Texas A&M Transportation Institute

Protocols for the Development of Emission Inventory Modeling Parameters and Calculation of Local Values for Texas

FINAL REPORT

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TECHNICAL MEMORANDUM – DRAFT FOR REVIEW

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Sub-Task 4.2 – Final Report

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Abstract: The draft report, developed by the Texas A&M Transportation Institute for the Texas Commission on Environmental Quality, focuses on standardizing the collection, analysis, processing, and dissemination of modeling parameters in the EPA's Motor Vehicle Emission Simulator (MOVES) format. These parameters are crucial for creating defensible, reproducible emissions inventories, developing state implementation plans (SIPs), and aiding transportation conformity. The report introduces automated Python scripts for processing these parameters, replacing previous manual methods, and includes a user-friendly dashboard for accessing these inputs. Individual chapters detail the data sources, methodologies, automation scripts, and quality assurance for parameters involving meteorology, fuels, vehicle age distribution, and alternative vehicle fuels technology (AVFT).

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AVFT	Alternative Vehicles Fuel Technology
BPA	Beaumont-Port Arthur
CDB	County database
CDO	Climate Data Online
CFR	Code of Federal Regulations
CG	Conventional Gasoline
CNG	Compressed Natural Gas
CO	Carbon Monoxide
COG	Council of Government
CSV	Comma-separated values
DFW	Dallas-Fort Worth
DOE	Department of Energy
EI	Emissions inventory
EIA	Energy Information Administration
EPA	Environmental Protection Agency
ERG	Eastern Research Group
ETBE	Ethyl Tertiary Butyl Ether
FCAA	Federal Clean Air Act
FIPS	Federal Information Processing Standards
FTD100	Fischer-Tropsch Diesel
GIS	Geographic information system
HGB	Houston-Galveston-Brazoria
HPMS	Highway Performance Monitoring System

ISD	Integrated surface data
MOVES	Motor Vehicle Emission Simulator
MPO	Metropolitan Planning Organization
MSA	Metropolitan Statistical Areas
MSAT	Mobile Source Air Toxic
MSN	Mnemonic Series Names
MTBE	Methyl Tertiary Butyl Ether
NA	Nonattainment Area
NAAQS	National Ambient Air Quality Standard
NCDC	National Climatic Data Center
NGMS	Northrop Grumman Mission Systems
NIPER	National Institute for Petroleum and Energy Research
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrogen Oxides
NWS	National Weather Service
PAH	Polycyclic Aromatic Hydrocarbon
PM	Particulate Matter
QA/QC	Quality assurance/quality control
RFG	Reformulated Gasoline
RVP	Reid Vapor Pressure
SEDS	State Energy Data System
SIP	State Implementation Plan
SQL	Structured query language
SUT	Source use types

SwRI	Southwest Research Institute
TAC	Texas Administrative Code
TAME	Tertiary Amyl Methyl Ether
TAMIS	Texas Air Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TTI	Texas A&M Transportation Institute
TxDMV	Texas Department of Motor Vehicles
TxDOT	Texas Department of Transportation
TxLED	Texas Low Emission Diesel
ULSD	Ultra Low Sulfur Diesel
UTC	Coordinated Universal Time
VOC	Volatile Organic Compound
VMT	Vehicle miles traveled

EXECUTIVE SUMMARY

This report was developed by the Texas A&M Transportation Institute (TTI) study team for the "*Protocols for Development of Emission Inventory Modeling Parameters and Calculation of Local Values for Texas*" study, sponsored by the Texas Commission on Environmental Quality (TCEQ). The goal is to develop standardized protocols for collecting, analyzing, processing, and publicizing input parameters in the Environmental Protection Agency's (EPA's) Motor Vehicle Emission Simulator (MOVES) format. These modeling parameters must be defensible and reproducible. They will be used to develop TCEQ mobile source emissions inventories (EI) and aid in state implementation plan (SIP) development and transportation conformity determination.

In addition to developing standardized protocols, the TTI team also created Python scripts to automate the processing of these modeling parameters from the latest available data. Previous techniques, involving using either Visual Basic or Microsoft Excel to process raw data into the MOVES format, needed to be fully automated and required staff to spend considerable time processing and quality-assuring the outputs. The new scripts allow automatic and seamless raw data processing into the desired formats. Additionally, since the scripts have been quality assured/quality controlled (QA/QC) in this study, where the outputs of the scripts were compared to those produced using the prior methods, less time will be needed to QA/QC the outputs. These new scripts have also eliminated much of the required manual editing under the old methods, reducing the potential for human errors.

This report presents a discussion of the standardized protocols and scripts produced to automate the processing of the meteorology, fuels, age distribution, and Alternative Vehicles Fuel Technology (AVFT) input parameters, as well as the Texas Low Emission Diesel (TxLED) post-processing factors. Following a chapter providing background, individual chapters by specific parameter cover the data sources used, the overall methodology, the automation scripts developed for the input parameter, and the QA/QC of the outputs.

This report also includes descriptions of dashboards for all the parameters and the user guides for the dashboards, which can be found under Chapter 6: Visualization[1]. The TTI

[1] The TTI team developed a series of visualization dashboards on Tableau. The development of these dashboards was not part of the grant activity description; it was extra work that the TTI team decided to perform as we believe it adds value to this study.

team developed a dashboard to visualize and aid users in downloading the input parameters based on their selection. Historically, the modeling input parameters were sent as needed and shared through electronic postings or email. The TTI team believes this dashboard will eliminate the need to request county or district-specific input parameters from TCEQ or TTI. Although this dashboard is not among the agreed-upon deliverables, the TTI study team developed it as it allows more access to the input parameters and can save staff time in the long run[2].

