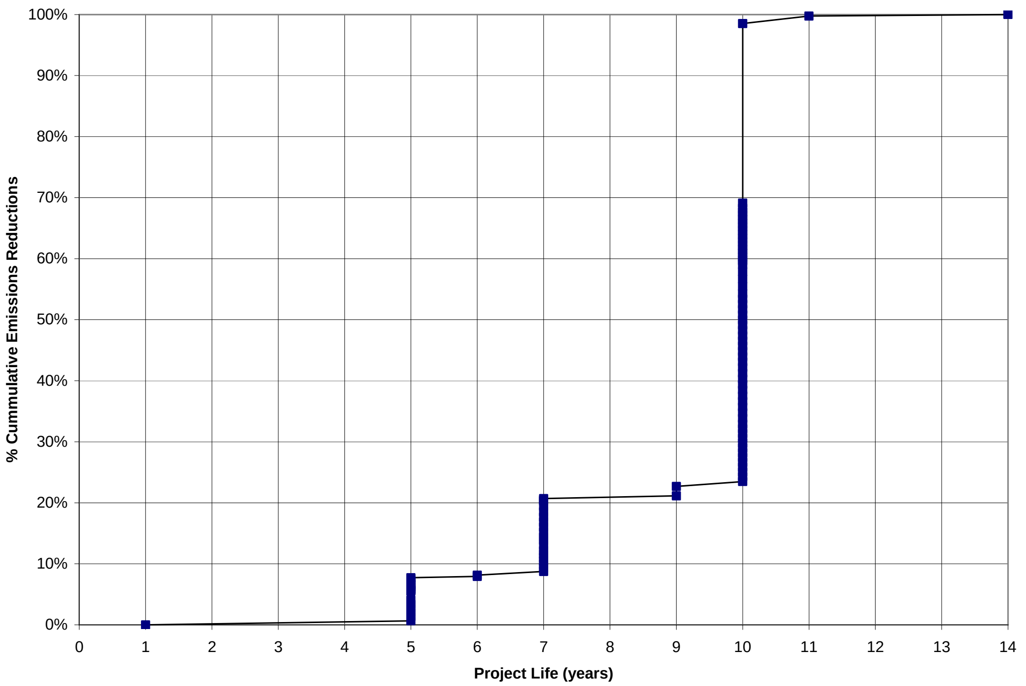

Figure 15. Cumulative distribution of NOx emission reductions as a function of **project life** for TERP funded and recommended **locomotive** projects to date in the **HGB area** (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

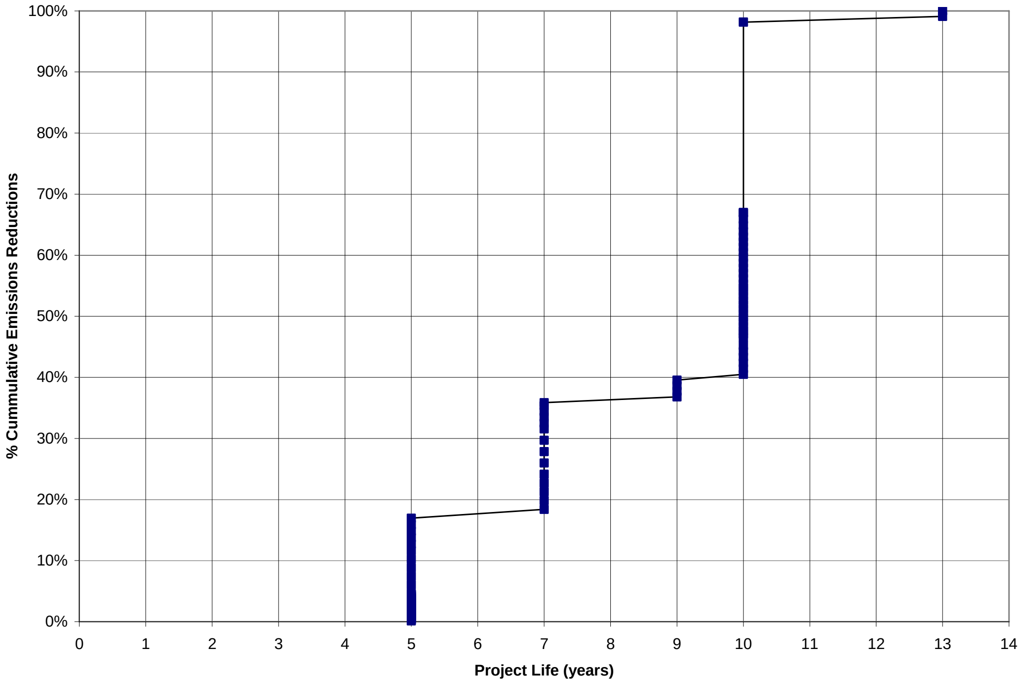

Figure 16. Cumulative distribution of NOx emission reductions as a function of **project life** for TERP funded and recommended **locomotive projects** to date in the **DFW area** (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

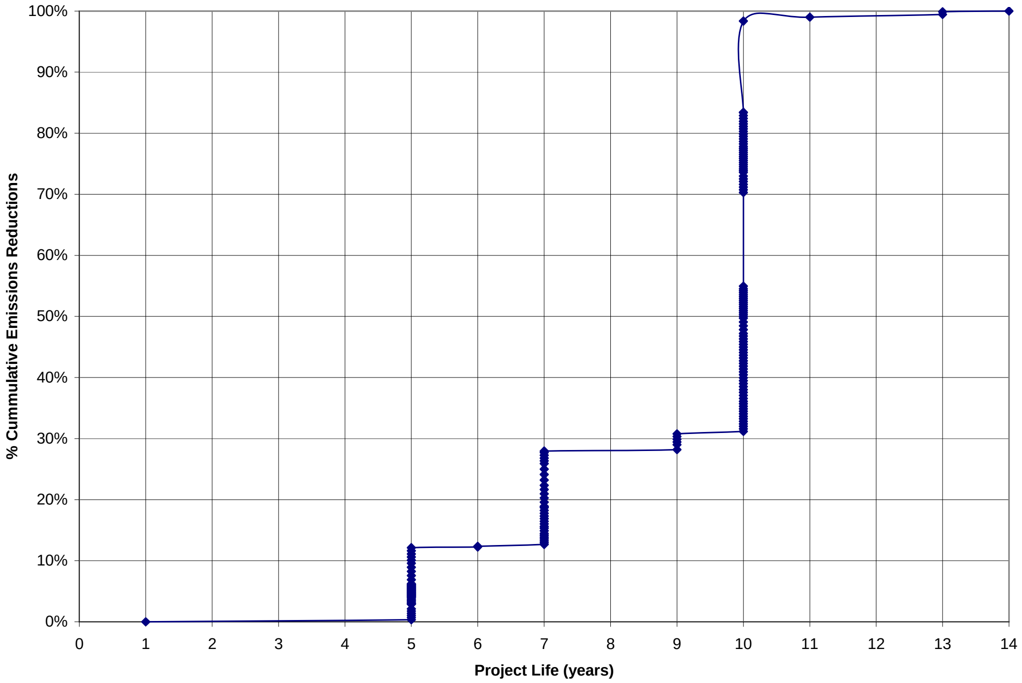

Figure 17. Cumulative distribution of NOx emission reductions as a function of **project life** for TERP funded and recommended **locomotive projects** to date in both the **HGB and DFW areas** (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

