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Texas Market Assessment for Converter Technology Inc. Retrofit Technology

FINAL REPORT

Prepared for
Texas Commission on Environmental Quality
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Texas Market Assessment for Converter Technology, Inc.

1.0 INTRODUCTION

This report was prepared by Good Company Associates as part of a New Technology Research and Development grant awarded by the Texas Commission on Environmental Quality (TCEQ) to Converter Technology Incorporated (CTI) in November 2004.

The purpose of this report is to identify for target retrofits the dominant on-road engine models contributing the most pollution in the major cities in Texas. This report focuses on those Texas counties within which emissions reduction projects are eligible for funding through the Texas Emission Reduction Plan (TERP). TERP is a state grant program with the goal of reducing emissions of oxides of nitrogen (NOx) from mobile sources such as heavy-duty trucks, construction equipment, mining equipment, marine vessels, and locomotives.

For this market assessment, only the TERP-eligible counties were included as these counties have the highest mobile emissions, and include the largest Texas cities. Also, many of the TERP-eligible counties are currently designated as nonattainment or near nonattainment areas for ozone by the Environmental Protection Agency or TCEQ. As nitrogen oxides are a primary contributor to the formation of ground-level ozone, TERP subsidizes the reduction of NOx emissions. Therefore, many vehicles powered by diesel engines and operated within the TERP-eligible counties could be likely candidates for funded retrofits to reduce emissions of NOx, as well as other pollutants.

The CTI retrofit technology is an after-treatment system for reducing diesel engine exhaust pollutants such as NOx, particulates, hydrocarbons, volatile organic compounds, carbon monoxide, and sulfur dioxide. As the CTI system does not require high exhaust temperatures to be effective, it is well-suited to stop-and-go urban driving cycles such as those of buses and refuse trucks. Such driving cycles have presented a challenge for other exhaust gas recirculation emission control retrofits on the market. The CTI system will function on new or old diesel engines, including mechanical types, and there is no requirement for the use of ultra low-sulfur diesel fuel. The installed price is expected to range from $10,000 to $14,000 per 100 vehicles, depending on vehicle size. In addition, the CTI retrofit systems have life spans of from seven to ten years and are reusable. For approximately $3,000, CTI retrofit systems can be removed from a truck or bus being retired and re-installed on a vehicle still in use, further improving the cost-effectiveness of retrofitting.

This report identifies on-road diesel engine models with large populations in major Texas cities and highlights specific engines and truck fleets that are likely candidates for cost-effective retrofits. Also provided is an overview of the TERP-eligible counties including population, NOx emissions, and estimated diesel vehicle populations. In addition,

specific scenarios have been developed to illustrate potential NOx emission reductions through the deployment of the CTI retrofit system.

2.0 METHODOLOGIES

Several public and private data sources were utilized in order to estimate NOx emissions, vehicle populations, engine populations, and truck miles traveled. These sources include, but are not limited to, the Houston Advanced Research Center (HARC), the Galveston-Houston Association for Smog Prevention (GHASP), the Texas Commission on Environmental Quality (TCEQ), the U.S. Census Bureau, diesel engine manufacturers, diesel retrofit system manufacturers and R.L Polk and Company. Specific sources are cited throughout the report as appropriate.

2.1 Vehicle Population Sizes

The heavy-duty diesel vehicle populations for the Dallas-Fort Worth (DFW) and Houston-Galveston-Brazoria (HGB) non-attainment areas in combination with the relative human population sizes of all TERP-eligible areas were utilized as the basis for estimating the total heavy-duty 2007 diesel vehicle populations for each of the remaining TERP-eligible areas. The estimated 2007 diesel vehicle populations for DFW and HGB were obtained from studies conducted by Environ for HARC, "Texas Emission Reduction Plan Assessment in the Dallas Fort-Worth Area" and "Texas Emission Reduction Plan Assessment in the Houston-Galveston-Brazoria Region".

2.2 NOx Emissions

The estimated on-road NOx emissions for the TERP areas were obtained from TCEQ and relevant State Implementation Plans.

2.3 Vehicles By Region, Model Year, Class

Projected 2007 population sizes of diesel vehicles by region, model year and gross vehicle weight rating (GVWR) of 8,500 lbs. and greater were calculated based largely on HARC data for HGB and DFW. Other inputs included school bus population data from GHASP (for HGB) and the North Central Texas Council of Governments (for DFW) and transit bus data from Capital Metro in Austin.

These inputs were used as the basis to calculate the relative percentages of vehicles by model year for the DFW and HGB areas. The relative percentages were then applied to the previously estimated diesel truck population totals for each area to derive estimated truck populations by truck size and model year for each TERP area.

2.4 Truck Miles Traveled

Truck miles traveled by engine size, model year, and class were estimated from data from the U.S.Census Bureau 2002 Vehicle and Inventory Use Survey for Texas.

3.0 TERP OVERVIEW

This report focuses on those Texas counties within which emissions reduction projects are eligible for grant funding through the Texas Emission Reduction Plan (TERP). TERP is a state grant program administered by the TCEQ. Its goal is to reduce emissions of nitrogen oxides from mobile sources like heavy-duty trucks, construction equipment, mining equipment, marine vessels, and locomotives.

There are forty-one counties within which TERP grants may be awarded. Grantees must meet multiple requirements, including a commitment to operate their equipment within an eligible county for at least 75% of the grant time period.

The forty-one TERP-eligible counties and their corresponding areas are listed in Table 3.1.

