TexN2 Utility Improvements and Updates for Compatibility with the US EPA MOVES5 Model

Final Report

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June 27, 2025

ERG No.: 0488.00.004

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TCEQ Contract No. 582-23-45976
Work Order No. 4

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ACRONYMS

AERR - Air Emissions Reporting Requirements

AWS – Amazon Web Services

CAP – Criteria Air Pollutant

CAPCOG – Capital Area Council of Governments

CDB – County Database

CERS – Consolidated Emissions Reporting Schema

CNG – Compressed Natural Gas

CO – Carbon Monoxide

DCE – Diesel Construction Equipment

DFW – Dallas-Fort Worth

EI – Emission Inventory

EIS – Emissions Inventory System

EPA – Environmental Protection Agency

ERG – Eastern Research Group, Inc.

GDP – Gross Domestic Product

GUI – Graphical User Interface

HAP – Hazardous Air Pollutant

HCI – Highway Cost Index

HGB – Houston-Galveston-Brazoria

HP – Horsepower

ICE – Internal Combustion Engine

L&G – Lawn and Garden

LPG – Liquified Petroleum Gas

MOVES – Motor Vehicle Emissions Simulator

NAA – Nonattainment Area

NAAQS – National Ambient Air Quality Standard

NAICS – North American Industry Classification System

NEI – National Emissions Inventory

NH_3 – Ammonia

NLCD – National Land Cover Database

NO_X – Nitrogen Oxides

OEM – Original Equipment Manufacturer

OSD – Ozone Season Day

PM_{10} – Particulate Matter less than 10 microns in diameter

$PM_{2.5}$ – Particulate Matter less than 2.5 microns in diameter

PSR – Power Systems Research

QA – Quality Assurance

RFG – Reformulated Gasoline

RFP – Reasonable Further Progress

SCC – Source Classification Code

SIP – State Implementation Plan

SO_2 – Sulfur Dioxide

TCEQ – Texas Commission on Environmental Quality

TERP – Texas Emission Reduction Plan

TexAER – Texas Air Emissions Repository

TexN – Texas Nonroad

TexN2 – Texas Nonroad version 2

TPD – Tons per Day

TPY – Tons per Year

TxDOT – Texas Department of Transportation

TxLED – Texas Low Emission Diesel

VOC – Volatile Organic Compounds

XML – Extensible Markup Language

1.0 Overview

This report is Deliverable 9.2 for the project "TexN2 Utility Improvements and Updates for Compatibility with the US EPA MOVES5 Model" (Contract Number 582-23-45976, Work Order 4).

The study updated the use of the Texas NONROAD version 2 (TexN2) utility with the Environmental Protection Agency's (EPA) MOVES5 model, updated equipment populations in the TexN2 database based off of data purchased from Power Systems Research, Economy.com, and developed a set of multipollutant, multiyear area-specific emissions inventories (EI) necessary to support reasonable further progress (RFP) analyses for all nonroad model mobile sources in the Houston-Galveston-Brazoria (HGB) six-county and Dallas-Fort Worth (DFW) nine-county ozone nonattainment areas under the 2015 ozone National Ambient Air Quality Standard (NAAQS). This study broadly included the multipollutant benefits of the Texas Emission Reduction Plan (TERP) program in regulatory EIs.

2.0 Background

The Texas Commission on Environmental Quality (TCEQ) contracted with Eastern Research Group (ERG), Inc. to develop TexN and TexN2 models, which are utilities for estimating Texas-specific emissions from nonroad mobile sources, excluding commercial marine vessels, locomotives, drilling rigs, and aircraft. The TexN model used the EPA NONROAD model to calculate emissions, whereas TexN2.5 used EPA's MOVES4 NONROAD model. MOVES is required by the EPA for developing nonroad emissions estimates for state implementation plan (SIP) revisions, national EIs, and reasonable further progress (RFP) analyses. Since TexN was first developed the TCEQ has frequently updated the Texas-specific data within the tool and enhanced the tool's functionality.

EPA's current release of MOVES is MOVES5 (US EPA, 2025), and TexN2 required modification under this project to ensure compatibility with the latest version of the model. The primary purpose of this project was to update TexN2 for use with MOVES5 and develop a set of area-specific EIs for all operating nonroad model mobile sources. These EIs are needed to support SIP development. ERG developed average summer weekday (tons per day) controlled and uncontrolled EI estimates of criteria air pollutants (CAP) and CAP precursors, focusing on nitrogen oxides (NO_X), volatile organic compounds (VOC), and particulate matter (PM) with an aerodynamic diameter equal to or less than 2.5 microns ($PM_{2.5}$). The EIs were developed within a framework based on methods consistent with the EPA requirements and guidance on development of actual EIs that were directed by the TCEQ Project Manager.

In order to develop potential SIP revision(s) for the 2015 eight-hour ozone National Ambient Air Quality Standard (NAAQS), ERG developed area-specific EIs necessary to support RFP analyses for the following areas: the Houston-Galveston-Brazoria (HGB) six-county and the Dallas-Fort Worth (DFW) nine-county nonattainment areas. The analysis years included base-year 2017, milestone years 2023, 2026, 2029, contingency years 2024, 2027, 2030 2033, and attainment year 2032.

A secondary purpose or phase of this work was to include development of an updated version of the TexN2 utility containing code updates to: (1) ensure compatibility with the EPA MOVES5 model; (2) automatically report TERP multi-pollutant emissions benefits as a separate line item in Automated RFP analyses for all calendar years for which applicable TERP data exist; (3) include TERP benefits in the fully controlled EI use case of TexN2; (4) add the calculation of $PM_{2.5}$ to the Automated RFP functionality and report; (5) add custom output queries to allow the export of equipment population, activity, load factors, and/or average horsepower (HP) directly from the TexN2 graphical user interface (GUI); (6) reduce disk space and runtime requirements; and (7) update the TexN2 database with equipment population projections that account for county-specific growth for diesel construction equipment (DCE) and electrification of all nonroad equipment types based on data to be obtained from Power Systems Research (PSR). The updates being applied to the TexN2 utility as part of this project resulted in an updated version of the utility, TexN2.6.

3.0 Update TexN2 Nonroad Equipment Population to Account for Electrification

ERG purchased electric equipment growth projection data from PSR that includes both total and electric in use population counts by source classification code (SCC) out to calendar year 2035 at the national level. ERG refined the national electrification fraction for Texas and implemented the data as part of the equipment populations update in the TexN2 database. Results were translated as updated equipment populations in the "populationYears" table of the TexN2 database, became a part of the updated utility, and will be used in the development of EIs under future work.

The proprietary PartsLink™ dataset detailed total estimated equipment counts and electric equipment counts by application type and power range. ERG obtained data for six application segments: Agricultural, Construction, Industrial, Lawn & Garden, Power Generation, and Recreational Production. The population trend data had over 250,000 lines of information. ERG matched the lines to specific SCCs which the TexN2 database uses to categorize sources of emissions.

After raw data fields were verified, ERG read in PSR's Master Dataset (Master_Dataset.xlsx), which contained the annual population of 2004 to 2035

Applications, separated by Segment, Original Equipment Manufacturer (OEM) Drive Type, HP Bin, and other specifications. The data was separated by Segment: Agricultural, Construction, Industrial, Lawn & Garden, Power Generation, and Recreational Production. While individually processing each segment, ERG split out the annual electric population, including both corded and battery electric OEM Drive Types. ERG summed the electric populations based on unique Application and HP Bin combinations, and compiled results, accounting for some combinations that did not have any battery or corded electric OEM Drive Types. This process was repeated for OEM Drive Types, including gas, hybrid, and electric, to account for the total population.

The electrification ratios were subsequently calculated for each year by dividing the electric and total results for each Application HP Bin combination. To ensure calculations, zeroes were filled in instances where electric population did not exist. Six files of electrification ratios, representing each segment, were produced (agr_data.csv, con_data.csv, ind_data.csv, power_data.csv, rec_data.csv, lawn_data.csv) and the ratios were applied to the TexN2 "populationYears" table to account for nonroad electrification.

Quality assurance efforts focused on verifying the electric percentage for each application segment. After linking the data to SCCs, the data was further broken down by HP bins. Different ranges of HP are expected to have varying levels of electrification. In general, higher power engines are expected to have lower levels of electrification.

ERG spoke with PSR regarding specific applications regarding instances where electrification trends did not match expectations, as summarized in Appendix A. After review, ERG concurs with PSR's responses with 2 exceptions:

- ERG is not confident in PSR's characterization of lawn and garden equipment electrification. For example, small handheld lawn & garden equipment had a lower level of electrification than expected and PSR did not start gathering data on electric trimmers until 2016 – by this time, electric lawn trimmers were already established in the market. Accordingly, ERG's update to the lawn & garden segment under an earlier project, which included surveys on 2022 residential lawn & garden equipment, was retained within the TexN database;
- ERG is not confident in PSR's characterization of transportation refrigeration unit (TRU) electrification.[1] In the absence of other information ERG retained the current Internal Combustion Engine (ICE) TRU populations in TexN.

[1] PSR claims electric TRUs are PTO at this time. See for example https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit/compliance-information/zero-emission-truck-tru.

ERG concurred with the remaining responses from PSR and combined the resulting electrification fractions with the latest growth factor projections to update the other equipment populations by calendar year, county, SCC, and HP bin.

ERG then conducted spot checks of the resulting equipment population time series for consistency and reasonableness. In Figures 1 through 8 below, the three blue series represent the DFW area, and three orange series represent the HGB area. The dotted series represent the existing populations in the prior TexN2 database; the dashed series with overlaid X marks show the populations after applying updated growth factors to year 2017 and later; and the solid line series represents the final populations in TexN2.6 reflecting updated growth factors as well as reductions in conventionally fueled equipment populations due to displacement by electric equipment. The dotted and X-mark dashed lines will always overlap for years 2004 to 2017 because the updated growth factors only change populations after 2017.

Figures 3 and 6 have small equipment populations because the left axis represents the modeled actual equipment population. For instance, in year 2017, there are only 4,471 forklifts in Texas in the TexN2 database, and 99% of the forklifts are greater than 50 HP. Total equipment count is then projected from a whole number in the base year and allocated to counties and HP bins. This results in small equipment populations, less than 1, for insignificant categories and is consistent with MOVES5 equipment populations.

Growth factor updates under this work only applied to diesel construction equipment greater than 25 HP, therefore dotted lines and X-dashed lines completely coincide in Figures 1, 3, and 6 due to their low HP. Equipment operating on gasoline fuel (Figure 8), Liquified Petroleum Gas (LPG), and Compressed Natural Gas (CNG) all received updated growth factors from MOVES5. Figures 4, 5, and 7 show that the larger HP equipment do not have any electric equipment according to the PSR data; therefore, the solid line series (final populations in TexN2.6) overlap the X-mark dashed series.