[2] In the TTI team's opinion, users are required to have some programming language knowledge to effectively use the provided scripts. Thus, the TTI team decided to develop the dashboard to aid in this process, with the goal of allowing users to visually check the data and download it.

1 BACKGROUND

The Texas Commission on Environmental Quality (TCEQ) works with local planning districts, the Texas Department of Transportation (TxDOT), and the Texas A&M Transportation Institute (TTI) to provide on-road mobile source emissions inventories (EIs) of air pollutants. The TxDOT typically funds transportation conformity determinations required under 40 Code of Federal Regulations (CFR) Part 93. The TCEQ funds mobile source EI work in support of Federal Clean Air Act (FCAA) requirements, such as supporting the attainment of the National Ambient Air Quality Standard (NAAQS) and the study and control of hazardous air pollutants, including those from motor vehicles and motor vehicle fuels (as mandated under FCAA sections 202 and 211).

The TCEQ and other Texas stakeholders use multiple local input parameters to develop improved EIs that support state implementation plans, motor vehicle emissions budget assessments, general conformity assessments, federal reporting requirements, and compliance demonstrations. Historically, individual developers developed these modeling input parameters as needed and shared them through electronic postings or e-mail. A standardized development and distribution process for the modeling parameters promotes documentation of information that is more consistent, accessible, and transparent than the current development and distribution process.

This study aimed to develop standardized protocols for collecting, analyzing, processing, and publicizing input parameters for developing TCEQ mobile source EIs. For the TCEQ to have defensible and reproducible modeling parameters for EI development, it was necessary to develop and document standard practice protocols, obtain consistent data sets, and publish results for access by all stakeholders.

1.1 MOVES Versions

The Environmental Protection Agency's (EPA's) official emission model is the Motor Vehicle Emission Simulator (MOVES). It calculates emissions for mobile sources, providing national, county, and project-level estimates for criteria air pollutants, greenhouse gases, and air toxics. MOVES4, released in September 2023, is the latest version of EPA's MOVES emission model that replaced the previous MOVES 3.1. EPA's release of MOVES4 for SIPs and transportation conformity analyses becomes effective on September 12, 2023. This marks the beginning of a two-year transportation conformity grace period, concluding on September 12, 2025. After this deadline, using MOVES4 becomes mandatory for new transportation conformity analyses outside of California for regional emissions and hot-spot analyses [1].

MOVES4 was released toward the end of this study. At the same time, most works were developed using MOVES3.1 as the input parameters for meteorology, fuels, registration, and AVFT developed in this study are compatible with MOVES3 [2], the protocols and scripts developed in this study were not altered with the version change. The effects of Texas Low Emission Diesel (TxLED) are not included in either version of MOVES; instead, TTI made modifications to the post-processing procedure, which, independently from MOVES, applies emissions adjustment factors to incorporate the effects of TxLED in EIs of the 110 Texas counties covered by the program[3]. Thus, the MOVES version update did not affect the protocols the TTI developed for TxLED.

1.2 Objectives

For this study, the TTI air quality and emissions team (henceforth known as "the TTI team") developed or refined existing protocols for processing EI development data into standard inputs. Modeling input parameter protocols were developed for:

1. Meteorological
    a. Temperature
    b. Humidity
    c. Barometric pressure
2. Fuel
    a. Fuel Formulation
    b. Fuel Supply
3. Vehicle Registration
    a. Age Distributions
    b. Statewide Alternative Vehicles Fuel Technology (AVFT)
4. TxLED

In addition, to reduce processing time and chances of human error, the TTI team also developed computing tools or scripts to automate the data processing for each category into standard formats and content for use in EI development. The processing protocols included geographic coverage and geographic boundaries consistent with emissions assessment requirements, as follows:

[3] A list of Texas counties affected by TxLED is available here: https://www.tceq.texas.gov/airquality/mobilesource/txled/txled-affected-counties.

1. The meteorological data was processed into inputs used for each Texas county, each TxDOT district, each metropolitan planning organization (MPO) jurisdiction area, and each nonattainment area (NA).
2. The fuel data was processed into inputs used for geographic boundaries based on the EPA's MOVES fuel regions.
3. The vehicle data was processed into vehicle population and age distributions for each MOVES source use type (SUT) and each Texas county.
4. The TxLED post-processing factors were developed using the processed fuel data. TxLED only affects 110 central and eastern Texas counties. To create the post-processing factors for TxLED counties, the TTI assumed that all counties within the same MOVES fuel region have the same fuel formulation.

To accomplish these tasks, the TTI team incorporated the most recently available data, as of the writing of this report, for each category. The primary data sources used were Texas county-level vehicle registration (provided by the TxDMV through TxDOT), monthly meteorological data, and seasonal fuel data encompassing results from the Summer Fuel Field Studies (provided by the TCEQ) and compliance data collected by the EPA for the Federal Reformulated Fuel Program, among others to be discussed in more detail in the following chapters.

1.3 Report Structure

This report represents the deliverable for this study's fourth and final task. The following four chapters discuss TTI's protocols for developing meteorology, fuel, vehicle age distribution, AVFT MOVES input parameters, and the TxLED post-processing factor, respectively. The last chapter includes a set of user guides for a dashboard that the TTI team developed to visualize and aid users in downloading the input parameters. Although this dashboard is not among the agreed-upon deliverables, the TTI team developed it as an extra as it allows more accessible access to the input parameters and can save staff time.

2 METEOROLOGY

The topics covered in this chapter were performed under Task 3.1 of this study, titled "Description of the protocol and scripts for processing Met Data including a list of references, data sources, and input and output electronic files." The technical memo for Task 3.1 was submitted to the TCEQ project manager on August 15^{th}, 2023.

