APPENDIX D

TEXN2.1 UTILITY DIESEL EQUIPMENT PROFILE AND GROWTH FACTOR UPDATES FOR USE WITH MOVES

Redesignation Request and Maintenance Plan State Implementation Plan Revision for the Freestone-Anderson and Titus 2010 Sulfur Dioxide National Ambient Air Quality Standard Nonattainment Areas

Project Number 2021-007-SIP-NR
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Eastern Research Group, Inc.

TCEQ Contract 582-19-90502
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ERG Deliverable 7.2

TexN2.1 Utility Diesel Equipment Profile and Growth Factor Updates for Use with MOVES

Final Report

Prepared for:

Texas Commission on Environmental Quality
Air Quality Division

Prepared by:

Eastern Research Group, Inc.

July 31, 2020

ERG No. 0433.00.003

TexN2.1 Utility Diesel Equipment Profile and Growth Factor Updates for Use with MOVES

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ACRONYMS

AEO – Annual Energy Outlook

AERR - Air Emissions Reporting Requirements

APO - Aggregate Processing Operations

BSFC – Brake-Specific Fuel Consumption

CARB – California Air Resources Board

CDB – County Database

DCE – Diesel Construction Equipment

EIA – Energy Information Administration

ERG – Eastern Research Group

GDP – Gross Domestic Product

HCI - Highway Cost Index

HP – Horsepower

MOVES – Motor Vehicle Emissions Simulator

MSHA – Mine Safety and Health Administration

NAICS - North American Industry Classification System

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

QA – Quality Assurance

SCC – Source Classification Code

TACA – Texas Aggregates and Concrete Association

TCEQ – Texas Commission on Environmental Quality

TFA – Texas Forestry Association

TLC – Texas Logging Council

TRU – Transportation Refrigeration Unit

TxDOT – Texas Department of Transportation

I. EXECUTIVE SUMMARY

The purpose of this study was to update selected nonroad diesel equipment profiles, equipment populations and growth factors contained in the TexN2.0 utility, developed to estimate nonroad equipment emissions for Texas. For this effort Eastern Research Group (ERG) updated the equipment populations and activity parameters associated with agricultural tractors and Texas Department of Transportation nonroad diesel equipment. ERG also obtained and applied updated engine load factors for selected diesel equipment types, as well as growth factors for the full range of nonroad equipment categories contained within the TexN utility for calendar years 2013 through 2050 in order to improve the accuracy of future activity and emission estimates. ERG also attempted to survey equipment owners and operators in the surface mining and logging sectors but did not obtain an adequate response due in part to the emergence of the pandemic in the spring of 2020.

Based on the agricultural tractor survey findings ERG revised the activity estimate for this equipment substantially downwards from 1,086 to 328 hours per year. ERG also used the survey results to develop a revised “scrappage curve” reflecting the unusually old model year distribution for tractors, with an average age of 18 years and maximum age of 50 years. As a result, the revised distribution is substantially older with higher emission rates than assumed by the prior TexN utility (with an average age of 8 years and maximum age of 22 years). The net effect of the hour per year change and the model year distribution change was to drastically lower total activity and fuel consumption relative to the previous TexN2.0 estimates (resulting in an 87.1 percent reduction) but providing a more modest reduction in $PM_{2.5}$ emissions (20.1 percent reduction).

Substantial changes to the TexN utility outputs also resulted from updates to engine load factors (based on improved estimates obtained from the California Air Resources Board) and population growth factors (developed by ERG for this effort). ERG conducted extensive quality assurance of the revised utility outputs to ensure consistency with the updated equipment population and load factor values. The net impact of all updates resulted in a 52.7 percent reduction in fuel consumption and a more modest 15.2 percent reduction in $PM_{2.5}$ at the state level. Table ES-1 directly below summarizes the resulting differences between the prior TexN2.0 utility and the new TexN2.1 version for selected regions across the state.

Table ES-1. Fuel Consumption and $PM_{2.5}$ Emissions Changes by Selected Region TexN2.0 vs. TexN2.1

	Fuel Consumption (Tons/day)				$PM_{2.5}$ (Tons/day)			
Region	***TexN2.0***	***TexN2.1***	***Delta***	***% Change****	***TexN2.0***	***TexN2.1***	***Delta***	***% Change****
Dallas/Fort Worth[1]	2,436	1,876	-560	-23.0%	1.58	1.44	-0.14	-9.1%
Houston/ Galveston/ Brazoria[2]	2,710	2,203	-506	-18.7%	1.70	1.69	-0.02	-1.0%
Beaumont/ Port Arthur[3]	194	118	-76	-39.2%	0.14	0.10	-0.03	-24.2%
El Paso[4]	608	182	-426	-70.0%	0.24	0.17	-0.07	-28.1%
San Antonio[5]	1,150	824	-325	-28.3%	0.74	0.72	-0.02	-2.4%
Austin[6]	1,096	766	-330	-30.1%	0.61	0.64	0.03	4.8%

* Percentage change relative to TexN2.0

[1] Collin, Dallas, Denton, and Tarrant Counties

[2] Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties

[3] Hardin, Jefferson, and Orange Counties

[4] El Paso County

[5] Atascosa, Bandera, Bexar, Comal, Guadalupe, Kendall, Medina, and Wilson Counties

[6] Bastrop, Caldwell, Hays, Travis, and Williamson Counties

II. INTRODUCTION

The Texas Commission on Environmental Quality (TCEQ) previously contracted with Eastern Research Group (ERG) to develop the TexN2.0 utility, a tool for estimating Texas-specific emissions from nonroad mobile sources, excluding commercial marine vessels, locomotives, drilling rigs, aircraft, and aircraft ground support equipment. The TexN2.0 utility uses the most recent version of the United States Environmental Protection Agency (EPA)'s Motor Vehicle Emission Simulator (MOVES) model (currently version 2014b) for developing emission estimates for state implementation plan development, federal emissions inventory requirements such as the Air Emissions Reporting Requirements (AERR) and emissions trend analyses. Since the initial development of the TexN utility, the TCEQ has updated the Texas-specific data within the tool and enhanced the tool's functionality to improve inventory accuracy. The most recent updates for the nonroad sector occurred in 2009 and 2014.

The purpose of this study was to update selected nonroad diesel equipment profiles, equipment populations and growth factors contained in the TexN2.0 utility. For this effort ERG updated the equipment populations and activity parameters associated with agricultural tractors and Texas Department of Transportation (TxDOT) nonroad diesel equipment. ERG also obtained and applied updated engine load factors for selected diesel equipment types, as well as growth factors for the full range of nonroad equipment categories contained within the TexN utility for calendar years 2013 through 2050 in order to improve the accuracy of future activity and emission estimates. ERG also attempted to survey equipment owners and operators in the surface mining and logging sectors but did not obtain an adequate response due in part to the emergence of the pandemic in the spring of 2020.

This report presents a comprehensive overview of the activities undertaken and the data collected and analyzed during the study. The report highlights major activities and key findings, provides pertinent analyses, describes problems encountered and associated corrective actions, quality assurance measures and relevant summary statistics, and recommendations for further study. The report concludes with instructions for how to replace the previous TexN2.0 utility and associated data files to incorporate all the updates resulting from the completion of the project. The updated utility, renamed TexN2.1, and associated supporting files have been provided to the TCEQ electronically. Directions on how users can update to the latest version, TexN 2.1, are provided in Appendix B, and can be found in the utility User's Guide available from the TCEQ upon request.

The following summarizes the procedures and findings associated with each project task.

III. DATA COLLECTION PLAN

The Data Collection Plan specifies the methods to be used to collect the required information from equipment operators, as well as the supplementary data sources, data processing steps, and Quality Assurance/Quality Control (QA/QC) and validation procedures for each survey approach to ensure precise, accurate, and fully defensible equipment profiles and populations.

The plan was designed to obtain reliable data, maximize cooperation and survey response rates, and provide a comprehensive data set for preparing the updated TexN2.0 utility data files. The ERG team maintained strict data recording and reporting controls in order to ensure that no confidential or business sensitive information obtained during the survey tasks is released.

A. Emission Sources

Targeted surveys focused on the following diesel-powered equipment classifications, including general Source Classification Code (SCC):

- Surface Mining (i.e., Construction and Mining) (SCC 22-70-002-XXX)
- Agricultural Tractors (SCC 22-70-005-015)
- Logging (SCC 22-70-007-XXX)

Only diesel-powered nonroad equipment greater than 25 horsepower (hp) was included in the data collection effort; equipment powered with other fuels (e.g., gasoline, compressed natural gas, liquefied petroleum gas, etc.) was excluded.

B. Data Collection Methods

The development of high-quality nonroad diesel data tables in TexN2.0 relies upon the collection of local, Texas-specific data. The ERG team attempted to collect information regarding activity and operating behavior using surveys to provide accurate characterization of the targeted nonroad diesel equipment populations within the State.

Survey Categories

ERG conducted random sample surveys to collect data from construction sand and aggregate surface mining locations, logging operations, and farming and ranching establishments using agricultural tractors.[7] For agricultural tractors and logging equipment, ERG identified potential operators by obtaining contact information from a

[7] The scope of work also included surveying and quantifying electric terminal tractor use at the Port of Houston. However, ERG identified only one such unit (currently part of a demonstration project), as discussed in Section 4. Accordingly, survey procedures were not developed for this equipment.

sample frame vendor based on the following North American Industry Classification System (NAICS) codes:

- 111 (Crop Production)
- 112 (Animal Production and Aquaculture)
- 113 (Forestry and Logging)
- For surface mining, ERG relied on state operating permit records, as discussed below.

Sampling Plan

The sampling plan accounted for the tradeoffs between the number of survey categories, precision targets, and available project resources for the random sample surveys. The sampling plan presented here discusses the sample frames needed to establish the survey contact lists, the sample size targets, and the supplementary data needed to extrapolate findings to the state level.

Survey Sample Frames

The ERG team identified sample frames with contact information for each survey category. The ideal sample frame includes information on all operators of targeted equipment, with no extraneous contacts (e.g., no ineligible respondents). Using such a complete, accurate sample frame would result in the most cost-effective survey execution. In actual practice, sample frames rely on different types of data sources, each with its own advantages and disadvantages. The specific sample frames recommended are discussed in Section 3.2.3.

- **Registration-based identification.** The most reliable sample frames are derived from regularly updated registration information such as operating permit records. These data sets help identify known operators with close to 100% accuracy.
- **NAICS-based identification.** Sample frames can be obtained for a subset of broad industry classifications based on NAICS codes. Such sample frames are most applicable to industry sectors with specialized equipment needs. Various data vendors can provide NAICS-based sample frames for Texas establishments, including company name and name, title, and phone number of primary contact. Ownership incidence rates may vary widely.
- **Supplementary contact information.** Supplementary contact information may be obtained through trade associations and stakeholder groups.

Sample Size and Accuracy Targets

The accuracy of estimates derived from a random survey of a population (e.g. average hours of equipment operation per year) depends on the variance of the parameter across the population, and the number of completed surveys. The greater the variance, the less accurate the estimate will be for any given number of "completes", and the more completes the more accurate the estimate will be.

The accuracy of survey estimates is typically expressed in terms of the result being within a given percentage range of the true value ("margin of error") for a given probability ("confidence level"). Using standard statistical assumptions, the target number of completes can be determined for a population of a given size in order to achieve estimates with the desired accuracy. While higher number of completes generally improves accuracy, for large populations the target number of completes is relatively invariant with the size of the population. Conversely, if the population is relatively small, a smaller number of completes will result in estimates that achieve the desired level of accuracy. Table 3-1 shows the number of completes needed to obtain different levels of accuracy, for a range of population sizes based on simple random sampling.

Table 3-1. Target Number of Completes as a Function of Survey Population

Population Size	Number of Completed Surveys	
	Margin of Error/Confidence Level	
	5%/95%	10%/95%
100	80	50
500	218	81
1,000	278	88
5,000	357	95
10,000	370	96
50,000	382	96

In practice one must back-calculate the required sample size (i.e. the number of survey phone/email contacts) drawn from a sampling frame accounting not only for total population size, desired margin of error and confidence interval, but also the anticipated non-response rate among sampled contacts (i.e. those refusing to participate plus those where no contact was achieved), and the presence of invalid records in the sample frame database itself (sampling frame "deficiencies"). Thus, in practice the sample obtained is likely to be substantially larger than the target number of completes dictated by the accuracy goals.

The number of surveys and stratifications is limited by the need to balance the precision of survey results with available data collection resources. ERG attempted to obtain approximately 100 valid, completed surveys for each survey category, roughly corresponding to a 10 percent margin of error at the 95 percent confidence interval.

The simple random sample methodology described above assumes that no information is known in advance regarding the relative importance of each respondent. For example, the call list for a particular equipment type will not indicate which contractors operate several units, or just one. However, in some cases, trade associations were requested to provide ERG with market share indicators that correlated with equipment use, allowing us to selectively and cost-effectively target those establishments responsible for the greatest amount of nonroad equipment activity.

Surrogate Expansion Factors

Different surrogates can be used to expand the random sample and industry survey findings to the state as a whole, and then to allocate equipment activity geographically (to the county level). Considerations for the selection of surrogates included correlation with horsepower-hours of use (and therefore with emissions), and representativeness (i.e., geographic coverage).

ERG obtained the surrogates listed in Table 3-2, specific to Texas, to expand and allocate equipment population and activity.

Table 3-2. Surrogates by Survey Category[8]

Survey Category	Surrogate(s)	Data Source
Above ground mining	Labor hours for quarry/pit employees	Mine Safety and Health Administration
Logging	County-level timber harvest volume	Texas A&M Forest Service

Random Sample Survey Data Collection

Required Data – Logging and Surface Mining

The following lists the survey data fields for the logging and surface mining sectors, differentiating between key fields (such as equipment type and horsepower) that must be provided for a survey to be considered "complete", and non-key fields that are helpful for QA and other purposes, but are not required for estimating emissions (e.g., equipment make/model).

The data elements collected during the surveys included the following:

- Population data by equipment type
  - Equipment type description
  - Engine model year

[8] Since agricultural tractor population data were not collected under this work order, surrogate expansion factors were not necessary for that survey. However, agricultural tractor populations were updated based on revised growth factors in the MOVES-Nonroad model, as discussed in Section V.C.

    - Maximum rated hp
    - Fuel consumption estimates, where available[9]
- Activity data
    - Annual hours of use (preferably based on engine clock hours)
    - Weekday/weekend, monthly/seasonal distributions
- Activity surrogates as appropriate (e.g., number of pit employees for above ground mining, thousand board feet harvested for logging.)
- Location data – county of primary use or estimated percent across multiple counties

Required Data – Agricultural Tractors

The agricultural tractor survey was more limited in scope, focusing on collecting data related to engine age, activity and horsepower. Requested data elements included:

- Tractor make
- Tractor model
- Model Year
- Horsepower
- Lifetime engine hours
- Information on engine rebuilds - yes/no, year of rebuild

Questionnaire Development

Questionnaires and survey administration procedures were developed to collect the data listed above for each survey. Hardcopy mailers including an introductory letter explaining the purpose of the study, a survey form, and a self-addressed stamped envelope for returns were sent in advance to all targeted respondents. ERG attempted to establish contact with all targeted respondents by phone approximately 1 week after mailer packets were mailed. Phone introductions explained the purpose of the survey, described any support received from trade associations, and clearly laid out all procedures used to maintain respondent confidentiality.

The specific wording of the introductory text and survey questions were designed to promote participation, minimize non-response, and ensure reporting accuracy and precision. For example, careful wording of questions can also help avoid certain types of reporting imprecisions commonly found in equipment use surveys. For instance, a rounding bias is often observed in activity estimates, with a large peak in responses seen at “40 hours per week”. ERG explicitly requested estimates of “engine-on” time rather than “hours of use” to minimize the incidence of such shorthand estimation errors, resulting in more accurate, continuous parameter distributions.

[9] Few operators keep fuel consumption records at the equipment unit level so ERG attempted to obtain fuel consumption at the fleet level.

The following presents a generalized template for the survey call scripts and questionnaires. Modified versions of each questionnaire were deployed electronically using Qualtrics survey software.

GENERAL INTRODUCTORY SCRIPTS AND QUESTIONNAIRE

Cold Call (First Contact) Script –

Good Morning/Afternoon, I'm calling on behalf of the Texas Commission on Environmental Quality. My name is ______________ and I work for Eastern Research Group. We have been hired to conduct an off-road diesel equipment survey for the state of Texas and ________ (name of business) is one of the types of businesses they have asked us to contact. You may have received a survey packet from us in the mail recently. Do you have a few minutes to talk?

Alternative First Contact Voicemail Script –

Good Morning/Afternoon, I'm calling on behalf of the Texas Commission on Environmental Quality. My name is _____________ and I work for Eastern Research Group. We have been hired to conduct an off-road diesel equipment survey for the state of Texas and ________ (name of business) is one of the types of businesses they have asked us to contact. You may have received a survey packet from us in the mail recently.

Please give me a call at _______. I will also send an email to _________ (respondent's email address, if available) with a letter describing the purpose of the study. Please email me anytime or call back between the hours of 8 a.m. and 5 p.m., Monday through Friday if you have any questions. Thank you.

Screening Questions –

Before we begin note that the survey is anonymous and confidential, and no identifying information will be sent to the state. Do you have any questions?

[If no questions proceed to #1]

a. Do you operate one or more pieces of diesel-powered off-road equipment greater than 25 hp?
b. How many pieces of these equipment do you operate in Texas?

If not eligible, surveyor thanks respondent for the time and records status.

Summarize the available options for completing the survey including using the self-addressed stamped envelope provided in the packet, phone, online, Excel template (provided via email), or fax. If phone is selected, provide an estimate of the time to complete the survey before proceeding – roughly 5-7 minutes for the first piece of equipment, plus an additional 3-5 minutes for each successive unit.

Main Survey Questions – Logging and Surface Mining Sectors[10]

1. What was the total diesel fuel consumption (in gallons) for your off-road diesel equipment in 2019?
2. What were the primary county/counties of operation for your equipment in 2019?
3. [Ask for relevant surrogate information (will vary by survey type). For example, "How many pit workers did you employ in 2019?"][11]
4. For each piece of equipment greater than 25 hp, please answer the following questions:
   i. What is the equipment type?*

      [Provide examples appropriate to survey, e.g. fellers bunchers for logging, excavators for surface mining, and cross reference against master list]

   ii. What is the equipment make?

      [Provide examples appropriate to survey]

   iii. What is the equipment model?

   iv. What is the equipment horsepower?*

      [Provide hp bins if they seem uncertain (e.g. 100-175)]

   v. What is the equipment model year?

   vi. Has the equipment received an exhaust retrofit to control emissions? (If Yes, specify diesel oxidation catalyst or particulate trap).

   vii. Has the equipment been repowered? (If Yes, specify model year or tier level of repowered engine).

   viii. What were the annual hours of engine on-time in 2019?*

      [If respondent is uncertain or provides a highly rounded estimate, request average hours per week and average weeks per year to derive estimate. If hours per week is "40" remind them we are looking for "engine on" time rather than time in the field.]

   ix. How were those hours typically split across weekdays and weekends?

      [Ask for percentages, must sum to 100%]

   x. How were the hours split across seasons?

      [Ask for percentages, must sum to 100%; summer Jun-Aug, fall Sep-Nov, winter Dec-Feb, spring Mar-May]

[Repeat questions for next piece of equipment until complete]

Thank you for the information. Just a couple more questions for you.

5. Is there any other information regarding your fleet that we should be aware of?

Thank you for your assistance and have a great morning/afternoon/evening!

ERG modified the above script to collect the data elements needed for agricultural tractors.

The following provides additional detail regarding each survey.

Above Ground Mining

Equipment Types

This survey attempted to collect population and activity information on all nonroad diesel equipment targeted by the study. ERG anticipated the most common equipment types would include loaders, dozers, excavators, off-highway trucks, miscellaneous utility equipment (e.g., backhoes), and material handling equipment.

Sample Frame Source(s)

ERG used the contact information contained in the registration permit records for aggregate production establishments, provided by the TCEQ's Water Quality Permits Division. It was assumed this source accounted for 100 percent of significant operators in this sector. ERG attempted to contact the entire list of permitted facilities involved with construction sand, gravel and aggregate mining.

Sector-specific Surrogates

Ideally ERG would use productivity estimates for above ground mining operations (e.g. tons of material produced per year) as the surrogate most closely correlated with nonroad equipment use. Since this information is not available from the Mine Safety and Health Administration (MSHA) database, ERG planned to use the MHSA's Yearly Employment/Production data set to obtain the number of employee hours worked at strips/quarries/open pits and other locations with significant nonroad equipment use as a surrogate for this sector.[12] This data could then be used to extrapolate the survey results to non-responding establishments. However, given the very poor survey response rates (see Section IV B), ERG did not conduct this analysis.

Industry Support and Contacts

ERG sought support from the Texas Aggregates and Concrete Association (TACA) for this survey.

Agricultural Tractors

Equipment Types

This survey collected information on nonroad diesel agricultural tractors > 25 hp.

[10] Mandatory questions marked with a *

[11] Each survey was tailored to ensure collection of surrogate data consistent with the data sources noted above, in order to expand and allocate the survey results.

[12] Only coal mining operations are required to report production levels.

Sample Frame Source(s)

ERG obtained contact information for establishments operating under NAICS codes 111 and 112 from Dynata.[13] Establishments were randomly selected for mailings and attempted contacts.

Industry Support and Contacts

ERG sought support from the Texas Farm Bureau for this survey.

Logging Sector

Equipment Types

This survey attempted to collect population and activity information on all nonroad diesel equipment targeted by the study. Currently, there are three equipment types (and associated SCCs) earmarked in MOVES/NONROAD to represent diesel-powered applications in the logging sector:

- 2270007005 Chainsaws
- 2270007010 Shredders > 6 hp
- 2270007015 All Other Forest Equipment (Feller Buncher, Skidder, etc.)

However, there are distinct methods and systems employed for timber harvesting – e.g., conventional ground-based systems, shovel logging, cable logging, etc. Each system typically includes a specific combination of equipment types to achieve the harvesting targets. For this reason, ERG expanded the number of individual equipment types, and developed a revised list for data collection purposes. The list of logging equipment types for the assessment included:[14]

- Feller Bunchers
- Forwarders
- Log Loaders/Picks, Self-Propelled
- Log Loaders/Picks, Stationary/Trailer Mount
- Skidders
- Tree Harvesters
- Chippers/Shredders
- Other Forestry Equipment, Self-Propelled
- Other Forestry Equipment, Stationary/Trailer Mount

[13] Dynata LLC. https://www.dynata.com/company/about-us/.

[14] While there are a nominal number of diesel-powered chainsaws, none are above 25 hp, and chainsaws were included in the survey.

Sample Frame Source(s)

ERG obtained contact information for establishments operating under NAICS code 113 from Dynata.

Sector-specific Surrogates

ERG planned to use by-county estimates of timber harvest volume provided by the Texas A&M Forest Service for 2016 as the surrogate for this sector. ERG could then adjust the 2016 data for the 2019 base year using County Business Pattern yearly employment data for 113 NAICS code establishments operating in Texas. However, given the very poor survey response rates (see Section IV C), ERG did not conduct this analysis.

Industry Support and Contacts

ERG sought support from the Texas Forestry Association (TFA) and Texas Logging Council (TLC) for this survey.

Random Sample Survey Procedures

ERG developed survey administration procedures to promote participation rates and ensure data quality. ERG use a combination of in-house and subcontractor support to administer the survey questionnaires. ERG first provided staff with background on the purpose of the study to familiarize them with the industry and equipment terminology they might encounter during survey efforts.

Since the available hours of the respondents vary, surveys were administered from as early as 7:00 a.m. to as late as 8:00 p.m. if requested, to maximize response rates. Contacts included in the sample frames were called, emailed, and/or faxed up to three times to establish phone contact. After three unsuccessful attempts, a phone number was removed from the call list.

Before initiating contact with a potential respondent, company websites were reviewed to determine hours of operation, corporate structure, and where available, fleet manager name and types of equipment used in order to improve the efficiency of the survey. After initial contact was made, a variable contact interval schedule was set up to optimize email open rates, and to coordinate the emails and phone calls. If a respondent callback responding to a voicemail was missed, calls were returned as soon as possible.

Once a respondent was successfully contacted, ERG first determined whether they were eligible to participate in the survey (i.e., whether they have owned/operated/used at least one target equipment type) before continuing. Eligible respondents were then given the option to provide information via mail, phone, electronically using a link provided by the surveyor or using a Microsoft (MS) Excel template delivered via email, or in selected cases by providing information directly from their company database reporting systems.

Emails were sent as soon as possible after phone calls to increase credibility and to provide context for follow-up contacts if necessary. An email application was used to automatically send out follow up emails at optimum times for response rates, either a time that had been requested by the business contact or as a default at 7 a.m.