Electrification adjustments clearly lower ICE equipment population estimates except for the higher power SCC/HP combinations without electric model penetration (forklifts 100-175 HP, excavators 175-300 HP, backhoes 100-175 HP) and lawn and garden equipment (residential lawn mowers 3-6 HP) which retained the prior electrification fraction adjustments.

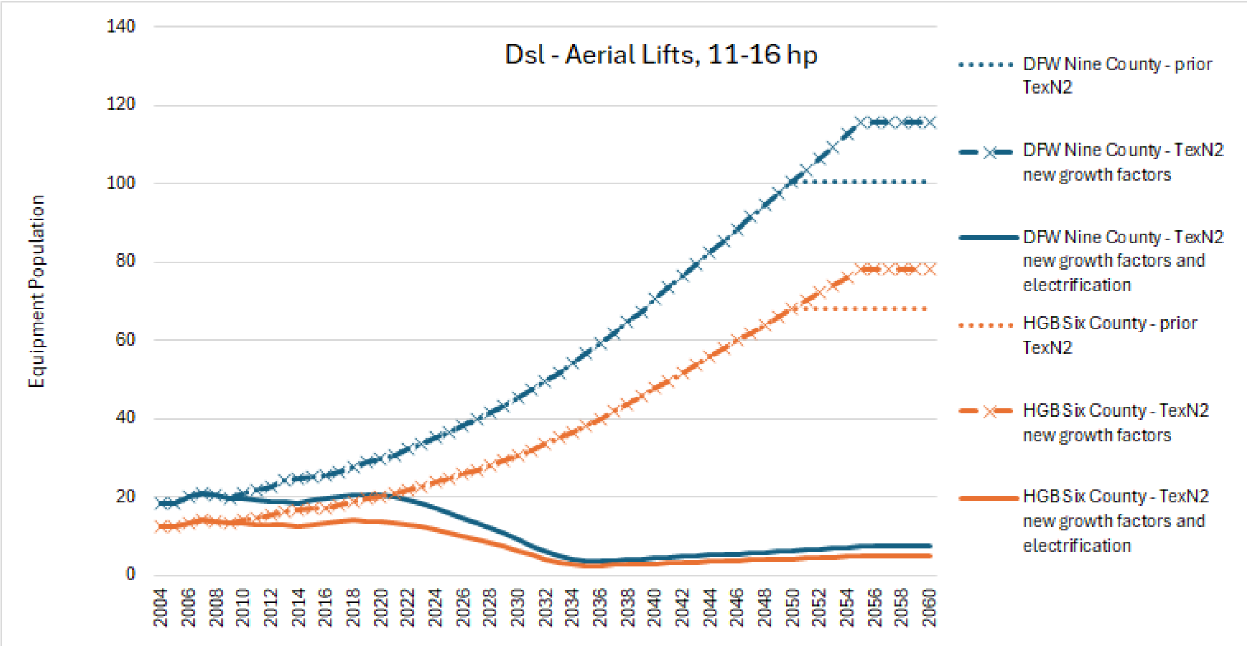

Figure 1. Electrification Adjustments to Aerial Lifts for HGB and DFW

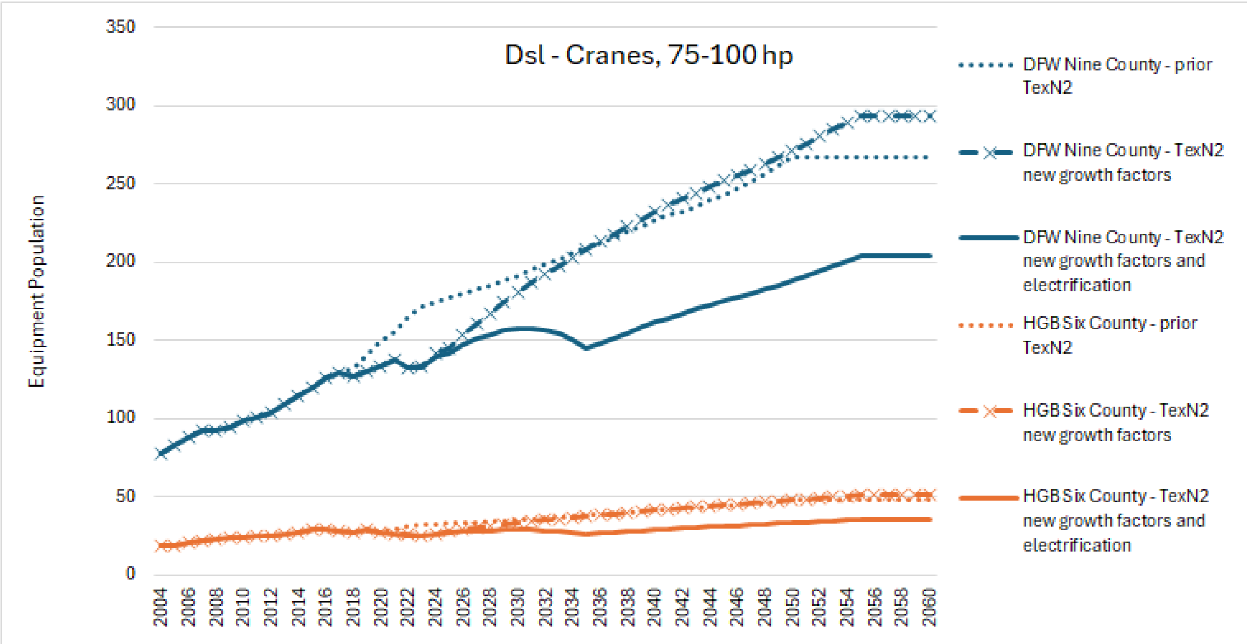

Figure 2. Electrification Adjustments to Cranes for HGB and DFW

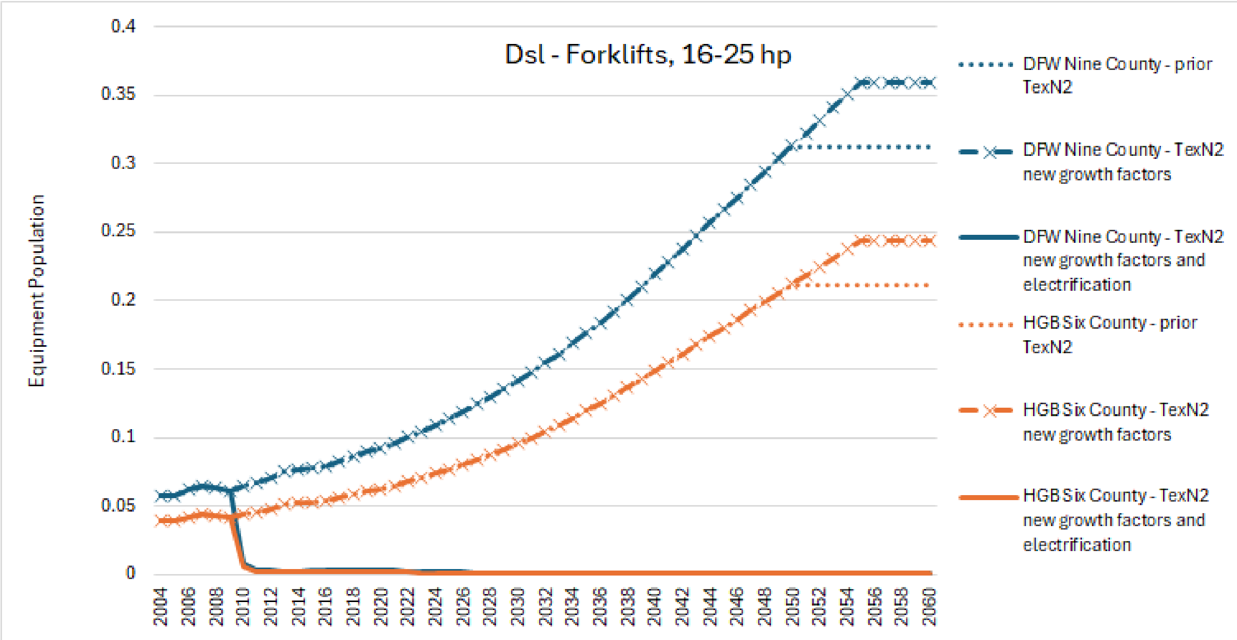

Figure 3. Electrification Adjustments to Forklifts (16 to 25 HP) for HGB and DFW

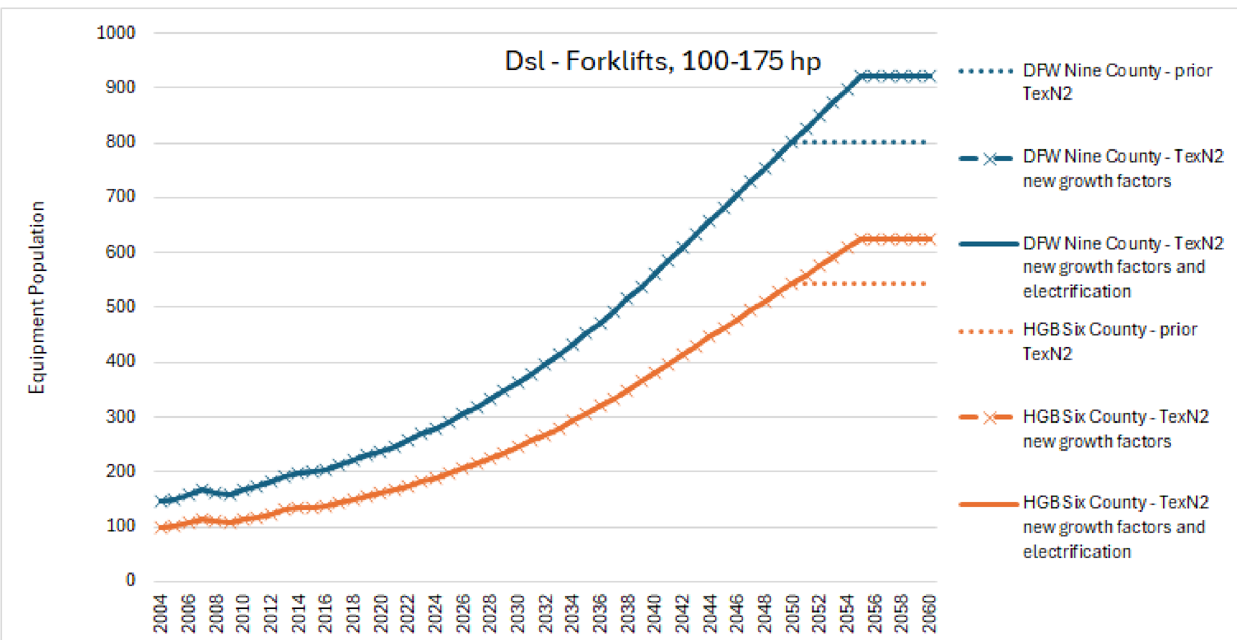

Figure 4. Electrification Adjustments to Forklifts (100 to 175 HP) for HGB and DFW