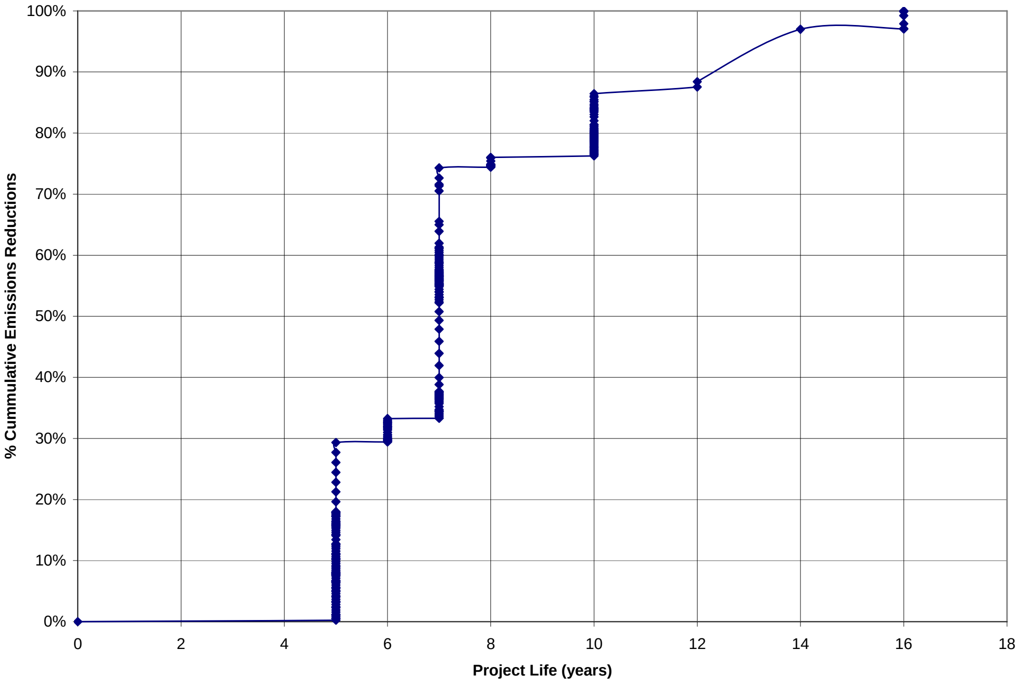

Figure 18. Cumulative distribution of NOx emission reductions as a function of **project life** for TERP funded and recommended **commercial marine vessel** projects to date in the **HGB area** (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Figures 15 to 17 show the cumulative distribution of emission reductions as a function of project life-years of funded and recommended locomotive projects to date for HGB, DFW, and HGB/DFW combined, respectively. As shown in these figures, more than 98% of the emission reductions in the HGB and DFW areas, and both the HGB and DFW areas, were from projects with a project life of 10 years or less. The average project life weighted by emission reductions was about 9 years for HGB, DFW or combined HGB and DFW areas.

Figure 18 shows the cumulative distribution of emission reductions as a function of project life-years of funded and recommended CMV projects to date for the HGB area. As shown in Figure 18, more than 75% of the emission reductions were from projects with a project life of 8 years or less; the average project life year weighted by emission reductions for CMV projects was also determined to be about 8 years.

EMISSION REDUCTION STRATEGIES FOR COMMERCIAL MARINE DIESEL ENGINES

The most likely technology to be employed in TERP for commercial marine emission sources is to repower the engines of vessels that spend most of their time within the nonattainment area, as have been demonstrated with the TERP funded projects for commercial harbor craft. The emission reductions are associated with the emission standards for marine engines as shown in Table 9. The emission reduction is calculated by comparing the new engine emission factor with the base emission factor (10 g/kW-hr) used in the inventory evaluation for towboats and harbor craft, with a typical engine displacement of less than 5 liters per cylinder.

Table 9. Emission factors for new commercial marine engines.

Subcategory (Liters/Cylinder)	Tier	Model Year	THC + NOx g/kW-hr	CO g/kW-hr	PM g/kW-hr
Power < 37 kW and disp. <0.9	Tier 2	2005	7.5	5.0	0.40
0.9 < disp. < 1.2	Tier 2	2004	7.2	5.0	0.30
1.2 < disp. < 2.5	Tier 2	2004	7.2	5.0	0.20
2.5 < disp. < 5.0	Tier 2	2007	7.2	5.0	0.20
5.0 < disp. < 15	Tier 2	2007	7.8	5.0	0.27
15 < disp. < 20 Power <3300 kW	Tier 2	2007	8.7	5.0	0.50
15 < disp. < 20 Power >3300 kW	Tier 2	2007	9.8	5.0	0.50
20 < disp. < 25	Tier 2	2007	9.8	5.0	0.50
25 < disp. < 30	Tier 2	2007	11.0	5.0	0.50

The HARC H8C study[16] provided emission estimates for commercial fishing boats, as well as revisited the ocean-going vessel emission estimates to better define ocean-going vessel dwelling and transit emission estimates. These two categories provide additional opportunities for emission reductions through TERP. The commercial fishing boats could apply for repowering projects in the same manner as tow boats and other harbor craft.

While it may be more difficult to address ocean-going vessels through TERP funding, it is difficult to ignore such a large source category. California has adopted regulations to reduce emissions from auxiliary diesel engines and diesel-electric engines operated on ocean-going vessels within California waters and 24 nautical miles of the California baseline via low sulfur marine distillate fuels or equally effective emission controls, starting in 2007. In addition, Ports of Los Angeles and Long Beach in California are investigating reducing dwelling (hotelling) emissions from marine vessels, such as container and crude oil tankers, via shoreside power

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[16] "Improvements to the Commercial Marine Vessel Emission Inventory in the Vicinity of Houston, Texas," Draft Final Report to Houston Advanced Research Center, The Woodlands, TX, by ERG and Starcrest, Austin, TX, July 28, 2003.

and/or shore-based aftertreatment systems. While Ports of Los Angeles, Long Beach and San Francisco in California are investigating the use of shoreside power for cruise ships, the Port of Seattle, Washington and Port of Juneau, Alaska, have already implemented shoreside power for cruise ships with shoreside power capability (e.g. some Princess cruise ships) to reduce hotelling emissions. Since 2001, the Ports of Los Angeles and Long Beach have also implemented a voluntary vessel speed reduction program (VSRP), via a memorandum of understanding between the ports, regulatory agencies, and terminal and vessel operators, to reduce NOx emissions from vessels by slowing vessels to 12 knots within 20 nautical miles of the ports' waters.