Data collected via phone was entered electronically during phone interviews. The surveyor entered a unique ID for each respondent. To ensure that the activity, hp, and model year data collected in the phone surveys were reasonable, these fields had pre-defined range checks associated with them. This allowed the person conducting the survey to ask for qualifying information if the responses were not realistic or consistent—for example, if the reported engine-on time was greater than a predefined amount (e.g., 2,000 hours/year).

Notes were kept on each call and any respondent concerns/objections regarding specific questions were noted and responded to with scripted answers.

Data Processing and Quality Assurance

Once surveys were completed and received by ERG, they were logged in a secure file to ensure respondent confidentiality. ERG then cleaned survey responses of all identifying participant information for further processing to maintain confidentiality, compiled and stored them in a standardized format, and subjected them to comprehensive range checks and quality assurance measures to ensure the accuracy of the data sets. Evaluations focused on assuring accurate assignment of equipment to appropriate SCCs, identification of missing hp values, refinement of equipment application assignments excluding any non-target equipment, and identification and treatment of suspected outliers.

ERG then reviewed the survey data set to identify any missing key data elements. ERG first attempted to resolve any issues directly with the respondent by email and phone, then drew on other resources as needed (e.g., equipment manufacturer websites or other publicly available web resources such as manufacturer websites) to obtain hp estimates and/or model years.

The final, quality-assured, gap-filled data set was stored in MS Excel format, containing data files that could be linked via a unique identifier assigned to each respondent. ERG then determined the number of completed surveys, the total number of eligible respondents, and the total completion and refusal rates for each survey.

The final survey data was merged with the corresponding surrogate data using MS Excel. Individual records were maintained for each piece of equipment surveyed.

Detailed comment fields were used when processing spreadsheets to document data sources, calculation methods, and assumptions.

The resulting data tables include base year populations and activity information by equipment type, and hp bin for each county. Population, activity, and temporal profile data were then aggregated across application categories to establish a single equipment profile for each nonroad diesel equipment type.

IV. SURVEY DATA COLLECTION

The following documents ERG's administration of the agricultural, logging and surface mining, and port sector surveys under Task 3 of the study. Call log spreadsheets summarizing correspondence with survey targets have been provided to the TCEQ separately in electronic format.

The preliminary contact strategy for the all three surveys consisted of approaching the relevant trade organizations and asking for their assistance communicating with their members. The Texas Farm Bureau, TACA, TFA and TLC were all approached for assistance co-signing introductory letters, posting a link to the survey on their websites, reaching out to their membership by phone and email, and/or verifying contact strategies and cohorts.[15]

The contact strategy for all respondents consisted of mailing copies of the surveys in advance with a self-addressed stamped return envelope, giving the person or organization an appropriate amount of time (typically 7 days) to review the contents and distribute the survey to the appropriate person, and then following up by phone and/or email to determine if they were willing to participate. Once contacted, potential respondents were informed that any information provided would be kept confidential and offered a variety of modes for completing the survey including online, Excel forms exchanged by email, fax, and the self-addressed prepaid mailers.

Specific details for each survey category are provided below.

A. Agricultural Sector Survey

ERG was unable to obtain the support of the Texas Farm Bureau for the agriculture survey after repeated attempts. ERG proceeded to contract with Dynata to obtain contact information for agricultural establishments, receiving a list with 21,370 names which were randomly spot-checked for accuracy, filtered by keywords and randomized for a final contact list of 1,999 potential respondents.[16]

[15] From ERG's recent experience with voluntary surveys, credibility is crucial. The use of surveys for marketing has become so prevalent that people tend to ignore them. Without a trustworthy reference, voluntary surveys are often seen as illegitimate. Obtaining the support of trade organizations, which represent the interests of their members and are directly in contact with the largest companies in their respective areas, are an effective means of quickly establishing legitimacy.

[16] Based on ERG's experience in 2019 with a similar survey in Oregon, the contact information available from vendors for agricultural establishments is single-sourced and is often of poor quality – outdated, and poorly correlated by name, address, phone number. For example, businesses were frequently miscategorized based solely on simple key words – e.g., "State Farm" and "Farmers" insurance companies were listed in the agricultural category as well as restaurants, apartments and schools, etc. with similar naming conventions. Accordingly, ERG spent significant time quality assuring and filtering the contact list before initiating the survey.

The surveys were sent out in four separate mailings during February of 2020. The final response results for the agricultural survey were as follows:

- 166 individuals viewed the survey online, with 12 surveys completed;
- 121 completed surveys were returned by mail;
- The 133 completed surveys included usable information (including model year and passed QA) on 475 tractors.

The final number of completed surveys exceeded the target of 100 (or a 10 percent margin of error at the 95 percent confidence interval) established in the Data Collection Plan. Assuming a population size of 198,172 establishments[17], 133 completed surveys provide a margin of error of 8 percent at the 95 percent confidence level.

B. Surface Mining Sector

ERG contacted TACA to request help reaching out to their membership in February and March of 2020. While sympathetic to the survey effort, TACA representatives indicated that they did not have the resources to reach out to their members on ERG's behalf due to operational constraints during the current pandemic.

ERG developed the contact list for this sector using information on Aggregate Processing Operations (APO) obtained from the TCEQ's Wastewater Permits Division, current as of 6-21-2019. ERG filtered the APO list by producer type (retaining industrial sand and construction sand and gravel industry codes), resulting in a target list of 344 establishments. The contact list was then researched thoroughly to ensure the phone number and address were consistent with the information in the APO data. The site mailing addresses, and phone numbers often were not closely connected with the contact information for the person listed. To avoid having to forward the mailer from the mine site, the surveys were sent directly to the corporate office when possible.

Because of concerns regarding the pandemic, ERG sent the first of two staggered mailers to larger companies with multiple APO entries, and to mining sites of over 80 acres in early March in an attempt to obtain an adequate response quickly. A second mailer was sent out in late March. The contacts for the mailers were called and the survey received a very poor reception - many of the potential recipients were working from home by that time and expressed doubt that the survey was viable due to lack of resources for data collection.

[17] The number of establishments operating tractors for agricultural purposes in Texas in 2017, according to the most recent U.S. Department of Agriculture Census – see https://www.nass.usda.gov/Quick_Stats/CDQT/chapter/1/table/45/state/TX.

Toward the end of March ERG reached out to TACA again which responded that the situation had changed for the worse across their membership, and that ERG should not expect a significant response since their operations have been “turned upside down".

Ultimately three surveys were returned through the beginning of April, only one of which was complete. Based on the extremely poor response the decision was made to terminate the survey efforts by the TCEQ Project Manager.

C. Logging Sector

Because of the geographically and financially concentrated nature of the logging industry in Texas, it is a fairly small cohort. Without active trade organization support and the cooperation of the larger landowners and logging companies, ERG expected it would be difficult to obtain adequate response rates from this sector. To this end, and with the help of Texas A&M and the State Forrester's Office, ERG contacted the TFA and their sister organization, the TLC. The TFA represents landowners, businesses and professionals in the logging industry and the TLC represents the specific interests of loggers. After an initial presentation of the project’s goals and methods both organizations offered to provide extensive outreach support.

ERG first asked the TFA/TLC if their 2020 Pro Logger Certification list would be representative of the industry and be preferable to the vendor list obtained from Dynata as the basis for compiling the survey contact list. They replied that they considered this to be a valid, up to date data set and encouraged its use. The organizations also committed to distributing the survey by email to the larger logging companies, asking the larger producers to participate, and publishing the link to the online survey in their newsletter.

The Pro Logger Certification data obtained from the TFA website[18] included names and addresses but did not provide phone numbers or other contact information. Therefore, each certified company was researched and validated online through paid and unpaid search engines. ERG identified establishments with a current certification status and distributed mailers to each during the month of April. Two staggered mailers were sent out, representing 199 companies operating at 729 locations. Though the mailing information was high quality (in terms of valid addresses that correlated well with business names and phone numbers), only three complete responses were obtained through mid-May. At that point ERG contacted the TFA/TLC and asked them to resend the survey link and re-contact both large producers and loggers and ask for their cooperation. After this second round of requests ERG received one additional response.

[18] See https://www.texasforestry.org/programs/logger-listing.

Given the poor response rate even with active support from the TFA/TLC, the logging survey was terminated at the request of the TCEQ Project Manager.

D. Port Sector

ERG contacted the Port of Houston Authority in order to adjust equipment populations for electric vehicle penetration in the terminal tractor fleet in Harris County. However, the Port responded that only one terminal tractor had been electrified to date, for demonstration purposes.[19] Given the minimal change in the terminal tractor profile the TCEQ agreed that an adjustment to the TexN equipment population files was not warranted at this time.

[19] Personal communication with Ken Gathright, Port of Houston Authority, January 8, 2020.

V. SUPPLEMENTARY EQUIPMENT PROFILE, POPULATION, ACTIVITY DATA AND GROWTH FACTOR UPDATES

The following discusses the collection, analysis, and quality assurance of the supplementary equipment profile, equipment population, activity data, and growth factor updates developed for the TexN2.0 utility.

A. TxDOT Subsector Update

TxDOT maintains unit-specific hours of use data for their entire nonroad diesel equipment fleet, at the county level. ERG contacted TxDOT to obtain the most recent data for equipment operating across the state in order to update the TexN2.0 inputs for this diesel construction equipment (DCE) subsector.[20] Key data fields included equipment description/category, make/model, engine model year, hp, and hours of use for the 2019 calendar year.

The records were obtained in electronic format and reviewed. Units identified as non-diesel, used for on-road applications, under 25 hp, or with zero hours of operation in 2019 were excluded from the analysis. Equipment make and model were used to gap-fill missing hp values based on manufacturer website searches.

In the initial dataset several hundred records had missing description/category fields. In these instances, makes and models were matched to preexisting descriptions/categories where possible. Several new nonroad equipment categories were identified that were not reported previously including generators, aerial lifts, pumps, and specialty vehicles/carts.

The TxDOT description/category fields were used to determine the TexN2.0 equipment type assignment. Five records did not have enough information to assign a TexN2.0 equipment type and were removed, leaving 2,474 records of interest. Table 5-1 shows the average hours per year, hp, and model year by TexN2.0 equipment type. A table of the number of TxDOT units that fall within specified hp bins, classified by TexN2.0 equipment type and county, was provided to the TCEQ in electronic format.

Table 5-1. TxDOT Average Equipment Usage per Year, Horsepower, and Model Year

Equipment Type	# Units	Average Hours/Year	Average hp	Average Model Year
Aerial Lifts	2	126	58	2006
Agricultural Tractors	104	107	90	2005
Chipper/Stump Grinder	8	51	107	2003

[20] Correspondence with Darah Waldrip, Information Specialist, TxDOT Fleet Operations Division, 1-17-2020. Darah.Waldrip@txdot.gov.

Table 5-1. TxDOT Average Equipment Usage per Year, Horsepower, and Model Year

Equipment Type	# Units	Average Hours/Year	Average hp	Average Model Year
Cranes	9	94	96	1997
Crawler Tractor/Dozer	23	328	137	2002
Excavators	117	523	195	2008
Generators	6	45	395	2002
Graders	446	461	155	2005
Other Construction Equipment	8	39	142	2014
Pavers	46	172	165	2007
Pumps	4	16	99	2011
Rollers	475	255	89	2009
Rough Terrain Forklifts	48	64	66	1999
Rubber Tire Loader	426	338	132	2004
Skid Steer Loaders	295	193	88	2011
Specialty Vehicles/Carts	1	20	87	2010
Surfacing Equipment	83	275	360	2010
Sweepers/Scrubbers	281	227	81	2009
Tractor/Loader/Backhoe	92	226	95	2004
Grand Total	2,474	294	124	2007

B. Engine Load Factor Estimates

The nonroad diesel engine load factor estimates used in the MOVES-Nonroad model were developed using a limited set of engine measurement data developed over 20 years ago, and are particularly uncertain.[21] ERG determined that updated estimates developed by the California Air Resources Board (CARB) offer the most comprehensive, consistent set of load factors available for updating TexN2.0.[22] CARB has undertaken many survey efforts over the past several years to collect fuel consumption, activity, and hp data for thousands of engines in order to update the load factors for the following equipment types:

- Construction/mining and industrial equipment[23]
- Agricultural equipment[24]

[21] U.S. EPA, *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emission Modeling.* NR-005d. July 2010. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P10081RV.pdf.

[22] The CARB factors have the added benefit of being part of an EPA-approved emission modeling system.

[23] California Air Resources Board, In-Use Off-Road Diesel-Fueled Fleets Regulation. https://ww2.arb.ca.gov/our-work/programs/use-road-diesel-fueled-fleets-regulation. Accessed 5-1-2020.

[24] California Air Resources Board. *Emission Inventory for Agricultural Diesel Vehicles.* December 2018. https://ww3.arb.ca.gov/msei/ordiesel/ag2011invreport.pdf. Accessed 5-1-2020.

- Cargo handling equipment[25]
- Transportation Refrigeration Units (TRUs)[26]
- Miscellaneous portable equipment (e.g., generators, compressors)[27]

The engine load factors developed by CARB cover 32 of the 56 diesel equipment categories included in TexN2.0. MOVES default factors were unchanged for the remaining categories. Table 5-2 presents the CARB and MOVES load factors, as well as the final values adopted for the TexN equipment categories.

Table 5-2. Engine Load Factor Updates

Equipment Category	Equipment Type	CARB Factor	MOVES Factor	Value Selected
Recreational vehicles	Specialty vehicles/carts	N/A	0.21	0.21
Agricultural	Agricultural mowers	N/A	0.59	0.59
Agricultural	Agricultural tractors	0.48	0.59	0.48
Agricultural	Balers	0.50	0.59	0.50
Agricultural	Combines	0.44	0.59	0.44
Agricultural	Irrigation sets	N/A	0.59	0.59
Agricultural	Other agricultural equipment	N/A	0.59	0.59
Agricultural	Sprayers	0.42	0.59	0.42
Agricultural	Swathers	0.48	0.59	0.48
Commercial	Air compressors	0.31	0.43	0.31
Commercial	Generators	0.31	0.43	0.31
Commercial	Hydro-power units	N/A	0.43	0.43
Commercial	Other commercial equipment	N/A	0.43	0.43
Commercial	Pressure washers	N/A	0.43	0.43
Commercial	Pumps	N/A	0.43	0.43
Commercial	Welders	N/A	0.21	0.21
Construction/ mining	Bore/drill rigs	0.50	0.43	0.50
Construction/ mining	Cement/mortar mixers	N/A	0.43	0.43
Construction/ mining	Concrete/industrial saws	N/A	0.59	0.59
Construction/ mining	Cranes	0.29	0.43	0.29
Construction/ mining	Crawler tractors/dozers	0.43	0.59	0.43

[25] California Air Resources Board. *Emission Inventory Development for Cargo Handling Equipment.* 2011. https://ww3.arb.ca.gov/regact/2011/cargo11/cargoappb.pdf. Accessed 5-1-2020.

[26] California Air Resources Board, Initial Statement of Reasons for Proposed Rulemaking: 2011 Amendments for the Airborne Toxic Control Measure for In-Use Diesel-Fueled Transportation Refrigeration Units (TRUs) and TRU Generator Sets, and Facilities where TRUs Operate. August 2011. https://ww2.arb.ca.gov/our-work/programs/transport-refrigeration-unit. Accessed 5-1-2020.

[27] California Air Resources Board. *2017 Diesel-Fueled Portable Equipment Emission Inventory – Technical Documentation.* March 2017. https://ww3.arb.ca.gov/msei/ordiesel/perp2017report.pdf. Accessed 5-1-2020.

Table 5-2. Engine Load Factor Updates

Equipment Category	Equipment Type	CARB Factor	MOVES Factor	Value Selected
Construction/ mining	Crushing/processing equipment	N/A	0.43	0.43
Construction/ mining	Dumpers/tenders	N/A	0.21	0.21
Construction/ mining	Excavators	0.38	0.59	0.38
Construction/ mining	Graders	0.41	0.59	0.41
Construction/ mining	Off-highway tractors	0.44	0.59	0.59[28]
Construction/ mining	Off-highway trucks	0.38	0.59	0.38
Construction/ mining	Other construction equipment	0.42	0.59	0.42
Construction/ mining	Pavers	0.42	0.59	0.42
Construction/ mining	Paving equipment	0.36	0.59	0.36
Construction/ mining	Rollers	0.38	0.59	0.38
Construction/ mining	Rough terrain forklifts	0.40	0.59	0.40
Construction/ mining	Rubber tire loaders	0.36	0.59	0.36
Construction/ mining	Scrapers	0.48	0.59	0.48
Construction/ mining	Signal boards/light plants	N/A	0.43	0.43
Construction/ mining	Skid steer loaders	0.37	0.21	0.37
Construction/ mining	Surfacing equipment	0.30	0.59	0.30
Construction/ mining	Tractors/loaders/backhoes	0.37	0.21	0.37
Construction/ mining	Trenchers	0.50	0.59	0.50
Industrial	Aerial lifts	0.31	0.21	0.31
Industrial	Forklifts	0.20	0.59	0.20
Industrial	Other general industrial equip.	0.34	0.43	0.34
Industrial	Other material handling equip.	0.40	0.21	0.40
Industrial	Sweepers/scrubbers	0.46	0.43	0.46
Industrial	Terminal tractors	0.39	0.59	0.39
Industrial	TRUs	0.46	0.43	0.46
Lawn and garden	Chippers/stump grinders	N/A	0.43	0.43
Lawn and garden	Commercial mowers	N/A	0.43	0.43
Lawn and garden	Commercial turf equipment	N/A	0.43	0.43
Lawn and garden	Lawn and garden tractors	N/A	0.43	0.43
Lawn and garden	Other lawn and garden equip.	N/A	0.43	0.43
Logging	Logging equipment	N/A	0.59	0.59
Other	Oilfield equipment	N/A	0.43	0.43
Other	Railway maintenance equip.	N/A	0.21	0.21
Recreational marine	Inboard/sterndrive motors	N/A	0.35	0.35

[28] The average hp values reported for off-highway tractors were substantially different between the MOVES and CARB data sets (722 vs. 184, respectively), leading ERG to believe these equipment categories are not defined consistently by the two agencies. Accordingly, the MOVES factors were retained to be conservative.

Table 5-2. Engine Load Factor Updates

Equipment Category	Equipment Type	CARB Factor	MOVES Factor	Value Selected
Recreational marine	Outboard motors	N/A	0.35	0.35

With limited exceptions,[29] the updated values are lower than the MOVES defaults, which will lower the corresponding emission estimates proportionally.

C. Growth Factor Updates

The TexN2.0 utility contains 25 subsectors with distinct equipment population and activity profiles. DCE comprise 23 of these subsectors. The two remaining subsectors include non-diesel-powered equipment (Non-DCE), and miscellaneous diesel equipment plus all equipment less than 25 hp. County-level growth factors have been developed for each of the DCE subsectors relative to a 2012 base-year population, extended through 2050. For example, the growth in landfill equipment activity between 2012 and 2018 in Dallas County is determined by calculating the ratio of the population estimate for 2018 by the estimate for 2012 (2,660,715/2,441,092 = 1.090). The base year (2012) equipment population for the county is then multiplied by the growth factor to estimate the corresponding equipment population for 2018 for inclusion in the utility. Growth factors for other counties, years, and DCE subsectors are calculated in a similar fashion.

Table 5-3 presents a summary of the growth surrogates used to develop the growth factors for each DCE subsector.

Table 5-3. DCE Subsector Growth Surrogates

Subsector	Growth Surrogate
Non-DCE	NONROAD default
Agricultural Activities	Texas Agricultural Census – acres under production
Boring & Drilling Equipment	Economy.com – NAICS-specific GDP[30]
Brick & Stone Operations	Economy.com – NAICS-specific GDP
City and County Road Construction	Texas State Data Center - county-level census population
Commercial Construction	Economy.com – NAICS-specific GDP
Concrete Operations	Economy.com – NAICS-specific GDP
County-Owned Construction Equipment	Texas State Data Center - county-level census population
Cranes	Economy.com – NAICS-specific GDP

[29] Bore/drill rigs, skid steer loaders, tractors/loaders/backhoes, aerial lifts, other material handling equipment, sweepers/scrubbers, and TRUs are assumed by CARB to have higher load factors than the corresponding MOVES defaults.

[30] Gross Domestic Product.

Table 5-3. DCE Subsector Growth Surrogates

Subsector	Growth Surrogate
Heavy-Highway Construction	Texas Comptroller's Office – Highway Construction and Maintenance Expenditures
Landfill Operations	Texas State Data Center - county-level census population
Landscaping Activities	Economy.com – NAICS-specific GDP
Manufacturing Operations	Economy.com – NAICS-specific GDP
Municipal-Owned Construction Equipment	Texas State Data Center - county-level census population
Transportation/Sales/Services	Economy.com – NAICS-specific GDP
Residential Construction	County-level housing permit data from the Texas A&M Real Estate Center for 2012 through 2018; County-level census projections from the Texas State Data Center for 2019 through 2050.
Rough Terrain Forklifts	Economy.com – NAICS-specific GDP
Scrap Recycling Operations	Economy.com – NAICS-specific GDP
Skid Steer Loaders	Economy.com – NAICS-specific GDP
Special Trades Construction	Economy.com – NAICS-specific GDP
Trenchers	Economy.com – NAICS-specific GDP
TxDOT Construction Equipment	Zero growth per TxDOT Equipment Replacement Policy
Utility Construction	Economy.com – NAICS-specific GDP
Mining & Quarry Operations	Economy.com – NAICS-specific GDP, MSHA employment data, and Annual Energy Outlook (AEO) lignite production projections for the Gulf Coast
Other - Off-road tractors, Miscellaneous, and all Equipment < 25 hp	NONROAD defaults

In the most recent growth factor update conducted for the TCEQ, ERG revised historical growth surrogates for each DCE subsector through 2012 and developed future year growth factors for years 2013 and beyond.[31] The current assessment replaces the prior projections for 2013 through 2019 with historical data, and updates the future year growth factors for the years 2020 through 2050. Factors for years prior to 2013 remain unchanged from the previous version of the TexN utility.

MOVES-Nonroad Default Categories

Default MOVES-Nonroad growth factors have been used for the Non-DCE and Other DCE subsectors in all prior versions of the TexN utility and are retained for this version.

[31] Eastern Research Group, 2014. Texas Nonroad Utility Update and Enhancement. Prepared for the Texas Commission on Environmental Quality. July 30, 2014.

Agricultural DCE Subsector

The amount of land in agricultural production was deemed the most suitable surrogate for this subsector and was updated using the 2017 Texas Agricultural Census[32] to reflect the most recent data. The acres of land in agricultural production is available for every five years from 1987 through 2017 and has been provided to the TCEQ in electronic format. Linear regressions using Excel's Forecast function was used to predict acreage for the full modeling period. For counties with decreasing acreage, trend projections were capped at 0 acres.

Single Family Housing Construction

The growth for single family housing construction activity is based on county-level housing permit data obtained from the Texas A&M Real Estate Center[33] for the years 2012 through 2018 (provided to the TCEQ in electronic format). The dataset contains permit information for all but 25 of the 254 counties in Texas. The missing counties are listed below.

- Borden
- Briscoe
- Concho
- Crocket
- Duval
- Edwards
- Glasscock
- Hartley
- Hudspeth
- Irion
- Jeff Davis
- Jim Hogg
- Kenedy
- King
- Leon
- Loving
- Menard
- McMullen
- Mills
- Roberts
- Sterling
- Stonewall
- Terrell
- Throckmorton
- Zapata

Data were missing from one or more years for 20 rural counties with very low housing construction activity. Rather than assuming 0 construction, missing years were gap-filled by assigning county averages for those years with complete data.

[32] 2017 Census of Agriculture, Volume 1, Chapter 2, Texas County Level Data, Table 8, from https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/. Accessed May 2020.

[33] Texas A&M Real Estate Center, Texas County Building Permit Activity Data, from https://www.recenter.tamu.edu/data/building-permits/#!/state/Texas/. Accessed May 2020.

County-level census projections from the Texas State Data Center[34] were used to develop growth factors for years 2019 through 2050 under the assumption that housing construction follows long-term population projections. These projections have been provided to the TCEQ in electronic format.

Single family housing growth factors were developed for each county for the 2012 base year by dividing permit estimates for each year by the associated 2012 total. Annual county totals of 0 for 2012 were reset to 0.5 to avoid base year projection difficulties.[35] The 25 counties with no permit information were assumed to follow the statewide average trend (shown in Table 5-4).

Table 5-4. Statewide Housing Trend

Year	Growth Factor
2012	1.00
2013	1.14
2014	1.26
2015	1.29
2016	1.30
2017	1.43
2018	1.55
2019	1.58
2020	1.62
2021	1.65
2022	1.69
2023	1.73
2024	1.76
2025	1.80
2026	1.84
2027	1.88
2028	1.92
2029	1.97
2030	2.01
2031	2.05

Year	Growth Factor
2032	2.10
2033	2.14
2034	2.19
2035	2.24
2036	2.28
2037	2.33
2038	2.38
2039	2.43
2040	2.48
2041	2.53
2042	2.59
2043	2.64
2044	2.70
2045	2.75
2046	2.81
2047	2.87
2048	2.93
2049	2.99
2050	3.06

[34] Texas State Data Center, 0.5 Growth Scenario, from https://demographics.texas.gov/Data/TPEPP/Projections/Index.aspx. Accessed May 2020.