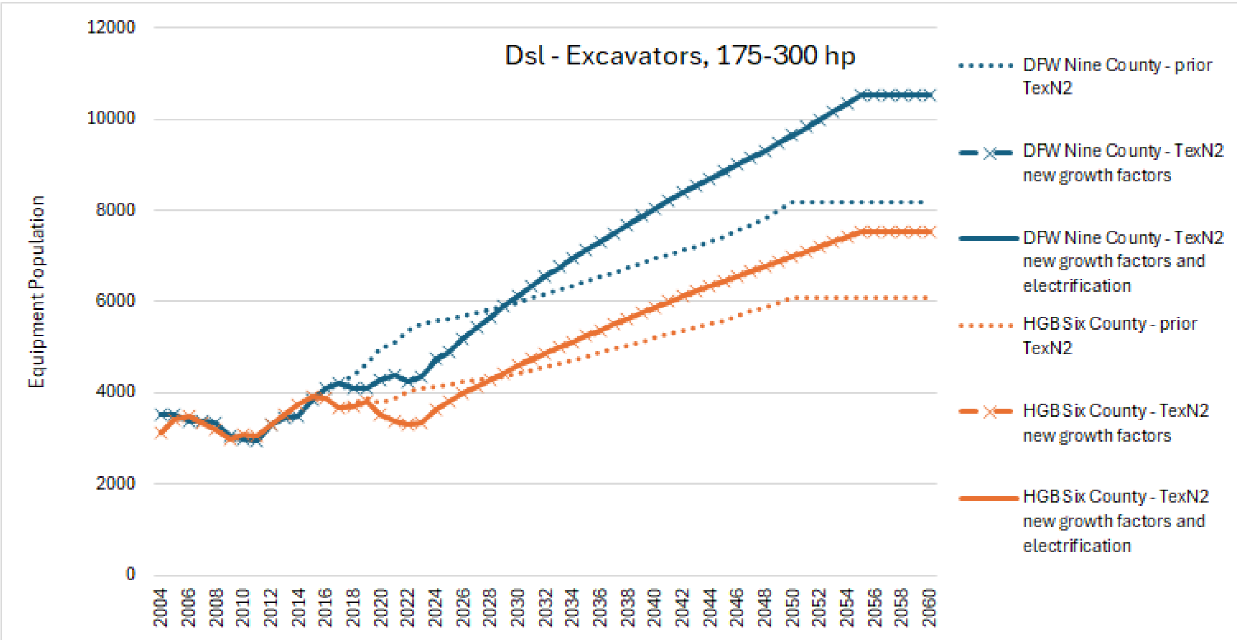

Figure 5. Electrification Adjustments to Excavators for HGB and DFW

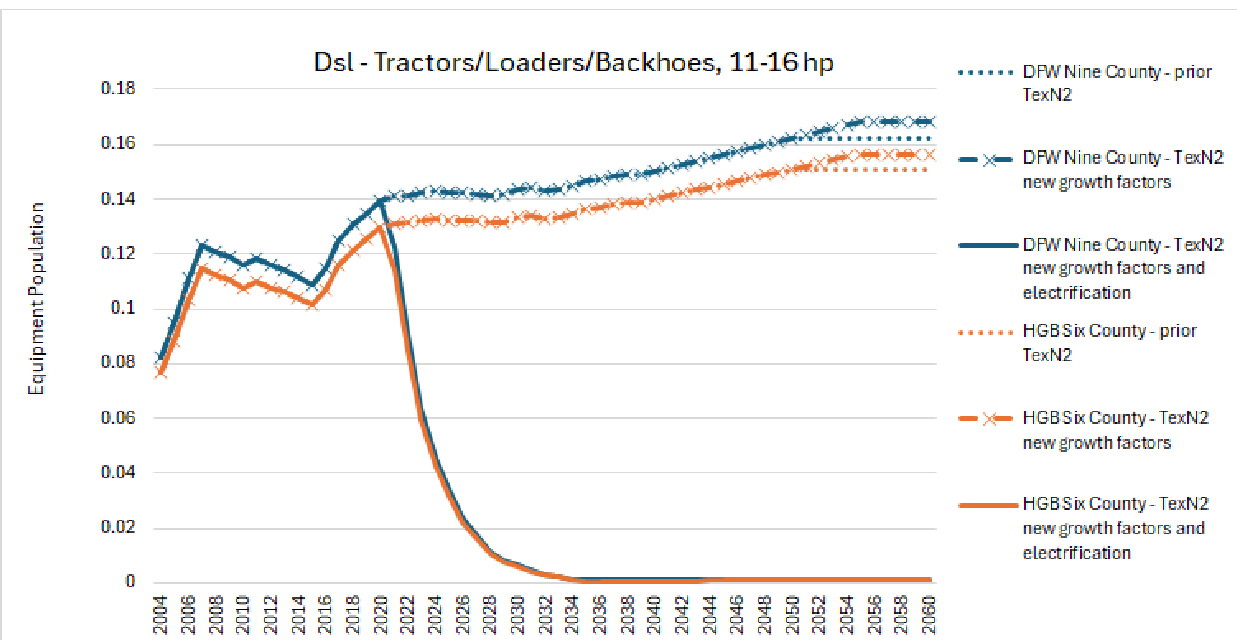

Figure 6. Electrification Adjustments to Tractors (11 to 16 HP) for HGB and DFW

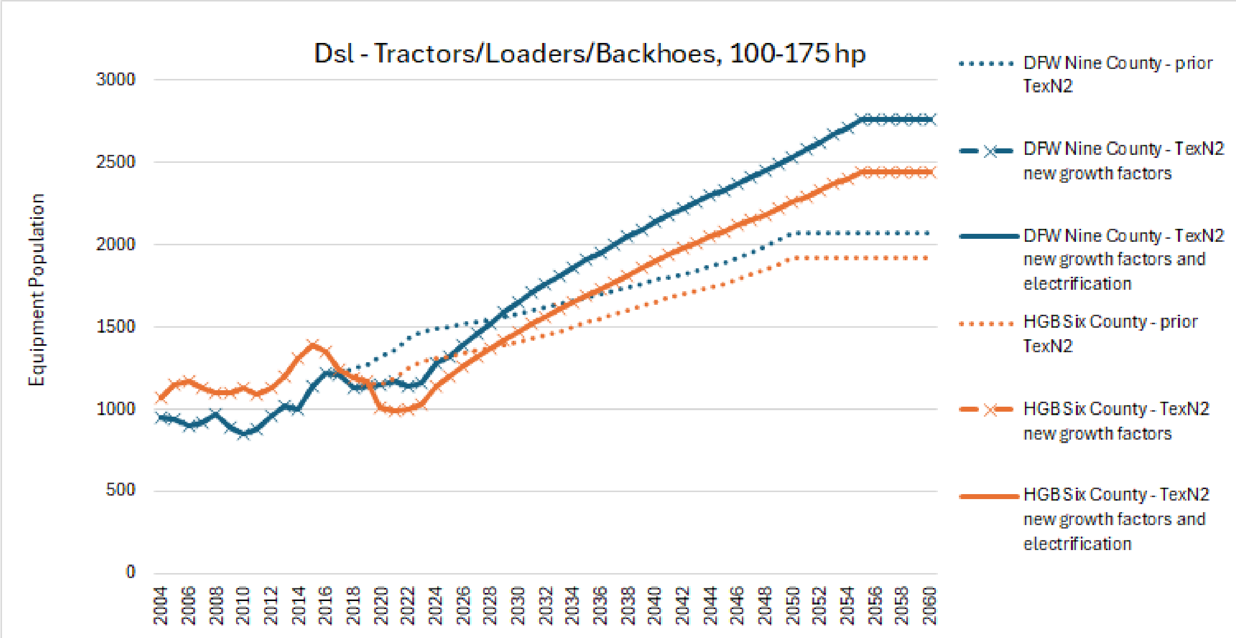

Figure 7. Electrification Adjustments to Tractors (100 to 175 HP) for HGB and DFW

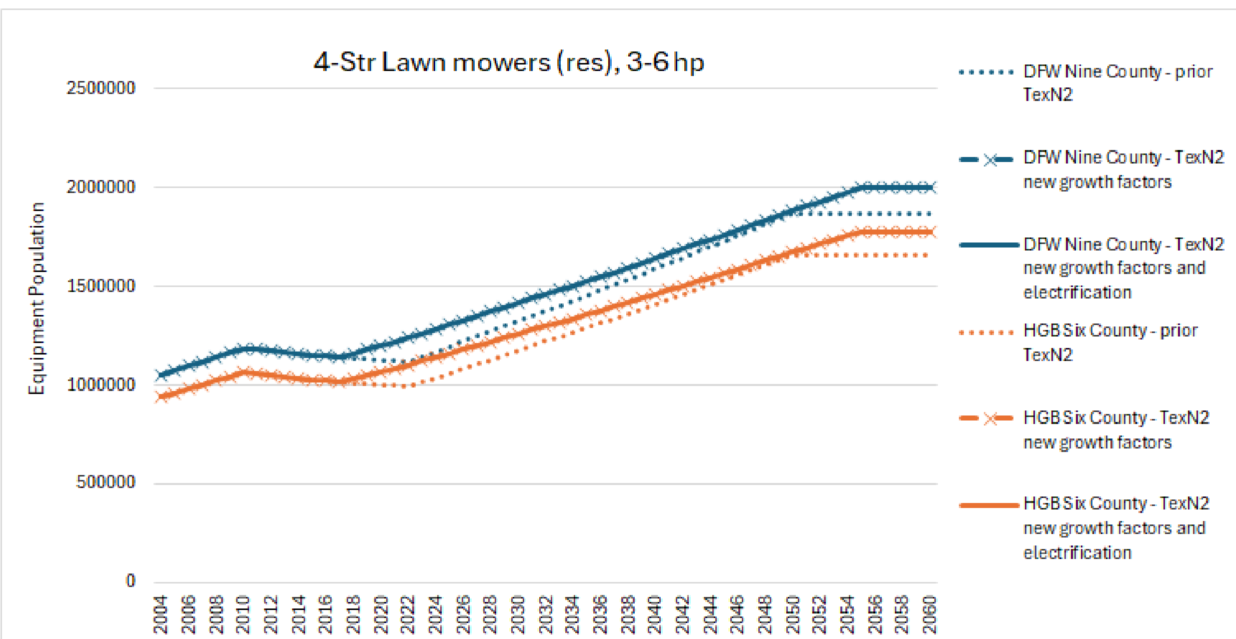

Figure 8. Electrification Adjustments to Lawn Mowers for HGB and DFW

4.0 Update TexN2 Nonroad Equipment Population to Account for Growth in DCE Sector

DCE is a primary area of interest for the characterization of nonroad emissions in the state of Texas. To appropriately model nonroad equipment activity, ERG obtained data surrogates tied to DCE equipment populations in each county over a range of modeling years. ERG identified multiple available surrogate data consistent with the updates made to TexN2 during the previous ERG project (Contract Number: 582-19-90502, Work Order Number: 582-20-11629-004). In consultation with the TCEQ Project Manager, ERG selected appropriate data sources and methods to project equipment growth from a base-year of 2017. Consistent with the previous 2020 TexN data update, ERG purchased, compiled, and used historical gross domestic product (GDP) estimates at the county level for the appropriate North American Industry Classification System categories from Economy.com to estimate equipment population growth for relevant TexN2 DCE subsectors. Inflation-adjusted GDP estimates for the base-year were used to develop the updated growth factors and increasing material costs over time were accounted for. ERG coordinated and merged the electrification fraction of nonroad equipment and growth factor data to update the “populationYears” table in the TexN2 database.