Table 3.1 TERP Eligible Counties

AREA	ELIGIBLE COUNTIES
Houston/Galveston	Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller
Dallas/Fort Worth	Collin, Dallas, Denton, Ellis, Henderson, Hood, Hunt, Johnson, Kaufman, Parker, Rockwall, and Tarrant
Beaumont/Port Arthur	Harden, Jefferson, and Orange
San Antonio	Bexar, Comal, Guadalupe, and Wilson
Austin/San Marcos	Travis, Williamson, Hays, Caldwell, and Bastrop
El Paso	El Paso
Tyler/Longview	Smith, Upshur, Harrison, Gregg, and Rusk
Corpus Christi	San Patricio and Nueces
Victoria	Victoria

4.0 ENGINE POPULATIONS

To determine the engine models that would most likely make up the CTI retrofit market, engine population data was obtained from R.L. Polk and Company[1]. These engine populations are based on vehicle registration data as of December, 2004 and do not include pick-up trucks. Registration data can only be used as an estimate of the location of actual engine and vehicle use.

[1] Engine population data obtained from R.L. Polk & Company Commercial Vehicle Group, March 2005

For model year engines 1985 and later, with Gross Vehicle Weight Ratings of 6,001 lbs. and above, the four largest on-road diesel engine populations are from the manufacturers International, Cummins, Caterpillar, and Detroit Diesel. The relative percentages of the most populous engines in the 41 TERP counties are shown in Table 4.1

Table 4.1 – Engine Populations Registered in 41 TERP Counties

ENGINE MAKE	NUMBER REGISTERED	% OF ENGINES
International	83,161	29%
Cummins	68,229	24%
Caterpillar	49,155	17%
Detroit Diesel	32,590	11%
Mack	16,147	6%
Isuzu	13,278	4%
All Others	25,786	9%
TOTAL	**288,346**	**100%**

Table 4.2 relates the gross vehicle weight rating to the truck classes defined by R.L. Polk, and Environ[2], which are utilized in this report.

Table 4.2 – Truck Class Definitions

R.L. Polk Class	Gross Vehicle Weight Rating (GVWR)	Environ-defined Group
2C	8,501 – 10,000 lbs.	Light-Heavy Duty (LHD)
3	10,0001 – 14,0000 lbs.	Light-Heavy Duty (LHD)
4	14,0001 – 16,000 lbs.	Light-Heavy Duty (LHD)
5	16,001 – 19,500 lbs.	Light-Heavy Duty (LHD)
6	19,501 – 26,000	Med-Heavy Duty (MHD)
7	26,001 – 33,000	Med-Heavy Duty (MHD)
8	33,001 and greater	Heavy-Heavy Duty (HHD)

For the four most populous engine makes, table 4.3 lists the most prevalent engine models for the model years 1985 to 2002, from vehicle registration data in the 41 TERP-eligible counties[3]. Vehicles of these model years are the most likely candidates for retrofits as model years earlier than 1985 and later than 2002 are technically more difficult to retrofit and provide less cost-effective results.

[2] Texas Emission Reduction Plan Assessment in the Dallas Fort-Worth Area", HARC, November 12, 2004; "Texas Emission Reduction Plan Assessment in the Houston-Galveston-Brazoria Region", HARC, May 19, 2004

[3] R.L. Polk & Company Commercial Vehicle Group, March 2005

The typical class listed in table 4.3 was determined from a subset of total vehicles registered. This subset consists of those vehicles registered by companies with fleets of twenty or more vehicles and contains 14,630 vehicles.

From table 4.3, it can be seen that the Detroit Diesel Series 60 engine is the predominant engine in class 8 vehicles of model years 1985 to 2002. For classes 2C through 7, the International T444E/7.3L is the most populous engine.

In the Texas market, these engines, as well as the International DT466, the Cummins 6B Series and N14, and the Caterpillar 3406 are strong candidates for retrofits as well as further testing for certification of the CTI retrofit technology.

Table 4.3 – Prevalent Engine Models Within TERP Counties

	ENGINE MODEL YEAR				
MFGR/MODEL	**1985-1990**	**1991-1997**	**1998-2002**	**Total**	**Typical Class**
CATERPILLAR					
3406	3,220	6,841	5,116	15,177	8
3116	244	3,886	500	4,630	6-7
3176	134	1,584	1	1,719	8
3126	0	288	9,172	9,460	6-8
3208	1,038	0	0	1,038	7-8
C-10	0	0	2,230	2,230	8
C-12	0	0	2,568	2,568	8
CUMMINS					
6B Series	399	8,276	8,687	17,362	3,6-7
N14	7,283	8,566	6,219	22,068	8
M11	0	3,773	5,606	9,379	8
6C Series	113	3,818	2,880	6,811	7-8
L10	1,579	3,185	119	4,883	8
DETROIT DIESEL					
Series 60	430	13,114	11,302	24,846	8
6V92	527	1,037	14	1,578	8
Series 50	0	511	649	1,160	8
8.2L	1,257	0	0	1,257	6-7
INTERNATIONAL					
T444E/7.3L	3,433	16,455	25,788	45,676	2C-7
DT466/DTA466	2,058	6,406	8,610	17,074	6-8
DTA360	799	2,147	0	2,946	6-7
6.9L	1,840	0	0	1,840	2C-7
9.0L	473	0	0	473	6-7

The engine models years were divided into three categories according to the NOx emissions standards for each model year. Table 4.4 shows the corresponding NOx emission standards in grams per brake horsepower-hour (g/bhp-hr).

Table 4.4 – NOx Emissions Standards by Model Year

1989 and earlier	10.7 g/bhp-hr
1990	6.0 g/bhp-hr
1991-1997	5.0 g/bhp-hr
1998-2003	4.0 g/bhp-hr
2004* – 2007	2.375 g/bhp-hr

*Some engines were required to meet the 2004 standards by October 2002.

Although this report focuses on engine models, further subcategories of EPA engine families or engine test group emissions certifications exist within model years.

5.0 TERP-ELIGIBLE COUNTY PROFILES

As an aid in determining the vehicle population sizes for the TERP areas, the human population size of each TERP-eligible area was utilized.