This chapter includes the following sections:

1. Introduction – A brief background on Texas meteorology inputs as well as details of the MOVES meteorology framework for inputs to MOVES,
2. Data sources – A description of the current data sources for developing Texas, local meteorology inputs to MOVES,
3. Methodology and Procedures – Provides details of the main assumptions and typical steps in the current process of applying the referenced data sources in developing and updating complete Texas meteorological input data sets,
4. Comprehensive Database and Processing Scripts – Describes the new database developed and Python scripts written to produce it.
5. QA/QC

2.1 INTRODUCTION

Accurate meteorological inputs (i.e., temperature, barometric pressure, and relative humidity) are essential to developing on-road EIs and supporting the TCEQ's development of state implementation plan (SIP) emission goals for Texas. Historically, the TTI team has used the meteorological input parameters developed by TCEQ when developing EIs. These input parameters were previously developed using an Excel-based approach. However, editing and updating a large Excel file with multiple sheets requires considerable staff knowledge, time, and effort.

The purpose of Task 3.1 was to develop standardized protocols for collecting, analyzing, processing, and publicizing meteorological inputs used in developing TCEQ mobile source EIs. This chapter documents the TTI team's procedures to automate the preparation of meteorological inputs for the EIs. The new automated process minimizes the effort and time needed for staff to prepare and maintain meteorological inputs and perform quality assurance/quality control (QA/QC) on them, ultimately expediting the development of the EIs.

2.1.1 MOVES Meteorology Data Framework

Meteorological data were utilized to create MOVES inputs for the EI modeling scenarios, specifically the 'county' table (containing barometric pressure [inch of mercury] and altitude) and the 'zonemonthhour' table (having temperature [Fahrenheit] and relative humidity [%RH]). The TCEQ meteorology data was provided in spreadsheet form. The TTI team then created a MySQL 'meteorological' database using TCEQ's data, which was subsequently queried to produce MOVES input parameters. Table 2-1 Shows an example of the "zonemonthhour" as prepared by TCEQ. In this case, the input table represents input data for Bexar County's summer season EI.

Table 2-1. Zonemonthhour Input Table for the Summer Season in Bexar County

monthID	zoneID	hourID	temperature	temperatureCV	relHumidity	heatIndex	specificHumidity	relativeHumidityCV
7	480290	1	78.04	\N	74.67	\N	\N	\N
7	480290	2	77.14	\N	77.64	\N	\N	\N
7	480290	3	76.5	\N	80.63	\N	\N	\N
7	480290	4	76.15	\N	81.99	\N	\N	\N
7	480290	5	75.91	\N	82.8	\N	\N	\N
7	480290	6	75.63	\N	83.57	\N	\N	\N
7	480290	7	75.96	\N	84.24	\N	\N	\N
7	480290	8	77.83	\N	82.47	\N	\N	\N
7	480290	9	80.4	\N	76.29	\N	\N	\N
7	480290	10	83.01	\N	68.42	\N	\N	\N
7	480290	11	85.44	\N	61.75	\N	\N	\N
7	480290	12	87.71	\N	54.9	\N	\N	\N
7	480290	13	89.65	\N	50.26	\N	\N	\N
7	480290	14	91.15	\N	47.13	\N	\N	\N
7	480290	15	92.59	\N	43.17	\N	\N	\N
7	480290	16	93.36	\N	40.94	\N	\N	\N
7	480290	17	93.61	\N	40.03	\N	\N	\N
7	480290	18	93.04	\N	39.65	\N	\N	\N
7	480290	19	91.25	\N	42.14	\N	\N	\N
7	480290	20	88.25	\N	46.53	\N	\N	\N
7	480290	21	85.24	\N	53.45	\N	\N	\N
7	480290	22	83.01	\N	59.96	\N	\N	\N
7	480290	23	81.22	\N	64.36	\N	\N	\N
7	480290	24	79.58	\N	69.47	\N	\N	\N

Table 2-2 Shows an example "county" input table as prepared by TCEQ. In this case, the input table represents inputs for Bexar County's summer season EI. Since MOVES3, two fields—CountyTypeID and Metropolitan Statistical Areas (MSA)—have been added to the county table. A CountyTypeID of 1 indicates that the county is an MSA county. The MSA column specifies which MSA the county belongs to; for example, Bexar County's MSA is 'San Antonio-New Braunfels; TX.' The off-network idling emission rates vary between MSA and non-MSA counties, making the distinction of the county type necessary.

Table 2-2. County Input Table for the Summer Season in Bexar County

county ID	state ID	county Name	altitude	GPAFract	Barometric Pressure	Barometric PressureCV	County TypeID	msa
48029	48	Bexar County	L	0	29.91	\N	1	San Antonio-New Braunfels; TX

2.1.2 Previous Texas-based Meteorological Inputs

The most recent Texas-based meteorological inputs were developed using Excel spreadsheets by TCEQ based on 2019 weather data. MonthID was used to represent the four seasons. The following are the monthIDs associated with each season in the MOVES meteorological inputs:

- Spring (March, April, and May): monthID = 4,
- Summer (June, July, and August): monthID = 7,
- Fall (September, October, and November): monthID = 10,
- Winter (December, January, and February): monthID = 1,

The 2019 meteorological inputs were developed for both the county and district levels. Each county has its county-specific meteorology for county-level inputs, whereas, for district-level inputs, all counties within that district share the district-average meteorology. Hence, two MariaDB databases, with the following tables, were developed from the 2019 meteorological inputs, which TCEQ provided:

- _2019met_seasonal_254counties_tceq
    - county_ann: county table for 254 counties with county-level annual average barometric pressure.