[35] Growth factors are expressed as a ratio relative to the 2012 base year activity, requiring all counties to have a non-zero activity level for that year.

Heavy-Highway Construction

ERG obtained comma separated variable data files containing county-specific expenditures for highway construction and maintenance for calendar years 2012, 2013, and 2017 through 2019 from the Texas Comptroller's office.[36] However, county level expenditures for 2014 through 2016 were not available in a useable format, and state-level expenditures were used to develop average growth factors applied uniformly to all counties for these years.

TxDOT state Highway Cost Index (HCI) values were applied to the Comptroller's expenditure data for each year from 2013 through 2019 to adjust to the 2012 base year, accounting for material and other cost inflation.[37] Table 5-5 presents the TxDOT HCI values for the 2012-2019 period, and Table 5-6 presents the unadjusted and adjusted statewide expenditures for 2014-2016, along with the corresponding growth factors relative to the 2012 base year.

Table 5-5. Texas Statewide Highway Cost Indices (2012 base year)

Year	HCI
2012	1.000
2013	1.114
2014	1.156
2015	1.249
2016	1.242
2017	1.147
2018	1.206
2019	1.267

Table 5-6. Historical Statewide Highway Construction and Maintenance Expenditures and Growth Factors

	2012	2014	2015	2016
Nominal Cost	4,186,493,637	5,305,157,884	5,192,846,124	6,159,245,504
HCI-Adjustment (2012 base)	4,186,493,637	4,588,173,557	4,157,614,260	4,957,214,624
Growth Factors (2012 base)	1.000	1.096	0.993	1.184

The county level HCI-adjusted expenditures for 2013 and 2017-2019 have been provided to the TCEQ in electronic format.

[36] See Texas State Expenditures by County, Texas Comptroller's Office, https://data.texas.gov/Government-and-Taxes/Texas-State-Expenditures-by-County-2019/2x5x-m677, https://data.texas.gov/Government-and-Taxes/Texas-State-Expenditures-by-County-2018/f2iw-dtqt.

[37] TxDOT Highway Cost Index. Provided electronically by Brianne Glover, Texas Transportation Institute, 5-11-20.

County-level GDP projections were obtained from Economy.com for NAICS code 2373 (Highway Street and Bridge Construction) for calendar years 2012 – 2050. ERG extended the growth factors using the Economy.com data in two steps. First the GDP estimate for each county from 2020-2050 was divided by the corresponding GDP estimate for 2019, creating growth factors relative to a 2019 base year. Next, these factors were adjusted to the 2012 base year by multiplying each value by the 2019 HCI shown in Table 5-5 (1.267). The resulting county-specific growth factors have been provided to the TCEQ in electronic format.

Skid Steer Loaders and Other Specialty Equipment

The population growth for skid steer loaders and other specialty equipment (including bore/drill rigs, cranes, rough terrain forklifts, and trenchers) was assumed to track with the total GDP for all construction sectors. GDP estimates were obtained at the county level through 2050 from Economy.com and summed across the NAICS industry codes shown in Table 5-7 (representing common users of these equipment).

Table 5-7. Construction Sector NAICS Codes

Sector	NAICS
Highway Construction	2373
Residential Building Construction	2361
Non-residential Building Construction	2362
Special Trades Contractors	238
Utility System Construction	2371

Growth factors relative to the 2012 base year were calculated based on these data as described for other sectors above. The county-specific factors for these DCE subsectors have been provided to the TCEQ for 2012 – 2050 in electronic format.

Municipal and County Fleets, City/County Road Construction, and Landfills

Texas State Data Center county-level census projections were used to develop growth factors for 2020 – 2050 and were provided to the TCEQ in electronic format. Growth scenario projection 0.5 was used based on Demographer recommendations, consistent with prior TexN updates.

Other Construction Applications

ERG obtained historical and projected inflation-adjusted GDP estimates for the 2012 base year at the county level for various NAICS categories from Economy.com. These data were used to develop the updated growth factors for the NAICS codes shown in Table 5-8.

Table 5-8. DCE Sectors Utilizing Economy.com Growth Surrogates

Sector	NAICS
Commercial Building Construction	2362
Utility System Construction	2371
Special Trades Contractors	238X
Manufacturing	31XX – 33XX*
Cement and Concrete Product Manufacturing	3273
Clay Product and Refractory Manufacturing	3271
Transportation/Sales/Services	42XX (wholesale), 44XX – 45XX (retail), 48 XX – 49XX (transportation and warehousing), 81XX (other services)
Landscaping Services	56173
Materials Recovery Facilities	562920

* Less cement, concrete, and clay product manufacturing

Mining and Quarry Operations, including Lignite Mine Activity Adjustments

Economy.com also provided GDP estimates for mining and quarry operations under NAICS code 212. However, unlike the NAICS code groupings listed above, county level mining and quarry operations can be dominated by a single facility, such as a coal mine. As such the opening or closure of a large coal mining facility can have a sudden, drastic impact on the growth factors for this sector. For this reason, ERG identified coal mining operations across the state and adjusted the county-specific growth factors as needed to reflect mine-specific activity changes.

Growth factors for counties with coal mining operations were developed using the following steps:

1. *Identify counties with lignite production between 2012 and 2019.* ERG obtained facility-specific information on annual Texas lignite coal production and employee hours from the MSHA.[38] The following 12 counties were determined to have active lignite mining operations during this period:

- Atascosa
- Freestone
- Harrison
- Hopkins
- Lee
- Leon
- Limestone
- Maverick
- Panola
- Robertson
- Rusk
- Titus

[38] U.S. Department of Labor, Mine Safety and Health Administration – Mine Employment and Coal Production (through 2019). https://www.msha.gov/mine-employment-and-coal-production. Accessed 5-15-2020.

2. *Develop growth factors for the 12 lignite-producing counties for the 2012-2019 time period using total employee hours as the growth surrogate.* Table 5-9 presents the total annual employee hours obtained from the MSHA dataset for both coal and other mining activities, as well as the corresponding 2012 base year growth factors.

Table 5-9. Mining/Quarry Subsector Labor Hours and Growth Factors (Counties w/ Lignite Operations)

County	Parameter	2012	2013	2014	2015	2016	2017	2018	2019
Atascosa	Coal Employee hrs	592,368	543,254	484,810	509,385	570,369	618,219	737,488	748,274
	Total Employee hrs	696,749	645,230	592,034	610,093	674,254	791,656	1,249,637	1,419,428
	Growth Factor	1.000	0.926	0.850	0.876	0.968	1.136	1.794	2.037
Freestone	Coal Employee hrs	507,950	549,241	466,228	296,092	227,951	208,725	73,174	34,949
	Total Employee hrs	507,950	549,241	466,228	296,092	227,951	208,725	73,174	34,949
	Growth Factor	1.000	1.081	0.918	0.583	0.449	0.411	0.144	0.069
Harrison	Coal Employee hrs	670,501	587,554	716,157	791,108	792,970	741,473	736,386	719,805
	Total Employee hrs	681,580	600,044	716,157	791,108	792,970	741,473	736,386	719,805
	Growth Factor	1.000	0.880	1.051	1.161	1.163	1.088	1.080	1.056
Hopkins	Coal Employee hrs	277,637	0	58,413	112,123	36,516	0	0	0
	Total Employee hrs	277,637	126,303	58,413	112,123	36,516	0	0	0
	Growth Factor	1.000	0.455	0.210	0.404	0.132	0.000	0.000	0.000
Lee	Coal Employee hrs	601,670	628,912	669,869	724,133	716,019	663,267	196,563	0
	Total Employee hrs	601,670	628,912	669,869	724,133	716,019	663,267	196,563	153,908
	Growth Factor	1.000	1.045	1.113	1.204	1.190	1.102	0.327	0.256
Leon	Coal Employee hrs	815,021	833,348	898,810	795,059	538,943	0	0	0
	Total Employee hrs	820,221	833,966	898,810	795,059	538,943	0	0	0
	Growth Factor	1.000	1.017	1.096	0.969	0.657	0.000	0.000	0.000
Limestone	Coal Employee hrs	722,720	735,511	724,453	674,660	755,127	723,776	769,783	792,632
	Total Employee hrs	1,106,781	1,122,587	1,150,871	1,136,214	1,115,295	1,117,655	1,156,939	1,216,577
	Growth Factor	1.000	1.014	1.040	1.027	1.008	1.010	1.045	1.099
Maverick	Coal Employee hrs	0	0	43,796	198,475	446,418	500,739	482,042	448,572
	Total Employee hrs	108,696	70,018	118,217	246,010	480,649	534,455	523,185	513,744
	Growth Factor	1.000	0.644	1.088	2.263	4.422	4.917	4.813	4.726
Panola	Coal Employee hrs	1,051,079	890,526	721,477	602,251	522,997	202,617	220,377	95,915
	Total Employee hrs	1,051,079	890,526	721,477	602,251	522,997	379,249	393,224	171,215
	Growth Factor	1.000	0.847	0.686	0.573	0.498	0.361	0.374	0.163
Robertson	Coal Employee hrs	214,278	222,377	213,265	237,941	237,702	204,546	200,945	224,815
	Total Employee hrs	214,278	222,377	213,265	237,941	237,702	204,546	200,945	224,815
	Growth Factor	1.000	1.038	0.995	1.110	1.109	0.955	0.938	1.049
Rusk	Coal Employee hrs	531,487	613,103	687,202	776,976	709,492	363,977	343,769	353,908
	Total Employee hrs	531,653	615,338	695,765	786,618	735,456	390,191	363,019	366,999
	Growth Factor	1.000	1.157	1.309	1.480	1.383	0.734	0.683	0.690
Titus	Coal Employee hrs	385,705	449,385	363,385	0	0	0	0	0
	Total Employee hrs	385,705	449,385	363,385	0	0	0	0	0
	Growth Factor	1.000	1.165	0.942	0.000	0.000	0.000	0.000	0.000

3. *Identify lignite mine closures during this period and adjust future growth factors.* According to the MSHA dataset the following mine closures occurred between 2012 and 2019:

County	Facility Name	Closure Date
Hopkins	Sulfur Springs Strip	01/21/2016
Leon	Jewett Mine	01/03/2017
Titus	Winfield South Strip	07/30/2014
Titus	Winfield North Strip	01/16/2015

The MSHA data also indicate there are no other mining/quarry operations in Hopkins, Leon and Titus Counties. Therefore, ERG set the growth factors to zero after the facility closure dates for these counties.

4. *Identify which counties have lignite mining facilities but no other mining/quarry operations during the 2012 – 2019 period.* Again, according to the MSHA dataset the following counties featured only lignite mining:
   - Freestone
   - Harrison
   - Lee
   - Robertson

5. *Apply future year lignite production estimates for these four counties.* The Energy Information Administration's (EIA's) Annual Energy Outlook (AEO) for 2020 provides coal production estimates for the Gulf Coast, as shown in Table 5-10.[39] Note that lignite is the only type of coal produced in the Gulf Coast region.[40]

Table 5-10. Projected Lignite Coal Production and Growth Factors (2019 Base), U.S. Gulf Coast Region

Year	Million Tons	Growth Factor
2019	24.67222	1.000
2020	23.08921	0.936
2021	11.25261	0.456
2022	9.652833	0.391

[39] Energy Information Administration, 2020 Annual Energy Outlook – Table 66. Coal Production by Region and Type. https://www.eia.gov/outlooks/aeo/data/browser/#/?id=95-AEO2020&region=0-0&cases=ref2020&start=2018&end=2050&f=A&linechart=~~~~~ref2020-d112119a.24-95-AEO2020~~&map=&ctype=linechart&sourcekey=0. Accessed 5-15-2020.

[40] The EIA performs its AEO projections on a regional basis, including information on lignite production. Plants that burn lignite are primarily located near the mine from which they receive their coal. As a result, most of the region's lignite production and consumption remains within Texas. Apart from the coal-fired plants in Texas, only one plant in Louisiana consumes lignite from the Gulf region, accounting for less than 10% of total region consumption.

Table 5-10. Projected Lignite Coal Production and Growth Factors (2019 Base), U.S. Gulf Coast Region

Year	Million Tons	Growth Factor
2023	10.52629	0.427
2024	11.80959	0.479
2025	13.15908	0.533
2026	17.51481	0.710
2027	17.69523	0.717
2028	17.82886	0.723
2029	17.97817	0.729
2030	18.06199	0.732
2031	18.16666	0.736
2032	18.19253	0.737
2033	18.29176	0.741
2034	18.36146	0.744
2035	18.20149	0.738
2036	17.75734	0.720
2037	17.70052	0.717
2038	17.82568	0.723
2039	17.81511	0.722
2040	17.78412	0.721
2041	17.78046	0.721
2042	17.78264	0.721
2043	17.74821	0.719
2044	17.3577	0.704
2045	16.23843	0.658
2046	17.63419	0.715
2047	17.70328	0.718
2048	17.70116	0.717
2049	17.70198	0.717
2050	17.66958	0.716

The factors presented in Table 5-10 were then used to extend the growth factors for Freestone, Harrison, Lee and Robertson Counties from 2019 through 2050, assuming all four mines would adjust their production over time by the same proportions.[41]

[41] The EIA 860 monthly generator report for January 2020 showed no planned retirements for lignite plants in Texas.

6. For counties with both lignite and other mine/quarry operations, estimate the fraction of employee hours attributable to lignite mining by year and county. Table 5-11 presents these fractions for the 2012-2019 time period, calculated using the employee hours presented in Table 5-10.

Table 5-11. Fraction of Mining/Quarry Sector Labor Hours Attributable to Lignite Operations

County	2012	2013	2014	2015	2016	2017	2018	2019
Atascosa	0.850	0.842	0.819	0.835	0.846	0.781	0.590	0.527
Limestone	0.653	0.655	0.629	0.594	0.677	0.648	0.665	0.652
Maverick	0.000	0.000	0.370	0.807	0.929	0.937	0.921	0.873
Panola	1.000	1.000	1.000	1.000	1.000	0.534	0.560	0.560
Rusk	1.000	0.996	0.988	0.988	0.965	0.933	0.947	0.964

7. *Project future year growth factors for these five counties.* ERG differentiated the future year growth factor estimation process, using coal production projections from AEO as the surrogate for lignite facilities, and Economy.com GDP projections as the surrogate for other mining/quarry activities. Specifically:

   a. ERG estimated the 2019 GDP associated with lignite facilities using the fraction of total employee hours attributable to coal mining (from MSHA – see Table 5-9) for each county and projected these values forward scaling by AEO's predicted coal production levels for the Gulf Coast region.

   b. ERG estimated the 2019 GDP associated with other mining facilities using the fraction of total employee hours not attributable to coal mining (from MSHA – see Table 5-9) for each county and projected these values forward scaling by the predicted GDP for the mining/quarry sector as a whole.[42]

   c. The projected employment hours were then summed across facility types for each county/year combination. Total hours by year and county were then used to estimate growth factors from 2020 through 2050.

The Economy.com data obtained for this task relies on state-level GDP estimates allocated to the county level, while the historical MSHA data is based specifically on the labor hours regularly reported for each mining location. ERG concluded the historical MSHA data should correlate more closely with actual equipment use at the county level than the allocated GDP estimates from Economy.com. For this reason, ERG updated the 2012 – 2019 growth factors using MSHA data for 161 non-lignite producing counties with non-zero employee hour totals for the 2012 base year. Since zero-hour values are unallowable in the base year, ERG used the Economy.com-based

[42] This approach does not account for product value differences across the mining/quarry sector and likely over-estimates the growth in equipment activity since the lignite produced per labor hour is probably more valuable than many other mining/quarry commodities (e.g. sand and aggregate).

growth factors for the 81 remaining counties for the 2012-2019 time period. Future year growth factors (2020+) for all producing counties continue to be based on the Economy.com projections.

The final growth factors for this subsector, adjusted for lignite mine activity changes, have been provided to the TCEQ in electronic format.

TxDOT Equipment

For estimating equipment emissions for the TxDOT DCE subsector, TexN2.0 uses the assumption that TxDOT maintains a constant inventory of their nonroad equipment fleet. This assumption is based on input received from the agency approximately 15 years ago. ERG requested historical equipment inventory information from TxDOT in order to confirm this assumption or revise the sector growth factors if needed. However, the requested information could not be obtained in time for completion of this task. As such, no growth (i.e., a constant equipment population) continues to be assumed across all years for this DCE subsector.

Quality Assurance Checks

ERG performed a systematic review of the updated growth factors using MS Excel charts, visually inspecting the 2012-2050 trends for outliers across counties and DCE subsectors. Growth factor trend lines were generated at the county level for all DCE subsectors for inspection – see Figure 5-1 for an example.[43] While the average population growth factor trends at the state level were robust for each DCE subsector, at the county-level there were some significant 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.

[43] Growth factor trend lines for all DCE subsectors have been provided to the TCEQ in electronic format.

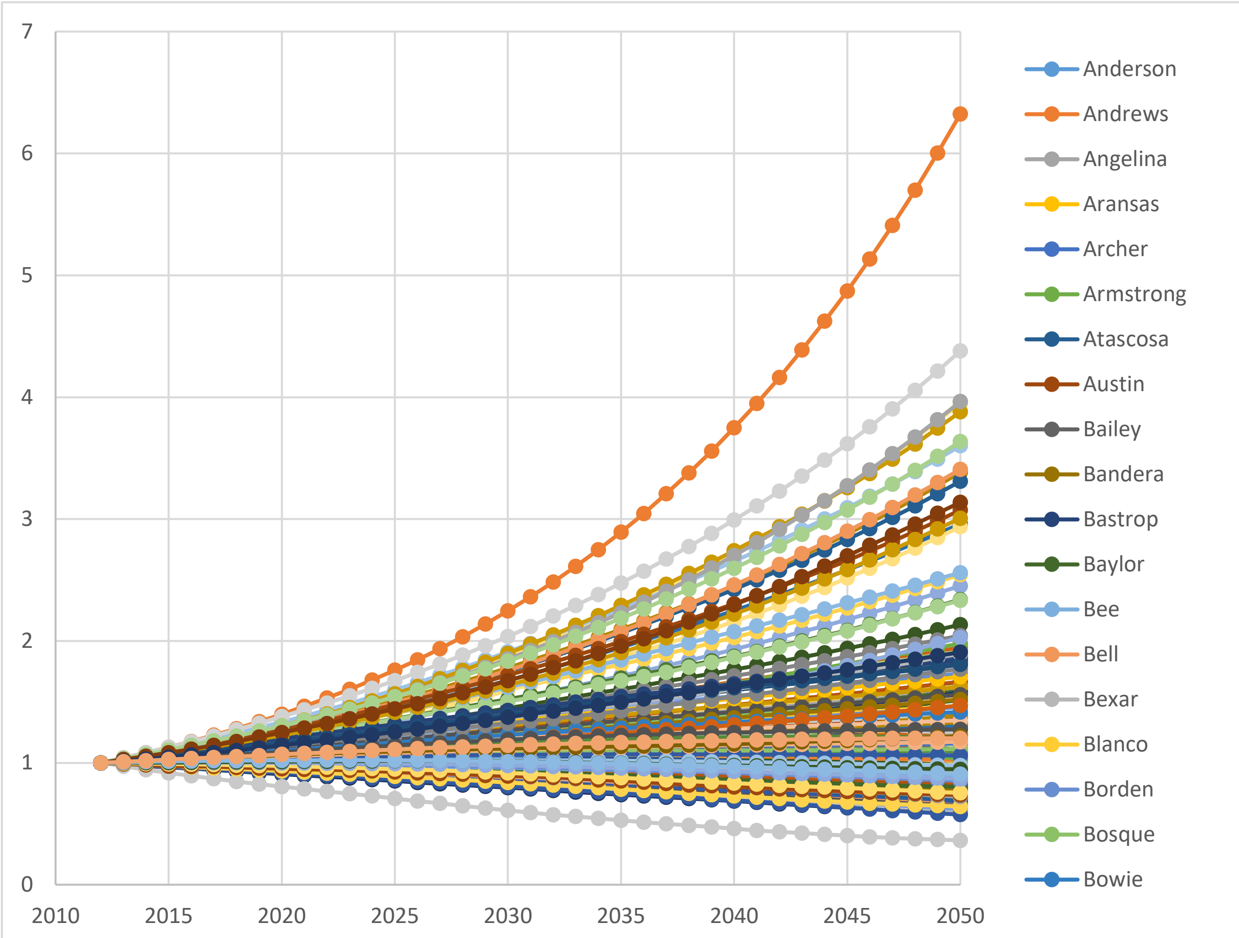


Figure 5-1. City and County Road Construction Growth Factor Trends by County[44]

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:

- Concrete Operations - Kendall, Milam, and Somervell Counties.
- Landscaping Activities - Hudspeth County.
- Mining & Quarry Operations - Howard County.

ERG conducted web searches to validate the presence of notable concrete operations and landscaping services in counties referenced above but the findings were inconclusive. ERG identified a mining operation in Howard County with a substantial amount of employee hours using the MSHA data (22,430 in 2019 compared to a statewide facility average of 44,785) which may explain much of the discrepancy.

[44] Complete list of 254 counties not shown in figure key.

Final Projection Datasets

ERG provided the TCEQ with the complete set of county-level growth factors for each DCE subsector in Excel format. While the growth factors were developed using the most up-to-date surrogates available, we acknowledge the future year estimates are particularly uncertain given the recent emergence of the coronavirus pandemic. Accordingly, ERG recommends replacing growth factors in the future. This will allow the TCEQ to adjust future year equipment populations once specific DCE subsector impacts are better known. Appendix B contains instructions on how the TCEQ may update growth factors at a later date.

VI. PROCESSING, ANALYSIS, AND QUALITY ASSURANCE OF COLLECTED DATA

The following summarizes the processing, data analysis, and quality assurance of the data collected during the study. The data analyses conducted included the following:

- Updating the TxDOT DCE subsector equipment profile
- Developing updated growth factors for all DCE subsectors
- Revising engine load factors for selected diesel equipment types
- Developing an updated scrappage curve and revised annual activity estimates for diesel agricultural tractors

The primary data analysis and quality assurance steps associated with preparing the TxDOT profile, updated growth factors and engine load factors are provided in Section 5. Details regarding the development of the agricultural tractor activity estimates and scrappage curve, and the subsequent loading of all data into the TexN2.0 utility are presented below. Supplemental electronic files used to perform the analysis and quality assurance have been provided to the TCEQ separately in electronic format.

A. Agricultural Tractor Activity Estimation and Scrappage Curve Development

ERG obtained responses from 133 survey respondents operating 477 tractors in Texas during the 2019 calendar year. ERG eliminated certain records due to lack of critical information and/or inconsistent data elements, as summarized below:

- 50 tractor records did not contain engine clock hour information. This information was critical for determining average hours per year and for validating equipment age. These records were dropped from the data set.
- Of the 31 records reporting an engine replacement, it appeared that 16 units had not had their clock hour reading updated since the original manufacture date. Since engine replacement will automatically result in a refreshed clock hour reading, it was not clear if these units had actually undergone engine replacement or not. Therefore, these records were dropped from the data set.
- 10 units (2.5% of the data set) were manufactured during the 1960s. At more than 50 years old, and with an average annual activity of just 107 hours per year, these units were substantially older and had lower utilization than the rest of the data set. As such, these units were designated as outliers and dropped from the analysis.

The remaining data set contained records on 399 tractors operated by 115 respondents. Nine of these records had missing hp values which were gap-filled via web searches based on equipment make, model and model year information. An additional 19 tractor records did not include model year, but in these cases make and model information were adequate for determining a reasonable age approximation.

Fifteen records in the final data set included an engine replacement year. The model year and engine age for these units were based on the engine replacement year rather than the reported year of manufacture. This adjustment assumes the new engines meet the emission standards in place at the time of the replacement year.

ERG also evaluated selected descriptive statistics to ensure the final data set contained reasonable values for key parameters. Although annual hours per year were not provided by the survey, ERG derived estimates by dividing the cumulative clock hour values by the engine age to obtain a lifetime average value. The corresponding hour per year distribution is presented in Figure 6-1. The maximum observed values were less than 2,000 hours per year, consistent with validated findings from similar surveys.