Table 5.1 lists the populations and estimated NOx emissions for the TERP-eligible counties in Texas, by area[4]. The highlighted counties are the largest population centers located within each area.

The **Houston-Galveston-Brazoria (HGB)** area has nonattainment status for ground-level ozone. This area is required to be in attainment with the EPA 1-hour ozone standard by 2007. On-road NOx emissions for 2007 are budgeted at 186 tons per day, to reach attainment[5]. In the HGB area, industrial point sources currently account for approximately 41% of the total NOx emissions while on-road NOx emissions make up 38% of NOx emissions in the area. By 2007, the NOx emissions contribution from industrial sources is forecasted to drop to 29% of the total, while the percentage of emissions from on-road sources will remain relatively steady at 39%[6].

Of the twelve counties in the **Dallas/Fort Worth (DFW)** region, nine are classified in nonattainment under the 1-hour ozone standard, 8-hour ozone standard, or both. This nine-county area has an attainment date of June, 2010 under the eight-hour ozone standard. Toward the goal of reaching attainment, the budgeted NOx emissions from on-road sources are 201 tons per day. The three remaining counties (Henderson, Hood, Hunt) are considered to be in attainment. Unlike HGB, the majority of NOx in the DFW

[4] Population data from U.S Census Bureau, County and City Data Book: 2000
[5] HGB 1-Hour Ozone Attainment Demonstration Mid-Course Review (Dec 2004) Executive Summary, www.tnrcc.state.tx.us/oprd/sips/siphga.html
[6] "TCEQ – Port Emissions & SIP Status", presented at the Maritime Air Technology Workshop, Houston, Texas, April 14, 2005. Document located at www.houston.org.

area comes from mobile sources, both on-road and non-road. On-road NOx emissions contribute 51% of NOx emissions in the DFW area, and reaching ozone attainment will require a substantial reduction of approximately 115 tons per day of NOx emissions from mobile sources[7].

The **San Antonio** region technically exceeds the 8-hour ozone standard and has become an Early Action Compact region in order to implement measures allowing the region to remain in overall attainment. Estimated 2007 NOx emissions from on-road sources are 82.3 tons per day, representing 36.5% of the total NOx emissions[8].

The **Austin-San Marcos** region is considered in attainment for ozone and has chosen to become an Early Action Compact region in order to remain in attainment. The 2007 NOx emissions from on-road sources are estimated at 60.5 tons per day, which is 47% of the total NOx emissions for the five county region[9].

The **Tyler-Longview** area, also referred to as Northeast Texas, is a near nonattainment area for ground-level ozone. After the one-hour ozone standard was violated in Gregg County, one of the area's five counties, voluntary NOx emissions reductions programs were agreed to. The area is now in attainment under the one-hour standard, but nearing non-attainment under the 8-hour standard. Tyler-Longview is now operating under an Early Action Compact with TCEQ in order to implement measures to remain in attainment. Estimated on-road NOx emissions for 2007 are 40 tons per day, which is 17% of the total projected NOx emissions[10].

The **Beaumont-Port Arthur (BPA)** area is in nonattainment for ground-level ozone. This area is required to meet the eight-hour ozone standard by June 2007. Projected 2007 on-road NOx emissions in the BPA area are 35 tons per day, comprising 16% of NOx emissions[11].

The **Corpus Christi** area, which includes San Patricio and Nueces counties, is in near nonattainment for ground-level ozone. Because Corpus Christi has come close to violating the one-hour ozone standard in the past, voluntary measures have been adopted to encourage emission reductions and keep the area in attainment. The 1999 emissions inventory data for the area estimate on-road NOx emissions to be 34 tons per day, representing 21% of the area's NOx emissions[12].

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[7] DFW Five Percent Increment of Progress SIP, April 27, 2005. www.tnrcc.state.tx.us/oprd/sips/sipdfw.html

[8] San Antonio Early Action Compact Attainment Demonstration SIP Narrative. www.tnrcc.state.tx.us/oprd/sips/sipsa.html

[9] Austin Area Early Action Compact Ozone State Implementation Plan Revision, November 17, 2004, http://www.tceq.state.tx.us/assets/public/policy/epi/sip/sipdocs/2004-06-AUS/AUS_narr_181104.pdf

[10] Northeast Texas Region SIP Revision, March 2002, www.tnrcc.state.tx.us/oprd/sips/sipeasttexas.html

[11] BPA Attainment Demonstration, April 2000, www.tnrcc.state.tx.us/oprd/sips/sipbpa.html

[12] Corpus Christi 1999 Summary of Emission Inventory Estimates, www.tnrcc.state.tx.us/oprd/sips/sipcc.html

El Paso was designated in nonattainment for particulate matter and carbon monoxide, as well as for ozone. However, recent studies show that El Paso could meet national ambient air quality standards if not for its proximity to Ciudad Juarez, Mexico. As of 1996, NOx emissions in El Paso from on-road sources were estimated at 39 tons per day, or 55% of NOx emissions for the area. Most of these emissions were generated by light duty gasoline-fueled vehicles[13].