- county_fal: county table for 254 counties with county-level fall season barometric pressure.
- county_spr: county table for 254 counties with county-level spring season barometric pressure.
- county_sum: county table for 254 counties with county-level summer season barometric pressure.
- county_win: county table for 254 counties with county-level winter season barometric pressure.
- zonemonthhour: zonemonthhour table for 254 counties with county-level four-season hourly temperature and humidity data.

- _2019met_seasonal_25districts_254counties_tceq.
    - county_ann: county table for 254 counties with district-level annual average barometric pressure.
    - county_fal: county table for 254 counties with district-level fall season barometric pressure.
    - county_spr: county table for 254 counties with district-level spring season barometric pressure.
    - county_sum: county table for 254 counties with district-level summer season barometric pressure.
    - county_win: county table for 254 counties with district-level winter season barometric pressure.
    - zonemonthhour: zonemonthhour table for 254 counties with district-level four-season hourly temperature and humidity data.

2.2 Data Sources

This section describes the data sources that the TTI team acquired to develop the meteorology input tables for MOVES. The two primary data sources that the TTI team used to create the meteorological inputs are the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) and the TCEQ's Texas Air Monitoring Information System (TAMIS).

2.2.1 NOAA'S NCDC

The NCDC's Climate Data Online (CDO) portal contains global historical weather and climate data archives. These data have been QA/QCd and include the daily, monthly, seasonal, and annual measurements of various meteorological data such as outdoor temperature, precipitation, wind direction, and wind speed. The TTI team downloaded the 2022 annual climate integrated surface data (ISD) from the NCDC website[4]. A screenshot of the raw 2022 ISD data is shown Figure 2-1.


```
0045010010999992019010410004+70939-008669FM-12+001099999V0203491N001219999999999999999+00151+00031101131ADDMA199999101011MD1
0045010010999992019010411004+70939-008669FM-12+001099999V0200551N002819999999999999999+00111+00001101131ADDMA199999101011MD1
0219010010999992019010412004+70939-008669FM-12+001099999V0202131N0043199999999010000199+00251+00061101171ADDAA106999999AY12106
0089010010999992019010413004+70933-008667FM-12+000999999V0202401N0050199999999N999999999+00181-00041101241ADDMA199999101121MD1
0053010010999992019010414004+70939-008669FM-12+001099999V0201381N004219999999999999999+00221-00041101261ADDMA199999101141MD1
0155010010999992019010415004+70939-008669FM-12+001099999V0202801N0100199999999010000199+00211-00021101281ADDAY121031AY221031GA
0053010010999992019010416004+70939-008669FM-12+001099999V0202481N003419999999999999999+00251-00071101371ADDMA199999101251MD1
0053010010999992019010417004+70939-008669FM-12+001099999V0201911N003419999999999999999+00221-00121101421ADDMA199999101301MD1
0206010010999992019010418004+70939-008669FM-12+001099999V0201971N0031199999999004500199+00271-00171101471ADDAA112999999AY12106
0045010010999992019010419004+70939-008669FM-12+001099999V0201291N002819999999999999999+00201-00071101481ADDMA199999101361MD1
0045010010999992019010420004+70939-008669FM-12+001099999V0200441N002319999999999999999+00121-00051101511ADDMA199999101391MD1
0045010010999992019010421004+70939-008669FM-12+001099999V0202161N002119999999999999999+00111-00061101511ADDMA199999101391MD1
0045010010999992019010422004+70939-008669FM-12+001099999V0201771N001319999999999999999+00111-00031101481ADDMA199999101361MD1
0045010010999992019010423004+70939-008669FM-12+001099999V0202031N003219999999999999999+00121+00001101491ADDMA199999101371MD1
```


Figure 2-1. Screenshot of Sample Raw NOAA'S NCDC ISD Data

As depicted in Figure 2-1, the raw data is presented in a fixed-length format. Information from NOAA's "*isd-format-document*" user guide[5] was used to parse the data for the following essential information necessary for developing the meteorological inputs:

- **Station information**: Including station identifiers, coordinates, and elevation. The information is used to determine a station's location and time zone.
- **Date and time**: Including the date and time the meteorological data was collected. The date and time are in the Coordinated Universal Time Code (UTC). All the dates and times are converted to the stations' locations and adjusted for daylight savings.
- **Meteorological data**: Including air temperature, air dew point temperature, atmospheric sea level pressure, and corresponding data quality information.

[4] The annual ISD meteorological data are available here: https://www.ncei.noaa.gov/data/global-hourly/.

[5] NOAA NCDC, "isd-format-document" https://www.ncei.noaa.gov/data/global-hourly/doc/, accessed July 5, 2022

2.2.2 TCEQ'S TAMIS

The TCEQ operated and maintained TAMIS[6] , which contains ambient air quality data values for various parameters, including meteorological data and pollutants. The TTI team downloaded the raw data reports containing air quality data and associated information stored in the TAMIS database. A guide to download this data is included in Appendix 1-A. The 2022 data were collected from approximately 230 Texas stations, including relative humidity, barometric pressure, and temperature information.

2.3 METHODOLOGY AND PROCEDURES

This section summarizes the methodology for processing the ISD and TCEQ's TAMIS data for 2022 meteorological inputs. The TTI team's procedures for preparing the 2022 meteorological inputs are shown in Figure 2-2.