The control strategies for ocean going vessels and commercial harbor craft are discussed in the following sections.

Ocean Going Vessels

Large ocean-going vessels are significant sources of NOx and PM emissions, mainly emitted from their propulsion and auxiliary engines and from other minor sources, such as on-board boilers or other combustion processes. Emission reduction strategies for engines used in large ocean-going vessels include the following general categories:

- Ship fuels and shipboard fuel modifications;
- Engine upgrades;
- Exhaust after-treatment techniques;
- Shoreside alternatives, such as shoreside power or aftertreatment controls at dock; and
- Operational control measures.

Table 10 lists some of these emission reduction technologies, along with their emission reduction potentials, focusing on reducing NOx emissions. While some of these control technologies can be applied to both propulsion and auxiliary engines, technologies discussed in this section focus on auxiliary engines.

Table 10. Summary of marine vessel engine NOx emission reduction strategies and potential.

Control Method	NOx Reduction Potential
Fuel Options	
Low Sulfur Diesel Fuel (TxLED)	Small
Fuel/Water Emulsion	Some
LNG	Potentially significant
Delay injector timing; injector upgrade	Small
EGR system or engine cycle modification	Potentially significant
Install an inlet air humidification system	Some
Modify cylinder heads for direct water injection	Some
Aftertreatment Methods	
Selective Catalytic Reduction (SCR)	Significant
Ionizing Wet Scrubber (IWS)	Minimal
Operational Measures	
Voluntary Speed Reduction	Some reductions during transit mode
Shoreside power	Significant reduction during hotelling mode

Clean fuels technologies could include cleaner diesel fuels, alternative diesel fuels, such as fuel/water emulsion, and in the case of LNG carriers, the use of natural gas for some operations. Clean diesel fuels can include moderately lower sulfur fuels that would be required if a SOx Emission Control Area (SECA) were established, to fuels with much lower sulfur levels such as marine gas oil or TxLED fuels. The fuels requirement under CARB's regulations for ocean-going vessel auxiliary engines mandates a sulfur level equivalent to marine gas oil for these engines (e.g. 0.5% sulfur level in 2007, and 0.1% sulfur level in 2010.) CARB estimated the cost effectiveness of the ocean going vessel auxiliary engines regulation to range from $66,000 to $73,000 per ton of NOx reduced. For the H-GAC, ENVIRON estimated the cost-effectiveness of such a measure to range from $50,000 to $60,000 per ton of NOx reduced.

The international Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI standards result in a minimal NOx reduction and no effect on PM. The EPA may adopt more stringent standards, but they would affect only U.S.-flagged vessels, which represent a small fraction of the ocean-going vessels, and reported that new marine diesel engines could be available with designs that may achieve up 30 percent lower NOx emissions than uncontrolled levels using a variety of measures.[17] For a Port of Long Beach study, ENVIRON estimated the cost effectiveness of replacing uncontrolled auxiliary engines with Tier 2 marine engines for different marine vessel applications to range from $14,000 to $300,000 per ton of NOx reduced.[18]

Exhaust aftertreatment controls for NOx emissions have been limited to a small number of marine engine applications, but a larger range of demonstrations exist for similar engines used in land-based applications. Selective catalytic reduction (SCR) is an aftertreatment control method for reducing NOx emissions and has been applied to several marine vessel and stationary diesel engines. In its Regulatory Support Document for the Category 3 Marine Engine Regulation, EPA provided lists of the marine applications that were equipped with SCR systems. The marine applications ranged from ferries, "Ro-Ros", RoPaxs, and ship propulsion, main, and auxiliary engines with capacity ranging from 900 to 7,000 KW.[17] Depending on the vessel types and port calls, in its Cold Ironing Feasibility Study for the Port of Long Beach ENVIRON estimated the cost effectiveness of using a SCR system for ocean going vessel auxiliary engines to range from $5,000 to $20,000 per ton of NOx reduced.

Shoreside power or other emission controls affect only the auxiliary engine emissions while the vessel is at dock, but have been one of the most cited control technologies for large vessels, including cruise ships, and container ships and crude oil tankers. Shoreside power is the other potential alternative to the use of low sulfur fuel in California waters as required by the recently adopted CARB regulation for ocean-going auxiliary engine and fuels. CARB estimated that the cost effectiveness of using shoreside power for marine vessels to range from $14,500 to $160,000 per ton of NOx reduced, depending on the vessel types, number of port calls, and berthing durations. ENVIRON's Cold Ironing Study for the Port of Long Beach estimated the

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[17] "Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or Above 30 Liters per Cylinder," EPA 420-R-03-004, Environmental Protection Agency, Ann Arbor, MI, January 2003.

[18] "Cold Ironing Cost Effectiveness Study: Volumes 1 and 2" Final Report to the Port of Long Beach, prepared by ENVIRON International Corp., March 2004. (http://www.polb.com/civica/filebank/blobdload.asp?BlobID=2157)

cost effectiveness of using shoreside power on marine vessels ranged from $9,000 to more than $400,000 per ton of all pollutants reduced.[19]

In addition, Shore-based aftertreatment systems are being investigated in Ports of Los Angeles and Long Beach to reduce emissions from auxiliary engines and boilers, including boilers to run cargo pumps for unloading crude oils or other liquid cargo. For the Port of Long Beach, ENVIRON, in 2004, evaluated a shore-based aftertreatment system concept named Advanced Maritime Emission Control System (AMECS) to reduce shoreside power emissions from ocean going vessels[20], and further evaluated the second generation of the AMECS concept.[21] As part of alternative control technologies review for the Port of San Francisco's Shoreside Power Feasibility Study for cruise ships, ENVIRON also evaluated the potential of using the AMECS to reduce shoreside power emissions from cruise ships.[22] These studies concluded that shore-based aftertreatment system to reduce hotelling/dwelling emissions from marine vessels are feasible, and, depending on the vessel types, port calls and berthing durations, the cost-effectiveness of such a strategy is estimated to be about $6,000 per ton of NOx reduced[20].

The primary operational measure for marine vessels is voluntary vessel speed reduction program, which the Ports of Los Angeles and Long Beach are currently encouraging through incentives. Other operational measures that would improve freight efficiency are methods to reduce the time in port either through reducing the time at anchor or through faster freight transfers while at dock.