The TexN model contains 25 distinct “subsectors” with distinct equipment population and activity profiles. DCE comprises 23 of these subsectors. The 2 remaining subsectors comprise miscellaneous and Non-DCE equipment. County-level growth factors have been developed for the sectors from 2017 base-year surrogate data extended to 2060. Table 1 presents a summary of the growth surrogates used to develop the growth factors for each subsector, and Appendix B describes growth surrogates less Economy.com data.

Table 1. DCE Subsector and Leveraged Growth Surrogate

Subsector	#	Growth Surrogate
Non-DCE*	0	NONROAD default
DCE - Agricultural Activities	1	2022 Texas Agricultural Census
DCE – Boring & Drilling Equipment	2	Economy.com
DCE – Brick & Stone Operations	3	Economy.com
DCE – City and County Road Construction	4	Texas State Data Center county-level census population
DCE – Commercial Construction	5	Economy.com
DCE – Concrete Operations	6	Economy.com
DCE – County-Owned Construction Equipment	7	Texas State Data Center county-level census population

Subsector	#	Growth Surrogate
DCE – Cranes	8	Economy.com
DCE – Heavy-Highway Construction	9	Economy.com
DCE – Landfill Operations	10	Texas State Data Center county-level census population
DCE – Landscaping Activities	11	Economy.com
DCE – Manufacturing Operations	12	Economy.com
DCE – Municipal-Owned Construction Equipment	13	Texas State Data Center county-level census population
DCE – Transportation/Sales/Services	14	Economy.com
DCE – Residential Construction	15	County-level housing permit data from the Texas A&M Real Estate Center for 2017 through 2024; County-level census projections from the Texas State Data Center for 2025 through 2060
DCE – Rough Terrain Forklifts	16	Economy.com
DCE – Scrap Recycling Operations	17	Economy.com
DCE – Skid Steer Loaders	18	Equipment Data Associates Sales
DCE – Special Trades Construction	19	Economy.com
DCE – Trenchers	20	Economy.com
DCE – TxDOT Construction Equipment*	21	Zero growth per TxDOT Equipment Replacement Policy
DCE – Utility Construction	22	Economy.com
DCE – Mining & Quarry Operations	23	Economy.com Mining Safety and Health Administration (MSHA) registered mine data Energy Information Administration (EIA) Gulf lignite production outlook
DCE – Other DCE (Off-road tractors, Miscellaneous, and all Equipment < 25 HP*)		NONROAD default

*Not updated under this project effort

Default MOVES5 model growth factors through 2060 were kept intact in the TexN model for two equipment subsectors – “Non-DCE” equipment and “Other DCE” equipment. Other DCE equipment include off-road tractors, miscellaneous equipment, and equipment under 25 HP, while all equipment categories other than diesel construction fall under Non-DCE equipment, including industrial, commercial, recreational, and other equipment categories. Growth factors for non-DCE were produced to match MOVES5. Similarly, previous ERG studies for TCEQ did not develop alternative growth factors for these two categories. Focus is directed towards DCE equipment because the category has the single largest impact on total NO_X emissions of all mobile equipment represented within the TexN model, a driving precursor to ozone formation.

For the DCE subsector growth factors utilizing surrogate county-level GDP data, projections were provided by Economy.com from the base-year of 2017 through 2055, in 2017 U.S. dollars. Because these GDP projections were not available for 2056-2060, ERG used the final calculated growth factor of year 2055 for years 2056 to 2060, making no assumption of increase or decline in growth for those five years.

For each of these subsectors, a specific North American Industry Classification System (NAICS) code or set of codes was applied to Economy.com's GDP projections model. Table 2 below shows the Economy.com-supported DCE subsectors and their associated NAICS codes.

Table 2. Economy.com DCE Subsector and NAICS Code Crosswalk

		DCE Subsector															
Code	NAICS Description	2 - Boring & Drilling	3 - Brick & Stone Operations	5 - Commercial Construction	6 - Concrete Operations	8 - Cranes	9 - Heavy Highway Construction	11 - Landscaping Operations	12 - Manufacturing Operations	14 - Transportation/Sales/Services	16 - Rough Terrain Forklifts	17 - Scrap Recycling Operations	18 - Skid Steer Loaders	19 - Special Trades Construction	20 - Trenchers	22 - Utility Construction	23 - Mining & Quarry Operations
2361	Residential Building Construction	X				X					X		X		X		
2362	Nonresidential Building Construction	X		X		X					X		X		X		
2371	Utility System Construction	X				X					X		X		X	X	
2373	Highway; Street; and Bridge Construction	X				X	X				X		X		X		
238	Specialty Trade Contractors	X				X					X		X	X	X		
31-33	Manufacturing								X								
3273	Cement and Concrete Product Manufacturing				X												
3271	Clay Product and Refractory Manufacturing		X														
56173	Services to Buildings and Dwellings							X									
562920	Remediation and Other Waste Management Services											X					
212	Mining (except oil and gas)																X
42	Wholesale Trade									X							
44-45	Retail Trade									X							
48-49	Transportation and Warehousing									X							
81	Other Services (except public administration)									X							

The DCE subsectors had detailed data surrogate considerations. For heavy-highway construction, nominal county-level cost data from the years 2017-2023 from the Texas Comptroller was used[2]. This cost data included two major spending categories, "highway construction-capital outlay" and "repairs and maintenance." Costs were then adjusted by the most recent Texas Department of Transportation (TxDOT) Highway Cost Index (HCI)[3]. Projections following HCI-adjusted cost data from 2024 through 2055 were resolved using (HCI-adjusted) growth in Economy.com GDP data associated with the subsector.

[2] Texas Comptroller of Public Accounts, 2024 State of Texas Annual Cash Report, November 2024, https://comptroller.texas.gov/transparency/reports/cash-report/2024/96-368.pdf
[3] Texas Department of Transportation, Highway Cost Index Report (2012 Base), April 2024, https://ftp.dot.state.tx.us/pub/txdot-info/cst/hci-binder.pdf

ERG performed a systematic review of the updated TexN2.6 growth factors using Microsoft (MS) Excel charts, visually inspecting the 2017-2060 trends for outliers across counties and DCE subsectors. While the average population growth factor trends at the state level were robust for each DCE subsector, at the county-level there were some observable deviations. However, although some growth factors were very high in comparison to other counties, these instances were almost always restricted to rural counties whose surrogate value in the year of the deviation was substantially less than the state average value, meaning any potential increase in the absolute level of emissions would be minimal. ERG conducted web searches to validate the presence of notable operations that could explain potential outliers. A small number of instances were identified where anomalously high growth factors associated with rural counties could result in a non-trivial increase in absolute emission levels. Additional notes on processing and QA are provided as supporting electronic data under Deliverables 5.1 and 9.3, and two subsectors are discussed below.

Within the Agricultural Activity DCE subsector, Aransas County had a projected growth factor of 1.8 by 2060, whereas the next highest projected that year is a growth factor of 1.3. This result is driven by a significant, but unexplained, 266% increase in reported agricultural acreage between the 1997 and 2002 agricultural censuses. As post-2002 censuses show acreage numbers comparable to 2002, lower pre-2002 data may be explained by undercounted acres or a difference in local data collection methods.

For the Boring & Drilling DCE subsector, spikes in growth factors represented sparsely populated rural counties for which one or two large construction projects can cause high variability. The highest growth was projected for counties on the fringe of major cities (e.g., Waller, Liberty, Kaufman, Rockwall, Wise) reflecting fast growing suburban and exurban areas. While the vast majority of counties have growth factors greater than one, representing increasing populations over time, the few that are substantially below one are rural, low-population counties.

TxDOT maintains a constant inventory of their nonroad equipment fleet. TxDOT's purchasing schedule only allows for the replacement of equipment that is "aging-out" of the inventory or needs to be replaced due to failure of the original equipment. This is part of the Texas State Vehicle Fleet Management Plan and Texas Government Code, §2171.104. Email correspondence with TxDOT staff confirmed use of "the same replacement/acquisitions criteria and process for both on-road and off-road equipment." Therefore, as the general rule, new equipment is only introduced as other equipment is removed from the fleet. As such, no growth (i.e., a constant equipment population) is assumed across all years for this DCE sector.

5.0 Development of Nonroad Model Mobile RFP Emissions Inventories for the HGB Six-County and DFW Nine-County Ozone Nonattainment Areas

ERG developed RFP EIs to assist the TCEQ in developing a potential SIP revision(s) for the 2015 eight-hour ozone NAAQS in the HGB six-county and the DFW nine-county nonattainment areas. The EIs include ozone season day (OSD) weekday estimates of VOC and NO_X for the base-year 2017, milestone years 2023, 2026, 2029, contingency years 2024, 2027, 2030, 2033, and attainment year 2032. The RFP EIs were generated using MOVES5 code version 5.0.0 with database version 'movesdb20241112' and TexN2 code version 2.6.0 with the TexN2 database last updated June 25, 2025. Deliverable 6.2 provides the individual control reduction calculations and EI summary data for all counties in the HGB and DFW nonattainment areas in MS Excel spreadsheets.

ERG implemented three key updates in the TexN2 database prior to developing the RFP EIs. The growth factors were first added, the electrification ratios were applied, and the TERP benefits were generalized to apply for all modeling years. These runs provide the most accurate emissions estimate for each county given the available Texas-specific data, therefore forming the basis of the emissions totals reported for the emissions inventory and this report. The TexN2 utility generates several standard reports providing emissions by various categories, such as by county, SCC, etc.

The geographic scope of the EIs includes the six-county HGB area (defined as Brazoria, Chambers, Fort Bend, Galveston, Harris, and Montgomery Counties) and the nine-county DFW area (defined as Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Tarrant, and Wise Counties).

The temporal scope of the EIs is OSD weekday for all modeling years. The period type "OSD weekday" represents weekday emissions averaged over the summer months June, July, and August. TexN2 allocates annual activity to these months with monthly and day type allocation factors contained in tables within the TexN2 utility database.
The meteorology data in the EIs was specific to the base-year 2017, applied to all RFP analysis years 2017, 2023, 2024, 2026, 2027, 2029, 2030, 2032, and 2033. The fuel types in each analysis year are specific to 2017 for the base-year and 2023 for all other years. At the time of writing (June 2025), year 2023 is the latest available fuel survey data contained in the TexN2 database.