[13] 1996 NOx emissions El Paso Ozone Non Attainment Area, http://www.tnrcc.state.tx.us/air/aqp/ei/rsumep.htm

Table 5.1 TERP County Characteristics

Area	Counties	Population	% of TX Population	Est. 2007 On-road NOx emissions (tpd)
Dallas / Fort Worth	Collin	597,147	2.70%	
	Dallas	2,284,096	10.33%	
	Denton	510,795	2.31%	
	Ellis	124,411	0.56%	
	Henderson	77,277	0.35%	
	Hood	45,046	0.20%	
	Hunt	81,024	0.37%	
	Johnson	139,068	0.63%	
	Kaufman	81,955	0.37%	
	Parker	97,480	0.44%	
	Rockwall	54,630	0.25%	
	Tarrant	1,559,148	7.05%	
Totals for Area		**5,652,077**	**25.55%**	**201**
Houston / Galveston	Brazoria	263,149	1.19%	
	Chambers	27,581	0.12%	
	Fort Bend	419,772	1.90%	
	Galveston	266,775	1.21%	
	Harris	3,596,086	16%	
	Liberty	74,117	0.34%	
	Montgomery	344,700	1.56%	
	Waller	34,579	0.16%	
Totals for Area		**5,026,759**	**22.73%**	**186**
San Antonio	Bexar	1,471,644	6.65%	
	Comal	87,785	0.40%	
	Guadalupe	97,101	0.44%	
	Wilson	35,244	0.16%	
Totals for Area		**1,691,774**	**7.65%**	**82**
Austin / San Marcos	Travis	857,204	3.88%	
	Williamson	303,587	1.37%	
	Hays	114,193	0.52%	
	Caldwell	35,572	0.16%	
	Bastrop	67,077	0.30%	
Totals for Area		**1,377,633**	**6.23%**	**61**
Tyler / Longview	Smith	184,015	0.83%	
	Upshur	36,959	0.17%	
	Harrison	62,708	0.28%	
	Gregg	113,941	0.52%	
	Rusk	47,255	0.21%	
Totals for Area		**444,878**	**2.01%**	**40**
El Paso	El Paso	705,436	3.19%	
Totals for Area		**705,436**	**3.19%**	**39**
Beaumont/Pt. Arthur	Hardin	49,634	0.22%	
	Jefferson	248,605	1.12%	
	Orange	84,390	0.38%	
Totals for Area		**382,629**	**1.73%**	**35**
Corpus Christi	San Patricio	68,050	0.31%	
	Nueces	315,206	1.43%	
Totals for Area		**383,256**	**1.73%**	**34**
Victoria	Victoria	85,395	0.39%	
Totals for Area		**85,395**	**0.39%**	**7**
	Total for all Areas	**15,749,837**	**71.21%**	**685**
	Total for Texas	**22,118,509**		

6.0 VEHICLE POPULATIONS

To provide a view of the potential retrofit market from a geographic perspective, estimates of the diesel vehicle populations were developed for each TERP area.

Tables 6.1 – 6.10 contain the estimated heavy-duty on-road diesel vehicle populations by model year group for each of the TERP-eligible areas. These populations include diesel vehicles with a GVWR of 8,500 lbs. or greater.

Although the Light Heavy-Duty vehicles represent 42% of the diesel vehicle population in HGB and DFW, it is the Heavy Heavy-Duty (HHD-Class 8) vehicles that account for 77% of the projected daily NOx emissions from heavy duty on-road vehicles in these two areas. The model years 2002 and older HHD-Class 8 vehicles alone account for almost 20% of the total heavy duty vehicle diesel NOx emissions in the combined HGB and DFW areas[14].

It should be noted that these projected vehicle populations may be conservative with respect to the age of vehicles. Registration data as of December 2004 shows approximately 38% of vehicles being 10 years old or older, while data from the HARC report shows approximately 18% of vehicles projected to be in this age range. The age of vehicle populations actually in use may be younger than reflected by registration data, as older vehicles may be registered, but not in operation. Also, although the HARC data may assume more rapid fleet modernization than has occurred in the past, this data was chosen as the basis for this report because it provided the most detail available on vehicle populations and corresponding emissions.

[14] "Texas Emission Reduction Plan Assessment in the Dallas Fort-Worth Area", HARC, November 12, 2004; "Texas Emission Reduction Plan Assessment in the Houston-Galveston-Brazoria Region", HARC, May 19, 2004

6.1 Houston-Galveston

With the exception of school buses, the estimated vehicle populations as of 2007 for the HGB area are from the previously cited HARC report[15]. The estimated school bus population is based on data from the Galveston-Houston Association for Smog Prevention[16]. The GHASP bus population data and forecasted changes from March 2004 and forecasted population growth were used to estimate the 2007 school bus population for HGB.

Table 6.1

Houston-Galveston-Brazoria Area estimated 2007 vehicle populations						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	410	505	1,381	812	45	3,153
1988-1990	451	523	1,082	893	43	2,992
1991-1997	3,640	2,912	7,507	2,110	505	16,674
1998-2001	8,048	3,949	7,193	1,866	349	21,405
2002-2006	28,853	9,411	13,711	2,297	480	54,752
2007+	4,440	862	1,939	138	44	7,423
Total	**45,842**	**18,162**	**32,813**	**8,115**	**1,466**	**106,398**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

6.2 Dallas-Fort Worth

For the DFW area, the estimated vehicle populations are from the HARC report[17], except for the school bus information. The estimated school bus population is based on school district and bus information from the North Central Texas Council of Governments[18].

Table 6.2

Dallas-Fort Worth Area estimated 2007 vehicle populations						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	199	204	386	410	33	1,232
1988-1990	420	501	714	492	31	2,158
1991-1997	3,755	2,418	2,303	2,380	368	11,224
1998-2001	5,699	3,277	7,088	2,216	254	18,534
2002-2006	25,166	8,700	17,399	2,462	350	54,077
2007+	4,323	893	1,910	246	32	7,404
Total	**39,562**	**15,993**	**29,800**	**8,207**	**1,068**	**94,630**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

6.3 Remaining TERP Areas

For each of the remaining TERP-eligible areas, relative population sizes and the diesel vehicle populations of DFW and HGB were utilized as the basis for estimating the total 2007 heavy-duty diesel vehicle populations.

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[15] Ibid

[16] "Reducing Air Pollution From Houston-Area School Buses", Galveston-Houston Association for Smog Prevention, March 2004.

[17] "Texas Emission Reduction Plan Assessment in the Dallas Fort-Worth Area" prepared for HARC by ENVIRON International Corporation, November 12, 2004.

[18] Email from Mindy Mize, Sr. Transportation Planner, NCTCOG, February 1,2005.