Commercial Harbor Craft

The harbor craft category encompasses a wide variety of vessel types: assist tugs, ocean-going towing tugs, ferries, small excursion craft, supply vessels (for off-shore service, cable laying, etc.), dredges, service vessels (such as fire, police, pilot boats, commercial fishing), and other miscellaneous vessels.

Harbor craft are largely U.S.-flagged vessels and, therefore, the engines used on the vessels fall under the regulatory authority of the EPA. These vessels are typically powered by smaller diesel engines and use a lower sulfur fuel than large ocean-going deep draft vessels that call at the major ports. The emissions from these engines were initially regulated through EPA Tier 1 regulation and phased-in more stringent Tier 2 emission standards from 2004 through 2007. EPA has announced its intention to issue more stringent regulations on these engines, though the level of the standard has not been proposed.

The strategies for harbor craft emission control include many of the same measures used for ocean-going vessels: lower emitting engines (such as those engine replacement projects funded

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[19] "Cold Ironing Cost Effectiveness Study: Volumes 1 and 2" Final Report to the Port of Long Beach, prepared by ENVIRON International Corp., March 2004. (http://www.polb.com/civica/filebank/blobdload.asp?BlobID=2157)

[20] "Report on Evaluation of Advanced Maritime Emissions Control System," prepared for the Port of Long Beach by ENVIRON International Corp., December 2, 2004.

[21] "Southeast Basin Vessel Emission Control System: Negative Declaration/Initial Study/Application Summary Report," Port of Long Beach, 2006. (http://www.polb.com/environment/environmental_documents.asp)

[22] "Shoreside Power Feasibility Study: Main Report & Appendices," (http://www.sfport.com/site/port_page.asp?id=34940)

by TERP and other incentive programs), cleaner fuels, aftertreatment controls, and shoreside power. New engines meeting lower emission standards are the primary method for reducing harbor craft emissions, but fuel options and, in some cases, aftertreatment controls have been used (e.g., on ferries serving the San Francisco Bay Area).

The funded projects in the Carl Moyer program showed that the cost effectiveness of replacing older commercial harbor craft engines with lower emission Tier 2 engines was about $1,800 per ton of NOx reduced. The average cost effectiveness value for TERP funded projects on commercial harbor craft applications was about $3,800 per ton of NOx reduced.

Table 11. Cost effectiveness estimates of engine replacing/repowering of uncontrolled engines with Tier 1 and Tier 2 engines in commercial harbor craft by different horsepower ranges.

	Marine Engine Power Range [hp]								
	50-101			**102-1340**			**> 1340**		
	Base	**Tier 1**	**Tier 2**	**Base**	**Tier 1**	**Tier 2**	**Base**	**Tier 1**	**Tier 2**
NOx (g/bhp-hr)	10.0	7.5	5.5	10.0	7.5	5.5	10.0	7.5	5.5
Average Horsepower (hp)	76	76	76	721	721	721	1,341	1,341	1,341
Load Factor	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43	0.43
Activity (hr/yr)	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Incremental Capital Cost		$7,550	$8,305		$72,100	$79,310		$134,100	$147,510
Useful Life (years)	8	8	8	8	8	8	8	8	8
Annualized Cost ($/yr)		$944	$1,038		$9,013	$9,914		$16,763	$18,439
NOx Emission Factor (g/hr)	324	243	178	3098	2323	1699	5762	4321	3160
NOx g/hr, corrected for TxLED	302	226	165	2,881	2,161	1,580	5,359	4,019	2,939
NOx (tons/year)	0.72	0.54	0.39	6.83	5.12	3.75	12.70	9.53	6.97
NOx Reduction (tons/year)		0.18	0.32		1.71	3.08		3.18	5.74
NOx reduction (tons/day)		0.0007	0.0013		0.0068	0.0123		0.0127	0.0229
Cost-Effectiveness ($/ton)		$5,278	$3,215		$5,278	$3,215		$5,278	$3,215
1-Year Cost-Effectiveness		$42,225	$25,720		$42,225	$25,720		$42,225	$25,720

Table 12. Cost effectiveness estimates of engine replacing/repowering of Tier 1 engines with Tier 2 engines in commercial harbor craft by different horsepower ranges.

	Marine Engine Power Range [hp]					
	50-101		**102-1340**		**> 1340**	
	Tier 1 Base	**Tier 2**	**Tier 1 Base**	**Tier 2**	**Tier 1 Base**	**Tier 2**
NOx (g/bhp-hr)	7.5	5.5	7.5	5.5	7.5	5.5
Average Horsepower (hp)	76	76	721	721	1,341	1,341
Load Factor	0.43	0.43	0.43	0.43	0.43	0.43
Activity (hr/yr)	2,000	2,000	2,000	2,000	2,000	2,000
Incremental Capital Cost		$8,305		$79,310		$147,510
Useful Life (years)	8	8	8	8	8	8
Annualized Cost ($/yr)		$1,038		$9,914		$18,439
NOx Emission Factor (g/hr)	243	178	2323	1699	4321	3160
NOx g/hr, corrected for TxLED	226	165	2,161	1,580	4,019	2,939
NOx (tons/year)	0.54	0.39	5.12	3.75	9.53	6.97
NOx Reduction (tons/year)		0.14		1.38		2.56
NOx reduction (tons/day)		0.0006		0.0055		0.0102
Cost-Effectiveness ($/ton)		$7,205		$7,205		$7,205
1-Year Cost-Effectiveness		$57,637		$57,637		$57,637

Table 11 shows the cost effectiveness estimates of replacing uncontrolled engines in commercial harbor craft with Tier 1 and Tier 2 engines by different engine horsepower ranges for a typical commercial application based on the TERP guidelines. For this case, 2,000 hours of average annual usage, 8 years of project life, and engine costs of $100 per hp for Tier 1 engines, and $110 per hp for Tier 2 engines were assumed. As shown in this table, the cost effectiveness values of replacing a baseline engine with a Tier 1 engine and Tier 2 engine were estimated to be about $5,300 and $3,200 per ton of NOx reduced, respectively.

Over time, the uncontrolled engines in the commercial harbor craft fleet turn over to newer engines (i.e. Tier 1 and Tier 2 engines) via normal fleet turnover, as well as accelerated fleet turnover through the TERP. Thus, the cost effectiveness value for such an engine repowering or replacement strategy is expected to increase as well. Table 12 shows the cost effectiveness estimates of replacing Tier 1 engines with Tier 2 engines. As shown in this table, the cost effectiveness values were estimated to be about $7,200 per ton of NOx reduced.