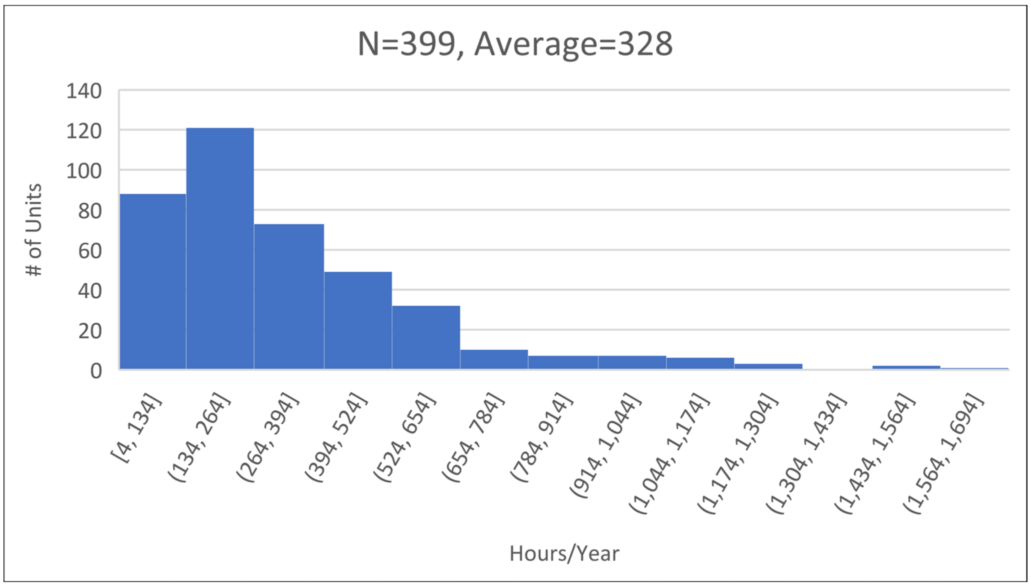


Figure 6-1. Agricultural Tractor Activity Distribution

The resulting average value for all tractors (328 hours per year) is approximately one third of the current value used in TexN2.0 (1,086 hours per year). However, this value is generally consistent with other estimates of agricultural tractor activity including the following:

- 357 hours/year for 100+ hp tractors operating in central Texas;45
- 279 hours/year for units > 25 hp (statewide average for Oregon);[46]
- MOVES default value of 475 hours/year.[47]

[45] Capital Area Council of Governments, Agricultural Tractor 2006 Ozone Season Weekday Emission Inventory for the CAPCOG Program Area, August 2013.

[46] Eastern Research Group, Oregon Nonroad Diesel Equipment Survey and Emissions Inventory, April 2020.

[47] MOVES2014b emissions model.

After consultation with the TCEQ project manager it was determined that ERG should update the TexN2.0 utility using the survey-based average value of 328 hours per year.

ERG also reviewed the hp distribution for the data set, shown in Figure 6-2. The average value from the survey (166 hp) is slightly higher but generally consistent with the default value from MOVES (139) and the value statewide average obtained for Oregon (122 hp).

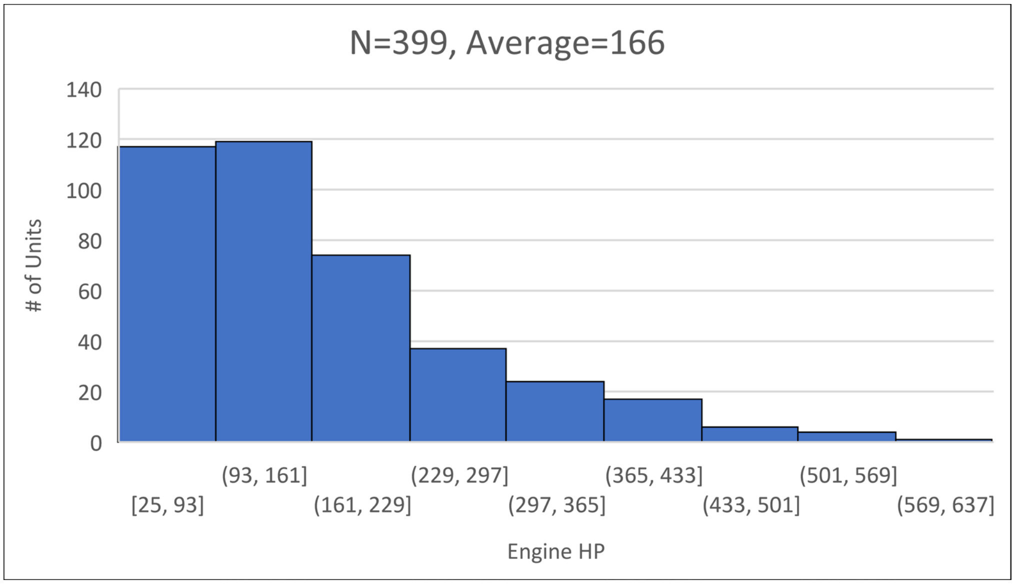


Figure 6-2. Agricultural Tractor HP Distribution

Next ERG compiled the model year distribution reported by the survey respondents, shown in Figure 6-3. The distribution is clearly skewed toward older units, displaying a long “tail” back to the early 1970s. The average age of the units (18 years) is quite similar to that found for the Oregon study (19 years), although substantially older than the MOVES default (8 years). The substantial difference with the MOVES model estimate results from differences in engine median life and scrappage rates, as discussed below.

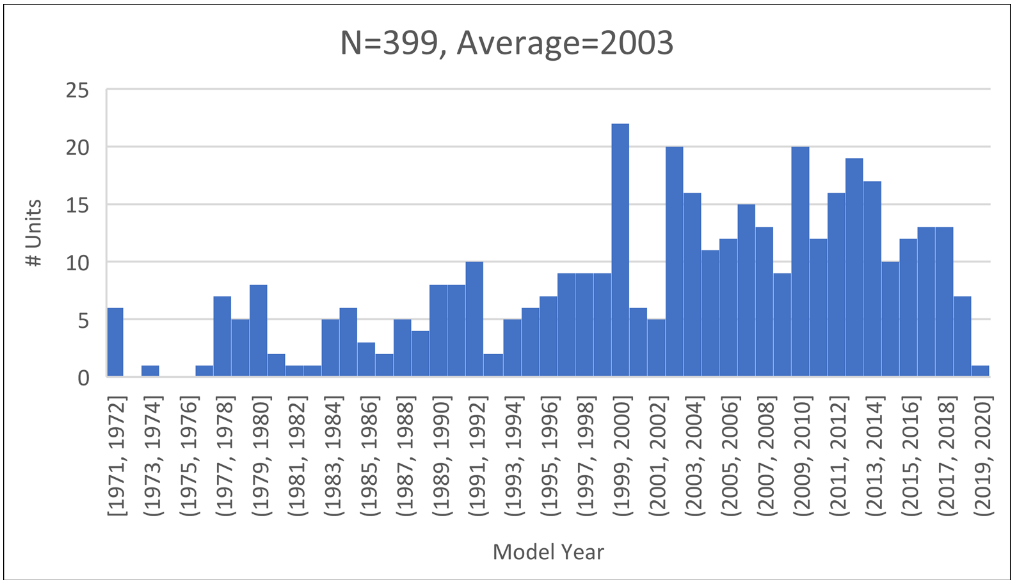


Figure 6-3. Agricultural Tractor Model Year Distribution

The tractor survey data only included information on tractors operating during the 2019 calendar year and cannot be used to assess changes in model year distributions over time. However, this information can be gleaned from the population growth rate data used by the MOVES model for agricultural tractors in Texas. As shown in Figure 6-4, with the exception of a relatively small peak in the mid-2000s the estimated rate of tractor population change is quite low, varying less than 3 percent between 1999 and 2050.

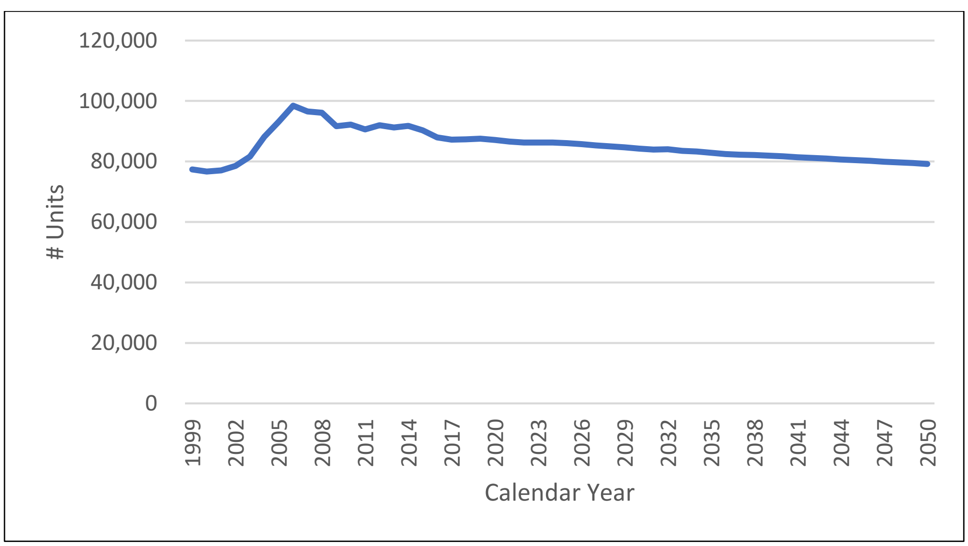


Figure 6-4. Texas Agricultural Tractor Population by Year (MOVES Default)

Given the relatively constant population over time, ERG assumed that annual equipment sales and retirements were effectively equal for modeling purposes. This assumption allows one to estimate equipment scrappage rates based on the single age distribution "snapshot" obtained from the survey responses.

In order to develop a scrap curve function, ERG aggregated tractors into age bins of varying widths which reduced the year-to-year variability (seen in Figure 6-3) for modeling purposes. A bin width of 7 years (shown in Figure 6-5) provides a reasonably clear and consistent pattern for estimating equipment scrappage rates. The variation in the first three bins is minimal, implying that significant scrappage does not begin until sometime between 16 and 22 years of age, at which time a sharp population decline begins due to increased scrappage.

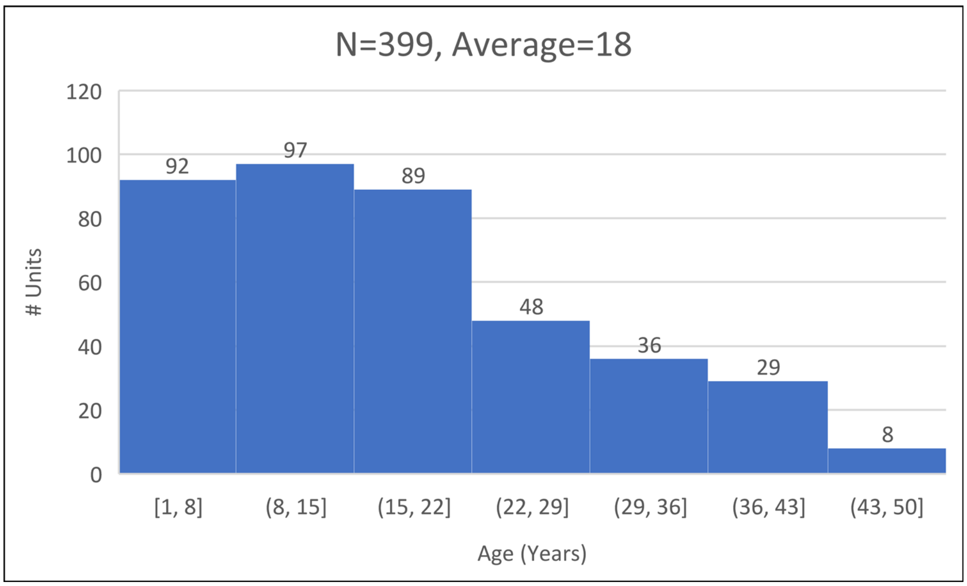


Figure 6-5. Observed Agricultural Tractor Age Distribution (Bin width = 7 years)

Table 6-1 summarizes the number of observations in each age bin, with the first three bins reflecting minimal scrappage over this period. The table also presents the percent of units appearing to be scrapped during each period, and the corresponding "life fraction". The percent of units scrapped while in an age bin is calculated based on the relative number of observations shown in Figure 6-5. For example, the number of units scrapped going from age bin 3 (16-22 years) to age bin 4 (23-29 years) equals 41 (89-48), or 46 percent (41/89). Incremental scrappage rates are calculated for each successive age bin and summed to create the cumulative percent scrappage values presented in Table 6-1. The corresponding life fraction values are calculated by dividing the average of the bin range by the oldest age in the data set (50) and multiplying by two. For example, the life fraction associated with the age bin ranging from 23 to 29 years is calculated as:

$$\{[(23 + 29) / 2] / 50\} \times 2 = 1.040$$

The above expression is multiplied by two in order to be consistent with the MOVES convention where a life fraction of 2.0 corresponds to the point at which 100 percent of units have been scrapped (assumed to occur at 50 years of age).

Table 6-1. Agricultural Tractor Scrappage and Life Fractions (Survey Basis)

Age Bin (Years)		# Surviving	% Scrapped	Life Fraction
Low	High			
1	8	399	0.0%	0.180
9	15	399	0.0%	0.480
16	22	399	0.0%	0.760
23	29	153	46.1%	1.040
30	36	108	59.6%	1.320
37	43	72	67.4%	1.600
44	50	45	91.0%	1.880
>50	>50	0	100.0%	2.000

The scrappage function table used in the MOVES model is constrained to 197 rows, each with a specified life fraction value. ERG linearly interpolated the values from Table 6-1 to populate the scrappage table to meet these constraints (see Appendix A). Figure 6-6 displays the resulting scrappage curve for agricultural tractors as well as the MOVES default scrappage curve.

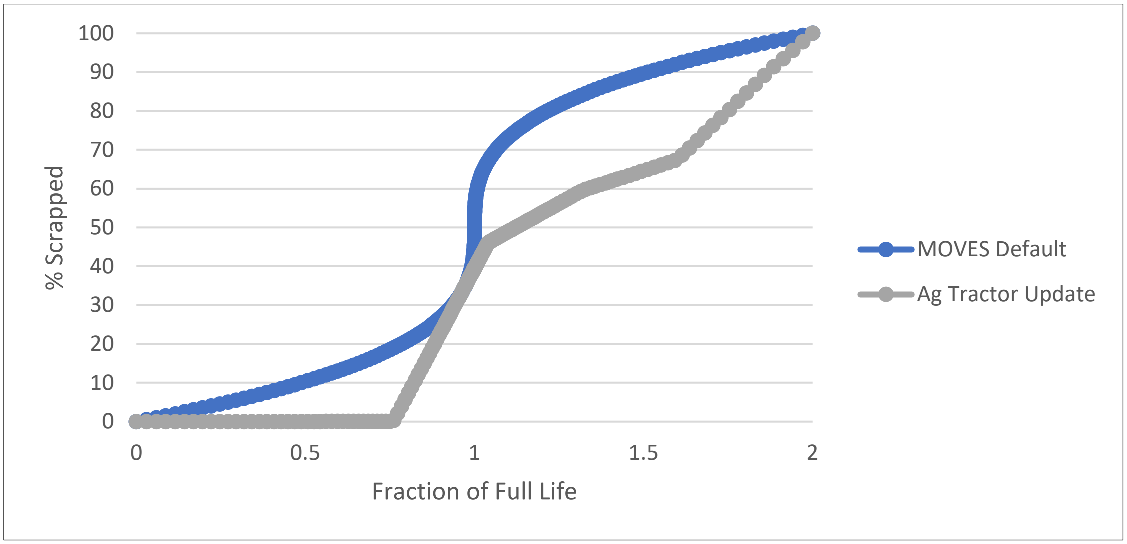


Figure 6-6. Agricultural Tractor Scrappage Curve

As shown in the figure, the survey data indicate that tractors are retired at slower rates than assumed by MOVES over most life fraction ranges, resulting in an older in-use fleet (see Figure 6-7).

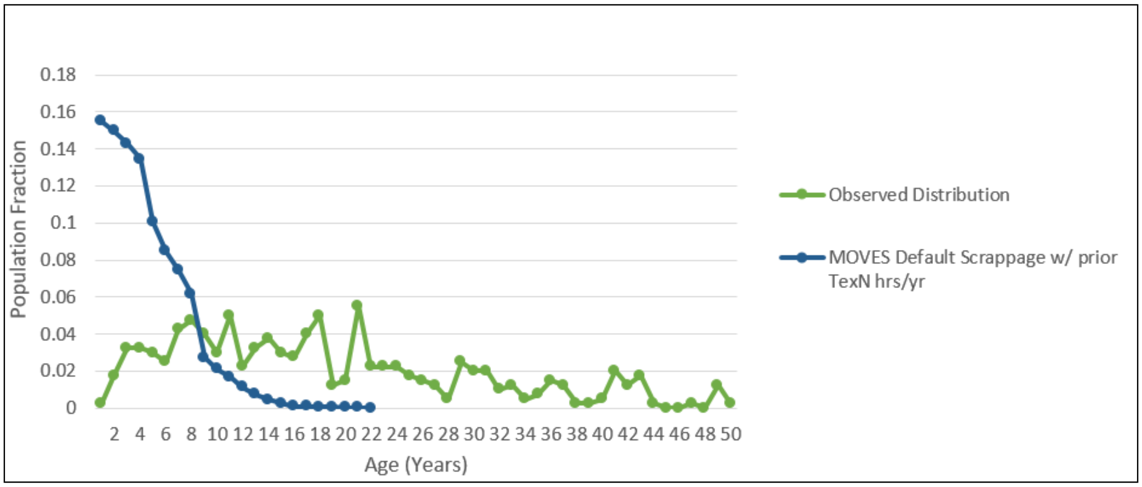


Figure 6-7. Agricultural Tractor Population Distribution

Note that the MOVES default curve shown in Figure 6-6 assumes a "symmetrical" population distribution, in that 50 percent of all retirements are assumed to occur by a life fraction of 1.0 (age 25), and 100 percent by a life fraction of 2.0 (age 50). However, the actual median age for tractors in the survey data is approximately 17 years due to the skewed age distributions shown in Figure 6-3 and Figure 6-5.[48] ERG consulted with EPA staff to determine if the MOVES algorithm utilized by the TexN2.0 utility required 50 percent of all units be scrapped by one half of the full life value, or if the scrappage function could reflect an asymmetrical age distribution. EPA indicated it was unknown how the MOVES model would respond to an asymmetrical distribution.

ERG investigated by running the utility scenarios using the updated scrap curve with the observed median life value (17 years), and with the median life set to 25 years (half of the maximum age in the survey dataset). Figure 6-8 presents the equipment age distribution output by TexN2.0 for both scenarios, along with the observed age distribution (averaged across the age bins shown in Figure 6-5). As seen, by setting median life to 17 years the MOVES scrappage algorithm forces the maximum age to equal twice the median life, or 34 years, resulting in a much newer equipment fleet than observed in the survey data. However, by setting median life equal to 25 years, the model year distribution output by the utility mirrors the observed distribution extremely closely. Since the model year distribution ultimately determines equipment emission rates for a given calendar year, this is the benchmark ERG used to assess the validity of the scrap curve-median life value combination, rather than the median life estimates alone. Therefore, ERG adopted the updated scrap curve with median life set to 25 years.

[48] To be precise, median life is actually defined in terms of hours of operation at full engine load, rather than by engine age. For example, for a median age of 25 years, median life = (25 years x 328 hours/year) x 0.48 (load factor) = 3,933 hours at full load.

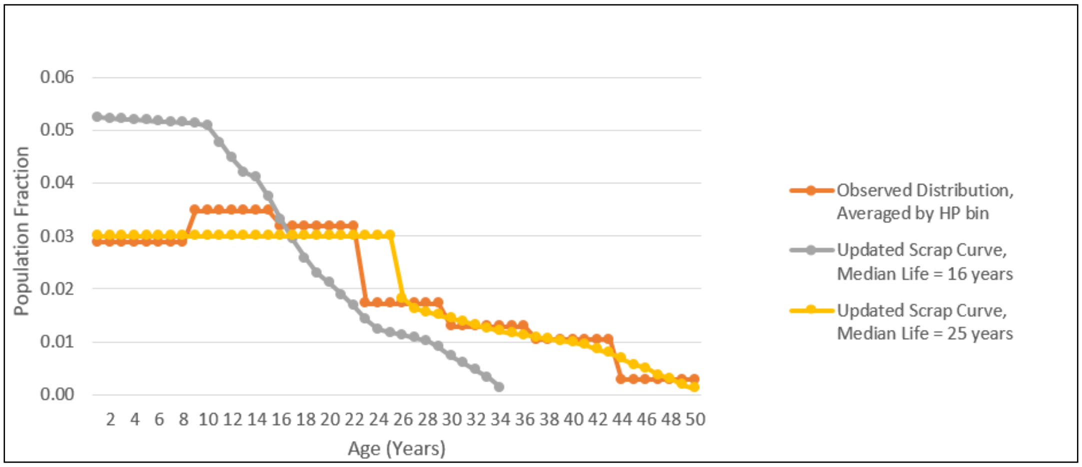


Figure 6-8. Modeled vs Observed Tractor Population Distributions

B. Processing Collected Data

ERG created a new version of the TexN2.1 utility database including several updates:

- Added the new table `nrscrappagecurveagtractor`
- Updated annual activity for diesel agricultural tractors to 328 hours/year
- Updated load factors for 31 diesel SCCs using CARB values
- Updated diesel equipment populations for years 2013-2050 for DCE subsectors 1-23 (listed in Table 6-2) to reflect the revised growth factors.
- Updated diesel equipment populations for years 1999-2050 for DCE subsectors 0 and 25 to reflect the latest updates in MOVES2014b

Table 6-2. Diesel Construction Equipment (DCE) Subsectors in TexN2.0

#	DCE Subsector
1	Agricultural Activities
2	Boring & Drilling Equipment
3	Brick & Stone Operations
4	City and County Road Construction
5	Commercial Construction
6	Concrete Operations
7	County-Owned Construction Equipment
8	Cranes
9	Heavy-Highway Construction
10	Landfill Operations
11	Landscaping Activities
12	Manufacturing Operations
13	Municipal-Owned Construction Equipment
14	Transportation/Sales/Services

Table 6-2. Diesel Construction Equipment (DCE) Subsectors in TexN2.0

#	DCE Subsector
15	Residential Construction
16	Rough Terrain Forklifts
17	Scrap Recycling Operations
18	Skid Steer Loaders
19	Special Trades Construction
20	Trenchers
21	TxDOT Construction Equipment*
22	Utility Construction
23	Mining & Quarry Operations

ERG also updated two supporting files in TexN2.1 that enable the use of the alternative scrappage curves for agricultural tractors and skid steers: *coreQueries.xml* and *QA_CDBqueries.xml*.

ERG previously delivered a spreadsheet of final growth factors to the TCEQ. The spreadsheet contained separate worksheets (1-23, one for each DCE subsector) with county-specific growth factors to scale 2012 populations to each year from 2013 to 2050. Two DCE subsectors – *Non DCE* (DCE subsector 0) and *Off-Road Tractors, Misc. Equipment, and all Equipment < 25 hp* (DCE subsector 25) were not included in the growth factor update file. ERG updated the equipment populations for the remaining two DCE subsectors to reflect the latest growth rates included in the MOVES2014b model.

ERG also updated selected load factors based on the latest CARB values for the 31 SCCs (see Table 6-3), reduced the annual activity of diesel agricultural tractors > 25 hp from 1,086 to 328 hours per year, and loaded the new scrappage curve for diesel agricultural tractors.

Table 6-3. Updates of TexN2.0 Load Factors to CARB Load Factors

Equipment Category	Equipment Type	SCC	Existing MOVES Load Factor	Updated CARB Load Factor
Agricultural	Agricultural tractors	2270005015	0.59	0.48
Agricultural	Balers	2270005025	0.59	0.50
Agricultural	Combines	2270005020	0.59	0.44
Agricultural	Sprayers	2270005035	0.59	0.42
Agricultural	Swathers	2270005045	0.59	0.48
Commercial	Air compressors	2270006015	0.43	0.31
Commercial	Generators	2270006005	0.43	0.31
Construction/mining	Bore/drill rigs	2270002033	0.43	0.50

Table 6-3. Updates of TexN2.0 Load Factors to CARB Load Factors

Equipment Category	Equipment Type	SCC	Existing MOVES Load Factor	Updated CARB Load Factor
Construction/mining	Cranes	2270002045	0.43	0.29
Construction/mining	Crawler tractors/dozers	2270002069	0.59	0.43
Construction/mining	Excavators	2270002036	0.59	0.38
Construction/mining	Graders	2270002048	0.59	0.41
Construction/mining	Off-highway trucks	2270002051	0.59	0.38
Construction/mining	Other construction equipment	2270002081	0.59	0.42
Construction/mining	Pavers	2270002003	0.59	0.42
Construction/mining	Paving equipment	2270002021	0.59	0.36
Construction/mining	Rollers	2270002015	0.59	0.38
Construction/mining	Rough terrain forklifts	2270002057	0.59	0.40
Construction/mining	Rubber tire loaders	2270002060	0.59	0.36
Construction/mining	Scrapers	2270002018	0.59	0.48
Construction/mining	Skid steer loaders	2270002072	0.21	0.37
Construction/mining	Surfacing equipment	2270002024	0.59	0.30
Construction/mining	Tractors/loaders/backhoes	2270002066	0.21	0.37
Construction/mining	Trenchers	2270002030	0.59	0.50
Industrial	Aerial lifts	2270003010	0.21	0.31
Industrial	Forklifts	2270003020	0.59	0.20
Industrial	Other general industrial equip.	2270003040	0.43	0.34
Industrial	Other material handling equip.	2270003050	0.21	0.40
Industrial	Sweepers/scrubbers	2270003030	0.43	0.46
Industrial	Terminal tractors	2270003070	0.59	0.39
Industrial	Transportation refrigeration units	2270003060	0.43	0.46

C. Quality Assurance Checks

ERG also performed a series of test runs to quality assure the processing steps of incorporating the updated information into the utility. ERG first conducted a series of runs for agricultural tractors in Harris County for 2018 to establish a baseline. Next, ERG incrementally made one data change to the utility tables at a time (starting with TexN2.0), running scenarios after each update (i.e. revising load factors, activity, scrappage, and population) and examined the MOVES County Databases (CDBs) and the output Excel reports to confirm the CDBs were appropriately updated with the new TexN2.1 data and that the output reports reflected the expected direction and magnitude of changes in population, fuel consumption, and emissions.