The relative percentages of vehicles by model year for DFW and HGB were applied to the previously estimated truck population totals for each area to derive estimated truck populations by truck size and model year for each TERP area.

Table 6.3

San Antonio Area estimated 2007 vehicle populations						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	67	69	130	138	11	415
1988-1990	141	169	240	166	10	726
1991-1997	1,263	814	775	801	124	3,777
1998-2001	1,918	1,103	2,385	746	85	6,236
2002-2006	8,468	2,927	5,854	828	118	18,195
2007+	1,455	300	643	83	11	2,491
Total	**13,311**	**5,381**	**10,027**	**2,761**	**359**	**31,840**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

For the Austin area, the transit bus population size and age was projected from data obtained from Capitol Metro[19].

Table 6.4

Austin Area estimated 2007 vehicle populations						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	55	56	106	112	-	329
1988-1990	115	137	196	135	-	583
1991-1997	1,029	663	631	652	40	3,016
1998-2001	1,562	898	1,943	607	252	5,263
2002-2006	6,801	2,385	4,769	675	85	14,715
2007+	1,185	245	524	67	13	2,034
Total	**10,747**	**4,384**	**8,169**	**2,250**	**390**	**25,940**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

Table 6.5

El Paso Area estimated 2007 vehicle populations						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	28	29	54	58	5	173
1988-1990	59	70	100	69	4	303
1991-1997	527	339	323	334	52	1,575
1998-2001	800	460	995	311	36	2,601
2002-2006	3,532	1,221	2,442	346	49	7,590
2007+	607	125	268	35	4	1,039
Total	**5,552**	**2,245**	**4,182**	**1,152**	**150**	**13,281**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

[19] Quality Assurance Department, Capitol Metro, Austin, Texas

Table 6.6

Tyler/Longview Area estimated 2007 vehicle populations						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	18	18	34	36	3	109
1988-1990	37	44	63	44	3	191
1991-1997	332	214	203	210	33	992
1998-2001	503	290	626	196	22	1,637
2002-2006	2,223	769	1,537	218	31	4,777
2007+	382	79	169	22	3	654
Total	**3,495**	**1,413**	**2,633**	**725**	**94**	**8,360**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

Table 6.7

Corpus Christi Area estimated 2007 vehicle populations						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	15	16	30	31	3	95
1988-1990	32	38	55	38	2	166
1991-1997	288	186	177	183	28	861
1998-2001	437	252	544	170	19	1,423
2002-2006	1,932	668	1,335	189	27	4,151
2007+	332	69	147	19	2	568
Total	**3,036**	**1,227**	**2,287**	**630**	**82**	**7,263**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

Table 6.8

Beaumont/Port Arthur Area estimated 2007 vehicle populations						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	15	15	29	31	2	93
1988-1990	32	38	54	37	2	163
1991-1997	284	183	174	180	28	847
1998-2001	430	247	535	167	19	1,399
2002-2006	1,900	657	1,314	186	26	4,083
2007+	326	67	144	19	2	559
Total	**2,987**	**1,208**	**2,250**	**620**	**81**	**7,145**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

Table 6.9

Victoria Area estimated 2007 vehicle populations						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	3	3	7	7	1	21
1988-1990	7	8	12	8	1	37
1991-1997	64	41	39	40	6	190
1998-2001	96	55	120	37	4	314
2002-2006	426	147	294	42	6	915
2007+	73	15	32	4	1	125
Total	**669**	**271**	**504**	**139**	**18**	**1,601**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

Table 6.10

Total estimated 2007 vehicle populations for all Areas						
MY	**LHDV**	**MHDV**	**HHDV**	**School Bus**	**Transit Bus**	**Total**
1987 and <	810	915	2,156	1,636	102	**5,619**
1988-1990	1,295	1,529	2,516	1,882	97	**7,318**
1991-1997	11,182	7,768	12,132	6,890	1,183	**39,156**
1998-2001	19,494	10,531	21,429	6,317	1,042	**58,812**
2002-2006	79,300	26,885	48,656	7,242	1,172	**163,254**
2007+	13,123	2,656	5,775	632	112	**22,298**
Total	**125,203**	**50,283**	**92,665**	**24,598**	**3,708**	**296,458**

LHDV (GVWR 8,500-19,500 lbs.), MHDV (GVWR 19,500-33,000 lbs.), HHDV (GVWR >33,000 lbs.)

7.0 FLEET INFORMATION and RETROFIT SCENARIOS

For this report, several fleets were examined as potential retrofit candidates. Fleets with the most eligible candidate vehicles based on model years and emissions were determined to be refuse trucks, quarry trucks, and school buses. In the following sections, each of these fleets is discussed and retrofit examples are provided.

7.1 Refuse Trucks

Based on population and an industry rule-of-thumb of one refuse truck per 3,000 persons, there are an estimated 5,250 refuse trucks in the TERP-eligible areas, about 65% of which are in non-governmental fleets. The Vehicle Inventory and Use Survey[20] indicates that refuse trucks each travel an estimated average of 35,000 miles annually.

Although the annual mileage of refuse trucks is relatively low, these fleets are an attractive target for emission reductions due to their frequent presence in residential areas and their stop and start driving cycles that produce high emissions per mile. Fuel consumption is the best measure for determining emissions from refuse trucks. Their high fuel consumption, roughly 8,000 gallons per year, enhances the cost-effectiveness of refuse truck retrofit projects. In addition to TERP funds, refuse trucks are also eligible for federal Congestion Mitigation/Air Quality Improvement funds (CMAQ) for retrofits.