In Texas, the Port of Houston has implemented a clean fleet policy to reduce NOx emissions from its on-road vehicle and non-road equipment fleet, as well as emulsified diesel fuel demonstration program for some commercial marine vessel applications. A memorandum of agreement was signed between TxDOT, H-GAC, and EPA to reduce NOx emissions from propulsion and auxiliary engines of the Bolivar ferries. H-GAC has also signed a MOA with the Texas Waterway Operators to reduce NOx emissions from tug and barge boats via engine repowering or replacement projects. Many of such projects have been funded by the TERP.

EMISSION REDUCTION STRATEGIES FOR LOCOMOTIVE ENGINES

Strategies to reduce railroad emissions include operational/infrastructure improvements to reduce idling and braking events, retrofit controls, new technologies (e.g. specialized hybrid or LNG switching locomotives), TxLED fuels, and repowering or replacing engines with engines meeting lower emission standards.

Locomotive engines are often kept idling and may idle for as long as eight hours while cars are switched or while the locomotive waits on a siding for other locomotives to pass. Idling may also be needed to keep the engine warm in cold weather, to keep car interiors at a comfortable temperature, to keep car accessories from freezing, and to prevent potential engine restart problems. However, locomotives are often kept idling even when there are no operational reasons to do so. In order to reduce idling time, fuel consumption and pollutant emissions, an APU can be used to provide power when a locomotive is idling. The CSX Corporation has developed an APU that automatically shuts down the main locomotive engine while maintaining all vital main engine systems, such as climate control and heating engine fluids in cold weather. The EPA has tested an APU system from Kim Hotstart Manufacturing Company combined with an automatic shut-down system from ZTR Control Systems in a pilot study conducted on a locomotive in Chicago, and found both systems to operate acceptably at temperatures as low as 0°F.[23]

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[23] "Case Study: Chicago Locomotive Idle Reduction Project," Report, United States Environmental Protection Agency, Office of Transportation and Air Quality, March 2004, EPA420-R-04-003.

For idling reductions, the degree to which idling reductions can result in lower NOx emissions is essential to estimate potential emission reductions. Using the data supplied by the EPA on 19 locomotive engines and the time-in-mode average activity for line-haul and switching, a fraction of the NOx emission due to idling was estimated to average 3.1% (38% of time-in-idle) for line-haul and 13.3% (60% of time-in-idle) for switching engines. Using these data, this idle time translates into 1 to 6% of line haul engine emissions, and 5 to 27% switching engine emissions.[24] However, a given yard's operation may include more idling time than EPA currently estimates.

Locomotive engines are also coming under potential anti-idling laws. The CARB has established a Rail Yard Agreement (Agreement) with Union Pacific Railroad Company (UPRR) and Burlington Northern and Santa Fe Railway Company (BNSF) to reduce diesel emissions in and around rail yards in California, including implementation of a statewide idling-reduction program.[25] The South Coast Air Quality Management District (SCAQMD) in California recently adopted regulations limiting idling of locomotives in switch yards to a maximum of 30 minutes, although this regulation is being challenged by rail companies and locomotive manufacturers.[26]

CSX provides one APU system for locomotives and the capital cost is approximately $30,000 per unit, without including potential fuel-savings benefits. This cost estimate is consistent with the cost estimates for the Kim Hotstart and ZTR APU/automatic shut-off systems reported in the Vancouver Switchyard Locomotive Idle Reduction Project[27] and the Chicago Locomotive Idle Reduction Project[28]. The Vancouver, WA and Chicago case studies calculated the cost effectiveness of a combination APU/automatic shut-off system for a locomotive at approximately $1,400 per ton of NOx and PM emissions reduced, assuming a conservative 10-year useful life of the equipment and not including fuel savings costs.

Selective catalytic reduction (SCR) technology is currently employed at many power plants to chemically reduce NOx emissions to nitrogen and water, but has only recently been adapted to vehicles and other mobile sources. SCR requires a reducing agent (ammonia or urea) to be injected into the exhaust stream. SCR has been shown to lower NOx emissions by 75 to 90 percent. While the SCR technology is verified by CARB for emission reductions on limited engine models for non-road applications, and several SCR demonstration projects have been funded by TERP or HGAC's VMEP program, none of these SCR technologies are verified for use on locomotives, and there is little experience using these devices on locomotives. However, TERP's NTRD program has funded a project to evaluate the use of a compact SCR system on switching locomotives.[29] Thus, further evaluation is needed to assess the feasibility of retrofitting such devices on current engine models. Also, because there is very little experience to date with retrofitting locomotives with exhaust aftertreatment devices, it is difficult to estimate the costs of these retrofits.

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[24] "Locomotive Emission Standards," Regulatory Support Document, United States Environmental Protection Agency, Office of Transportation and Air Quality, April 1997.

[25] http://www.arb.ca.gov/railyard/ryagreement/ryagreement.htm

[26] http://www.aqmd.gov/news1/2006/LocomotiveCourtChallengePR.html

[27] "Vancouver, WA Switchyard Locomotive Idle Reduction Project." Final Report to U.S Environmental Protection Agency, Southwest Clean Air Agency, Vancouver, WA, October 2005.

[28] "Case Study: Chicago Locomotive Idle Reduction Project." EPA420-R-04-003, U.S. Environmental Protection Agency, March 2004.

[29] http://www.tercairquality.org/NTRD/Projects/N-011

Another technology employed in TERP has been the use of hybrid electric locomotives, which use small diesel generators to charge a battery bank. This technology can only be used for switching engines given their duty cycle. A smaller diesel engine meets lower emission standards of 4.9 g/hp-hr of NMHC + NOx for small generators and 6.7 g/hp-hr for locomotive NOx-only in 2004, and 3.0 g/hp-hr for small generators and 5.0 g/hp-hr for locomotives in 2006. This smaller diesel engine runs higher loads where engines are more efficient and have lower effective emission rates. In addition, idling is reduced to nothing as the engine is used only when the battery bank needs charging. Overall, 70% to 90% emission reduction is expected depending upon the in-use modes of operation where greater emission reduction would be experienced during low load conditions. One example of a hybrid electric switching locomotive is called the "Green Goat" that is manufactured by RailPower. The TERP has funded several "Green Goat" switching locomotive projects with reported NOx emission reduction of 80 to 90%. The cost estimate for a 2000-horsepower "Green Goat" switching locomotive range from $600,000 to $750,000, and the average cost-effectiveness value for this technology range from $5,000 to $10,000 per ton of NOx reduced.

In March 2004, the SCAQMD in California funded a LNG short haul locomotive demonstration project, and the primary goal of the project is to reduce truck and locomotive emissions between the Ports of Los Angeles and Long Beach.[30] The total program cost was estimated to be about $2.2 million, and the total NOx emission reduction was estimated to be about 70 tons per year. Assuming a project life of 10 years, the estimated cost-effectiveness value for this LNG short-haul locomotive project is about $3,300 per ton of NOx reduced.