Table 6-4 through Table 6-8 show the impacts of the data changes for the agricultural tractor test runs. The tests were incremental to ensure that each data element was properly loaded and carried through the modeling process to the utility reports. Table 6-4 shows the impact of changing the load factor for diesel agricultural tractors from 0.59 to 0.48, a decrease of 18.6%. Table 6-4 shows no impact on population, as expected. The impact on fuel consumption (BSFC[49]) scales directly with load factor, also as expected. Fine particulate matter ($PM_{2.5}$) emissions have a proportionally smaller change (4.3% total) as the age distribution shifts older with decreasing hp-hours of operation (hp-hours = hp x hours x load factor).

Table 6-4. Impact of Agricultural Tractor Load Factor Change, Harris County (FIPS=48201)

SCC 2270005015	*Baseline (LF = 0.59)*			*Update (LF = 0.48)*			*% Change (Update-Base) /Base*		
HP bin	**BSFC**	**$PM_{2.5}$**	**Pop**	**BSFC**	**$PM_{2.5}$**	**Pop**	**BSFC**	**$PM_{2.5}$**	**Pop**
16 < hp <= 25	70.1	0.1	25.3	57.1	0.1	25.3	-18.6%	-17.7%	0.0%
25 < hp <= 40	291.8	0.1	68.0	237.4	0.1	68.0	-18.6%	10.2%	0.0%
40 < hp <= 50	238.3	0.1	38.9	193.9	0.1	38.9	-18.6%	10.2%	0.0%
50 < hp <= 75	505.1	0.3	61.5	410.9	0.3	61.5	-18.6%	1.1%	0.0%
75 < hp <= 100	616.2	0.6	54.2	501.3	0.6	54.2	-18.6%	2.9%	0.0%
100 < hp <= 175	1,435.9	0.9	90.4	1,168.2	0.9	90.4	-18.6%	6.8%	0.0%
175 < hp <= 300	2,190.4	0.8	77.9	1,782.1	0.9	77.9	-18.6%	14.9%	0.0%
300 < hp <= 600	1,989.4	1.2	40.3	1,618.5	1.2	40.3	-18.6%	-2.4%	0.0%
Total	**7,337.3**	**4.0**	**456.5**	**5,969.3**	**4.2**	**456.5**	**-18.6%**	**4.3%**	**0.0%**

Table 6-5 shows the impact of changing the agricultural tractor activity from 1,086 to 328 hours per year, a decrease of 69.8%. The relative impact of the activity decrease tracks with the load factor update. Fuel consumption scales directly with the reduction of hours of operation, while $PM_{2.5}$ totals decrease by just 9.6%. This differential is again due to decreased scrappage associated with fewer annual hp-hours of operation.

Table 6-5. Impact of Agricultural Tractor Activity Hour Change, Harris County (FIPS=48201)

SCC 2270005015	*Baseline (Hours = 1,086)*			*Updated (Hours = 328)*			*% Change (Update-Base) /Base*		
HP bin	**BSFC**	**$PM_{2.5}$**	**Pop**	**BSFC**	**$PM_{2.5}$**	**Pop**	**BSFC**	**$PM_{2.5}$**	**Pop**
16 < hp <= 25	57.1	0.1	25.3	17.2	0.0	25.3	**-69.8%**	**-37.9%**	**0.0%**
25 < hp <= 40	237.4	0.1	68.0	71.7	0.1	68.0	**-69.8%**	**21.0%**	**0.0%**
40 < hp <= 50	193.9	0.1	38.9	58.6	0.1	38.9	**-69.8%**	**21.0%**	**0.0%**
50 < hp <= 75	410.9	0.3	61.5	124.1	0.4	61.5	**-69.8%**	**22.2%**	**0.0%**

[49] Brake-specific fuel consumption.

Table 6-5. Impact of Agricultural Tractor Activity Hour Change, Harris County (FIPS=48201)

SCC 2270005015	Baseline (Hours = 1,086)			Updated (Hours = 328)			% Change (Update-Base) /Base		
HP bin	BSFC	$PM_{2.5}$	Pop	BSFC	$PM_{2.5}$	Pop	BSFC	$PM_{2.5}$	Pop
75 < hp <= 100	501.3	0.6	54.2	151.4	0.5	54.2	**-69.8%**	**-22.1%**	**0.0%**
100 < hp <= 175	1,168.2	0.9	90.4	352.8	0.8	90.4	**-69.8%**	**-15.5%**	**0.0%**
175 < hp <= 300	1,782.1	0.9	77.9	538.2	1.1	77.9	**-69.8%**	**19.2%**	**0.0%**
300 < hp <= 600	1,618.5	1.2	40.3	488.8	0.8	40.3	**-69.8%**	**-31.2%**	**0.0%**
Total	**5,969.3**	**4.2**	**456.5**	**1,802.9**	**3.8**	**456.5**	**-69.8%**	**-9.6%**	**0.0%**

Next ERG examined the impact of changing equipment populations using the new growth factors. Agricultural tractors are in the “Non-DCE” subsector with growth factors obtained from the latest version of MOVES2014b. The corresponding impact was a decrease in the Harris County tractor population from 456.5 to 239.0 (-47.6% change) in 2018 (see Table 6-6). Because a population change does not shift the age of the fleet, all other parameters change one to one with population.

Table 6-6. Impact of Agricultural Tractor Population (Growth Factor) Change, Harris County (FIPS=48201)

SCC 2270005015	Baseline (Total Population=456.5)			Updated (Total Population= 239.1)			% Change (Update-Base) /Base		
HP bin	BSFC	$PM_{2.5}$	Pop	BSFC	$PM_{2.5}$	Pop	BSFC	$PM_{2.5}$	Pop
16 < hp <= 25	17.2	0.0	25.3	9.0	0.0	13.2	**-47.8%**	**-47.8%**	**-47.8%**
25 < hp <= 40	71.7	0.1	68.0	37.5	0.1	35.6	**-47.6%**	**-47.6%**	**-47.6%**
40 < hp <= 50	58.6	0.1	38.9	30.7	0.1	20.4	**-47.6%**	**-47.6%**	**-47.6%**
50 < hp <= 75	124.1	0.4	61.5	65.0	0.2	32.2	**-47.6%**	**-47.6%**	**-47.6%**
75 < hp <= 100	151.4	0.5	54.2	79.3	0.2	28.4	**-47.6%**	**-47.6%**	**-47.6%**
100 < hp <= 175	352.8	0.8	90.4	184.6	0.4	47.3	**-47.7%**	**-47.7%**	**-47.7%**
175 < hp <= 300	538.2	1.1	77.9	281.9	0.6	40.8	**-47.6%**	**-47.6%**	**-47.6%**
300 < hp <= 600	488.8	0.8	40.3	255.9	0.4	21.1	**-47.6%**	**-47.6%**	**-47.6%**
Total	**1,802.9**	**3.8**	**456.5**	**944.0**	**2.0**	**239.0**	**-47.6%**	**-47.6%**	**-47.6%**

Table 6-7 shows the impact of the new scrappage curve and median life update on agricultural tractor fuel consumption, $PM_{2.5}$ emissions, and population. Shifting the year in which equipment is replaced shifts the age and engine tier level distribution of the population, which impacts emissions (but not population or fuel consumption since activity is unchanged). The net impact of this update is to reduce the rate at which engines are scrapped compared to MOVES defaults, thereby increasing the relative number of older engines in operation, which in turn increases emissions.

Table 6-7. Impact of Updated Agricultural Tractor Scrappage Curve and Median Life, Harris County (FIPS=48201)

SCC 2270005015	*Baseline*			*Update*			*% Change (Update-Base) /Base*		
HP bin	**BSFC**	**$PM_{2.5}$**	**Pop**	**BSFC**	**$PM_{2.5}$**	**Pop**	**BSFC**	**$PM_{2.5}$**	**Pop**
16 < hp <= 25	9.0	0.0	13.2	9.0	0.0	13.2	**0.0%**	**75.8%**	**0.0%**
25 < hp <= 40	37.5	0.1	35.6	37.5	0.1	35.6	**0.0%**	**70.8%**	**0.0%**
40 < hp <= 50	30.7	0.1	20.4	30.7	0.1	20.4	**0.0%**	**70.8%**	**0.0%**
50 < hp <= 75	65.0	0.2	32.2	65.0	0.3	32.2	**0.0%**	**17.3%**	**0.0%**
75 < hp <= 100	79.3	0.3	28.4	79.3	0.3	28.4	**0.0%**	**15.8%**	**0.0%**
100 < hp <= 175	184.6	0.5	47.3	184.6	0.6	47.3	**0.0%**	**20.6%**	**0.0%**
175 < hp <= 300	281.9	0.7	40.8	281.9	0.9	40.8	**0.0%**	**23.0%**	**0.0%**
300 < hp <= 600	255.9	0.6	21.1	255.9	0.8	21.1	**0.0%**	**33.3%**	**0.0%**
Total	**944.0**	**2.5**	**239.0**	**944.0**	**3.2**	**239.0**	**0.0%**	**26.7%**	**0.0%**

Table 6-8 presents the net impact of the incremental changes presented in Table 6-4 through Table 6-7. The 87.2 percent reduction in fuel consumption is due to the combined impact of the population reduction (47.6 percent), the activity reduction (69.8 percent), and the load factor reduction (18.6 percent). The increased age of the fleet resulting from the scrap curve and median life changes largely offset the above decreases, resulting in a 20.1 percent decrease in $PM_{2.5}$ emissions.

Table 6-8. Net Impact of Agricultural Tractor Updates, Harris County (FIPS=48201)

SCC 2270005015	*Baseline*			*Update*			*% Change (Update-Base) /Base*		
HP bin	**BSFC**	**$PM_{2.5}$**	**Pop**	**BSFC**	**$PM_{2.5}$**	**Pop**	**BSFC**	**$PM_{2.5}$**	**Pop**
16 < hp <= 25	70.1	0.1	25.3	9.0	0.0	13.2	**-87.2%**	**-43.6%**	**-47.8%**
25 < hp <= 40	291.8	0.1	68.0	37.5	0.1	35.6	**-87.1%**	**41.8%**	**-47.6%**
40 < hp <= 50	238.3	0.1	38.9	30.7	0.1	20.4	**-87.1%**	**42.0%**	**-47.6%**
50 < hp <= 75	505.1	0.3	61.5	65.0	0.3	32.2	**-87.1%**	**-10.2%**	**-47.6%**
75 < hp <= 100	616.2	0.6	54.2	79.3	0.3	28.4	**-87.1%**	**-43.5%**	**-47.6%**
100 < hp <= 175	1,435.9	0.9	90.4	184.6	0.6	47.3	**-87.1%**	**-27.4%**	**-47.7%**
175 < hp <= 300	2,190.4	0.8	77.9	281.9	0.9	40.8	**-87.1%**	**16.5%**	**-47.6%**
300 < hp <= 600	1,989.4	1.2	40.3	255.9	0.8	21.1	**-87.1%**	**-36.2%**	**-47.6%**
Total	**7,337.3**	**4.0**	**456.5**	**944.0**	**3.2**	**239.0**	**-87.1%**	**-20.1%**	**-47.6%**

VII. DEVELOPMENT OF EMISSION INVENTORY FOR QUALITY ASSURANCE

ERG ran statewide scenarios using the prior and updated versions of the TexN2.0 utility for selected outputs (BSFC and $PM_{2.5}$) in the 2020 calendar year.[50] BSFC was selected as an output since fuel consumption provides a direct measure of engine activity, independent of emission tier level distributions. Alternatively, $PM_{2.5}$ was selected in order to focus specifically on the influence of changing model year distributions, as discussed below.

The TexN utility was run for all counties, assuming fully controlled ozone season weekday periods with typical meteorological conditions. DCE subsectors were individually run with the prior TexN2.0 and updated TexN2.1 databases to help isolate changes affecting the subsectors' emissions and activity outputs. The previous and updated databases were used for 25 and 27 runs, respectively. The introduction of scrap curves for diesel agricultural tractors and skid steer loaders required the use of split runs for the non-DCE and skid steer loader subsectors, respectively. For instance, the non-DCE subsector required one run for the agricultural tractor SCC and one run of the rest of the subsector.

After run completion, TexN-generated reports detailing emissions and population data by county and SCC were produced. Report outputs were broken out by county, DCE subsector, and SCC in order to ensure the data table changes were accurately reflected in the utility reports. Updates to the data tables included:

- Engine load factors for selected SCCs
- Growth factors and equipment populations
- Annual hours per year and equipment categories for the TxDOT DCE subsector
- Scrappage rates and model year distributions for agricultural tractors

Detailed quality assurance checks associated with the agricultural tractor scrappage update are presented in Section 6. The following presents the findings of the quality assurance checks associated with the engine load factor, equipment population and TxDOT DCE subsector updates, and highlights key similarities and differences between the new results and the prior TexN utility outputs.

A. Quality Assurance Findings

ERG conducted various checks to confirm the direction and general magnitude of fuel consumption and emissions changes between the prior, and updated versions of the utility were as expected, based on the corresponding input changes. ERG began by

[50] Parameter outputs were limited to BSFC and $PM_{2.5}$ in order to minimize the extensive run and processing time requirements associated statewide modeling scenarios.

confirming the SCCs with non-zero emissions in each DCE subsector were the same in the prior and updated versions of the utility, ensuring equipment type consistency.

ERG then spot-checked the outputs for different county/DCE subsector combinations to evaluate activity and emissions changes. Equipment activity is defined in terms of hp-hours of engine use, which determines fuel consumption (BSFC). Changes in hp-hours and BSFC will occur in direct proportion to corresponding changes in equipment population, engine load factor, and in the case of the TxDOT DCE subsector, changes to the annual hours of use.

The following example illustrates how the population and load factor updates for one DCE subsector (#2, Boring and Drilling Equipment) and one county (Harris), influence overall equipment activity and fuel consumption estimates.

- 2020 Equipment Population, prior TexN2.0 version: 282
- 2020 Equipment Population, updated TexN2.1 version: 229
- Population reduction: 19%
- Engine load factor, prior TexN2.0 version: 0.43
- Engine load factor, updated TexN2.1 version: 0.50
- Load factor increase: 16%
- Net activity reduction from prior TexN2.0 version: 1- (229 x 1.16) / 282 = 6%
- BSFC estimate, prior TexN2.0 version: 2,429 tons
- BSFC estimate, updated TexN2.1 version: 2,291 tons
- BSFC reduction: 6%

The above example demonstrates that the change in fuel consumption estimated using TexN2.1 is effectively equal to the expected change based on the population and load factor updates for this DCE subsector/county combination. ERG repeated this assessment for each DCE subsector[3] for various counties of interest. Table 7-1 presents the findings of this exercise, broken out by SCC. Aside from minor differences attributable to rounding[51], the results show full consistency between activity input changes and utility outputs.

[51] MOVES only allows for one decimal place in the equipment population field.

Table 7-1. Activity Checks by DCE Subsector

SCC	Population			Load Factor			Net Change	BSFC Output (tons)		
	Prior	Update	% Change	Prior	Update	% Change		Prior	Update	% Change
Subsector 0: Non-DCE Harris County										
2270001060	177.10	104.10	-41.2%	0.21	0.21	0.0%	**-41.2%**	0.61	0.358528	**-41.5%**
2270003010	1091.13	674.81	-38.2%	0.21	0.31	47.6%	**-8.7%**	3.28	2.99308	**-8.7%**
2270003020	796.70	493.20	-38.1%	0.59	0.20	-66.1%	**-79.0%**	47.18	9.901247	**-79.0%**
2270003030	672.10	416.20	-38.1%	0.43	0.46	7.0%	**-33.8%**	20.60	13.64927	**-33.7%**
2270003040	793.90	491.51	-38.1%	0.43	0.34	-20.9%	**-51.0%**	20.91	10.23848	**-51.0%**
2270003050	103.45	63.95	-38.2%	0.21	0.40	90.5%	**17.7%**	0.81	0.950481	**17.6%**
2270003060	4369.90	2907.20	-33.5%	0.43	0.46	7.0%	**-28.8%**	64.24	45.72079	**-28.8%**
2270003070	410.40	254.10	-38.1%	0.59	0.39	-33.9%	**-59.1%**	29.73	12.16732	**-59.1%**
2270004031	68.90	72.30	4.9%	0.43	0.43	0.0%	**4.9%**	0.02	0.017927	**4.9%**
2270004046	1307.50	1371.20	4.9%	0.43	0.43	0.0%	**4.9%**	6.21	6.515719	**4.9%**
2270004066	777.20	815.20	4.9%	0.43	0.43	0.0%	**4.9%**	14.29	14.99247	**4.9%**
2270004071	65.10	68.50	5.2%	0.43	0.43	0.0%	**5.2%**	1.91	2.00597	**5.0%**
2270004076	12.40	12.80	3.2%	0.43	0.43	0.0%	**3.2%**	0.08	0.082947	**2.9%**
2270005010	40.00	20.20	-49.5%	0.59	0.59	0.0%	**-49.5%**	0.14	0.072037	**-49.5%**
2270005020	20.00	10.20	-49.0%	0.59	0.44	-25.4%	**-62.0%**	1.19	0.452679	**-61.9%**
2270005025	62.30	31.50	-49.4%	0.59	0.50	-15.3%	**-57.2%**	1.38	0.591728	**-57.0%**
2270005030	78.70	39.80	-49.4%	0.59	0.59	0.0%	**-49.4%**	1.51	0.765022	**-49.4%**
2270005035	53.10	26.90	-49.3%	0.59	0.42	-28.8%	**-63.9%**	1.60	0.576156	**-63.9%**
2270005040	17.50	8.90	-49.1%	0.59	0.59	0.0%	**-49.1%**	0.40	0.206148	**-48.5%**
2270005045	20.30	10.30	-49.3%	0.59	0.48	-18.6%	**-58.7%**	0.46	0.191855	**-58.5%**
2270005055	14.90	7.50	-49.7%	0.59	0.59	0.0%	**-49.7%**	0.66	0.330827	**-49.6%**
2270005060	31.50	15.90	-49.5%	0.59	0.59	0.0%	**-49.5%**	2.25	1.138812	**-49.4%**
2270006015	2621.70	1023.20	-61.0%	0.43	0.31	-27.9%	**-71.9%**	47.93	13.48605	**-71.9%**

Table 7-1. Activity Checks by DCE Subsector

SCC	Population			Load Factor			Net Change	BSFC Output (tons)		
	Prior	Update	% Change	Prior	Update	% Change		Prior	Update	% Change
2270006025	5386.10	2102.40	-61.0%	0.21	0.21	0.0%	**-61.0%**	24.43	9.534495	**-61.0%**
2270006030	1172.70	457.80	-61.0%	0.43	0.43	0.0%	**-61.0%**	2.34	0.914711	**-61.0%**
2270006035	156.30	60.90	-61.0%	0.43	0.43	0.0%	**-61.0%**	2.08	0.805745	**-61.3%**
2270007015	8.90	17.40	95.5%	0.59	0.59	0.0%	**95.5%**	0.81	1.570094	**93.7%**
2285002015	48.20	27.90	-42.1%	0.21	0.21	0.0%	**-42.1%**	1.01	0.588989	**-41.6%**
DCE Subsector 1: DCE - Agricultural Activities Cameron County										
2270002018	1.00	1.00	0.0%	0.59	0.48	-18.6%	**-18.6%**	0.07	0.0536	**-18.6%**
2270002036	4.40	4.20	-4.5%	0.59	0.38	-35.6%	**-38.5%**	0.49	0.30802	**-37.6%**
2270002048	2.80	2.80	0.0%	0.59	0.41	-30.5%	**-30.5%**	0.15	0.105549	**-30.5%**
2270002051	3.20	3.20	0.0%	0.59	0.38	-35.6%	**-35.6%**	0.88	0.564596	**-35.6%**
2270002060	6.70	6.50	-3.0%	0.59	0.36	-39.0%	**-40.8%**	0.86	0.51502	**-39.9%**
2270002066	55.80	54.30	-2.7%	0.21	0.37	76.2%	**71.5%**	0.87	1.488932	**71.4%**
2270002069	27.30	26.40	-3.3%	0.59	0.43	-27.1%	**-29.5%**	1.83	1.287196	**-29.7%**
DCE Subsector 2: DCE – Boring & Drilling Equipment Harris County										
2270002033	282.20	228.8	-18.9%	0.43	0.50	16.3%	**-5.7%**	8.48	8.00	**-5.7%**
DCE Subsector 3: DCE – Brick & Stone Operations Dallas County										
2270002036	19.40	17.20	-11.3%	0.59	0.38	-35.6%	**-42.9%**	2.81	1.614565	**-42.6%**
2270002048	2.40	2.10	-12.5%	0.59	0.41	-30.5%	**-39.2%**	0.13	0.081082	**-39.2%**
2270002060	14.80	12.90	-12.8%	0.59	0.36	-39.0%	**-46.8%**	2.96	1.569975	**-46.9%**
2270002066	9.10	8.00	-12.1%	0.21	0.37	76.2%	**54.9%**	0.13	0.19727	**55.3%**
2270002069	9.70	8.40	-13.4%	0.59	0.43	-27.1%	**-36.9%**	0.63	0.401729	**-36.4%**

Table 7-1. Activity Checks by DCE Subsector

SCC	Population			Load Factor			Net Change	BSFC Output (tons)		
	Prior	Update	% Change	Prior	Update	% Change		Prior	Update	% Change
DCE Subsector 4: DCE – City and County Road Construction Tarrant County										
2270002003	143.30	148.60	3.7%	0.59	0.42	-28.8%	**-26.2%**	0.20	0.148598	**-26.2%**
2270002015	286.60	297.20	3.7%	0.59	0.38	-35.6%	**-33.2%**	0.40	0.268456	**-33.2%**
2270002048	71.60	74.30	3.8%	0.59	0.41	-30.5%	**-27.9%**	0.11	0.08065	**-27.9%**
2270002060	71.60	74.30	3.8%	0.59	0.36	-39.0%	**-36.7%**	0.25	0.156808	**-36.7%**
2270002069	143.30	148.60	3.7%	0.59	0.43	-27.1%	**-24.4%**	3.29	2.48681	**-24.4%**
DCE Subsector 5: DCE – Commercial Construction Montgomery County										
2270002003	92.70	226.80	144.7%	0.59	0.42	-28.8%	**74.2%**	0.17	0.293478	**74.2%**
2270002015	92.70	226.80	144.7%	0.59	0.38	-35.6%	**57.6%**	0.21	0.331918	**57.6%**
2270002036	92.70	226.80	144.7%	0.59	0.38	-35.6%	**57.6%**	0.12	0.193477	**57.6%**
2270002048	92.70	226.80	144.7%	0.59	0.41	-30.5%	**70.0%**	0.28	0.481574	**70.0%**
2270002066	138.10	338.00	144.8%	0.21	0.37	76.2%	**331.2%**	0.35	1.496555	**331.1%**
2270002069	185.40	453.60	144.7%	0.59	0.43	-27.1%	**78.3%**	3.59	6.397397	**78.3%**
DCE Subsector 6: DCE – Concrete Operations Collin County										
2270002015	0.60	0.60	0.0%	0.59	0.38	-35.6%	**-35.6%**	0.02	0.01366	**-35.6%**
2270002024	0.30	0.30	0.0%	0.59	0.30	-49.2%	**-49.2%**	0.03	0.017322	**-49.2%**
2270002036	4.70	5.90	25.5%	0.59	0.38	-35.6%	**-19.1%**	0.69	0.571336	**-16.8%**
2270002048	0.50	0.60	20.0%	0.59	0.41	-30.5%	**-16.6%**	0.03	0.023207	**-16.6%**
2270002060	4.00	5.00	25.0%	0.59	0.36	-39.0%	**-23.7%**	0.32	0.243963	**-23.7%**
2270002066	1.80	2.30	27.8%	0.21	0.37	76.2%	**125.1%**	0.02	0.047483	**125.9%**
2270002069	2.90	3.60	24.1%	0.59	0.43	-27.1%	**-9.5%**	0.19	0.161862	**-13.6%**