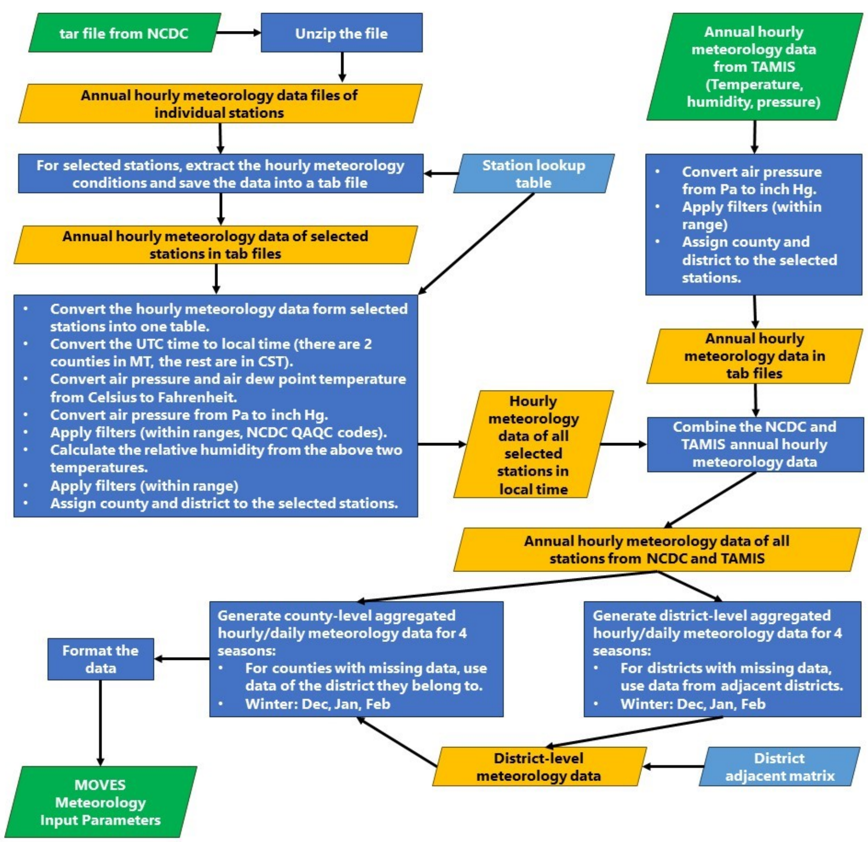

Figure 2-2. Overview of the TTI Procedures for Preparing Meteorological Inputs

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[6] The annual meteorological data from TAMIS database are available for download from this website: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome.

2.3.1 Processing of NCDC's ISD Data

A Python script was developed to automate the following steps to process the ISD data, as depicted in Figure 2-2:

1. Unzip the downloaded ISD data.
2. For stations within the boundaries of Texas, extract the hourly met conditions and save the data into a tab-delimited file using the station lookup table.
3. Combine the hourly met data from different stations into one table.
4. Convert the Coordinated Universal Time (UTC) stamps to local time stamps. (252 out of 254 counties are in the central time zone, and 2 out of 254 counties are in the mountain time zone)
5. Convert the air temperature unit and air dew point temperature unit from °C (raw ISD data) to °F (MOVES data requirement) using the formula:

   $$T_F = (T_C \times 1.8) + 32$$

   Where T_F is the air temperature or air dew temperature in °F, , and T_C is the air temperature or air dew temperature in °C.
6. Apply temperature filters to filter out abnormal data points. (outside the range of -20 and 120 °F)
7. Convert air pressure data from hectopascal (raw ISD data) to inches of mercury (MOVES data requirement) using the formula:

   $$air_{press\_hg} = air_{press\_hp} \times 0.02953$$

   Where air_{press_hg} is the air pressure in inches of mercury, and air_{press_hp} is the air pressure in hectopascal?
8. Apply air pressure filters to filter out abnormal data points. (Outside the range of 20 and 35 inches of mercury)
9. Calculate the relative humidity from the air dew point and air temperatures. Since the ISD does not contain relative humidity data needed by MOVES, the TTI team applied the following equation to estimate the relative humidity (air_{RH}) using air dew point temperature and air temperature:

   $$air_{RH} = 100 \times e^{\frac{17.625 \times TD}{243.04+TD}} / e^{\frac{17.625 \times T}{243.04+T}}$$

Where TD is the dew point temperature ℃, , and T is the air temperature in ℃.

10. Apply humidity filters to filter out abnormal data points. (outside the range of 1 percent and 100 percent)

11. Apply a quality control filter to filter out the records whose quality code is "Suspect" or "Erroneous" in the ISD data.

12. Process meteorological data and create hourly air temperature, air relative humidity, and air pressure data for each station located within Texas or offshore of Texas in the ISD data for the entire year. An example of the processed hourly temperature data is shown in Table 2-3.

Table 2-3. Hourly Temperature for Station "720110_53983" from January 8th - 14th, 2022

HourID	Jan 8th	Jan 9th	Jan 10th	Jan 11th	Jan 12th	Jan 13th	Jan 14th
1	64.4	29.6	21.2	32.6	35.6	34.4	27.8
2	62.0	28.4	19.4	39.2	34.4	30.8	25.4
3	60.8	26.6	19.4	33.2	32.6	30.8	23
4	62.6	24.8	18.8	31.4	32.0	29.0	21.2
5	62.6	23.0	17.0	27.2	32.0	27.8	20.6
6	62.6	21.8	15.8	25.4	31.4	27.8	19.4
7	61.4	21.2	17.0	25.4	30.2	26.6	18.8
8	59.6	21.2	15.8	26	29.6	27.2	19.4
9	59.0	23.6	23.0	32.6	36.8	37.4	24.2
10	63.8	27.8	32.0	44.6	49.4	43.4	29.6
11	68.0	32.0	41.0	50.6	58.4	42.8	31.4
12	71.6	36.2	48.2	58.4	63.2	44	33.2
13	76.4	39.8	53.0	63.8	65.6	45.2	36.2
14	77.6	42.8	55.4	67.4	68.0	47.6	39.2
15	78.8	44.6	59.0	69.8	68.6	46.4	40.4
16	77.6	44.6	59.0	69.8	69.2	46.4	41.0
17	77.0	44.6	59.0	68.0	68.0	45.8	41.0
18	71.6	42.2	54.2	63.2	64.4	42.8	40.4
19	61.4	35.6	47.6	57.2	56.0	38.6	39.2
20	58.4	30.8	39.8	51.8	48.8	37.4	39.2
21	41.6	27.2	38.0	43.4	48.8	34.4	39.2
22	35.6	27.2	31.4	39.8	42.8	32.0	38.0
23	33.8	26.0	32.0	38.6	38.6	30.2	37.4
24	31.4	24.2	32.6	38.0	35.0	29.0	38.6