The Texas Low Emission Diesel (TxLED) fuel is not current mandated to be used on locomotives as locomotives are source categories that can move outside the HGB and DFW nonattainment areas. For diesel engines without an active exhaust gas recirculation system, such as those for locomotives, the TxLED NOx emission benefit is estimated to be about 6.8%. For a HGAC study, the cost of TxLED was estimated to range from 5 to 10 cents more than diesel #2 fuels, and the cost-effectiveness value for TxLED was estimated to range from $2,000 to $10,000 per ton of NOx reduced.[31] The CARB in November 2004 has approved new requirements for fuel used in intrastate locomotives; requiring diesel fuel sold for use in intrastate diesel-electric locomotives operating in California must meet the specifications of the CARB on-road diesel fuel starting January 1, 2007.[32] CARB estimated the CARB diesel fuel was about 3 cents more than the federal diesel fuel, and the cost-effectiveness value for the regulation ranged from $2,500 to $3,500 per ton of NOx+PM emissions reduced[33].

Often referred to as fleet modernization programs, upgrading the locomotive fleet with lower emission engines is another opportunity to reduce emissions from switching locomotives. However, this strategy may require the premature retirement of old locomotives that would otherwise have additional years of useful life.

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[30] http://www.aqmd.gov/hb/2006/February/06028a.html;
http://www.westcoastdiesel.org/grants/files/LNG%20Locomotive%20Project%20Fact%20Sheet.pdf

[31] "Evaluation of Mobile Source Control Strategies for the Houston-Galveston-Brazoria State Implementation Plan," Draft Final Report to Houston-Galveston Area Council, prepared by ENVIRON International Corp., Novato CA, May 2006.

[32] http://www.arb.ca.gov/regact/carblohc/rfro.pdf

[33] http://www.arb.ca.gov/regact/carblohc/isor.pdf

Table 13. Locomotive emission estimates and standards for switching engines.

Standard	Effective Date	NOx Standard	NOx Reduction
Pre-controlled	<1973 and <1999 (prerebuild)	17.4 estimated	0%
Tier 0	1973 – 2001 (with rebuild)	14.0	20%
Tier 1	2002 – 2004	11.0	37%
Tier 2	>2005	8.1	53% (42% from Tier 0)

As shown in Table 13, replacing a pre-controlled locomotive with a Tier 0, Tier 1 or Tier 2 locomotive will provide about 20%, 37%, and 53% NOx emission reductions, respectively. Also, replacing a Tier 0 engine with Tier 1 or Tier 2 engine would provide about 21% and 42% NOx emission reductions, respectively, and replacing a Tier 1 engine with a Tier 2 engine would provide about 26% NOx emission reductions.

Such an accelerated fleet turnover or fleet modernization for locomotives has been implemented in California. A Memorandum of Understanding signed in 1998 between the CARB, SCAQMD, EPA and the BNSF & UP Railroads includes provisions for early introduction of clean locomotives, including linehaul locomotives, with a fleet average in the South Coast Air Basin (SCAB) equivalent to the Tier 2 locomotive standard by 2010.[34] In Texas, TERP has funded many railroad projects to replace uncontrolled switching locomotives with hybrid-electric switching locomotives in the HGB and DFW areas.

A new Tier 2 switching locomotive is estimated to be about $1.0 million to $1.5 million, and the cost effectiveness value is estimated to be on the high end of the range for the hybrid electric locomotive of $5,000 to $10,000 per ton of NOx reduced.

Table 14 shows the cost effectiveness estimates of replacing an uncontrolled, Tier 0, Tier 1 or Tier 2 switching locomotive with a hybrid-electric switching locomotive for a typical switching application. For this case, 50,000 gallon of annual fuel usage, 14 years of project life, and a capital cost of $750,000 for a hybrid-electric switching locomotive were assumed. As shown in this table, the cost effectiveness estimate of replacing an uncontrolled switching locomotive with a hybrid electric switching locomotive was about $3,100 per ton of NOx reduced.

Over time, the switching locomotive fleet will eventually turn over to fewer uncontrolled locomotives and more Tier 0, Tier 1 and Tier 2 locomotives as shown earlier in Figures 1 and 2 via normal fleet turnover, as well as accelerated fleet turnover through the TERP. Thus, the cost effectiveness value for such strategy is expected to increase as well. Table 14 shows the cost effectiveness estimates increase to about $4,000, $5,300 and $7,700 per ton of NOx reduced when replacing a Tier 0, Tier 1 and Tier 2 switching locomotive, respectively, with a hybrid electric switching locomotive.

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[34] http://www.arb.ca.gov/msprog/offroad/loco_flt.pdf

Table 14. Cost effectiveness estimates of replacing an uncontrolled engines, Tier 0, Tier 1 or Tier 2 switching locomotive with a hybrid electric locomotive.

	Base	**APU-Hybrid**	**Tier 0**	**APU-Hybrid**	**Tier 1**	**APU-Hybrid**	**Tier 2**	**APU-Hybrid**
NOx (g/bhp-hr)	17.4	3.0	14	3.0	11	3.0	8.1	3.0
Average Horsepower (hp)	2000	671	2000	671	2000	671	2000	671
Energy Consumption Factor (bhp-hr/gal)	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8
Fuel Usage (gal/yr)	50,000	30,000	50,000	30,000	50,000	30,000	50,000	30,000
Fuel Cost ($/yr)	$100,000	$60,000	$100,000	$60,000	$100,000	$60,000	$100,000	$60,000
Fuel Saving ($/yr)		$40,000		$40,000		$40,000		$40,000
Incremental Capital Cost		$750,000		$750,000		$750,000		$750,000
Activity Life (years)		14		14		14		14
Annualized Capital Cost ($/yr)		$55,556		$55,556		$55,556		$55,556
NOx Emission Factor (g/gal)	361.9	62.4	291.2	62.4	228.8	62.4	168.5	62.4
NOx (tons/year)	19.9	2.1	16.0	2.1	12.6	2.1	9.3	2.1
NOx Reduction (tons/year)		17.88		13.99		10.55		7.22
NOx Reduction (tons/day)		0.0490		0.0383		0.0289		0.0198
Cost-Effectiveness ($/ton)		$3,106		$3,972		$5,267		$7,692
CE Including Fuel ($/ton)		$870		$1,112		$1,475		$2,154
One-Year Cost-Effectiveness		$41,937		$53,625		$71,111		$103,844

EMISSION REDUCTION POTENTIALS FOR COMMERCIAL MARINE VESSELS AND LOCOMOTIVES

The emission reductions, funding, numbers of projects and activities, and cost-effectiveness values for TERP funded commercial marine vessel and locomotive projects through FY' 06 are summarized in Table 15. As shown in Table 15, the emission reductions for railroad projects were 6.38 and 5.87 tpd for HGB and DFW with funding levels of $83.2 million and $58.6 million, respectively. The emission reductions for CMV projects were 4.61 tpd for HGB with a funding level of $28.7 million. As discussed earlier, the cost effectiveness values for railroad and CMV projects were $3,800 and $3,200 per ton of NOx reduced.