Table 7-1. Activity Checks by DCE Subsector

SCC	Population			Load Factor			Net Change	BSFC Output (tons)		
	Prior	Update	% Change	Prior	Update	% Change		Prior	Update	% Change
DCE Subsector 7: DCE – County-Owned Construction Equipment Bexar County										
2270002003	2.80	2.90	3.6%	0.59	0.42	-28.8%	**-26.3%**	0.19	0.13652	**-26.3%**
2270002015	28.90	30.40	5.2%	0.59	0.38	-35.6%	**-32.3%**	0.55	0.371206	**-32.1%**
2270002018	1.00	1.00	0.0%	0.59	0.48	-18.6%	**-18.6%**	0.00	3.36E-05	**-18.6%**
2270002021	10.70	11.30	5.6%	0.59	0.36	-39.0%	**-35.6%**	0.22	0.14183	**-36.2%**
2270002024	0.50	0.50	0.0%	0.59	0.30	-49.2%	**-49.2%**	0.02	0.012302	**-49.2%**
2270002036	5.60	5.90	5.4%	0.59	0.38	-35.6%	**-32.1%**	0.38	0.258411	**-32.1%**
2270002048	11.20	11.80	5.4%	0.59	0.41	-30.5%	**-26.8%**	0.42	0.308848	**-26.7%**
2270002060	12.20	12.80	4.9%	0.59	0.36	-39.0%	**-36.0%**	0.19	0.122439	**-35.9%**
2270002066	2.80	3.00	7.1%	0.21	0.37	76.2%	**88.8%**	0.02	0.027999	**86.4%**
2270002069	5.10	5.40	5.9%	0.59	0.43	-27.1%	**-22.8%**	0.07	0.057157	**-22.7%**
DCE Subsector 8: DCE – Cranes Williamson County										
2270002045	97.60	99.80	2.3%	0.43	0.29	-32.6%	**-31.0%**	6.62	4.561548	**-31.1%**
DCE Subsector 9: DCE – Heavy-Highway Construction Travis County										
2270002003	1.10	0.90	-18.2%	0.59	0.42	-28.8%	**-41.8%**	0.03	0.015561	**-38.5%**
2270002015	24.00	22.10	-7.9%	0.59	0.38	-35.6%	**-40.7%**	0.41	0.242817	**-40.6%**
2270002018	5.40	4.80	-11.1%	0.59	0.48	-18.6%	**-27.7%**	0.83	0.606321	**-26.7%**
2270002021	4.80	4.40	-8.3%	0.59	0.36	-39.0%	**-44.1%**	0.18	0.103127	**-44.1%**
2270002024	4.00	3.70	-7.5%	0.59	0.3	-49.2%	**-53.0%**	0.38	0.174491	**-53.9%**
2270002036	16.70	15.20	-9.0%	0.59	0.38	-35.6%	**-41.4%**	1.41	0.826634	**-41.3%**
2270002048	14.30	13.20	-7.7%	0.59	0.41	-30.5%	**-35.9%**	0.98	0.628235	**-35.7%**
2270002060	16.10	14.80	-8.1%	0.59	0.36	-39.0%	**-43.9%**	0.93	0.51793	**-44.1%**

Table 7-1. Activity Checks by DCE Subsector

SCC	Population			Load Factor			Net Change	BSFC Output (tons)		
	Prior	Update	% Change	Prior	Update	% Change		Prior	Update	% Change
2270002066	15.10	13.80	-8.6%	0.21	0.37	76.2%	**61.0%**	0.11	0.174222	**60.7%**
2270002069	14.10	13.00	-7.8%	0.59	0.43	-27.1%	**-32.8%**	0.74	0.494139	**-32.9%**
DCE Subsector 10: DCE – Landfill Operations Fort Bend County										
2270002015	5.70	6.40	12.3%	0.59	0.38	-35.6%	**-27.7%**	2.79	2.010371	**-28.0%**
2270002018	1.90	2.20	15.8%	0.59	0.48	-18.6%	**-5.8%**	0.20	0.185354	**-6.5%**
2270002036	1.80	2.00	11.1%	0.59	0.38	-35.6%	**-28.4%**	0.46	0.317157	**-30.8%**
2270002048	2.50	2.80	12.0%	0.59	0.41	-30.5%	**-22.2%**	0.27	0.209113	**-21.9%**
2270002060	1.20	1.30	8.3%	0.59	0.36	-39.0%	**-33.9%**	0.14	0.090289	**-36.2%**
2270002069	3.60	4.00	11.1%	0.59	0.43	-27.1%	**-19.0%**	1.07	0.884521	**-17.6%**
DCE Subsector 11: DCE – Landscaping Activities Harris County										
2270002015	3.70	4.40	18.9%	0.59	0.38	-35.6%	**-23.4%**	0.13	0.100769	**-23.5%**
2270002018	0.90	1.00	11.1%	0.59	0.48	-18.6%	**-9.6%**	0.08	0.075001	**-9.6%**
2270002024	4.00	4.70	17.5%	0.59	0.3	-49.2%	**-40.3%**	0.61	0.363576	**-40.3%**
2270002036	18.10	21.40	18.2%	0.59	0.38	-35.6%	**-23.9%**	0.90	0.692223	**-23.2%**
2270002048	9.60	11.40	18.7%	0.59	0.41	-30.5%	**-17.5%**	0.50	0.413867	**-17.5%**
2270002060	17.30	20.20	16.8%	0.59	0.36	-39.0%	**-28.8%**	1.19	0.859061	**-28.1%**
2270002066	867.30	1028.70	18.6%	0.21	0.37	76.2%	**109.0%**	9.94	20.78216	**109.0%**
2270002069	64.10	76.10	18.7%	0.59	0.43	-27.1%	**-13.5%**	3.19	2.753524	**-13.7%**
DCE Subsector 12: DCE – Manufacturing Operations El Paso County										
2270002036	1.20	0.60	-50.0%	0.59	0.38	-35.6%	**-67.8%**	0.19	0.064252	**-66.4%**
2270002051	1.30	0.80	-38.5%	0.59	0.38	-35.6%	**-60.4%**	0.35	0.142518	**-59.9%**
2270002060	3.20	1.90	-40.6%	0.59	0.36	-39.0%	**-63.8%**	0.52	0.181252	**-65.2%**

Table 7-1. Activity Checks by DCE Subsector

SCC	Population			Load Factor			Net Change	BSFC Output (tons)		
	Prior	Update	% Change	Prior	Update	% Change		Prior	Update	% Change
2270002066	6.70	4.10	-38.8%	0.21	0.37	76.2%	**7.8%**	0.08	0.090106	**7.8%**
2270002069	9.30	5.70	-38.7%	0.59	0.43	-27.1%	**-55.3%**	0.66	0.289759	**-56.3%**
DCE Subsector 13: DCE – Municipal-Owned Construction Equipment										
Denton County										
2270002003	0.70	0.80	14.3%	0.59	0.42	-28.8%	**-18.6%**	0.00	0.00106	**-18.6%**
2270002015	24.40	26.10	7.0%	0.59	0.38	-35.6%	**-31.1%**	0.10	0.065499	**-31.1%**
2270002018	1.50	1.60	6.7%	0.59	0.48	-18.6%	**-13.2%**	0.05	0.047017	**-13.2%**
2270002021	1.40	1.60	14.3%	0.59	0.36	-39.0%	**-30.3%**	0.01	0.008337	**-30.3%**
2270002036	4.40	4.80	9.1%	0.59	0.38	-35.6%	**-29.7%**	0.24	0.16703	**-30.2%**
2270002048	17.00	18.20	7.1%	0.59	0.41	-30.5%	**-25.6%**	0.37	0.272001	**-25.7%**
2270002060	8.90	9.50	6.7%	0.59	0.36	-39.0%	**-34.9%**	0.23	0.150581	**-34.9%**
2270002066	74.70	79.80	6.8%	0.21	0.37	76.2%	**88.2%**	1.69	3.187983	**88.5%**
2270002069	17.80	19.00	6.7%	0.59	0.43	-27.1%	**-22.2%**	0.38	0.297758	**-22.2%**
DCE Subsector 14: DCE – Transportation/Sales/Services **Kaufman County**										
2270002015	2.80	6.00	114.3%	0.59	0.38	-35.6%	**38.0%**	0.07	0.090913	**37.7%**
2270002018	10.00	21.50	115.0%	0.59	0.48	-18.6%	**74.9%**	0.56	0.981398	**74.6%**
2270002024	8.10	17.30	113.6%	0.59	0.30	-49.2%	**8.6%**	1.33	1.437994	**8.2%**
2270002036	30.10	64.60	114.6%	0.59	0.38	-35.6%	**38.2%**	3.70	5.100469	**38.0%**
2270002048	13.90	30.00	115.8%	0.59	0.41	-30.5%	**50.0%**	0.80	1.206517	**50.4%**
2270002051	7.20	15.50	115.3%	0.59	0.38	-35.6%	**38.7%**	1.38	1.927545	**39.4%**
2270002060	31.90	68.40	114.4%	0.59	0.36	-39.0%	**30.8%**	3.54	4.614067	**30.2%**
2270002066	91.20	196.10	115.0%	0.21	0.37	76.2%	**278.8%**	1.94	7.337415	**278.7%**
2270002069	32.30	69.30	114.6%	0.59	0.43	-27.1%	**56.4%**	3.05	4.776138	**56.7%**

Table 7-1. Activity Checks by DCE Subsector

SCC	Population			Load Factor			Net Change	BSFC Output (tons)		
	Prior	Update	% Change	Prior	Update	% Change		Prior	Update	% Change
DCE Subsector 15: DCE – Residential Construction Hays County										
2270002003	2.60	4.30	65.4%	0.59	0.42	-28.8%	**17.7%**	0.19	0.228296	**17.7%**
2270002015	18.80	31.10	65.4%	0.59	0.38	-35.6%	**6.5%**	0.76	0.810552	**6.5%**
2270002024	11.10	18.50	66.7%	0.59	0.30	-49.2%	**-15.3%**	0.59	0.4974	**-15.0%**
2270002036	22.30	36.90	65.5%	0.59	0.38	-35.6%	**6.6%**	3.36	3.584888	**6.5%**
2270002048	2.60	4.30	65.4%	0.59	0.41	-30.5%	**14.9%**	0.12	0.141921	**14.9%**
2270002060	24.30	40.20	65.4%	0.59	0.36	-39.0%	**0.9%**	1.04	1.045342	**0.9%**
2270002069	25.30	41.90	65.6%	0.59	0.43	-27.1%	**20.7%**	1.43	1.727643	**20.6%**
DCE Subsector 16: DCE – Rough Terrain Forklifts Jefferson County										
2270002057	158.20	196.30	24.1%	0.59	0.40	-32.2%	**-15.9%**	5.64	4.743826	**-15.9%**
DCE Subsector 17: DCE – Scrap Recycling Operations Bexar County										
2270002036	19.70	18.40	-6.6%	0.59	0.38	-35.6%	**-39.8%**	2.54	1.519635	**-40.1%**
2270002060	10.20	9.60	-5.9%	0.59	0.36	-39.0%	**-42.6%**	0.86	0.493996	**-42.7%**
2270002066	0.20	0.20	0.0%	0.21	0.37	76.2%	**76.2%**	0.00	0.000327	**76.2%**
2270002069	0.70	0.70	0.0%	0.59	0.43	-27.1%	**-27.1%**	0.14	0.105006	**-27.1%**
DCE Subsector 18: DCE – Skid Steer Loaders Orange County										
2270002072	137.90	144.40	4.7%	0.21	0.37	76.2%	**84.5%**	1.37	2.529129	**84.5%**
DCE Subsector 19: DCE – Special Trades Construction Hardin County										
2270002003	8.40	15.90	89.3%	0.59	0.42	-28.8%	**34.7%**	0.44	0.584531	**33.6%**
2270002015	12.20	22.90	87.7%	0.59	0.38	-35.6%	**20.9%**	0.52	0.632688	**21.1%**

Table 7-1. Activity Checks by DCE Subsector

SCC	Population			Load Factor			Net Change	BSFC Output (tons)		
	Prior	Update	% Change	Prior	Update	% Change		Prior	Update	% Change
2270002036	116.60	220.20	88.9%	0.59	0.38	-35.6%	**21.6%**	2.34	2.842926	**21.6%**
2270002048	32.70	61.80	89.0%	0.59	0.41	-30.5%	**31.3%**	1.57	2.064418	**31.4%**
2270002060	67.00	126.50	88.8%	0.59	0.36	-39.0%	**15.2%**	7.46	8.595902	**15.2%**
2270002066	945.90	1787.10	88.9%	0.21	0.37	76.2%	**232.9%**	7.16	23.84202	**232.9%**
2270002069	48.20	91.00	88.8%	0.59	0.43	-27.1%	**37.6%**	1.41	1.941357	**37.8%**
DCE Subsector 20: DCE – Trenchers Liberty County										
2270002030	30.20	25.20	-16.6%	0.59	0.50	-15.3%	**-29.3%**	1.04	0.734411	**-29.6%**
DCE Subsector 22: DCE – Utility Construction Chambers County										
2270002003	8.10	18.00	122.2%	0.59	0.42	-28.8%	**58.2%**	0.03	0.045652	**58.2%**
2270002015	16.10	36.10	124.2%	0.59	0.38	-35.6%	**44.4%**	0.05	0.065164	**44.4%**
2270002036	16.10	36.10	124.2%	0.59	0.38	-35.6%	**44.4%**	0.52	0.745411	**44.4%**
2270002066	8.10	18.00	122.2%	0.21	0.37	76.2%	**291.5%**	0.00	0.0116	**291.5%**
2270002069	16.10	36.10	124.2%	0.59	0.43	-27.1%	**63.4%**	0.27	0.447938	**63.4%**
DCE Subsector 23: DCE – Mining & Quarry Operations Bexar County										
2270002018	6.20	8.20	32.3%	0.59	0.48	-18.6%	**7.6%**	1.04	1.117024	**7.6%**
2270002036	12.80	17.00	32.8%	0.59	0.38	-35.6%	**-14.5%**	4.19	3.584348	**-14.5%**
2270002048	5.40	7.20	33.3%	0.59	0.41	-30.5%	**-7.3%**	0.19	0.17356	**-7.3%**
2270002051	43.50	57.50	32.2%	0.59	0.38	-35.6%	**-14.9%**	11.39	9.695715	**-14.9%**
2270002060	64.70	85.40	32.0%	0.59	0.36	-39.0%	**-19.5%**	20.76	16.72451	**-19.4%**
2270002066	38.40	50.70	32.0%	0.21	0.37	76.2%	**132.6%**	0.91	2.122533	**132.6%**
2270002069	13.60	18.00	32.4%	0.59	0.43	-27.1%	**-3.5%**	2.65	2.557057	**-3.5%**

Table 7-1. Activity Checks by DCE Subsector

SCC	Population			Load Factor			Net Change	BSFC Output (tons)		
	Prior	Update	% Change	Prior	Update	% Change		Prior	Update	% Change
DCE Subsector 25: Off-road tractors, Miscellaneous, and all Equipment < 25 hp Harris County										
2270002003	1.90	1.40	-26.3%	0.59	0.42	-28.8%	**-47.5%**	0.02	0.008129	**-47.5%**
2270002006	45.90	32.70	-28.8%	0.43	0.43	0.0%	**-28.8%**	0.03	0.020686	**-28.8%**
2270002009	400.90	285.30	-28.8%	0.43	0.43	0.0%	**-28.8%**	0.48	0.340062	**-28.8%**
2270002015	226.70	161.40	-28.8%	0.59	0.38	-35.6%	**-54.1%**	1.12	0.515689	**-54.1%**
2270002021	55.20	39.30	-28.8%	0.59	0.36	-39.0%	**-56.6%**	0.14	0.061877	**-56.6%**
2270002024	18.60	13.30	-28.5%	0.59	0.30	-49.2%	**-63.6%**	0.10	0.035897	**-63.7%**
2270002027	1175.00	836.60	-28.8%	0.43	0.43	0.0%	**-28.8%**	4.92	3.502969	**-28.8%**
2270002030	3.40	2.40	-29.4%	0.59	0.50	-15.3%	**-40.2%**	0.02	0.010154	**-40.7%**
2270002033	6.50	4.60	-29.2%	0.43	0.50	16.3%	**-17.7%**	0.02	0.015063	**-18.0%**
2270002036	84.90	60.40	-28.9%	0.59	0.38	-35.6%	**-54.2%**	0.79	0.361988	**-54.2%**
2270002039	120.20	85.70	-28.7%	0.59	0.59	0.0%	**-28.7%**	1.49	1.065735	**-28.6%**
2270002042	266.20	189.50	-28.8%	0.43	0.43	0.0%	**-28.8%**	0.71	0.506911	**-29.0%**
2270002054	165.00	117.40	-28.8%	0.43	0.43	0.0%	**-28.8%**	7.28	5.182942	**-28.8%**
2270002057	4.00	2.80	-30.0%	0.59	0.40	-32.2%	**-52.5%**	0.03	0.012461	**-52.5%**
2270002060	0.80	0.60	-25.0%	0.59	0.36	-39.0%	**-54.2%**	0.01	0.002882	**-54.2%**
2270002066	44.10	31.50	-28.6%	0.21	0.37	76.2%	**25.9%**	0.21	0.270478	**25.8%**
2270002072	1249.00	889.20	-28.8%	0.21	0.37	76.2%	**25.4%**	3.62	4.53955	**25.4%**
2270002075	76.40	54.20	-29.1%	0.59	0.59	0.0%	**-29.1%**	19.34	13.71665	**-29.1%**
2270002078	72.70	51.80	-28.7%	0.21	0.21	0.0%	**-28.7%**	0.25	0.179916	**-28.8%**
2270002081	227.20	161.70	-28.8%	0.59	0.42	-28.8%	**-49.3%**	18.52	9.37112	**-49.4%**

In addition to changes caused by increases or decreases in activity, emissions also change as a result of shifts in equipment model year distributions. For example, increases in engine load factor cause an engine to reach the end of its useful life more rapidly, at which point it is replaced by an engine meeting the newest emission standards. As a result, emission rates decrease more rapidly than the comparable changes in population and activity shown in Table 7-1. Similarly, decreases in load factor extend engine life leading to higher emission rates.

To ensure the relative changes in emissions were as expected, ERG compared the change in $PM_{2.5}$ emissions generated by the utility with the corresponding change in fuel consumption.[52] For those SCCs where there was no change in load factor, the change in emissions was comparable to the change in fuel consumption, as expected. For those SCCs where load factors changed relative to their prior values, the change in emissions varied as expected from the change in fuel consumption for most, but not all, DCE subsector/SCC combinations. Table 7-2 presents the findings of this comparison with inconsistent DCE subsector/SCC combinations highlighted with red font. Most notably, the results were inconsistent with expectations for every SCC in subsectors 4 (City and County Road Construction), 5 (Commercial Construction), and 22 (Utility Construction). In addition, one or more SCCs had inconsistent findings for subsector 0 (Non-DCE), 7 (County-Owned Construction Equipment), 9 (Heavy-Highway Construction), 13 (Municipal-Owned Construction Equipment), 17 (Scrap and Recycling), and 25 (Miscellaneous).

After further investigation ERG determined that the DCE subsector/SCC combinations highlighted in Table 7-2 all have relatively low activity levels, with an average of 144 hours per year across 29 cases. At these usage levels annual equipment scrappage rates are very low, and any emission changes due to replacement with cleaner equipment is outpaced by deterioration effects on existing equipment. On the other hand, the DCE subsector/SCC combinations exhibiting the expected relationship between $PM_{2.5}$ and fuel consumption changes had substantially higher activity rates (averaging 1,017 hours per year across 117 cases), leading to higher scrappage rates and more significant reductions in $PM_{2.5}$ emission rates. Accordingly, ERG concluded the activity and emission outputs associated with the TexN2.1 utility were consistent with the modified inputs.

[52] $PM_{2.5}$ was chosen for the QA assessment because the relative impact of emission standard changes and deterioration on $PM_{2.5}$ emission rates are greater than other criteria pollutants. Accordingly, any unexpected changes in emissions are easier to identify and diagnose.

Table 7-2. Emission Change Consistency Check

SCC	Load Factor Change	BSFC Change	$PM_{2.5}$ Output (tons)			Consistent?
			Prior	Update	% Change	
Subsector 0: Non-DCE (excluding agricultural tractors)						
Harris County						
2270001060	0.0%	**-41.5%**	0.00142129	0.00083	**-41.5%**	Y
2270003010	47.6%	**-8.7%**	0.006721218	0.00612	**-8.9%**	Y
2270003020	-66.1%	**-79.0%**	0.009199628	0.00892	**-3.0%**	Y
2270003030	7.0%	**-33.7%**	0.006988092	0.00433	**-38.0%**	Y
2270003040	-20.9%	**-51.0%**	0.010880915	0.00667	**-38.7%**	Y
2270003050	90.5%	**17.6%**	0.001192868	0.00157	**31.8%**	N
2270003060	7.0%	**-28.8%**	0.022371926	0.01436	**-35.8%**	Y
2270003070	-33.9%	**-59.1%**	0.0067244	0.00476	**-29.1%**	Y
2270004031	0.0%	**4.9%**	4.25337E-05	0.00004	**4.9%**	Y
2270004046	0.0%	**4.9%**	0.006649733	0.00697	**4.9%**	Y
2270004066	0.0%	**4.9%**	0.014497905	0.01521	**4.9%**	Y
2270004071	0.0%	**5.0%**	0.001179756	0.00124	**5.0%**	Y
2270004076	0.0%	**2.9%**	0.000125979	0.00013	**2.9%**	Y
2270005010	0.0%	**-49.5%**	0.000182153	0.00009	**-49.5%**	Y
2270005020	-25.4%	**-61.9%**	0.001323066	0.00088	**-33.5%**	Y
2270005025	-15.3%	**-57.0%**	0.003617539	0.00167	**-54.0%**	Y
2270005030	0.0%	**-49.4%**	0.003942526	0.00199	**-49.4%**	Y
2270005035	-28.8%	**-63.9%**	0.003058102	0.00125	**-59.0%**	Y
2270005040	0.0%	**-48.5%**	0.000616738	0.00032	**-48.7%**	Y
2270005045	-18.6%	**-58.5%**	0.001052833	0.00059	**-44.2%**	Y
2270005055	0.0%	**-49.6%**	0.000411705	0.00021	**-49.4%**	Y
2270005060	0.0%	**-49.4%**	0.000760837	0.00038	**-49.4%**	Y
2270006005	-27.9%	**-71.9%**	0.09074167	0.02737	**-69.8%**	Y
2270006010	0.0%	**-61.0%**	0.022789319	0.00890	**-61.0%**	Y
2270006015	-27.9%	**-71.9%**	0.034710201	0.01382	**-60.2%**	Y
2270006025	0.0%	**-61.0%**	0.054572372	0.02130	**-61.0%**	Y
2270006030	0.0%	**-61.0%**	0.002589571	0.00101	**-61.0%**	Y
2270006035	0.0%	**-61.3%**	0.001557808	0.00060	**-61.2%**	Y
2270007015	0.0%	**93.7%**	0.000201877	0.00039	**92.0%**	Y
2285002015	0.0%	**-41.6%**	0.002023009	0.00118	**-41.6%**	Y
DCE Subsector 1: DCE - Agricultural Activities Cameron County						
2270002018	-18.6%	**-18.6%**	2.83454E-05	0.00003	**5.3%**	Y
2270002036	-35.6%	**-37.6%**	0.000207859	0.000233181	**12.2%**	Y