Of the approximately 315 non-governmental fleets with 20 or more registered vehicles, about 13 are registered as refuse/sanitation fleets. These 13 list approximately 870 vehicles of model years 1985-2002, predominately Class 8[21]. Predominant engines among these vehicles are:

Cat 3306
Cummins 6C Series
Cummins L10
Mack E7-300
Mack EM7-300
Volvo VE-D7

[20] Vehicle Inventory and Use Survey for Texas, U.S. Census Bureau, 2002 Economic Census
[21] Fleet registration data from R.L. Polk & Co., as of December, 2004.

7.1A Refuse Truck Scenarios

Table 7.1 illustrates two possible scenarios for retrofits of refuse trucks. These scenarios assume the retrofits reduce NOx emissions by 50%, which is conservative relative to preliminary test results indicating up to 70% emission reductions[22]. The remaining lifespans correspond to the TERP guidelines for the "activity life" of these types of vehicles, with five years the minimum and seven years the maximum allowed. The calculations were performed using the emissions factors and methods per the TERP guidelines[23]. At approximately $3,500 to $5,300 per ton of NOx reduced, the cost of refuse truck retrofits are at or well below the TCEQ goal of $5,000 per ton for the TERP program.

Table 7.1 – Refuse Truck Retrofit Examples

Model Year	1987	1997
Remaining Lifespan (yrs)	5	7
Fuel Consumption (gal/yr)	8,000	8,000
Base emission factor (g/bhp-hr)	10.7	5.0
Emissions reduction	50%	50%
NOx reduction/vehicle/yr (tons/yr)	.79	.38
NOx reduction/vehicle/day (tons/day) (260/yr)	.003	.001
Total NOx reduction/vehicle (tons)	3.94	2.66
Retrofit Cost	$14,000	$14,000
Cost/ton NOx reduced	$3,556	$5,263

7.2 Quarry Trucks

Another potential target market for emission-reducing retrofits is the population of haul trucks used at rock mining facilities. These trucks typically accumulate high mileage, 80,000 to 100,000 miles annually, making them cost-effective candidates for retrofits. Also, they usually travel locally and they are frequently older model year trucks. Local travel helps such vehicles meet the TERP requirements of operating 75% of the time in TERP-eligible counties. There are approximately 320 mines and quarries in Texas[24], utilizing an estimated 3,000 haul trucks.

[22] Ray Kammel, Converter Technology, Inc.
[23] "Texas Emissions Reduction Plan: Guidelines for Emissions Reduction Incentive Grants", Texas Commission on Environmental Quality, May 2004; "Emissions Reduction Incentive Grants Program Technical Supplement No. 1 – On-road Heavy-Duty Vehicles", October 19, 2004. www.terpgrants.org
[24] "Statistics on Mining Industries", U.S. Census Bureau, 1997 Economic Census: Summary Statistics for Texas http://www.census.gov/epcd/ec97/tx/TX000.HTM

Table 7.2 – Quarry Truck Retrofit Examples

Model Year	1993	2001
Remaining Lifespan (yrs)	5	7
Miles per year	75,000	100,000
Base emission factor (g/bhp-hr)	5.0	4.0
Emissions reduction	50%	50%
NOx reduction/vehicle/yr (tons/yr)	.61	.63
NOx reduction/vehicle/day (tons/day) (260 days/year)	.002	.002
Total NOx reduction/vehicle (tons)	3.03	4.41
Retrofit Cost	$14,000	$14,000
Cost/ton NOx reduced	$4,620	$3,175

The remaining lifespans correspond to the TERP guidelines for the "activity life" of these types of vehicles, with five years the minimum and seven years the maximum allowed. Regarding the annual mileage, newer trucks in fleets tend to be driven more than older trucks. The calculations were performed using the emissions factors and methods per the TERP guidelines. The cost-effectiveness of quarry truck retrofits fall well under the TERP goal of $5,000 per ton.

7.3 School Buses

The 2007 school bus population in the TERP-eligible areas is projected to be approximately 24,600 buses, of which approximately 74% are estimated to be at least five years old. School buses can be ideal candidates for retrofits as the fleets tend to be kept in service longer than other fleet vehicles (especially as compared to transit buses) and their emissions can affect the health of children and others while riding the bus, waiting in their neighborhoods, or waiting near idling buses at school. Also, school districts cannot easily afford to replace older buses and may be more willing to retrofit such buses.

Table 7.3 shows two examples of the costs and effects of retrofitting school buses for NOx emissions reductions. Although the cost per ton of NOx reduced is high, retrofitting school buses could be made more cost effective by including particulate matter in the emissions reduced. Although particulate matter reductions are not currently funded by TERP and are beyond the scope of this report, it is worth noting that ultrafine diesel particulate matter emissions are known to increase the risk for cancer[25]. Also, with the HGB region approaching nonattainment for particulate matter and the Environmental

[25] "Pollution Risk Is Found On Diesel School Buses", Nicholas Bakalar, The New York Times, April 26, 2005.

Protection Agency reviewing standards, it is likely that such emissions will be considered of consequence in Texas in the near future.

Also, it should be noted that the CTI retrofit systems are reusable and have life spans of from seven to ten years. A system can be removed from a retired bus or truck and re-installed on another vehicle for approximately $3,000. Reuse of the retrofit systems in this way could drive the cost-effectiveness of school bus retrofits down to approximately $3,000 to $5,500 per ton of NOx emissions reduction for the second installation of the retrofit.

Table 7.3 – School Bus Retrofit Examples

Model Year	1983	1999
Remaining Lifespan (yrs)	5	10
Miles per year	12,000	18,000
Base emission factor (g/bhp-hr)	10.7	4.0
Emissions reduction	50%	50%
NOx reduction/vehicle/yr (tons/yr)	.11	.11
NOx reduction/vehicle/day (tons/day) (180 days/yr)	.001	.001
Total NOx reduction/vehicle (tons)	.54	1.12
Retrofit Cost	$14,000	$14,000
Cost/ton NOx reduced	$25,902	$12,513

If 50% of the diesel school buses of model year 2002 and older in the TERP-eligible areas were retrofitted, NOx emissions would be reduced by an estimated total of 995 tons per year, or 5.5 tons per day (assuming 180 days per school year) in these combined areas, assuming emission reductions of 50% per retrofitted vehicle. The remaining lifespans correspond to the TERP guidelines for the "activity life" of school buses with five years the minimum and 20 years the maximum allowed. In these scenarios, ten years was chosen as the maximum remaining lifespan, as older buses were used as examples. Also, annual mileage differs for the two examples, as newer buses are driven more miles than are older buses. The calculations were performed using the emissions factors and methods per the TERP guidelines[26].