Table 15. Summary of TERP funded CMV and locomotive projects to date in the HGB and DFW areas (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

	HGB	**DFW**	**HGB+DFW**
Railroad Projects (FYs 02 to 06)			
NOx Emission Reductions (tpd)	6.38	5.87	12.3
TERP Funding ($MM)	$83.2	$58.6	$141.8
No. of Projects	11	8	19
No. of Activities	136	122	258
TERP Cost-Effectiveness ($/ton)	$3,870	$3,598	$3,753
Commercial Marine Vessel Projects (FYs 02 to 06)			
NOx Emission Reductions (tpd)	4.61		
TERP Funding ($MM)	$28.7		
No. of Projects	49		
No. of Activities	389		
TERP Cost-Effectiveness ($/ton)	$3,185		

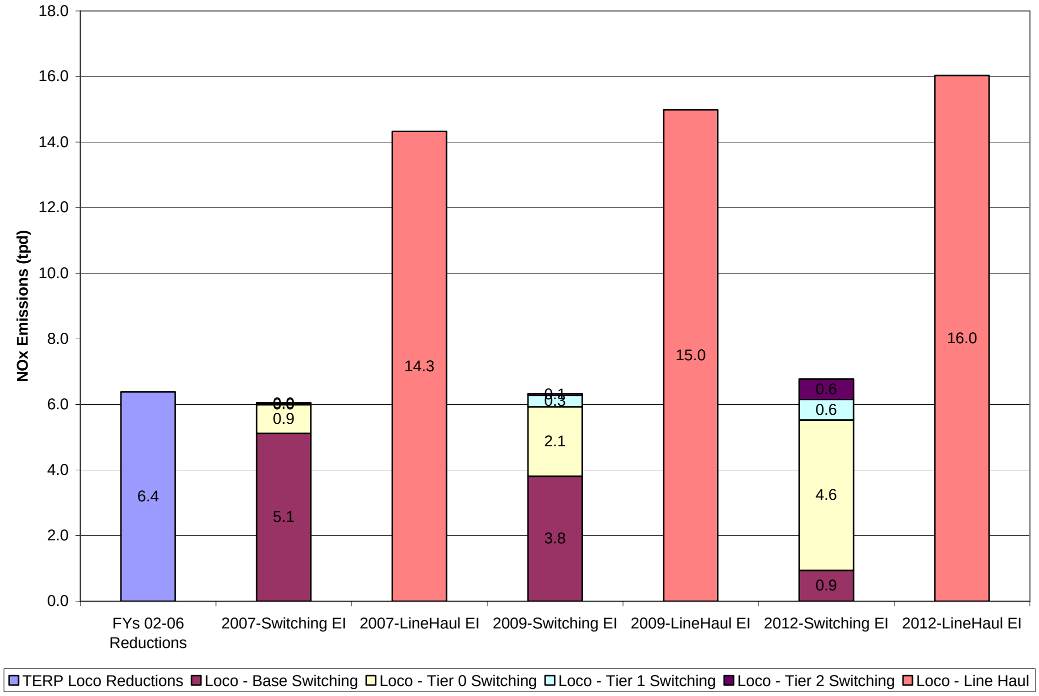

Figure 19. Comparison of TERP emission reductions for railroad projects and 2007, 2009 and 2012 locomotive emission inventory estimates in the HGB area (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

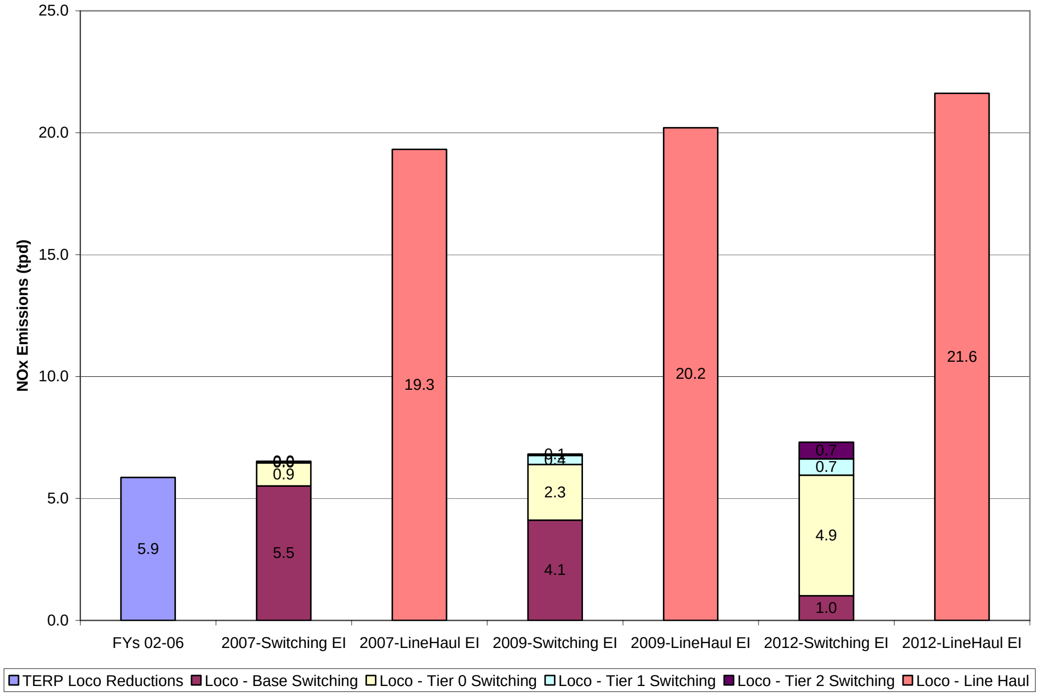

Figure 20. Comparison of TERP emission reductions for railroad projects and 2007, 2009 and 2012 locomotive emission inventory estimates in the DFW area (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Table 15 also shows that the numbers of funded railroad projects and activities were 11 and 136 for the HGB area, and 8 and 122 for the DFW area. As for the CMV projects, the numbers of TERP funded project and activity were 49 and 389 for the HGB area.