The TexN2 utility estimates nonroad emissions by SCC and county for all fuel types. In addition, it allows for the disaggregation of diesel construction equipment SCCs into unique DCE subsectors to account for differences in equipment activity by use in different sectors. Each DCE/SCC combination requires a separate MOVES-Nonroad run, resulting in up to 24 runs for each county, with a separate CDB created by TexN2 for each run.

The RFP EIs include VOC, NO_X, and $PM_{2.5}$ emissions from ten separate runs that the TexN2 utility automatically initiates in sequence corresponding to the scenarios listed in Table 3. The first scenario represents a case without any emission controls. The second through tenth RFP scenarios add successive federal and state emissions controls. TexN2 sets up the MOVES runs for each scenario using alternate versions of the MOVES input table that describes technology fractions by equipment model year. TexN2 disables the inclusion of reformulated gasoline (RFG) in the HGB and DFW areas, until the final RFP scenario, *allRules_cntl*, representing the fully controlled scenario. RFG fuels, where they are in use, are implemented as the final control strategy in all six HGB counties and four of the nine applicable DFW counties (Collin, Dallas, Denton, and Tarrant). Five of the DFW counties do not have RFG fuel, so these areas do not receive any emissions benefits from RFG. Similarly, the benefits of Texas Low Emission Diesel (TxLED) fuel are delayed until the final RFP scenario, where they are included as a post-processing adjustment to NO_X from diesel-fueled equipment. All 15 counties are part of the 110-county TxLED fuel control area. Per direction from the TCEQ, ERG did not apply any TxLED benefit post-2020.

Table 3. Reasonable Further Progress Run Scenarios

RFP Scenario Name	Description
smallSprk1_uncntl	No controls
smallSprk1_cntl	Controls through Small nonroad spark ignition (SI) engines (Phase 1)
Tier1_cntl	Controls through Tier 1 nonroad diesel engines
Tier2_3_cntl	Controls through Tiers 2 and 3 nonroad diesel engines
smallSprk2_cntl	Controls through Small nonroad SI engines (Phase II)
largeSprk_cntl	Controls through Large nonroad SI engines
Tier4_cntl	Controls through Tier 4 nonroad diesel engines
recMarine_cntl	Controls through Diesel recreational marine engines
smallSI_cntl	Controls through SI marine engines
allRules_cntl	Controls through SI marine engines, includes RFG and TxLED fuel controls

Tables 4 through 9 show NO_X, VOC, and $PM_{2.5}$ emissions results for each RFP scenario for the HGB area and DFW areas, respectively. They include separate line items showing RFG and TxLED benefits as control scenarios number 9 and 10, and the TERP benefit as control scenario 11. The final scenario (Fully Controlled) corresponds to the "allRules_cntl" RFP scenario. The Fully Controlled case contains the same values as the prior TERP line item because TexN2 does not model any further emission controls after TERP. It remains in the tables for clarity to indicate the cumulative effect of all controls. TxLED benefits (differences from the "RFG" line item) only appear for the analysis year 2017. In the later years, the benefits from TxLED were set to zero.

Table 4. NO_X Emissions for the HGB Six-County Area (Tons/Day)

Emissions Control Scenario	2017	2023	2024	2026	2027	2029	2030	2032	2033
Uncontrolled	122.94	135.98	141.24	151.00	155.97	166.24	171.66	182.60	188.31
1. smallSprk1_cntl	128.60	142.21	147.58	157.54	162.62	173.12	178.66	189.82	195.64
2. Tier1_cntl	127.81	141.96	147.38	157.54	162.68	173.33	178.87	190.08	195.94
3. Tier2_3_cntl	123.15	139.64	145.13	155.68	160.99	172.16	177.80	189.33	195.35
4. smallSprk2_cntl	119.11	135.19	140.60	151.00	156.24	167.25	172.81	184.18	190.12
5. largeSprk_cntl	81.39	85.96	89.33	95.46	98.46	104.77	107.91	113.89	116.94
6. Tier4_cntl	40.44	32.78	32.93	32.13	32.04	31.49	31.95	32.47	32.59
7. recMarine_cntl	40.42	32.76	32.91	32.10	32.01	31.46	31.91	32.44	32.55
8. smallSI_cntl	36.75	28.41	28.46	27.46	27.29	26.55	26.91	27.28	27.32
9. RFG	36.75	28.56	28.61	27.62	27.44	26.71	27.08	27.44	27.48
10. TxLED	35.51	28.56	28.61	27.62	27.44	26.71	27.08	27.44	27.48
11. TERP	35.40	28.46	28.50	27.52	27.35	26.62	26.99	27.38	27.42
Fully Controlled	35.40	28.46	28.50	27.52	27.35	26.62	26.99	27.38	27.42

Table 5. VOC Emissions for the HGB Six-County Area (Tons/Day)

Emissions Control Scenario	2017	2023	2024	2026	2027	2029	2030	2032	2033
Uncontrolled	178.26	196.69	200.31	207.12	210.71	218.14	222.12	229.52	233.35
1. smallSprk1_cntl	131.60	145.45	148.38	153.88	156.76	162.69	165.84	171.70	174.71
2. Tier1_cntl	126.88	140.34	143.22	148.69	151.55	157.46	160.58	166.42	169.43
3. Tier2_3_cntl	125.89	139.84	142.75	148.31	151.21	157.22	160.37	166.27	169.32
4. smallSprk2_cntl	76.96	85.55	87.57	91.47	93.49	97.70	99.88	104.10	106.30
5. largeSprk_cntl	64.64	69.41	70.80	73.41	74.78	77.63	79.12	81.86	83.26
6. Tier4_cntl	55.06	57.84	58.58	59.89	60.66	62.23	63.17	64.82	65.66
7. recMarine_cntl	55.06	57.84	58.58	59.88	60.66	62.23	63.17	64.82	65.66
8. smallSI_cntl	38.29	37.70	38.06	38.66	39.08	39.92	40.49	41.45	41.94
9. RFG	37.78	37.32	37.67	38.26	38.67	39.51	40.07	41.02	41.50
10. TxLED	37.78	37.32	37.67	38.26	38.67	39.51	40.07	41.02	41.50
11. TERP	37.76	37.31	37.66	38.26	38.67	39.50	40.06	41.01	41.49
Fully Controlled	37.76	37.31	37.66	38.26	38.67	39.50	40.06	41.01	41.49

Table 6. $PM_{2.5}$ Emissions for the HGB Six-County Area (Tons/Day)

Emissions Control Scenario	2017	2023	2024	2026	2027	2029	2030	2032	2033
Uncontrolled	11.32	11.96	12.41	13.11	13.47	14.12	14.53	15.23	15.55
1. smallSprk1_cntl	11.13	11.77	12.23	12.93	13.28	13.94	14.35	15.06	15.37
2. Tier1_cntl	10.86	11.57	12.02	12.75	13.12	13.80	14.21	14.92	15.24
3. Tier2_3_cntl	10.23	11.26	11.73	12.51	12.90	13.65	14.08	14.83	15.17
4. smallSprk2_cntl	10.00	11.00	11.46	12.24	12.63	13.36	13.79	14.52	14.86
5. largeSprk_cntl	9.95	10.94	11.40	12.17	12.56	13.29	13.71	14.45	14.79
6. Tier4_cntl	4.49	3.85	3.85	3.74	3.72	3.65	3.68	3.70	3.69
7. recMarine_cntl	4.49	3.85	3.85	3.74	3.72	3.65	3.68	3.69	3.69
8. smallSI_cntl	4.35	3.67	3.67	3.55	3.53	3.45	3.48	3.49	3.48
9. RFG	4.35	3.67	3.67	3.55	3.53	3.45	3.48	3.49	3.48
10. TxLED	4.35	3.67	3.67	3.55	3.53	3.45	3.48	3.49	3.48
11. TERP	4.34	3.66	3.66	3.55	3.52	3.44	3.47	3.49	3.48
Fully Controlled	4.34	3.66	3.66	3.55	3.52	3.44	3.47	3.49	3.48

The NO_X, VOC, and $PM_{2.5}$ emissions generally decline from Uncontrolled to Fully Controlled except for small nonroad SI engines Phase 1 (smallSprk1_cntl), which increases NO_X by approximately 6 tons per day in 2017. The minor NO_X increase was allowed under the small SI rule, where some equipment have their standards defined in terms of combined hydrocarbons plus NO_X.

The pre-Tier 4 scenarios all show increased NO_X and $PM_{2.5}$ emissions over the period from 2017 to 2033, whereas the Tier 4 and later controls scenarios show NO_X and $PM_{2.5}$ declines then levels off over the same period despite a gradual growth in equipment population. The fully controlled scenarios for both nonattainment areas show a slight VOC increase comparing 2033 to 2017 because the emission standards are less stringent for this pollutant, and they're not sufficient to overcome the VOC emissions from increasing equipment populations in both areas over this period. Increasing gasoline equipment counts are in part responsible for the VOC increases.

The HGB and DFW nonattainment area RFP EIs were reviewed and quality assured by ERG to ensure the emissions from nonroad model mobile sources appear reasonable. Similar trends were observed when compared to the previous RFPs developed using TexN2.5 running MOVES4 (ERG, 2024). For 2017 RFP analyses, accounting for electrification reduced the overall NO_X emissions by 1% for all levels of control. Electrification in 2017 reduced VOC emissions under uncontrolled and fully controlled emissions control scenarios by 4% and 3%, respectively. The impact of DCE growth rates and electrification generally lowered NOx and VOC emissions by 2% to 6% for 2023 and 2026 RFP scenarios, except for 2023, where the NOx emissions were reduced by about 10% for both HGB and DFW. ERG maintains a record of all electronic files developed or used in conjunction with the completion of this project.