Typical engines in school buses include the International T444E, the International DT466, the Caterpillar 3116 and the Caterpillar 3126.

[26] "Texas Emissions Reduction Plan: Guidelines for Emissions Reduction Incentive Grants", Texas Commission on Environmental Quality, May 2004; "Emissions Reduction Incentive Grants Program Technical Supplement No. 1 – On-road Heavy-Duty Vehicles", October 19, 2004. www.terpgrants.org

Funding to school districts for school bus retrofits may be available from a variety of sources. Congress has allocated the Clean School Bus USA program $7.5 million for fiscal year 2005 for a cost-shared grant program to school districts to upgrade their diesel fleets and $10 million for fiscal year 2006.

Clean School Bus USA
http://www.epa.gov/cleanschoolbus/funding.htm

Adopt-A-School Bus Program
Barry Feldman
U.S. EPA
(214) 665-7439
www.adopt-a-schoolbus.org

Clean Cities/Clean Vehicles – CMAQ funds
Jason Salinas
Houston-Galveston Area Council
jason@h-gac.com
(713)993-4559

In addition, bills currently pending before the Texas Legislature may, if passed, earmark specific funds for a Clean School Bus Program. This program may provide funding to reduce school bus emissions of NOx or particulate matter through a variety of methods, including retrofits. Passage of this bill would be particularly helpful to Texas school districts, as school buses typically do not qualify for current TERP grants, due to their relatively low annual mileage.

7.4 HGB Retrofit Scenarios

Since CTI is having the International 7.3L and CAT 3406 engines certified for emissions control, scenarios have been developed to illustrate the possible emission reductions from retrofitting vehicles with these engines.

The following examples pertain to vehicles in the HGB area and assume 50% NOx reduction with the CTI technology. Table 7.5 shows an example of possible emission reductions achieved by retrofitting 90% of the designated International and Caterpillar engines of model years 1985 through 1989. Table 7.5 illustrates possible emission reductions achieved by retrofitting 50% of the designated engines of model years 1990 – 2002. Table 7.6 provides the total potential emission reductions from these scenarios, which are 2,155 tons per year, or 8.2 tons per day, assuming a 260-day work year.

The costs per ton of the retrofits range from about $5,000 per ton to just under $13,000 per ton. Mileage assumptions used in the examples, which vary from 20,000 to 49,000 annual miles, may be conservative when compared to actual mileage as the assumption was that newer trucks are driven significantly more annual miles than older trucks.

Mileage for Class 2C through Class 8 trucks typically ranges from 20,000 to 75,000 annual miles, depending on model year.[27]

Table 7.4 – HGB NOx Reduction Example for 1985-1989 Engines

	LHD	MHD	HHD	Total
Engine Make/Model	Intl 7.3L	Intl 7.3L	CAT 3406	
Number of 1985-1989 engines	257	257	744	
Retrofit Price	$10,000	$12,000	$14,000	
Avg. Annual Mileage	20,000	20,000	22,000	
Market Penetration	90%	90%	90%	
Average NOx reduction/vehicle/year	.18	.25	.39	
Total NOx Reduction (tons/year)	43	57	260	360
Total NOx Reduction (tons/day)	.17	.22	1.0	1.39
Avg. Cost/Ton – 5yr Life	$10,872	$9,659	$7,206	
Avg. Cost/Ton – 7yr Life	$7,766	$6,899	$5,147	

Table 7.5 – HGB NOx Reduction Example for 1990-2002 Engines

	LHD	MHD	HHD	Total
Engine Make/Model	Intl 7.3/T444E	Intl 7.3/T444E	CAT 3406	
Number of 1990 - 2002 engines	7,175	7,175	3,102	
Avg. Annual Mileage	43,500	48,500	49,000	
Market Penetration	50%	50%	50%	
Average NOx reduction/vehicle/year	.15	.27	.35	
Total NOx Reduction (tons/year)	580	1076	499	2,155
Total NOx Reduction (tons/day)	2.2	4.1	1.9	8.2
Avg. Cost/Ton – 5yr Life	$12,380	$8,002	$8,698	
Avg. Cost/Ton – 7yr Life	$8,843	$5,716	$6,212	

[27] Vehicle Inventory and Use Survey for Texas, U.S. Census Bureau, 2002 Economic Census; http://www.census.gov/prod/ec02/ec02tv-tx.pdf

Table 7.6 – HGB NOx Example Totals for 1985-2002 Engines

	LHD	MHD	HHD	Total
Total NOx Reduction (tons/year)	623	1133	759	2,515
Total NOx Reduction (tons/day)	2.4	4.3	2.9	9.6
Overall Avg. Cost/Ton – 5yr Life	$12,277	$8,086	$8,187	
Overall Avg. Cost/Ton – 7yr Life	$8,769	$5,775	$5,848	

7.5 DFW Retrofit Scenarios

Since CTI is having the International 7.3L and CAT 3406 engines certified for emissions control, scenarios have been developed to illustrate the possible emission reductions from retrofitting vehicles with these engines.