2.3.2 Processing of TCEQ's TAMIS Data

A sample of raw hourly air pressure data from TAMIS is shown in Table 2-4. Since the TAMIS raw data directly provides air temperature, air relative humidity, and air barometric pressure in units MOVES required, comparatively fewer steps were needed to process the raw data into the MOVES format.

Table 2-4. Sample Hourly Air Pressure Data from TAMIS for Dallas County, Texas

County	Site ID	Date	Time	Air pressure
113	69	20220101	0:00	989.029
113	69	20220101	1:00	988.916
113	69	20220101	2:00	988.581
113	69	20220101	3:00	988.464
113	69	20220101	4:00	988.096
113	69	20220101	5:00	988.462
113	69	20220101	6:00	988.376
113	69	20220101	7:00	988.198
113	69	20220101	8:00	988.219
113	69	20220101	9:00	989.133
113	69	20220101	10:00	989.659
113	69	20220101	11:00	989.819
113	69	20220101	12:00	989.143
113	69	20220101	13:00	988.682
113	69	20220101	14:00	990.156
113	69	20220101	15:00	992.893
113	69	20220101	16:00	995.093
113	69	20220101	17:00	996.408
113	69	20220101	18:00	997.68
113	69	20220101	19:00	999.006
113	69	20220101	20:00	1000.47
113	69	20220101	21:00	1002.35
113	69	20220101	22:00	1003.97
113	69	20220101	23:00	1004.9

The Python scripts mainly focused on automating the following tasks:

1. The Convert unit from hectopascal to inch of mercury uses hectopascal to inch of mercury using the same formula presented previously in processing NCDC's ISD data.

2. Apply the following filters used by TCEQ to the TAMIS meteorological data to filter out abnormal data points (outside of the ranges):

$$1 \leq air_{RH} \leq 100$$

$$27 \leq air_{press\_hg} \leq 32$$

$$1.5 \leq air_{temp} \leq 113$$

3. Process the meteorological data into hourly temperature, relative humidity, and air pressure data for each station in the TAMIS data for 2022.

2.3.3 Meteorological Inputs Development

The meteorological data of all the stations in the two data sources, NCDC and TAMIS, were combined into one database to develop the MOVES meteorological inputs. TTI's EI procedure requires meteorological inputs at various temporal and spatial resolutions:

- Temporal resolution (month or group of months)
  - Monthly,
  - Seasonal.
- Spatial resolution (group of counties)
  - Each Texas county (254 counties)
  - Each TxDOT District (26 districts in total[7])
  - Each MPO jurisdiction area (21 MPOs in total)
  - Each NA (4 regions, 20 counties in total[8])

The hourly data of individual stations in the database were aggregated into the required temporal and regional resolution by taking the average data collected within the necessary month group from all stations within the counties. As a calculation example,

[7] For El Paso district (D11), the data was separated into two districts: El Paso Central (D11C) and El Paso Mountain (D11M) due to the different time zone of these two districts, which led to different time processes in meteorological monitoring reports.

[8] **San Antonio Region (1 county):** Bexar; **Houston-Galveston-Brazoria (HGB) Region (8 counties):** Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller; **Dallas-Fort Worth (DFW) Region (10 counties):** Collin, Dallas, Denton, Ellis, Johnson, Kaufman, Parker, Rockwall, Tarrant, Wise; **El Paso Region (1 county):** El Paso.

Table 2-5 shows the average hourly meteorological data for the winter seasons of 2022 within the Dallas district. The data were created by taking the average hourly temperature, relative humidity, and barometric pressure data for winter months (December, January, and February) from all stations in the Dallas district.

Table 2-5. Hourly Temperature, Relative Humidity, and Barometric Pressure in Winter Season of 2022 for Dallas District, Texas

HourID	Air Temp (F)	Relative Humidity (%)	Barometric Pressure (inch of mercury)
1	43.82	67.92	30.12
2	43.06	69.71	30.12
3	42.38	71.34	30.12
4	41.78	72.59	30.12
5	41.14	73.99	30.12
6	40.64	74.60	30.12
7	40.11	75.42	30.12
8	39.97	75.77	30.12
9	42.02	70.93	30.12
10	45.00	63.42	30.12
11	47.95	56.88	30.12
12	50.41	52.17	30.12
13	52.30	48.67	30.12
14	53.75	46.15	30.12
15	54.63	44.95	30.12
16	54.91	44.93	30.12
17	54.36	46.27	30.12
18	52.54	49.65	30.12
19	50.35	53.80	30.12
20	48.73	56.73	30.12
21	47.50	59.40	30.12
22	46.47	61.53	30.12
23	45.53	63.67	30.12
24	44.64	65.77	30.12

In some cases, the meteorological inputs at the required temporal or regional resolution can be missing or incomplete because the corresponding raw data is missing (e.g., no station in some counties) or incomplete (e.g., missing data for some hours). The TTI team followed the methods used by TCEQ to fill in the missing or incomplete data at the county or district level:

- For districts with missing or incomplete data, their data was replaced entirely by the average of corresponding data from adjacent districts.
- For counties with missing or incomplete data, their data was replaced entirely by the corresponding data of the districts in which they are located.