Table 7. NOx Emissions for the DFW Nine-County Area (Tons/Day)

Emissions Control Scenario	2017	2023	2024	2026	2027	2029	2030	2032	2033
Uncontrolled	130.46	148.16	154.98	165.42	170.82	181.95	187.88	199.65	205.73
1. smallSprk1_cntl	137.04	155.39	162.34	173.02	178.54	189.94	196.01	208.03	214.24
2. Tier1_cntl	135.76	154.68	161.68	172.61	178.22	189.79	195.86	207.94	214.21
3. Tier2_3_cntl	130.76	151.80	158.82	170.18	175.97	188.19	194.40	206.90	213.38
4. smallSprk2_cntl	126.06	146.63	153.56	164.75	170.45	182.48	188.60	200.92	207.31
5. largeSprk_cntl	88.49	97.78	102.71	109.69	113.20	120.62	124.36	131.39	134.92
6. Tier4_cntl	44.57	37.30	37.67	36.61	36.51	35.72	36.22	36.72	36.73
7. recMarine_cntl	44.57	37.30	37.66	36.60	36.50	35.71	36.21	36.71	36.71
8. smallSI_cntl	40.45	32.52	32.79	31.55	31.36	30.38	30.79	31.12	31.04
9. RFG	40.45	32.68	32.95	31.72	31.53	30.56	30.97	31.30	31.23
10. TxLED	39.06	32.68	32.95	31.72	31.53	30.56	30.97	31.30	31.23
11. TERP	38.91	32.54	32.83	31.60	31.42	30.47	30.89	31.23	31.17
Fully Controlled	38.91	32.54	32.83	31.60	31.42	30.47	30.89	31.23	31.17

Table 8. VOC Emissions for the DFW Nine-County Area (Tons/Day)

Emissions Control Scenario	2017	2023	2024	2026	2027	2029	2030	2032	2033
Uncontrolled	198.09	220.13	224.36	232.05	236.16	244.63	249.17	257.61	261.97
1. smallSprk1_cntl	144.45	161.13	164.54	170.69	173.96	180.66	184.22	190.85	194.25
2. Tier1_cntl	141.37	157.87	161.26	167.42	170.68	177.40	180.94	187.57	190.98
3. Tier2_3_cntl	140.29	157.28	160.69	166.95	170.26	177.10	180.67	187.38	190.83
4. smallSprk2_cntl	83.95	94.71	97.10	101.42	103.71	108.45	110.91	115.66	118.12
5. largeSprk_cntl	71.36	78.38	80.15	83.19	84.82	88.19	89.96	93.19	94.83
6. Tier4_cntl	61.13	65.18	66.10	67.69	68.61	70.46	71.56	73.49	74.47
7. recMarine_cntl	61.13	65.18	66.10	67.69	68.61	70.46	71.56	73.49	74.47
8. smallSI_cntl	42.37	42.76	43.26	44.08	44.60	45.66	46.33	47.49	48.06
9. RFG	41.98	42.30	42.79	43.60	44.12	45.15	45.82	46.96	47.53
10. TxLED	41.98	42.30	42.79	43.60	44.12	45.15	45.82	46.96	47.53
11. TERP	41.97	42.28	42.78	43.59	44.11	45.14	45.81	46.95	47.52
Fully Controlled	41.97	42.28	42.78	43.59	44.11	45.14	45.81	46.95	47.52

Table 9. $PM_{2.5}$ Emissions for the DFW Nine-County Area (Tons/Day)

Emissions Control Scenario	2017	2023	2024	2026	2027	2029	2030	2032	2033
Uncontrolled	12.48	13.74	14.35	15.11	15.53	16.31	16.79	17.62	17.99
1. smallSprk1_cntl	12.26	13.52	14.13	14.89	15.32	16.09	16.58	17.40	17.77
2. Tier1_cntl	11.98	13.32	13.93	14.74	15.17	15.98	16.46	17.29	17.67
3. Tier2_3_cntl	11.29	12.95	13.57	14.44	14.90	15.78	16.29	17.17	17.57
4. smallSprk2_cntl	11.03	12.65	13.27	14.12	14.58	15.45	15.95	16.83	17.22
5. largeSprk_cntl	10.98	12.60	13.21	14.06	14.52	15.39	15.89	16.76	17.15
6. Tier4_cntl	5.10	4.44	4.45	4.31	4.28	4.18	4.21	4.22	4.20
7. recMarine_cntl	5.10	4.44	4.45	4.31	4.28	4.18	4.21	4.22	4.20
8. smallSI_cntl	4.96	4.25	4.25	4.11	4.08	3.97	4.00	4.00	3.98
9. RFG	4.96	4.25	4.25	4.11	4.08	3.97	4.00	4.00	3.98
10. TxLED	4.96	4.25	4.25	4.11	4.08	3.97	4.00	4.00	3.98
11. TERP	4.94	4.24	4.24	4.10	4.07	3.96	3.99	4.00	3.98
Fully Controlled	4.94	4.24	4.24	4.10	4.07	3.96	3.99	4.00	3.98

Tables 7 through 9 for the nine-county DFW area show similar trends to the HGB area. NO_X emissions slightly increase with *smallSprk1_cntl*, then decline or stay the same for all other successive controls.

6.0 Code Changes to the TexN2.6 Utility

The TexN2.6 utility has several changes from the TexN2.5 version. The utility looks for a MOVES5 default database name, uses updated run specification (input file) templates, and follows the format of the MOVES5 table definitions. Additional updates in the TexN2.6 utility include improved TERP handling, the inclusion of $PM_{2.5}$ to the Automated RFP functionality, custom output queries to allow the export of equipment population, activity, load factors, and average HP directly from the TexN2 GUI, and a reduction in disk space and runtime requirements.

The ten TERP program areas (Austin, Beaumont-Port Arthur, Corpus Christi, DFW, El Paso, HGB, San Antonio, Tyler-Longview, Victoria, and Other) include one or more counties, depending on the area and grant type. For equipment operating at seaports or railyards, Figure 9 shows the applicable TERP counties. For all other nonroad equipment TERP grants, Figure 10 shows the applicable counties.

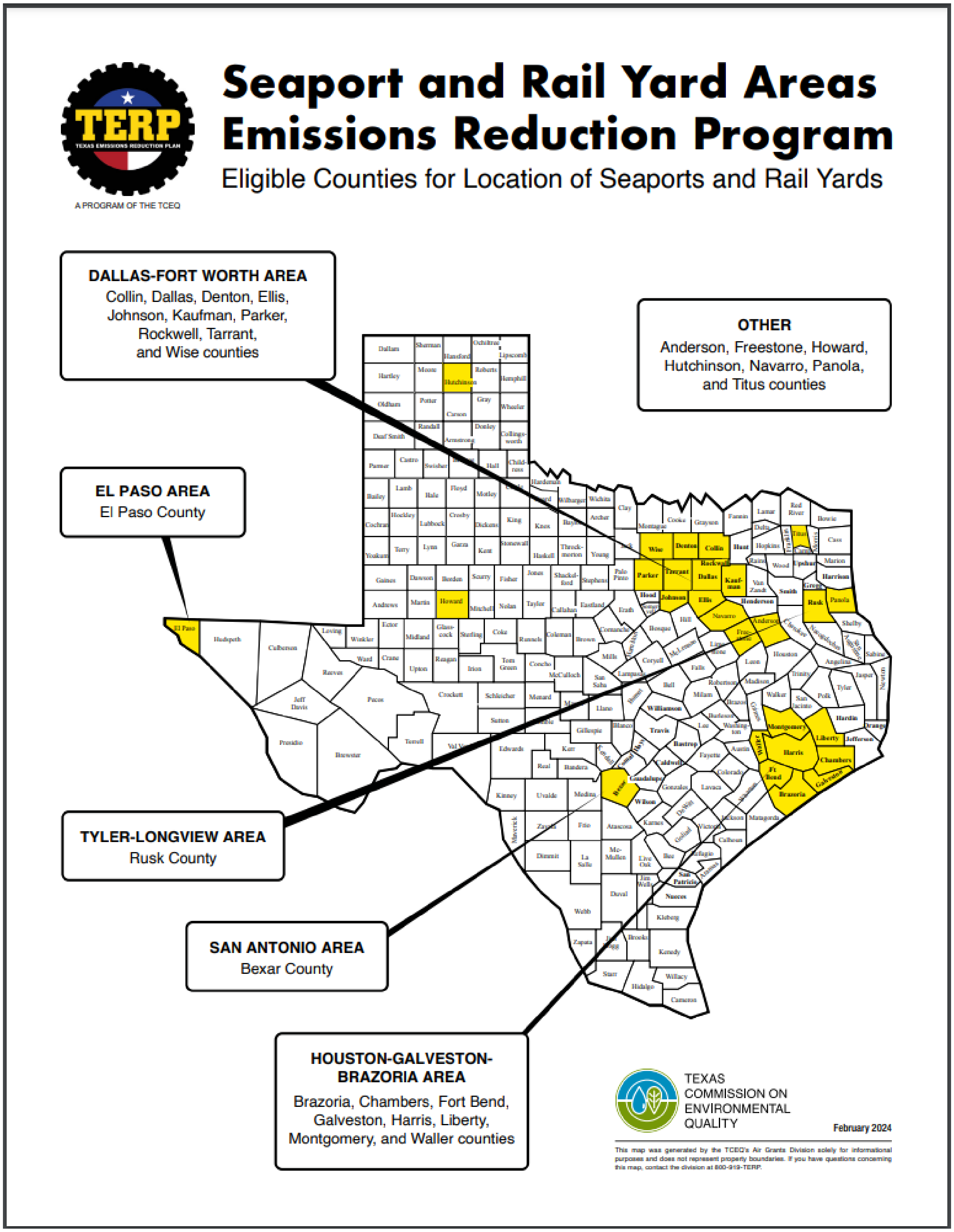

Figure 9. Eligible Counties by TERP Area, Seaport and Railyard Grants[4]

[4] https://www.tceq.texas.gov/downloads/air-quality/terp/spry/spry-24-eligible-counties-location.pdf

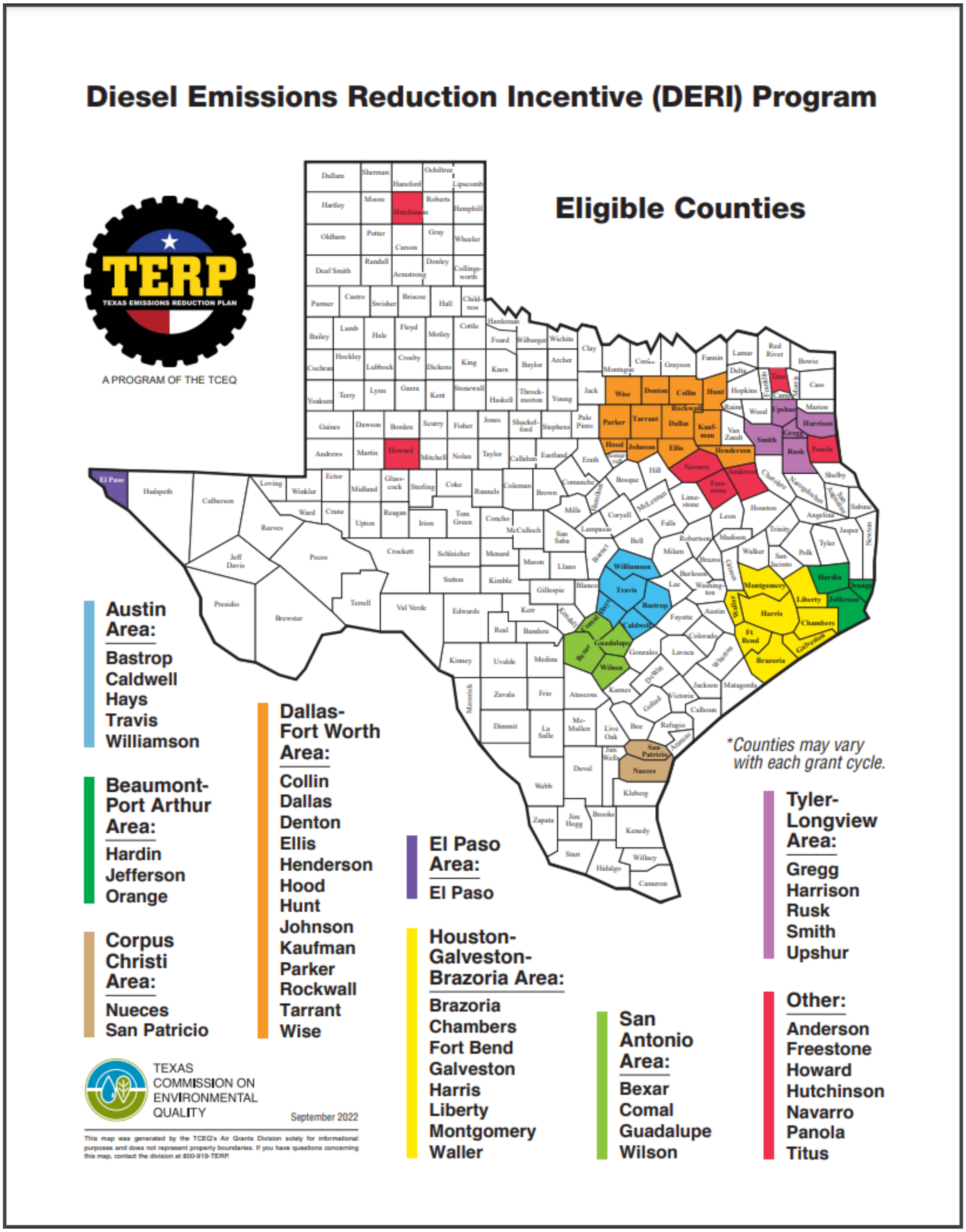

Figure 10. Eligible Counties by TERP Area, DERI Grants[5]