The following examples pertain to vehicles in the DFW area and assume 50% NOx reduction with the CTI technology. Table 7.7 shows an example of possible emission reductions achieved by retrofitting 90% of the designated International and Caterpillar engines of model years 1985 through 1989. Table 7.8 illustrates possible emission reductions achieved by retrofitting 50% of the designated engines of model years 1990 – 2002. Table 7.9 provides the total potential emission reductions from these scenarios, which are 2,977 tons per year, or 11.5 tons per day, assuming a 260-day work year.

The costs per ton of the retrofits range from about $5,000 per ton to just under $13,000 per ton. Mileage assumptions used in the examples, which vary from 20,000 to 49,000 annual miles, may be conservative when compared to actual mileage as the assumption was that older model trucks are driven for significantly less miles than are newer trucks. Mileage for Class 2C through Class 8 trucks typically ranges from 20,000 to 75,000 annual miles, depending on model year.[28]

[28] Vehicle Inventory and Use Survey for Texas, U.S. Census Bureau, 2002 Economic Census; http://www.census.gov/prod/ec02/ec02tv-tx.pdf

Table 7.7 – DFW NOx Reduction Example for 1985-1989 Engines

	LHD	MHD	HHD	Total
Engine Make/Model	Intl 7.3L	Intl 7.3L	CAT 3406	
Number of 1985-1989 engines	287	287	837	
Avg. Annual Mileage	20,000	20,000	22,000	
Market Penetration	90%	90%	90%	
Average NOx reduction/vehicle/year	.18	.25	.39	
Total NOx Reduction (tons/year)	48	64	293	405
Total NOx Reduction (tons/day)	.18	.25	1.1	1.53
Avg. Cost/Ton – 5yr Life	$10,872	$9,659	$7,206	
Avg. Cost/Ton – 7yr Life	$7,766	$6,899	$5,147	

Table 7.8 – DFW NOx Reduction Example for 1990-2002 Engines

	LHD	MHD	HHD	Total
Engine Make/Model	Intl 7.3/T444E	Intl 7.3/T444E	CAT 3406	
Number of 1990 - 2002 engines	8,257	8,259	4,031	
Avg. Annual Mileage	43,500	48,500	49,000	
Market Penetration	50%	50%	50%	
Average NOx reduction/vehicle/year	.15	.27	.35	
Total NOx Reduction (tons/year)	656	1214	702	2,572
Total NOx Reduction (tons/day)	2.5	4.7	2.7	9.9
Avg. Cost/Ton – 5yr Life	$12,584	$8,161	$8,040	
Avg. Cost/Ton – 7yr Life	$8,989	$5,829	$5,743	

Table 7.9 – DFW NOx Example Totals for 1985-2002 Engines

	LHD	MHD	HHD	Total
Total NOx Reduction (tons/year)	704	1278	995	2,977
Total NOx Reduction (tons/day)	2.7	5.0	3.8	11.5
Overall Avg. Cost/Ton – 5yr Life	$12,469	$8,236	$7,794	
Overall Avg. Cost/Ton – 7yr Life	$8,906	$5,883	$5,568	

8.0 CONCLUSIONS AND RECOMMENDATIONS

As the Houston-Galveston-Brazoria and Dallas-Fort Worth areas encompass major urban centers and have large populations of diesel vehicles, these areas are likely to be the best initial markets for commercial retrofitting of on-road diesel vehicles. Already, retrofit projects of government-owned fleets have begun in the Houston area. In addition, HGB and DFW are classified in nonattainment for ground-level ozone, and have the greatest need for reduction of NOx emissions.

Although Beaumont-Port Arthur and El Paso are also in nonattainment for ground-level ozone, these areas are affected by other factors that may make them secondary, rather than primary markets for large numbers of retrofits. In Beaumont-Port Arthur, only 16% of projected NOx emissions are attributed to on-road sources, providing less opportunity for significant emission reductions from these sources than in HGB or DFW. In El Paso, although on-road sources account for a majority of NOx emissions, these sources are predominately gasoline-powered and may be located or operated primarily in Mexico.

The Class 8, Heavy-Heavy Duty vehicles make up the second largest population class in HGB and DFW, but account for over three-fourths of the estimated on-road NOx emissions in these areas. Therefore, this class of vehicles should be considered a primary target for retrofits. Predominant engines in this class in the TERP counties are the Detroit Diesel Series 60 and the Cummins N14.

Although they make up 41% of the heavy duty diesel population in HGB and DFW, the light-heavy duty diesel vehicles, such as delivery vans, are less likely candidates for cost-effective retrofits. One obstacle to retrofitting these vehicles is that they often accumulate relatively low annual mileage, narrowing the possible funding sources for retrofits. Also, the contribution of NOx emissions of this class of vehicles is relatively low, comprising less than 9% of daily emissions in HGB and DFW[29]. However, the large population of these trucks makes them worth reconsidering if they were to be retrofitted in conjunction with vehicle replacements or with PM retrofits.

Specific fleets to target for cost-effective retrofits include refuse trucks and quarry trucks. In general, fleets with high mileage vehicles or vehicles with high fuel use are likely potential customers for retrofits. Also, CTI retrofit systems are well-suited to urban duty driving cycles that generate low exhaust temperatures, as is the case with refuse trucks. Although retrofitting school buses is less cost-effective than for other fleets, such retrofits benefit the health of children, have wide-spread political support, and have dedicated funding sources.

Finally, although this report focused on larger fleets, many of the older trucks tend to be driven by owner-operators as part of small businesses. An idea that may be worthy of

[29] "Texas Emission Reduction Plan Assessment in the Dallas Fort-Worth Area", HARC, November 12, 2004; "Texas Emission Reduction Plan Assessment in the Houston-Galveston-Brazoria Region", HARC, May 19, 2004

future study is the development of a program to retrofit trucks being purchased by small businesses to replace the oldest trucks on the road. Such a combination retrofit/replacement program would increase the viable market for CTI retrofit systems and extend the benefits of employing emissions reduction technology to a wider vehicle population than would be reached through the current TERP program.