2.4 Comprehensive Database and Processing Scripts

This section discusses the Python script developed to automate the data processing procedures as discussed in Section 2.3.

2.4.1 Data Structure

The data structure for the monthly or seasonal region-level table and the zonemonthhour table in the database are as follows:

- Monthly/Seasonal Region-level table:
    - countyID - This column lists the county code.
    - stateID – For Texas, the value is 48.
    - countyName - This column lists the name of the county.
    - barometricPressure - This column lists the calculated barometric pressure.
    - countyTypeID - This column lists the MSA type, where 0 indicates non-MSA and 1 indicates MSA.
    - msa - This column lists the MSA name.
- zonemonthhour table:
    - monthID - This column lists the month of the data, ranging from 1 to 12.
    - zoneID - This column lists the zoning code, countyID, with a "0" at the end. For example, for countyID "48001", the zoneID is "480010".
    - hourID - This column lists the hour of the data, ranging from 1 to 24, where hourID = 1 refers to the hour beginning at 12:00 midnight.
    - temperature - This column lists the calculated temperature (Fahrenheit).
    - relHumidity - This column lists the calculated relative humidity (%RH).

2.4.2 Python Scripts

Following the steps shown in the overview (Figure 2-2) as well as the information described in the Section 11, the TTI team developed separate Python scripts to complete the following tasks:

1. MET_Data_Processing.py - Process the raw data into MET .tab (tab-delimited) files.
2. QAQC.py - Provide QA/QC for the developed .tab files.
3. Tab_to_Database.py - Transform the information in the .tab files into a database in the format required by MOVES.

The Python scripts are included in Appendix 1-B, supporting files, an example working folder, and a readme file. Below are descriptions of the individual functions available in the Python scripts:

1. Tarfile_unload() - unzip the compressed tar files from NCDC.
2. Convert_datetime_timezone() - revising the time format.
3. Isd_parser() - prepare and process the ISD data from TAMIS.
4. Tamis_county_name_match() - adding FIPS information to the county by name.
5. Tamis_metdata_processor - processing the TAMIS data.
6. Ncdc_metdata_processor() - processing the NCDC data.
7. District_table_fill() - adding district information from mapping files.
8. mpo_table_fill() - adding MPO information from mapping files.
9. nonattain_table_fill() - adding Non-Attainment area information from mapping files.

2.4.3 Output

As previously discussed, meteorological inputs were developed for all twelve months and individual seasons (spring, summer, fall, winter, and annual). The inputs were also developed at the county, district, MPO, and NA levels. In county-level inputs, each county has its county-specific meteorological data. For district-level inputs, all counties within that district share district-averaged meteorology. All counties within the same NA share regionally averaged meteorology for NA-level inputs. In total, the 2022 meteorological inputs were developed into six MariaDB databases, which are included in Appendix 1-C alongside a description document:

- Monthly meteorological MOVES input database:
    - 2022met_monthly_254counties_tceq
    - 2022met_monthly_26districts_254counties_tceq
    - 2022met_monthly_4nonattain_20counties_tceq
- Seasonal meteorological MOVES input database:
    - 2022met_monthly_254counties_tceq
    - 2022met_monthly_26districts_254counties_tceq
    - 2022met_monthly_4nonattain_20counties_tceq

2.5 QA/QC

To QA/QC the data, the TTI team employed the same validation method as the TCEQ by plotting the meteorological inputs and checking for reasonableness through visual and calculated comparisons [3]. The TTI team developed QA/QC scripts to perform typical checks, including comparing seasonal differences (e.g., the temperature is lowest in winter months), comparing regional differences (e.g., hourly temperature changes are milder for offshore locations while more significant for inland locations), and identifying anomalies (e.g., sudden or drastic changes). The data validation step also involved the comparison with the 2019 meteorological inputs to identify abnormal differences.

Figure 2-3 And Figure 2-4 compare the average monthly and hourly temperatures, pressure, and relative humidity for the entire state of Texas between the 2022 and the 2019 data, respectively. The results were compared with local observations and data from the National Weather Service (NWS) website[9]. The TTI team validated the results aligned with the local and NWS data.

[9] National Weather Service. Available at: https://www.weather.gov/

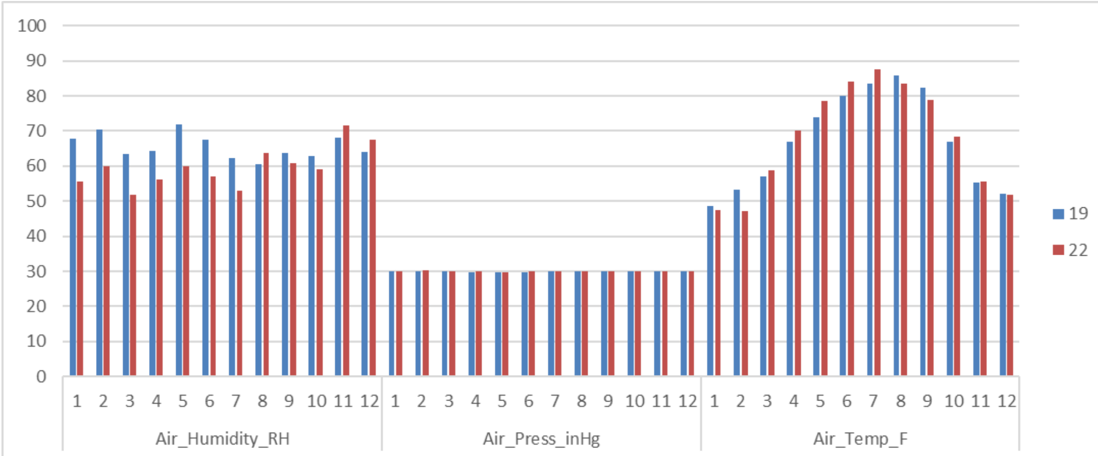

Figure 2-3. Comparison of Aggregated Average Monthly Meteorological Parameters by All Districts in Texas between 2022 data and 2019 data.