[5] https://www.tceq.texas.gov/downloads/air-quality/terp/rebate/rebate-23-eligible-counties-map.pdf

The TexN2.6 utility can now model TERP program benefits for all calendar years. The user may select any pollutants and counties, and the reports of TERP benefits will match the resolution of these choices. The new method applies TERP benefits for each applicable equipment replacement listed in the TERP data equipment replacement list by calculating the difference in emissions per unit for each old equipment and new equipment directly from the scenario output database. Previously, TERP benefits were calculated using the "TERPemissions" table from the TexN2 database and could only be applied for analysis years 2017, 2023, and 2026. The new method no longer requires the "TERPemissions" table and can be applied to all analysis years (2001 and later) that are covered in the TERP data equipment replacement list. This update both broadens the existing capability and will no longer require manual modification of database table updates for future analyses.

The Automated RFP functionality historically produced only NO_X and VOC emissions. The pollutant $PM_{2.5}$ was added, and ERG configured the resultant tables to adjust to the inclusion. ERG conducted a high-level review of the $PM_{2.5}$ outputs in the automated RFP report for quality assurance purposes. The total exhaust $PM_{2.5}$ and NO_X values for the 6 county HGB region in 2017 were reviewed. As expected, the $PM_{2.5}$ reductions associated with the fuel strategies (TxLED and RFG) as well as the diesel recreational marine rule are responsible for less than 0.02% of total $PM_{2.5}$ reductions, as the fuel strategies target NO_X and the diesel recreational marine rule impacts very few sources in the state. Alternatively, the three rules targeting non-marine diesel engines (Tier 4, Tier 2/3, and the original Tier 1 heavy-duty nonroad engine rule) are responsible for over 55% of all $PM_{2.5}$ reductions. Small SI engines contribute a small but non-trivial amount of PM due to incomplete combustion, with the Phase I, II and III rules providing about 5% of total $PM_{2.5}$ RFP reductions.

ERG created a new feature of TexN2.6 on the Run tab that allows the user to export load factors, average HP, and annual hours of operation associated with the user selections made in the Scenario tab (i.e. year), Region tab (i.e., counties), and Sources tab (i.e., equipment SCCs). This new reporting feature is a convenient way to interact with the TexN2 database, and it may be executed before, after, or not in any association with a particular TexN2 run. If a TexN2 user has not made a required selection, for example, no counties are selected, a warning message will appear. The new checkboxes are described below.

- Equipment Population: checking this box prior to clicking the Export Reports button will output the number of equipment units in the TexN2 database for the year specified in the Scenario tab, the counties specified in the Region tab, and the SCCs specified in the Sources tab.

- Equipment Activity: checking this box prior to clicking the Export Reports button will output the annual hours of activity for each SCC specified in the Sources tab in the counties specified in the Region tab. The activity per unit per year generally does not vary by county, but there are sometimes differences for the Houston-Galveston-Brazoria and Dallas-Fort Worth area equipment compared to the rest of the state for certain SCCs.

- Equipment Load Factors: checking this box prior to clicking the Export Reports button will output load factors for each SCC specified in the Sources tab for each county specified in the Region tab.

- Equipment Average HP: checking this box prior to clicking the Export Reports button will output average HP for each HP bin associated with each SCC specified in the Sources tab.

- Export Reports: clicking this button generates the reports checked above and writes them to the output directory specified in the Scenario tab in a subfolder named equipment_data_reports. The filenames of the reports using a naming convention specified below. The {scenarioName} is the scenario name the user specified in the Scenario tab prior to exporting reports.

    - equipment_population_{scenarioName}.csv

    - equipment_activity_{scenarioName}.csv

    - equipment_avg_HP_{scenarioName}.csv

    - equipment_load_factors_{scenarioName}.csv

To reduce the operating requirements of TexN2, ERG adjusted the process in which TexN2 intermediate run specification files and MOVES outputs are handled, reducing the resultant databases previously retained during an HGB 6-county Automated RFP run from 93.6 GB to 40.5 GB, representing a 2.3-fold improvement in disk space requirements. The TexN2 runtime, a variable dependent on the specific machine running TexN2, its compute load, and its active MOVES workers, was also reduced from improved MOVES output handling. These improvements will streamline the process of TexN2.6 runs for TCEQ and other users of the utility.

7.0 Recommendations

TexN2.6 is an emissions modeling utility used to model emissions in the state of Texas. Due to the data ERG has collected over numerous projects with TCEQ, TexN2.6 can account for growth factors and local projects that are specific to counties/years, instead of a default curve modeling function. Given the uncertainties associated with PSR's characterization of the Lawn & Garden sector, ERG recommends conducting periodic updates to the residential sector survey ERG initially conducted in 2023, and expansion of the survey to the commercial Lawn & Garden sector.

ERG could conduct a future project involving the research of grid connection potential for high-HP equipment like excavators. These units potentially offer cost-effective targets for conversion from diesel, especially for fixed location operations such as surface mining in urban or suburban areas.

ERG could obtain alternate sources of data to further characterize the electrification of transportation refrigeration units (e.g., Equipment Data Associates sales data), which would lead to lower emissions for the application.

TCEQ has run into cases where automatic Windows updates force machines running TexN2 to restart. ERG could implement multithreading so that TexN2 performs post-processing on each MOVES output database in the background as it executes the next MOVES run. This would further improve runtime and lead to fewer cases of complex modeling runs that are interrupted by mandatory network updates.

ERG could improve the GUI experience during Automated RFP report generation stages. Currently, the GUI is inoperable while making the Automated RFP report. The Log tab could be updated to report intermittent progress. Additionally, terminating a TexN2 mid-run currently requires the use of Windows Task Manager. However, TexN2 could be configured to allow direct user termination.

8.0 References

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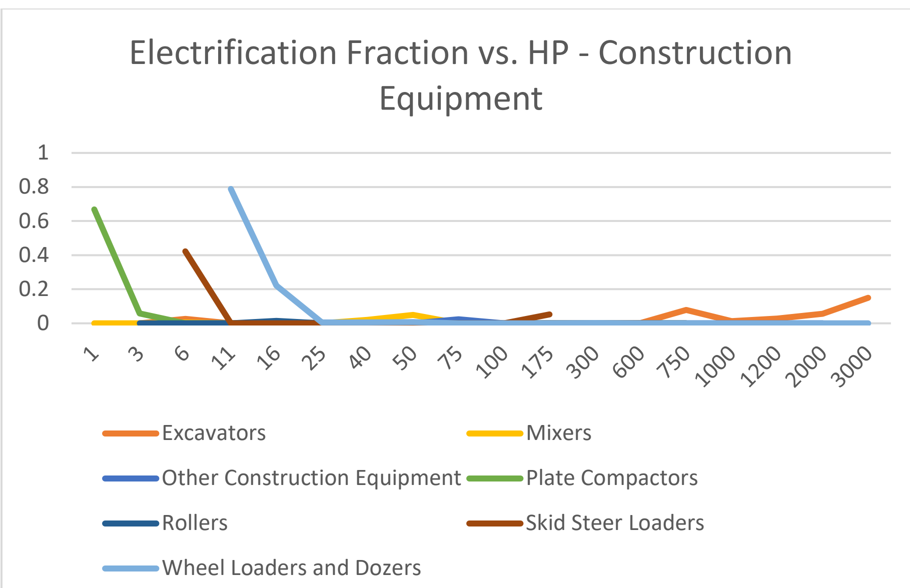
Appendix A: Quality Assurance of PSR Electrification Projections

ERG reviewed PSR's projections of equipment electrification fractions between 2004 and 2035, broken out by equipment type (SCC) and TexN HP bin. In general ERG expected to see two trends – increasing electrification over time for a given SCC/HP combination (due to technology development and market trends) and decreasing electrification with increasing HP for a given SCC (due to the difficulty of meeting sustained energy demands via electric power at higher HP levels). To identify exceptions to these trends ERG first flagged electrification fractions by SCC/HP that did not increase monotonically (or remain constant) over PSR's projection period. Of the 674 unique SCC/HP combinations provided by PSR, 54 (8%) had at least one year where the estimated electrification fraction decreased relative to a prior year. However, 49 of these exhibited very minor, short lived reductions that were deemed insignificant. ERG flagged the remaining 5 for further inquiry:

- Aerial lifts 11-16 HP
- Sweepers/scrubbers 11-16 HP
- Concrete mixers 3-6 HP
- Concrete mixers 25-40 HP
- Underground mining equipment 600-750 HP

ERG also identified SCCs that did not exhibit a clear decrease in electrification fraction with increasing HP. The chart below shows the relationship between electrification fraction and HP for selected construction equipment. Disregarding small increases in electrification at higher power levels (e.g., 5% or less), the equipment types shown below demonstrate the expected relationships except for excavators above 1000 HP.[6]



[6] Electrification at the highest HP values for excavators and bore/drill rigs is reasonable as a result of direct grid connection. For example see https://www.volvoce.com/europe/en/about-us/news/2024/volvo-ew240-electric-material-handler-sets-new-standard-for-decarbonization/.

ERG compiled a list of unexpected electrification data from the above analyses, along with additional questions based on staff's familiarity with nonroad equipment applications for PSR review and comment. The questions along with PSR's responses are provided below.

Construction Sector

1a) Skid steers have zero electrification except at lowest (< 6*HP*) and highest (100-175)* HP *- unexpected since Bobcat already has electric units available for purchase.