Table 7-2. Emission Change Consistency Check

SCC	Load Factor Change	BSFC Change	$PM_{2.5}$ Output (tons)			Consistent?
			Prior	Update	% Change	
2270002048	-30.5%	**-30.5%**	6.50857E-05	7.80947E-05	**20.0%**	Y
2270002051	-35.6%	**-35.6%**	0.000189004	0.00024449	**29.4%**	Y
2270002060	-39.0%	**-39.9%**	0.000230392	0.000289643	**25.7%**	Y
2270002066	76.2%	**71.4%**	0.001827349	0.001423114	**-22.1%**	Y
2270002069	-27.1%	**-29.7%**	0.000620275	0.000683245	**10.2%**	Y
DCE Subsector 2: DCE – Boring & Drilling Equipment Harris County						
2270002033	16.3%	**-5.7%**	0.009055	0.0077	**-15.3%**	Y
DCE Subsector 3: DCE – Brick & Stone Operations Dallas County						
2270002036	-35.6%	**-42.6%**	0.001058585	0.00110	**3.8%**	Y
2270002048	-30.5%	**-39.2%**	6.28356E-05	6.28758E-05	**0.1%**	Y
2270002060	-39.0%	**-46.9%**	0.000295533	0.000384849	**30.2%**	Y
2270002066	76.2%	**55.3%**	0.000346471	0.000274378	**-20.8%**	Y
2270002069	-27.1%	**-36.4%**	0.000297313	0.000294103	**-1.1%**	Y
DCE Subsector 4: DCE – City and County Road Construction Tarrant County						
2270002003	-28.8%	**-26.2%**	0.000242034	0.00018	**-27.0%**	N
2270002015	-35.6%	**-33.2%**	0.000531793	0.000348708	**-34.4%**	N
2270002048	-30.5%	**-27.9%**	0.000126331	8.99715E-05	**-28.8%**	N
2270002060	-39.0%	**-36.7%**	0.000240982	0.000148962	**-38.2%**	N
2270002069	-27.1%	**-24.4%**	0.004069278	0.002862762	**-29.6%**	N
DCE Subsector 5: DCE – Commercial Construction Montgomery County						
2270002003	-28.8%	**74.2%**	0.000204869	0.00035	**71.6%**	N
2270002015	-35.6%	**57.6%**	0.000252633	0.000389194	**54.1%**	N
2270002036	-35.6%	**57.6%**	0.000117533	0.000183822	**56.4%**	N
2270002048	-30.5%	**70.0%**	0.000258072	0.000432119	**67.4%**	N
2270002066	76.2%	**331.1%**	0.000755576	0.003410346	**351.4%**	N
2270002069	-27.1%	**78.3%**	0.003501206	0.00597727	**70.7%**	N
DCE Subsector 6: DCE – Concrete Operations Collin County						
2270002015	-35.6%	**-35.6%**	1.66744E-05	0.00002	**4.3%**	Y
2270002024	-49.2%	**-49.2%**	3.32527E-05	1.96618E-05	**-40.9%**	Y
2270002036	-35.6%	**-16.8%**	0.000258465	0.00039054	**51.1%**	Y
2270002048	-30.5%	**-16.6%**	1.31138E-05	1.79962E-05	**37.2%**	Y

Table 7-2. Emission Change Consistency Check

SCC	Load Factor Change	BSFC Change	$PM_{2.5}$ Output (tons) Prior	Update	% Change	Consistent?
2270002060	-39.0%	**-23.7%**	8.63025E-05	0.000131101	**51.9%**	Y
2270002066	76.2%	**125.9%**	5.16313E-05	4.47625E-05	**-13.3%**	Y
2270002069	-27.1%	**-13.6%**	8.65216E-05	0.000117302	**35.6%**	Y
DCE Subsector 7: DCE – County-Owned Construction Equipment						
Bexar County						
2270002003	-28.8%	**-26.3%**	6.43079E-05	0.00007	**12.8%**	Y
2270002015	-35.6%	**-32.1%**	0.000789177	0.000625494	**-20.7%**	Y
2270002018	-18.6%	**-18.6%**	3.50846E-08	2.85411E-08	**-18.7%**	N
2270002021	-39.0%	**-36.2%**	0.000273683	0.000161676	**-40.9%**	N
2270002024	-49.2%	**-49.2%**	2.63527E-05	1.19122E-05	**-54.8%**	N
2270002036	-35.6%	**-32.1%**	0.000176453	0.00021056	**19.3%**	Y
2270002048	-30.5%	**-26.7%**	0.00035791	0.000372698	**4.1%**	Y
2270002060	-39.0%	**-35.9%**	0.000278621	0.000164022	**-41.1%**	N
2270002066	76.2%	**86.4%**	3.98208E-05	7.6984E-05	**93.3%**	N
2270002069	-27.1%	**-22.7%**	0.000109411	7.88904E-05	**-27.9%**	N
DCE Subsector 8: DCE – Cranes **Williamson County**						
2270002045	-32.6%	**-31.1%**	0.002815204	0.00342	**21.4%**	Y
DCE Subsector 9: DCE – Heavy-Highway Construction **Travis County**						
2270002003	-28.8%	**-38.5%**	2.26574E-05	0.00002	**-9.7%**	Y
2270002015	-35.6%	**-40.6%**	0.000567806	0.000409619	**-27.9%**	Y
2270002018	-18.6%	**-26.7%**	0.000407766	0.000385137	**-5.5%**	Y
2270002021	-39.0%	**-44.1%**	0.000151454	0.00015381	**1.6%**	Y
2270002024	-49.2%	**-53.9%**	0.000422056	0.00020253	**-52.0%**	Y
2270002036	-35.6%	**-41.3%**	0.000534262	0.000593705	**11.1%**	Y
2270002048	-30.5%	**-35.7%**	0.000345778	0.000351387	**1.6%**	Y
2270002060	-39.0%	**-44.1%**	0.000401848	0.000455158	**13.3%**	Y
2270002066	76.2%	**60.7%**	0.000286262	0.000517799	**80.9%**	N
2270002069	-27.1%	**-32.9%**	0.000391604	0.000411374	**5.0%**	Y
DCE Subsector 10: DCE – Landfill Operations **Fort Bend County**						
2270002015	-35.6%	**-28.0%**	0.000209405	0.000332736	**58.9%**	Y
2270002018	-18.6%	**-6.5%**	0.000145187	0.000178954	**23.3%**	Y
2270002036	-35.6%	**-30.8%**	3.83928E-05	5.74168E-05	**49.6%**	Y

Table 7-2. Emission Change Consistency Check

SCC	Load Factor Change	BSFC Change	$PM_{2.5}$ Output (tons)			Consistent?
			Prior	Update	% Change	
2270002048	-30.5%	**-21.9%**	5.06562E-05	6.91336E-05	**36.5%**	Y
2270002060	-39.0%	**-36.2%**	3.49151E-05	5.0124E-05	**43.6%**	Y
2270002069	-27.1%	**-17.6%**	7.76126E-05	0.000119592	**54.1%**	Y
DCE Subsector 11: DCE – Landscaping Activities Harris County						
2270002015	-35.6%	**-23.5%**	8.4074E-05	0.000108416	**29.0%**	Y
2270002018	-18.6%	**-9.6%**	2.30878E-05	3.1082E-05	**34.6%**	Y
2270002024	-49.2%	**-40.3%**	0.000409172	0.000439534	**7.4%**	Y
2270002036	-35.6%	**-23.2%**	0.000412187	0.000589876	**43.1%**	Y
2270002048	-30.5%	**-17.5%**	0.000234821	0.000319422	**36.0%**	Y
2270002060	-39.0%	**-28.1%**	0.000354219	0.000546555	**54.3%**	Y
2270002066	76.2%	**109.0%**	0.02267019	0.020754555	**-8.5%**	Y
2270002069	-27.1%	**-13.7%**	0.001433683	0.001965424	**37.1%**	Y
DCE Subsector 12: DCE – Manufacturing Operations El Paso County						
2270002036	-35.6%	**-66.4%**	7.61505E-05	4.661E-05	**-38.8%**	Y
2270002051	-35.6%	**-59.9%**	7.1407E-05	6.12851E-05	**-14.2%**	Y
2270002060	-39.0%	**-65.2%**	9.09232E-05	7.24908E-05	**-20.3%**	Y
2270002066	76.2%	**7.8%**	0.000198749	9.99026E-05	**-49.7%**	Y
2270002069	-27.1%	**-56.3%**	0.000317492	0.000208526	**-34.3%**	Y
DCE Subsector 13: DCE – Municipal-Owned Construction Equipment Denton County						
2270002003	-28.8%	**-18.6%**	2.72472E-06	2.08739E-06	**-23.4%**	N
2270002015	-35.6%	**-31.1%**	0.000185575	0.00011844	**-36.2%**	N
2270002018	-18.6%	**-13.2%**	5.52875E-05	4.61809E-05	**-16.5%**	N
2270002021	-39.0%	**-30.3%**	1.6245E-05	1.03262E-05	**-36.4%**	N
2270002036	-35.6%	**-30.2%**	0.000117863	0.000153532	**30.3%**	Y
2270002048	-30.5%	**-25.7%**	0.000489968	0.000415651	**-15.2%**	Y
2270002060	-39.0%	**-34.9%**	0.000239192	0.00025249	**5.6%**	Y
2270002066	76.2%	**88.5%**	0.001956404	0.001571976	**-19.6%**	Y
2270002069	-27.1%	**-22.2%**	0.000501192	0.000461795	**-7.9%**	Y
DCE Subsector 14: DCE – Transportation/Sales/Services Kaufman County						
2270002015	-35.6%	**37.7%**	5.67647E-05	0.00012864	**126.6%**	Y
2270002018	-18.6%	**74.6%**	0.000300792	0.000755334	**151.1%**	Y
2270002024	-49.2%	**8.2%**	0.000844126	0.001760342	**108.5%**	Y

Table 7-2. Emission Change Consistency Check

SCC	Load Factor Change	BSFC Change	PM2.5 Output (tons)			Consistent?
			Prior	Update	% Change	
2270002036	-35.6%	**38.0%**	0.001049426	0.002787314	**165.6%**	Y
2270002048	-30.5%	**50.4%**	0.000336845	0.000872283	**159.0%**	Y
2270002051	-35.6%	**39.4%**	0.000434948	0.001184703	**172.4%**	Y
2270002060	-39.0%	**30.2%**	0.00099335	0.00270351	**172.2%**	Y
2270002066	76.2%	**278.7%**	0.003333643	0.005729734	**71.9%**	Y
2270002069	-27.1%	**56.7%**	0.000840761	0.002151547	**155.9%**	Y
DCE Subsector 15: DCE – Residential Construction Hays County						
2270002003	-28.8%	**17.7%**	6.44701E-05	0.00014085	**118.5%**	Y
2270002015	-35.6%	**6.5%**	0.00050631	0.000865971	**71.0%**	Y
2270002024	-49.2%	**-15.0%**	0.000566137	0.000663704	**17.2%**	Y
2270002036	-35.6%	**6.5%**	0.001581832	0.003069958	**94.1%**	Y
2270002048	-30.5%	**14.9%**	6.85375E-05	0.000132683	**93.6%**	Y
2270002060	-39.0%	**0.9%**	0.000670582	0.001150691	**71.6%**	Y
2270002069	-27.1%	**20.6%**	0.000721757	0.001359046	**88.3%**	Y
DCE Subsector 16: DCE – Rough Terrain Forklifts Jefferson County						
2270002057	-32.2%	**-15.9%**	0.003641403	0.005209465	**43.1%**	Y
DCE Subsector 17: DCE – Scrap Recycling Operations Bexar County						
2270002036	-35.6%	**-40.1%**	0.000400412	0.000493197	**23.2%**	Y
2270002060	-39.0%	**-42.7%**	0.000234596	0.000276046	**17.7%**	Y
2270002066	76.2%	**76.2%**	3.73799E-07	6.70979E-07	79.5%	N
2270002069	-27.1%	**-27.1%**	1.16051E-05	1.61225E-05	**38.9%**	Y
DCE Subsector 18: DCE – Skid Steer Loaders Orange County						
2270002072	76.2%	**84.5%**	0.001013783	0.000898051	**-11.4%**	Y
DCE Subsector 19: DCE – Special Trades Construction Hardin County						
2270002003	-28.8%	**33.6%**	0.0001175	0.000254214	**116.4%**	Y
2270002015	-35.6%	**21.1%**	0.000221509	0.000508263	**129.5%**	Y
2270002036	-35.6%	**21.6%**	0.001569561	0.003162706	**101.5%**	Y
2270002048	-30.5%	**31.4%**	0.000790571	0.001794323	**127.0%**	Y
2270002060	-39.0%	**15.2%**	0.00106949	0.002713203	**153.7%**	Y
2270002066	76.2%	**232.9%**	0.019553259	0.058249741	**197.9%**	Y
2270002069	-27.1%	**37.8%**	0.001218107	0.002431206	**99.6%**	Y

Table 7-2. Emission Change Consistency Check

SCC	Load Factor Change	BSFC Change	$PM_{2.5}$ Output (tons) Prior	Update	% Change	Consistent?
DCE Subsector 20: DCE – Trenchers Liberty County						
2270002030	-15.3%	**-29.6%**	0.000476929	0.000430574	**-9.7%**	Y
DCE Subsector 22: DCE – Utility Construction Chambers County						
2270002003	-28.8%	**58.2%**	3.68158E-05	5.6651E-05	**53.9%**	N
2270002015	-35.6%	**44.4%**	5.495E-05	7.71971E-05	**40.5%**	N
2270002036	-35.6%	**44.4%**	0.000652323	0.000857049	**31.4%**	N
2270002066	76.2%	**291.5%**	7.07072E-06	2.85273E-05	**303.5%**	N
2270002069	-27.1%	**63.4%**	0.00024183	0.000383934	**58.8%**	N
DCE Subsector 23: DCE – Mining & Quarry Operations Bexar County						
2270002018	-18.6%	**7.6%**	0.000534401	0.000732708	**37.1%**	Y
2270002036	-35.6%	**-14.5%**	0.000933201	0.001662628	**78.2%**	Y
2270002048	-30.5%	**-7.3%**	0.000167812	0.000219836	**31.0%**	Y
2270002051	-35.6%	**-14.9%**	0.002644003	0.004634958	**75.3%**	Y
2270002060	-39.0%	**-19.4%**	0.003223177	0.00559821	**73.7%**	Y
2270002066	76.2%	**132.6%**	0.001754618	0.001927169	**9.8%**	Y
2270002069	-27.1%	**-3.5%**	0.00021442	0.000343145	**60.0%**	Y
DCE Subsector 25: Off-road tractors, Miscellaneous, and all Equipment < 25 hp Harris County						
2270002003	-28.8%	**-47.5%**	1.3975E-05	7.56765E-06	**-45.8%**	Y
2270002006	0.0%	**-28.8%**	4.53513E-05	3.23091E-05	**-28.8%**	Y
2270002009	0.0%	**-28.8%**	0.000657367	0.000467789	**-28.8%**	Y
2270002015	-35.6%	**-54.1%**	0.001080146	0.000532167	**-50.7%**	Y
2270002021	-39.0%	**-56.6%**	0.000156617	8.09808E-05	**-48.3%**	Y
2270002024	-49.2%	**-63.7%**	9.28861E-05	5.17312E-05	**-44.3%**	Y
2270002027	0.0%	**-28.8%**	0.004813602	0.003427672	**-28.8%**	Y
2270002030	-15.3%	**-40.7%**	1.60218E-05	9.82102E-06	**-38.7%**	Y
2270002033	16.3%	**-18.0%**	2.13043E-05	1.59029E-05	**-25.4%**	Y
2270002036	-35.6%	**-54.2%**	0.000724762	0.000333834	**-53.9%**	Y
2270002039	0.0%	**-28.6%**	0.001382741	0.000986974	**-28.6%**	Y
2270002042	0.0%	**-29.0%**	0.001094317	0.000778042	**-28.9%**	Y
2270002054	0.0%	**-28.8%**	0.003860081	0.002746333	**-28.9%**	Y
2270002057	-32.2%	**-52.5%**	2.38777E-05	1.23645E-05	**-48.2%**	Y
2270002060	-39.0%	**-54.2%**	5.67114E-06	2.82745E-06	**-50.1%**	Y

Table 7-2. Emission Change Consistency Check

SCC	Load Factor Change	BSFC Change	$PM_{2.5}$ Output (tons)			Consistent?
			Prior	Update	% Change	
2270002066	76.2%	**25.8%**	0.000214708	0.000211913	**-1.3%**	Y
2270002075	0.0%	**-29.1%**	0.011527595	0.00817485	**-29.1%**	Y
2270002078	0.0%	**-28.8%**	0.000719528	0.000512129	**-28.8%**	Y
2270002081	-28.8%	**-49.4%**	0.015617538	0.011264098	**-27.9%**	Y

B. Comparison of Prior and Updated TexN Utility Outputs

The following tables compare the fuel consumption and emission outputs from the prior TexN2.0 and updated TexN2.1 utility. Table 7-3 summarizes the state level $PM_{2.5}$ totals for each DCE subsector. Table 7-4 presents fuel consumption and emission totals summed across all DCE subsectors for the Dallas/Fort Worth, Houston/Galveston/Brazoria, Beaumont/Port Arthur, San Antonio and El Paso non-attainment areas, as well as for the Austin area.

As shown in Table 7-3, the TexN2.1 statewide fuel consumption estimates are reduced by over 50 percent relative to the prior TexN2.0 values. $PM_{2.5}$ reductions are also seen, although the relative change is much lower at 15 percent. In absolute terms most of the activity and emission changes are associated with the Non-DCE subsector, primarily driven by population updates, with secondary contributions from selected load factor updates. This is to be expected as the Non-DCE subsector is the largest overall contributor to activity and emissions.

Other notable activity reductions are seen in the crane, heavy-highway, rough terrain forklift, and mining/quarry subsectors, while substantial increases are evident in the transportation/sales/services and skid steer loader subsectors.

Table 7-4 also shows a general decrease in fuel consumption for selected regions of the state, although most of the regional reductions are less substantial than at the state level in percentage terms (typically 20 to 30 percent). Similarly, small emission reductions are seen for most counties. However, a small increase in emissions is seen for the Austin region (4.8 percent). In addition, a few counties experienced very substantial changes relative to the TexN2.0 utility, including Hardin (-67.6%) and Comal (+49.5%).[53]

[53] ERG identified an error in the TexN2.0 utility associated with DCE subsector 19 (Special Trades Contractors) during final QA. Specifically, the emissions associated with this subsector were assigned incorrectly to the Texas counties. The assignment has been corrected for TexN2.1. Since this subsector contributes a relatively small amount of $PM_{2.5}$ emissions (about 2 percent of the state total), substantial variation from the TexN2.0 estimates are most pronounced for small counties (e.g. Hardin and Comal).

Table 7-3. Statewide Fuel Consumption and $PM_{2.5}$ Emissions by DCE Subsector TexN2.0 vs. TexN2.1

DCE Subsector	Fuel Consumption (Tons/day)				$PM_{2.5}$ (Tons/day)			
	TexN2.0	*TexN2.1*	*Delta*	*% Change**	*TexN2.0*	*TexN2.1*	*Delta*	*% Change**
Non-DCE	33,200	8,486	-24,714	-74.4%	21.22	15.99	-5.24	-24.7%
Agricultural Activities	388	335	-53	-13.6%	0.24	0.23	-0.01	-4.1%
Boring & Drilling Equipment	72	75	3	4.0%	0.08	0.07	-0.01	-6.8%
Brick & Stone Operations	87	48	-39	-45.0%	0.03	0.03	0.00	-3.0%
City/County Road Construction	81	59	-22	-26.7%	0.08	0.07	-0.01	-12.0%
Commercial Construction	1,017	696	-321	-31.6%	1.11	0.84	-0.28	-24.9%
Concrete Operations	106	80	-25	-23.9%	0.04	0.06	0.01	24.6%
County Construction Equip.	62	42	-20	-32.4%	0.06	0.05	-0.01	-18.7%
Cranes	1,213	812	-402	-33.1%	0.40	0.48	0.08	19.6%
Heavy-Highway Construction	756	234	-522	-69.1%	0.47	0.23	-0.25	-52.2%
Landfill Operations	327	225	-102	-31.3%	0.04	0.05	0.01	31.5%
Landscaping Activities	330	758	428	129.6%	0.51	0.71	0.19	38.1%
Manufacturing Operations	143	81	-62	-43.2%	0.06	0.05	-0.01	-14.4%
Municipal Construction Equip	289	366	77	26.8%	0.33	0.27	-0.06	-18.4%
Transportation/Sales/Services	1,434	2,838	1,404	97.9%	0.72	1.87	1.15	159.4%
Residential Construction	1,072	917	-155	-14.5%	0.60	0.84	0.24	40.8%
Rough Terrain Forklifts	1,791	1,081	-709	-39.6%	1.16	1.19	0.03	2.7%
Scrap Recycling Operations	159	315	156	97.9%	0.03	0.12	0.09	300.8%
Skid Steer Loaders	1,735	2,346	612	35.3%	1.28	0.83	-0.45	-35.1%
Special Trades Construction	271	316	45	16.6%	0.32	0.54	0.22	68.6%
Trenchers	1,675	1,273	-403	-24.0%	0.77	0.75	-0.02	-2.8%
TxDOT Equipment	86	48	-39	-44.9%	0.13	0.07	-0.06	-46.8%
Utility Construction	498	299	-199	-39.9%	0.58	0.33	-0.25	-43.3%
Mining & Quarry Operations	3,988	2,195	-1,792	-44.9%	0.75	0.71	-0.04	-5.8%
Misc. and Equipment < 25 hp	360	241	-120	-33.3%	0.29	0.20	-0.09	-30.2%
Total	**51,140**	**24,166**	**-26,974**	**-52.7%**	**31.33**	**26.57**	**-4.76**	**-15.2%**

* Percentage change relative to TexN2.0

Table 7-4. Fuel Consumption and $PM_{2.5}$ Emissions by Selected Region TexN2.0 vs. TexN2.1

County	Fuel Consumption (Tons/day)				PM2.5 (Tons/day)			
	TexN2.0	*TexN2.1*	*Delta*	*% Change**	*TexN2.0*	*TexN2.1*	*Delta*	*% Change**
Dallas/Fort Worth								
Collin	444	301	-143	-32.2%	0.31	0.27	-0.04	-13.0%
Dallas	1,103	856	-247	-22.4%	0.72	0.64	-0.07	-10.2%
Denton	277	260	-17	-6.0%	0.14	0.17	0.03	20.6%
Tarrant	612	458	-153	-25.1%	0.41	0.35	-0.06	-14.6%
Region Total	**2,436**	**1,876**	**-560**	**-23.0%**	**1.58**	**1.44**	**-0.14**	**-9.1%**
Houston/Galveston								
Brazoria	199	131	-69	-34.4%	0.12	0.12	-0.01	-4.7%
Chambers	45	18	-27	-60.3%	0.03	0.03	0.00	-14.2%
Fort Bend	260	151	-109	-42.0%	0.18	0.14	-0.04	-21.9%
Galveston	143	115	-28	-19.8%	0.08	0.09	0.00	5.1%
Harris	1,729	1,513	-216	-12.5%	1.08	1.08	0.00	0.1%
Liberty	80	48	-32	-39.6%	0.05	0.05	0.00	-8.8%
Montgomery	187	203	16	8.5%	0.11	0.15	0.04	34.7%
Waller	67	25	-42	-62.9%	0.04	0.04	-0.01	-16.0%
Region Total	**2,710**	**2,203**	**-506**	**-18.7%**	**1.70**	**1.69**	**-0.02**	**-1.0%**
Beaumont/Port Arthur								
Hardin	44	16	-29	-64.4%	0.04	0.01	-0.03	-67.6%
Orange	122	82	-40	-33.0%	0.08	0.07	-0.01	-7.9%
Jefferson	28	20	-7	-25.9%	0.02	0.02	0.00	-0.6%
Region Total	**194**	**118**	**-76**	**-39.2%**	**0.14**	**0.10**	**-0.03**	**-24.2%**
El Paso								
El Paso	608	182	-426	-70.0%	0.24	0.17	-0.07	-28.1%
San Antonio								
Atascosa	78	30	-48	-61.2%	0.05	0.04	-0.01	-20.4%
Bandera	14	8	-6	-45.6%	0.01	0.01	0.00	-14.5%
Bexar	527	460	-66	-12.6%	0.37	0.36	0.00	-0.3%
Comal	157	182	25	16.2%	0.07	0.11	0.04	49.5%
Guadalupe	121	50	-71	-58.9%	0.08	0.07	-0.01	-16.7%
Kendall	32	21	-11	-33.9%	0.02	0.02	0.00	-5.3%
Medina	123	46	-77	-62.7%	0.08	0.07	-0.01	-14.4%
Wilson	98	27	-71	-72.4%	0.07	0.05	-0.01	-22.7%

Table 7-4. Fuel Consumption and $PM_{2.5}$ Emissions by Selected Region TexN2.0 vs. TexN2.1

County	Fuel Consumption (Tons/day)				PM2.5 (Tons/day)			
	TexN2.0	*TexN2.1*	*Delta*	*% Change**	*TexN2.0*	*TexN2.1*	*Delta*	*% Change**
Region Total	**1,150**	**824**	**-325**	**-28.3%**	**0.74**	**0.72**	**-0.02**	**-2.4%**
Austin/San Marcos								
Bastrop	96	50	-46	-48.0%	0.06	0.06	0.00	-1.6%
Caldwell	57	24	-33	-58.5%	0.04	0.04	0.00	-4.6%
Hays	81	59	-23	-27.9%	0.05	0.05	0.00	8.4%
Travis	433	371	-62	-14.3%	0.27	0.29	0.02	7.7%
Williamson	429	263	-166	-38.8%	0.19	0.20	0.01	3.7%
Region Total	**1,096**	**766**	**-330**	**-30.1%**	**0.61**	**0.64**	**0.03**	**4.8%**

* Percentage change relative to TexN2.0

VIII. RECOMMENDATIONS

ERG recommends the TCEQ consider undertaking the following to improve the accuracy of the TexN2.1 utility in the future.