Other than the one funded railroad project to install anti-idling devices on 35 locomotives in the DFW area, the rest of the railroad projects were repowering or replacement of uncontrolled switching locomotives with low emitting or hybrid-electric switching locomotives. As for the CMV projects, most of the TERP funded projects were repowering or replacement of uncontrolled auxiliary and/or propulsion engines with lower emitting engines.

Figures 19 and 20 show the comparison of TERP emission reductions for railroad projects and the 2007, 2009, 2012 emission inventories for switching and linehaul locomotives estimated based on the H18 study that includes switching and linehaul locomotive fraction in the HGB and DFW areas, respectively. These figures show that the TERP emission reductions to date were 90% to more than 100% of the available switching locomotive emissions in 2007, 2009 or 2012. This finding suggests that further review or research work would be required to determine uncertainties and/or discrepancies of the data used in the analysis (e.g. emission inventories, locomotive counts, TERP reductions, variations from data sources, EPA default values, etc.)

Table 16. Comparison of number of activities (locomotives) for TERP railroad projects and the 2003 locomotive unit inventories estimated in the HARC H18 study, and ENVIRON's projected 2007, 2009 and 2012 locomotive unit inventories.

	TERP FY02-06 Activity	HARC H18 2003	Projected by ENVIRON[1]		
			2007	2009	2012
HGB (Number of Locomotive Estimates)					
Switching	136	206	222	232	249
Specific Linehaul	NA	13,199	14,236	14,890	15,929
General Linehaul		1,008	1,087	1,137	1,216
DFW (Number of Locomotive Estimates)					
Switching	122	128	138	144	154
Specific Linehaul	NA	22,608	24,384	25,505	27,285
General Linehaul		693	747	781	836
[1] Note: Projections were estimated based on the locomotive emission growth rates provided by TCEQ for the H42 Study. The growth rates of the number of locomotives were assumed the same as those for the locomotive emissions.					

The HARC H18 study also estimated the number of locomotives by switching, specific linehaul, and general linehaul locomotives in these areas in the Houston and Dallas Fort-Worth areas in 2003. Table 16 shows the 2003 number of locomotives estimated in the H18 study and the TERP activities for the TERP funded railroad projects. Since number of locomotives for future year are not available, ENVIRON projected the 2007, 2009, and 2012 number of locomotive estimates based the locomotive emissions growth rates provided by TCEQ, assuming that the number of locomotive growth rates were the same as those for the emission inventories.

Table 16 shows that they should be additional 85 or more (e.g. 222 – 136 = 86 in 2007) switching locomotives for potential future year TERP projects in the HGB area, about 15 or more in the DFW area. However, Figures 19 and 20 show that there are no excess emissions from switching locomotives. Also, the railroad companies listed in the H18 study's 2003 switching locomotive list did not include BNSF, but TERP has listed about 60 activities for the

TERP funded projects for BNSF. These observations further confirm the needs of research work to resolve these discrepancies or issues.

Based on existing available information or data on the locomotive emission inventories and TERP emission reduction estimation from funded railroad projects, there would be limited emission reduction potentials from switching locomotives. Another source of potential emission reductions from locomotives is reducing idling emissions from linehaul locomotives. Based on existing emission inventories, ENVIRON estimated the idling emissions to range from 0.5 to 06 tpd in HGB area, and 0.7 to 0.8 tpd in the DFW area in 2007, 2009 or 2012.

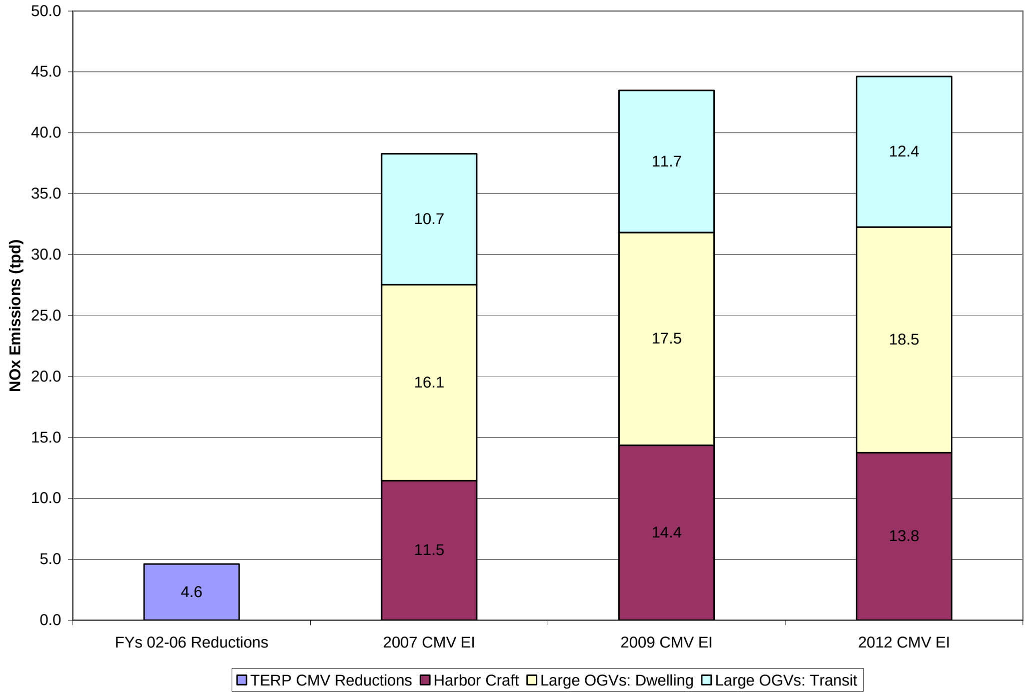

Figure 21. Comparison of TERP emission reductions for CMV projects and 2007, 2009 and 2012 CMV emission inventory estimates in the HGB area (as of 9/11/06 for 3rd party grants projects &10/3/06 for ERIG/ERRG projects).

Figure 21 shows the comparison of TERP emission reductions for commercial projects and the 2007, 2009, 2012 emission inventories by commercial harbor craft and large ocean going vessels in the HGB area. As shown in this figure, the TERP emission reductions to date were only 30 to 40% of the available commercial harbor craft emissions in 2007, 2009 or 2012, indicating commercial harbor craft is still one of the major emission sources for substantial TERP emission reductions with an additional of about 7 to 10 tpd of NOx emission reduction potential. Currently, all of the TERP funded projects on commercial marine vessels were for commercial harbor craft. If accounting for the dwelling (hotelling) emissions from large OGVs, the TERP emission reduction potentials on commercial marine vessels would further increase to 23 to 28 tpd. However, as discussed earlier, reducing dwelling emissions from commercial marine vessels would require substantial shoreside and shipside modifications for a shoreside power system, and shoreside modification for a shore-based aftertreatment system.