1b) As a counter example, excavators show consistent increases in electric fractions over time.

PSR Response:

1a: Bobcat does have two models of battery electric available (offered for sale) but we believe they are still in the early stages of selling these with any sizable unit volumes. We researched these at the last ConExpo and even though they had the battery electric units on display, Bobcat shared with us that it will be some time and trials before the demand picks up for these. The battery electric units are much more expensive than the traditional ICE units so at this point it is a very niche market where these are used indoors and for special use/rental. In fact, Bobcat has partnered with Sunbelt Rentals to help get these electric skid steers into rental use so end users can see the benefits of an electric skid steer loader vs. ICE.

1b: Mini excavators are much better suited for battery electric (relative to skid steers) as they are built for small spaces and have a high demand for work in residential and urban areas. Plus, many of the Japanese OEMs have introduced viable models and made this product competitive which has brought prices into a more reasonable price range which has led to greater adoption of mini excavators relative to skid steers.

2: Certain application/*HP *combinations have unexpected peak electrification fractions prior to 2034 - 3-6 and 25-40* HP *mixers, and 600-750* HP *underground mining equipment. Is there a reason why these would exhibit declining electric fractions in the out years?

PSR Response: The challenge for mixers 25-40 HP and underground mining 600-750 HP is that both of these HP ranges have very low unit volume so the trend towards electric can be impacted if there are very few OEMs that participate in this HP range and if that HP range is a very small overall percentage of the units-in-service. The key is that the overall trend is growing towards a greater percentage of electric units in 2034 compared to the population in 2025 for both mixers and underground mining equipment.

Industrial/Commercial

1: Refrigeration/AC Equipment shows 0 electrification. This is not accurate - there are multiple vendors that offer fully electric TRUs now. Please advise.

PSR Response: We have models that are non-ICE shown as power takeoff (PTO) driven - this is why they are not showing up under battery electric drive type.

2: Aerial lifts between 100 and 175 HP ***have a peak in electric fraction in 2023 – can you explain why?***

PSR Response: The percent electric vs. ICE in any given year is dependent upon the demand for battery electric vs. ICE in that year and thus more or less battery electric units will be added into population. The percent electric vs. ICE in population is a result of how those sales are trending electric vs. ICE in addition to considering the attrition of units that are in-service and fall out of population during that year due to attrition (retirement). We don't have a specific reason why a certain HP range may peak and then decline as it is a result of this demand year to year of one versus the other (battery vs. ICE).

3: Scrubbers/Sweepers between 11 and 16 HP ***peak in 2015 - same question.***

PSR Response: Same reasoning as explained in question 2.

<u>Recreational</u>

1: On the whole, there's a surprisingly low electric fraction for most application/HP ***combinations, except for golf carts.***

PSR Response: Golf carts by far have the greatest adoption of battery electric - it is a mature market compared to other applications in the Rec Products segment. With battery electric - the duty cycle of the equipment needs to align well with the use case for battery electric in terms of having enough battery capacity to perform over the duration of regular usage. For golf carts, this is not an issue and golf carts have been electrified for some time. Snowmobiles, for example, do not have a good adoption because the range limitations exist and current technology has not led to a wide adoption for battery electric in snowmobiles.

2: 175 - 300 HP ***motorcycles and ATVs clearly peak in 2017 and decline thereafter – please explain.***

PSR Response: Although electric motorcycles in the 175-300 HP Range reached a peak in 2017 in terms of overall percentage of in-service population, the volume in population for electric motorcycles in this power range is very small compared to the in-service volume of ICE motorcycles. For example, the in-service population of electric motorcycles in 2017 in the 175-300 HP Range was 353 units while ICE units were 21,131 units. Any small gains in ICE sales in a given year will tend to drown out a solid growth pattern of the electric motorcycles. This is simply because the in-service volume of ICE motorcycles in the 175-300 HP Range is orders of magnitude larger than the electric motorcycles. Growth of electric motorcycles in the 175-300 HP Range is still happening on a steady growth curve but the actual gain in terms of units vs.

ICE are not having a sizable impact in terms of what we see in the overall percent electric vs. percent ICE.

Lawn and Garden

1: In the Lawn & Garden Segment, we're observing lower electrification percentages than what we'd expect to see. For example, we expect Trimmers to have very significant electrification, including in the mid 2010's. In the data, we don't see any trimmer electrification until 2016. Were only 3% of 3-6 HP Trimmers in 2016?

PSR Response: We started tracking electric trimmers in 2016. That is the 1st year we have production/sales data for trimmers. The data ramps up from 2016 onward.

Appendix B: Additional Data Surrogates for Growth Factors

01_2017_AgriculturalActivity.xlsx

- This spreadsheet file was used to produce growth factor data for DCE subsector 1, Agricultural Activity. Each county's acreage in agricultural production was used as a proxy for overall agricultural activity. Historical growth of productive acreage was derived from agricultural census data collected at five-year intervals between 1987 and 2022. These trends were used to forecast future agricultural acreage (and thus subsector activity) using linear regression. Growth factors were calculated from a 2017 base-year.
- Source:
  - Agricultural Production Acreage, USDA AgCensus: https://www.nass.usda.gov/Publications/AgCensus/2022/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/txv1.txt

04_2017_CityCountyRoadConstruction.xlsx

- This spreadsheet file was used to produce growth factor data for DCE subsector 4, City and County Road Construction. Each county's population growth was used as a proxy for projecting city and county road construction activity. The Texas State Data Center provided county-level population growth projections under a 0.5 migration scenario for long-term planning (i.e., assuming half the migration rates of actual 2010-2020 census data in counties' annual population projections from 2020 to 2060). Growth factors were calculated from a 2017 base-year.
- Source:
  - County-Level Population Growth, Texas State Data Center: https://www.demographics.texas.gov/Projections/2022/

07_2017_CountyOwnedConstEquipment.xlsx

- This spreadsheet file was used to produce growth factor data for DCE subsector 7, County Owned Construction Equipment. Each county's population growth was used as a proxy for projecting activity utilizing county-owned construction equipment. The Texas State Data Center provided county-level population growth projections under a 0.5 migration scenario for long-term planning (i.e., assuming half the migration rates of actual 2010-2020 census data in counties' annual population projections from 2020 to 2060). Growth factors were calculated from a 2017 base-year.
- Source:
  - County-Level Population Growth, Texas State Data Center: https://www.demographics.texas.gov/Projections/2022/

09_2017_HeavyHighwayConstruction.xlsx

- This spreadsheet file was used to produce growth factor data for DCE subsector 9, Heavy Highway Construction. County-level expenditures from 2017 to 2023 reported to the Texas Comptroller's Office, specifically those categorized as "Highway Construction – Capital Costs" and "Repairs and Maintenance," as well as Economy.com GDP projections from 2024 to 2055, were used as a proxy for heavy highway construction activity. To produce growth factors from 2017 to 2023, nominal reported costs were adjusted by TxDOT's highway cost index (HCI) growth factors over the same years. Economy.com GDP growth was substituted in cases where certain counties were missing expenditure data in the reporting years. Further, Economy.com GDP projections were the basis for calculating growth factors from 2024 to 2055, as expenditure data was not available beyond 2023.
- Sources:
    - HCI, TxDOT: https://ftp.dot.state.tx.us/pub/txdot-info/cst/hci-binder.pdf
    - County-Level Expenditures, Texas Open Data Portal
        - 2023: https://data.texas.gov/dataset/Texas-State-Expenditures-By-County-2023/iyey-5sid/about_data
        - 2022: https://data.texas.gov/dataset/Texas-State-Expenditures-by-County-2022/xys8-xb33/about_data
        - 2021: https://data.texas.gov/dataset/Texas-State-Expenditures-by-County-2021/tup7-smjg/about_data
        - 2020: https://data.texas.gov/dataset/Texas-State-Expenditures-by-County-2020/aact-g69n/about_data
        - 2019: https://data.texas.gov/Government-and-Taxes/Texas-State-Expenditures-by-County-2019/2x5x-m677
        - 2017-18: https://data.texas.gov/Government-and-Taxes/Texas-State-Expenditures-by-County-2018/f2iw-dtqt

10_2017_LandfillOperations.xlsx

- This spreadsheet file was used to produce growth factor data for DCE subsector 10, Landfill Operations. Each county's population growth was used as a proxy for projecting activity of landfill operations. The Texas State Data Center provided county-level population growth projections under a 0.5 migration scenario for long-term planning (i.e., assuming half the migration rates of actual 2010-2020 census data in counties' annual population projections from 2020 to 2060). Growth factors were calculated from a 2017 base-year.
- Source:
    - County-Level Population Growth, Texas State Data Center: https://www.demographics.texas.gov/Projections/2022/

13_2017_MunicipalOwnedEquipment.xlsx

- This spreadsheet file was used to produce growth factor data for DCE subsector 13, Municipal-Owned Equipment. Each county's population growth was used as a proxy for projecting activity utilizing municipal-owned equipment. The Texas State Data Center provided county-level population growth projections under a 0.5 migration scenario for long-term planning (i.e., assuming half the migration rates of actual 2010-2020 census data in counties' annual population projections from 2020 to 2060). Growth factors were calculated from a 2017 base-year.
- Source:
  - County-Level Population Growth, Texas State Data Center: https://www.demographics.texas.gov/Projections/2022/

15_2017_ResidentialConstruction.xlsx

- This spreadsheet file was used to produce growth factor data for DCE subsector 15, Residential Construction. Residential single-family home construction permits were used as a proxy for residential construction activity. This data for most counties was available through 2024, and permit projections through 2060 were calculated by applying county population projections as a secondary proxy for permitting growth. For 32 counties without permit data, 0.5 was applied as a non-zero number of permits to avoid calculation errors in the growth factors. Growth factors were calculated from a 2017 base-year.
- Sources:
  - Residential Permits, Texas A&M:
  - County-Level Population Growth, Texas State Data Center: https://www.demographics.texas.gov/Projections/2022/

23_2017_MiningQuarryOperations.xlsx

- This spreadsheet file was used to produce growth factor data for DCE subsector 23, Mining and Quarry Operations. For counties with coal mines, mine production and total employment hours data was used as a proxy for overall mining activity. Gulf states' projected lignite production provided a proxy for coal county activity growth, however, mine closures in various years between 2017 and 2024 were accounted for with little to no projected growth. For non-coal counties, Economy.com GDP data was used to calculate growth. Growth factors were calculated from a 2017 base-year.
- Sources:
  - Mine Productivity, Mine Safety and Health Administration (MSHA): https://arlweb.msha.gov/OpenGovernmentData/DataSets/MinesProdYearly.zip
  - Mine IDs, MSHA: https://www.msha.gov/data-and-reports/mine-data-retrieval-system

- Gulf Lignite Production, EIA: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=95-AEO2023&region=0-0&cases=ref2023&start=2021&end=2050&f=A&linechart=ref2023-d020623a.2-95-AEO2023~ref2023-d020623a.24-95-AEO2023&ctype=linechart&sourcekey=0