1. Reattempt survey efforts for the surface mining and logging sectors.
2. Adjust equipment population growth factors to account for the economic downturn in 2020 and beyond.
3 Obtain annual equipment inventory information from TxDOT to determine if the growth factors used in the utility should be adjusted.

While items 1 and 2 must be deferred until the impacts of the current pandemic are better understood, the TxDOT equipment growth assessment may proceed at any time.

Appendix A –
Agricultural Tractor Scrappage and Life Fractions
(MOVES Table Format)

Agricultural Tractor Scrappage and Life Fractions (MOVES Table Format)

Life Fraction	% Scrapped
0.0000	0.0%
0.0294	0.0%
0.0588	0.0%
0.0871	0.0%
0.1153	0.0%
0.1424	0.0%
0.1694	0.0%
0.1954	0.0%
0.2213	0.0%
0.2462	0.0%
0.2710	0.0%
0.2948	0.0%
0.3185	0.0%
0.3412	0.0%
0.3639	0.0%
0.3856	0.0%
0.4073	0.0%
0.4280	0.0%
0.4486	0.0%
0.4683	0.0%
0.4880	0.0%
0.5067	0.0%
0.5254	0.0%
0.5432	0.0%
0.5610	0.0%
0.5779	0.0%
0.5948	0.0%
0.6108	0.0%
0.6268	0.0%
0.6419	0.0%
0.6570	0.0%
0.6713	0.0%
0.6856	0.0%
0.6991	0.0%
0.7125	0.0%
0.7252	0.0%
0.7379	0.0%
0.7498	0.0%
0.7617	0.3%
0.7729	2.1%
0.7840	3.9%
0.7945	5.7%
0.8049	7.4%
0.8147	9.0%
0.8244	10.6%
0.8335	12.1%
0.8425	13.6%
0.8510	15.0%
0.8594	16.4%
0.8672	17.6%
0.8750	18.9%
0.8822	20.1%
0.8894	21.3%
0.8961	22.4%
0.9027	23.5%
0.9088	24.5%
0.9148	25.5%
0.9204	26.4%
0.9259	27.3%
0.9310	28.1%
0.9360	29.0%
0.9406	29.7%
0.9451	30.5%
0.9492	31.1%
0.9533	31.8%
0.9570	32.4%
0.9607	33.0%
0.9640	33.6%
0.9672	34.1%
0.9701	34.6%
0.9730	35.0%
0.9755	35.5%
0.9780	35.9%
0.9802	36.2%
0.9824	36.6%
0.9843	36.9%
0.9862	37.2%
0.9878	37.5%
0.9894	37.7%
0.9907	38.0%
0.9920	38.2%
0.9931	38.4%
0.9942	38.5%
0.9951	38.7%
0.9959	38.8%
0.9966	38.9%
0.9973	39.0%
0.9978	39.1%
0.9983	39.2%
0.9987	39.3%
0.9990	39.3%
0.9993	39.4%
0.9995	39.4%
0.9997	39.4%
0.9998	39.5%
0.9999	39.5%
0.9999	39.5%
1.0000	39.5%
1.0000	39.5%
1.0001	39.5%
1.0001	39.5%
1.0002	39.5%
1.0002	39.5%
1.0004	39.5%
1.0005	39.6%
1.0008	39.6%
1.0010	39.7%
1.0014	39.7%
1.0017	39.8%
1.0022	39.8%
1.0027	39.9%

Life Fraction	% Scrapped
1.0034	40.0%
1.0041	40.2%
1.0050	40.3%
1.0058	40.4%
1.0069	40.6%
1.0080	40.8%
1.0093	41.0%
1.0106	41.2%
1.0122	41.5%
1.0138	41.8%
1.0157	42.1%
1.0176	42.4%
1.0198	42.7%
1.0220	43.1%
1.0245	43.5%
1.0270	43.9%
1.0299	44.4%
1.0328	44.9%
1.0361	45.4%
1.0393	46.0%
1.0430	46.2%
1.0467	46.4%
1.0508	46.6%
1.0549	46.8%
1.0595	47.0%
1.0640	47.2%
1.0691	47.5%
1.0741	47.7%
1.0797	48.0%
1.0852	48.2%
1.0913	48.5%
1.0973	48.8%
1.1040	49.1%
1.1106	49.5%
1.1178	49.8%
1.1250	50.2%
1.1328	50.5%
1.1406	50.9%

Life Fraction	% Scrapped
1.1491	51.3%
1.1575	51.7%
1.1666	52.2%
1.1756	52.6%
1.1854	53.1%
1.1951	53.5%
1.2056	54.0%
1.2160	54.5%
1.2272	55.1%
1.2383	55.6%
1.2502	56.2%
1.2621	56.8%
1.2748	57.4%
1.2875	58.0%
1.3010	58.6%
1.3144	59.3%
1.3287	59.8%
1.3430	60.2%
1.3581	60.6%
1.3732	61.0%
1.3892	61.5%
1.4052	61.9%
1.4221	62.4%
1.4390	62.9%
1.4568	63.4%
1.4746	63.9%
1.4933	64.4%
1.5120	64.9%
1.5317	65.5%
1.5514	66.1%
1.5721	66.6%
1.5927	67.2%
1.6144	68.6%
1.6361	70.5%
1.6588	72.4%
1.6815	74.3%
1.7053	76.3%
1.7290	78.3%

Life Fraction	% Scrapped
1.7539	80.4%
1.7787	82.5%
1.8047	84.7%
1.8306	86.8%
1.8577	89.1%
1.8847	91.4%
1.9130	93.5%
1.9412	95.6%
1.9706	97.8%
2.0000	100.0%

Appendix B–
Summary of Changes and How to Use the TexN2.1 Utility

Appendix B - Summary of Changes and How to Use the TexN2.1 Utility

This appendix contains the following:

1. Comprehensive list of changes in the TexN2.1 utility

2. How to install the new TexN2.1 utility

3. How to execute TexN2.1 runs to properly account for scrappage

4 How to update growth factors in the future (optional)

1. Comprehensive list of changes in TexN2.1

- Updated equipment populations for years after 2012
- Updated diesel agricultural tractor activity to 328 annual hours
- Updated diesel agricultural tractor median life
- Added new diesel agricultural tractor scrappage curve
- Updated TexN2.1 utility to use alternative scrappage curves for skid steer and agricultural tractor MOVES runs
- Updated load factors using CARB values
- Added 2 SCCs to the TxDOT DCE
- Updated the TxDOT DCE activity hours and population
- Corrected the FIPS codes for Special Trades Construction DCE populations

2. How to install the new TexN2.1 utility

ERG will provide a link to the new utility posted on ERG's FTP site, TexN2_v0_1_2_17jul20.zip. Use the link to download the zip file to your local computer and unzip.

Users who have older versions of TexN2 will need to either rename the old TexN2 database or delete it. ERG recommends renaming the TexN2 database if users may occasionally want to run older versions of the utility. In this case, a helpful name change could be `texn2` database to `texn2_may2019utility`, for example. If the user does not have a need to run previous versions of TexN2, delete the prior TexN2 database.

- To rename the old TexN2 database, navigate to the MySQL localhost (most likely C:\ProgramData\MySQL\MySQL Server 5.7\Data), right click on 'texn2' folder and select Rename to provide a different name.
- To delete the prior TexN2 database, the user may open MySQL Workbench and execute the query "DROP DATABASE IF EXISTS texn2;" (without the quotation marks).

After renaming/deleting the prior TexN2 database, please follow the directions in the User Guide section entitled "Setting up TexN2". TexN2 requires MOVES2014b (and MySQL) be already installed.

3. How to execute TexN2.1 runs to properly account for scrappage

The MOVES model does not have the capability of applying different scrappage to different SCCs within a single MOVES run. Instead, it can only apply a single scrappage curve to all SCCs included in a given run. This limitation dictates how TexN2 must be run. Any comprehensive inventory that includes skid steers, agricultural tractors and any other SCC must be run three separate times.

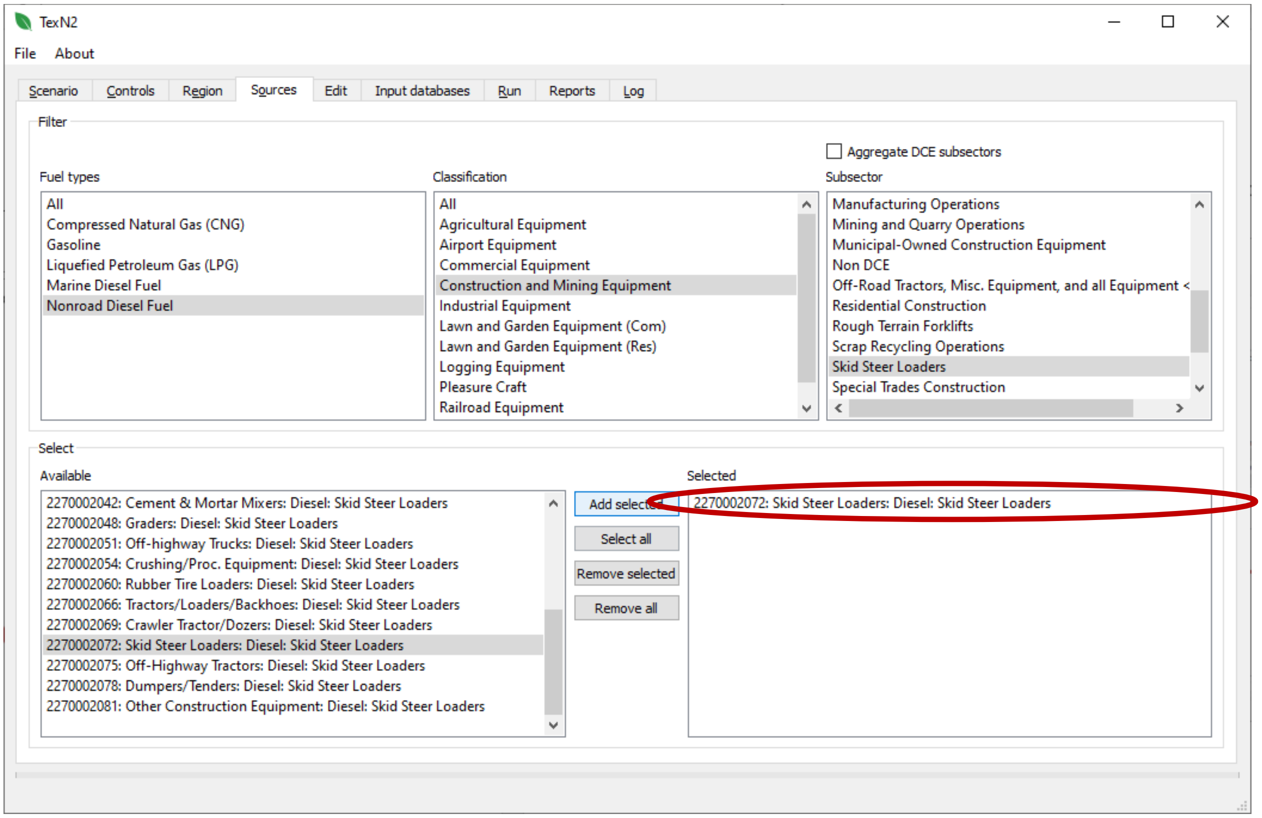
Note that tripling the number of runs does not triple the runtime. The additional two runs are much smaller because they only evaluate one SCC each. The three separate runs are described below with screenshots of SCC selections in the TexN2 GUI.

- Diesel Skid Steer Loaders Only
- Diesel Agricultural Tractors Only
- Everything Else

4.1 Setup of a TexN2 Run for Diesel Skid Steer Loaders Only

The diesel skid steer loader SCC is 270002072. The scrap curve only applies to diesels above 25 hp, which limits required selections to one DCE subsector.

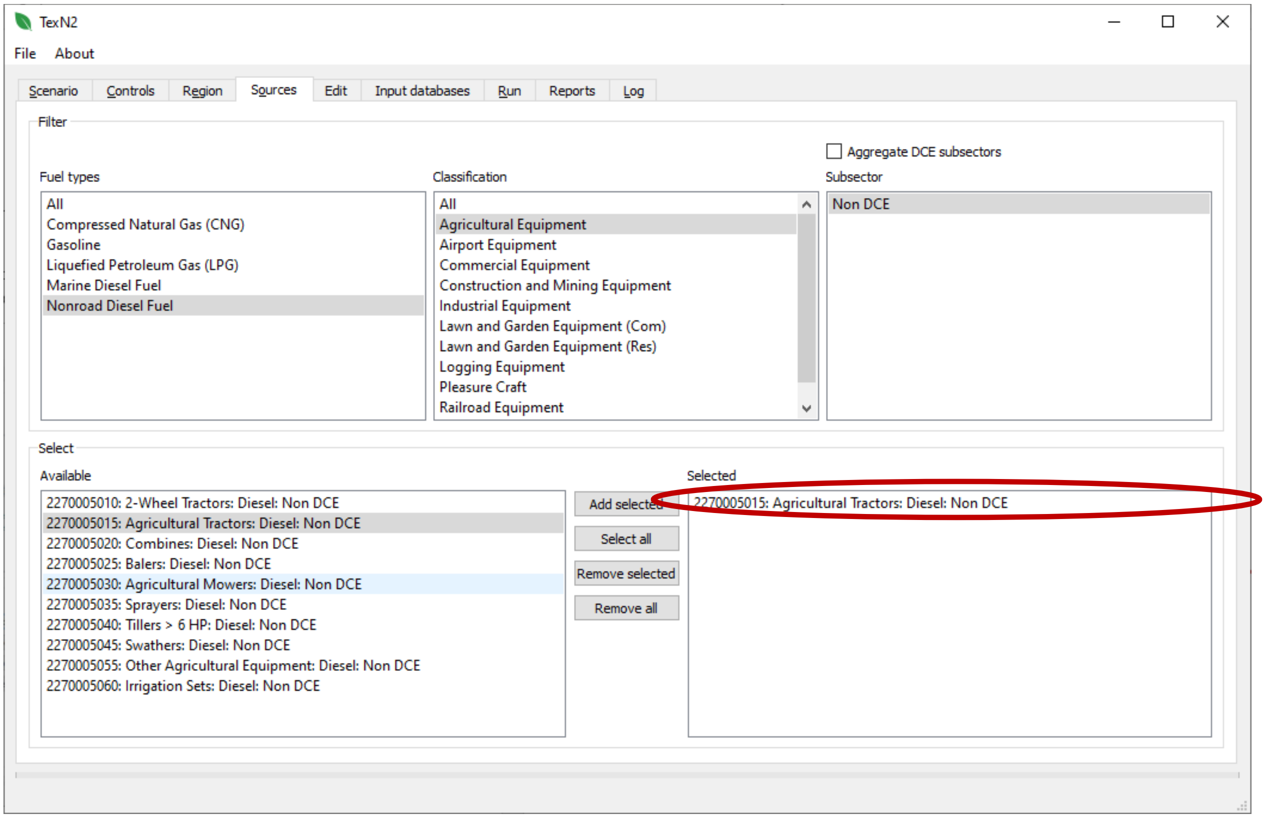
- Select the Skid Steer Loaders subsector
- Scroll through the "Available" box and select 270002072
- Click "Add selected" to add it to the "Selected" box.



4.2 Setup of a TexN2 Run for Diesel Agricultural Tractors Only

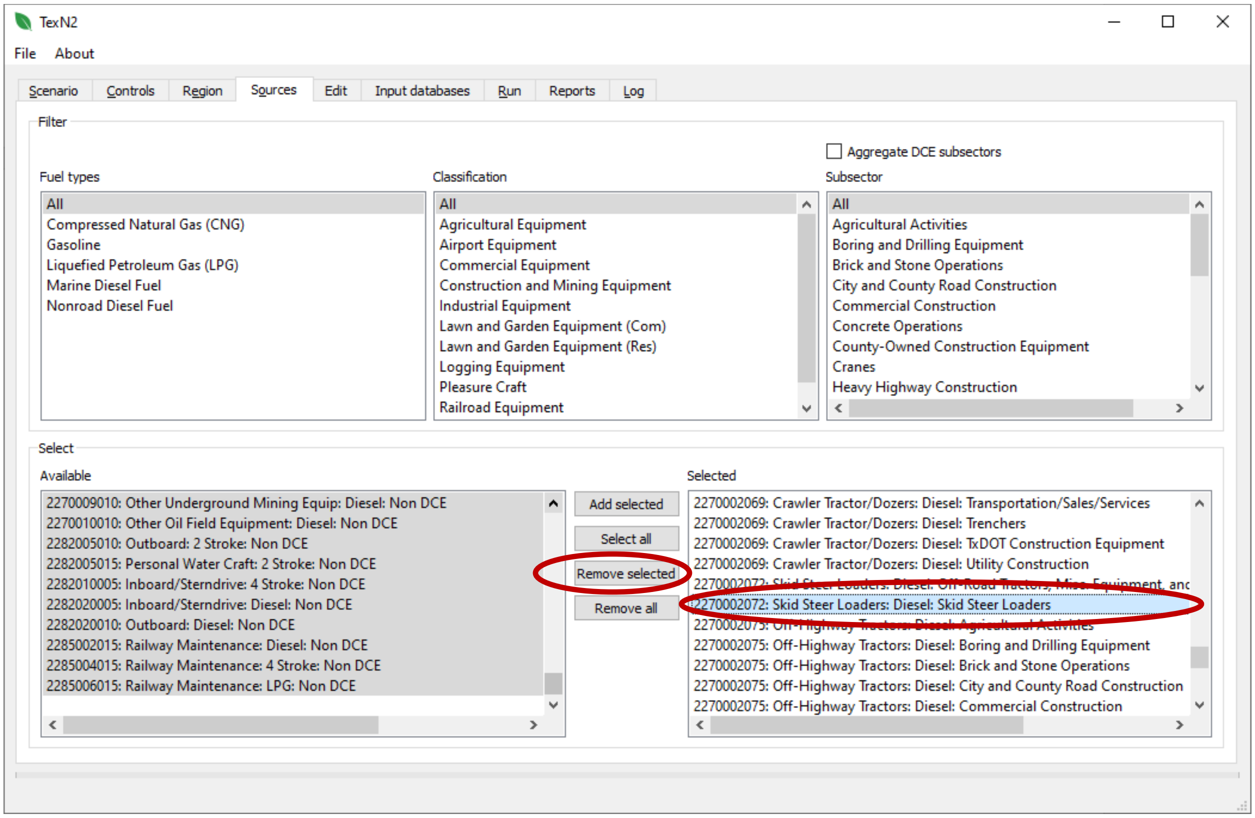
The agricultural tractor scrap curve only applies to diesel equipment above 25 hp. The associated SCC is 2270005015, and it is included in the Non-DCE subsector. The GUI will have the selection shown below.

- Select the Non-DCE subsector
- Select 2270005015 from the “Available” box
- Click “Add selected” to add it to the “Selected” box.

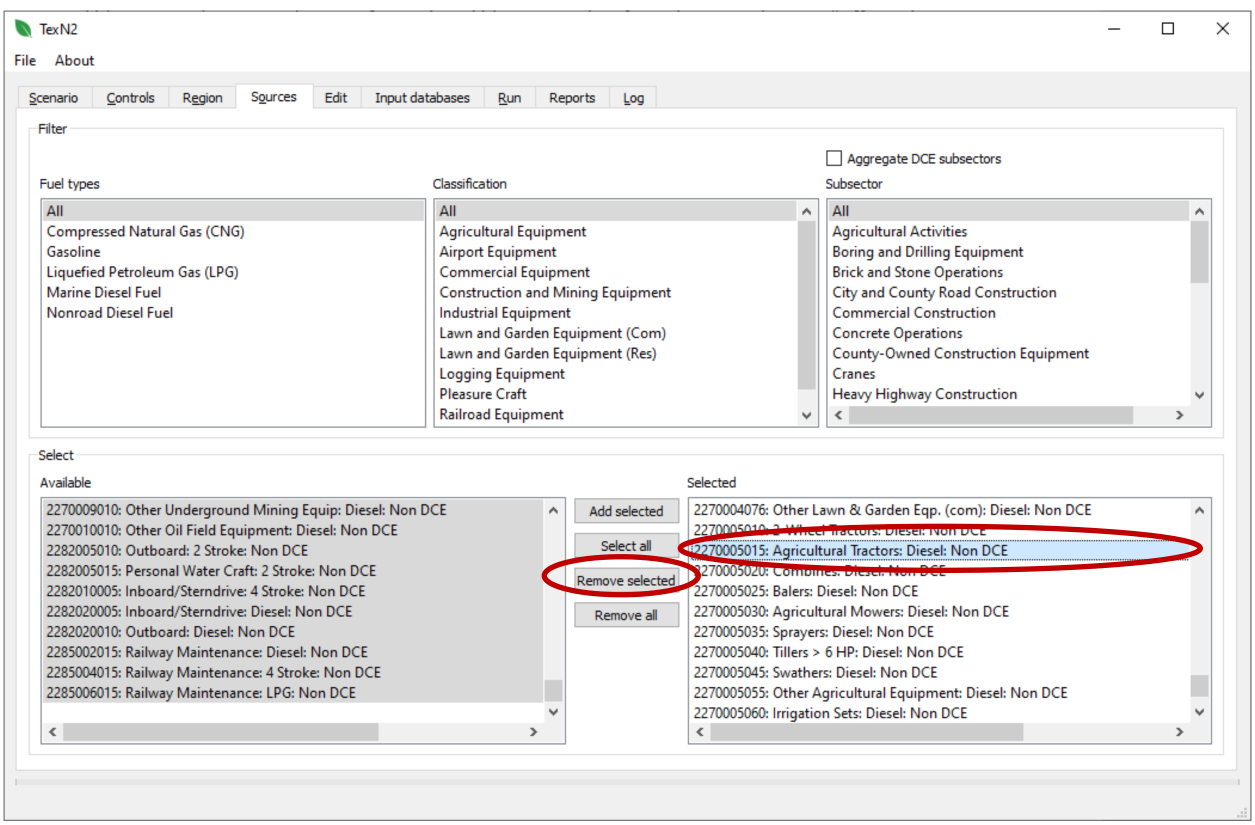


3.3 Setup of the "Everything Else" Run

To set up the "everything else" run, use the "select all features" to add all SCCs to the Selected box. Then scroll within the "Selected" box to click and remove the 270002072 and 2270005015 SCCs. The example below shows a fully populated SCC list, and the removal of Skid Steers (270002072) in the Skid Steer Loaders DCE subsector. [Note Skid Steer Loaders from the DCE subsector "Off-Road Tractors…" should remain in the third run because it should receive the default scrappage curve.]



Repeat the process to remove diesel agricultural tractors, as shown below.



Tip: When working from saved versions of .JSON files, double-check the intended selections on the Controls tab (e.g., in order to execute TxLED adjustments). These selections are not saved as part of the .JSON file; rather they refer to a TexN2 configuration file that changes according to the most recent run performed. **Please ensure these selections are correct in the current run before executing.**

4. How to update growth factors in the future (optional)

The zip file **Optional_Future_Update_TexN2_Pop_via_Growth_Factors.zip** posted on ERG's FTP site allows the TCEQ to change equipment populations in the future, once the effects of the coronavirus pandemic are better understood.

There are at least two options for the TCEQ to implement updated equipment populations. The simplest way is by using the TexN2 utility GUI `Edit` tab. However, this is only practical for updating a small number of county/SCC combinations.

In case the TCEQ wishes to update a large number equipment of populations for many counties and DCE subsectors, the ZIP file includes a MySQL script named ***_ImportGrowth_forTCEQ.sql*** along with **24 template CSV files** that contain county-level growth factors relative to year 2012. The TCEQ should use the template CSV files and make edits directly to these files to reflect desired alternate growth factors. Do not change the CSV file names or format of the contents (including county spelling/capitalization). The template CSVs are named according to the DCE subsector ID code. First, save the script and CSVs to a location on your local computer. A suggested location is inside your utility directory (create a new "growth" folder such as C:\TexN2_v0_1_2_17jul2020\growth). Second, make any desired changes to the CSV files to reflect alternate growth factors. Lastly, open MySQL Workbench and click "File>Open SQL script" to navigate to the script to open it. Once the script is open in Workbench, follow the instructions in the header of the script to update the CSV file paths and execute the script. The script can take up to 30 minutes to finish because the script is rebuilding the `populationyears` table from growth factors, and the table has nearly 115 million rows. ***Executing this script makes permanent changes to the TexN2 database.***