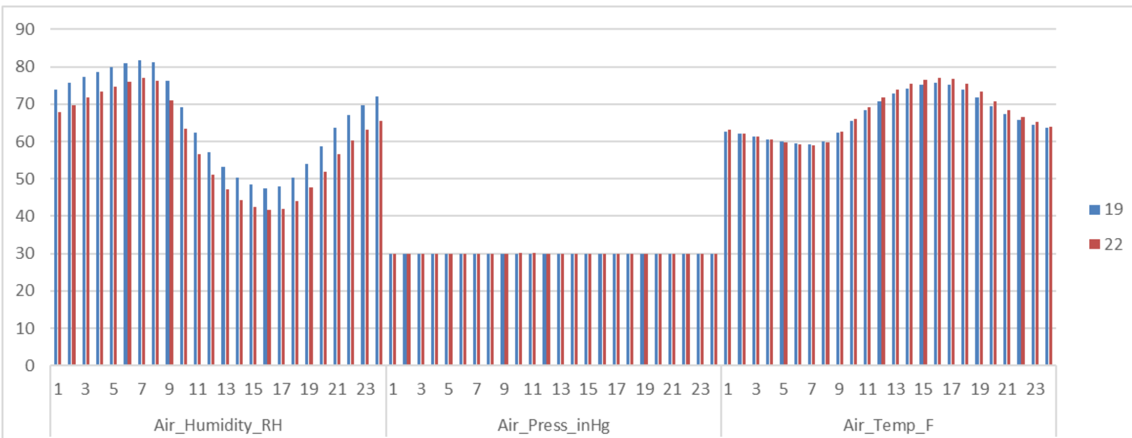

Figure 2-4. Comparison of Aggregated Average Hourly Meteorological Parameters by All Districts in Texas between 2022 data and 2019 data.

2.5.1 Future Improvement to the Parameters and Scripts

The automation developed under this task is expected to reduce the workload to prepare the meteorological inputs and speed up the EI development process. In addition to the work performed, the TTI team also recommends the following improvements to the procedures and Python scripts in the future:

- Improve validation methods and methods to fill in missing or incomplete data.
- Incorporate more data sources to improve the data coverage.
- Utilize a geographic information system (GIS) system for improved regional resolutions and applicability

3 FUELS

The topics covered in this chapter were performed under Task 3.2 of this study. The technical memo was submitted to the TCEQ project manager on October 15th, 2023.

This chapter includes the following sections:

1. Introduction – A brief background on Texas local fuels inputs and the basic framework for fuels inputs to MOVES (fuel types and subtypes, geography, seasons), including crucial input table consistency requirements,
2. Data sources – A description of the current data sources for developing Texas, local fuel formulation inputs to MOVES,
3. Methodology and Procedures – Provides details of the main assumptions and typical steps in the current process of applying the referenced data sources in developing and updating complete Texas fuel formulation input data sets for historical and future year emissions analyses,
4. Comprehensive Database and Processing Scripts – Describes the new database developed and Python scripts written to produce it.

3.1 Introduction

The U.S. EPA's MOVES requires fuel formulation input parameters, such as Reid Vapor Pressure (RVP) and sulfur content, to estimate on-road mobile source emissions. Accurate, local fuel formulation inputs are essential in EI development using MOVES. The TTI team produces fuel formulation inputs to MOVES for on-road EI estimates to support the TCEQ's development of SIP emission goals and the TxDOT transportation conformity demonstrations. The TTI team currently develops the fuel formulation inputs using a combination of analyzed Texas-based local fuel survey sample data and MOVES defaults in an Excel-based approach, which requires considerable effort to maintain and update relative to other potentially more automated approaches.

The TTI team has produced fuel formulation inputs for EPA's official on-road emissions models for SIP and conformity EI analyses for over 20 years. These fuel formulation inputs are primarily developed using the best available local fuel survey data. When local data is unavailable, TTI utilizes MOVES defaults or other data, as needed, as secondary data sources. While TTI's general methodology for developing these inputs has remained consistent over time, there have been periodic updates to keep up with the latest EPA technical guidance.

In the early stages, the EPA guidance recommended using local survey data as the primary source for fuel property inputs, if available. However, more recent EPA guidance mainly encourages using MOVES default fuel formulations, with few noted exceptions. Despite this shift, TTI continues using local fuel survey data as the primary source due to the extensive local fuel survey data available across Texas. TTI then supplements these local data with MOVES defaults or other data, as needed.

The purpose of this report is to document the TTI team's current method and procedures for developing MOVES fuel formulation inputs for on-road EIs. This detailed record of the present method is a reference for future research into approaches for automating and streamlining the process. The overarching goal is to reduce the effort involved in developing, maintaining, updating, and refining Texas local fuel formulation inputs to MOVES and make the inputs more easily accessible to Texas MOVES emissions modelers. Ultimately, the TTI team created a database that maximizes flexibility for future use. Anticipating the need for updates, the team plans to refresh the database annually or triennially, incorporating new survey data and other critical information. This strategy ensures the efficient and timely processing of the latest data for MOVES emissions analyses.

3.1.1 MOVES' Fuels Framework

For on-road mobile sources (or MOVES source use types, i.e., vehicle types in the model such as motorcycles, passenger cars, school buses, and long-haul trucks), MOVES includes the five fuel types listed in Table 3-1.

Table 3-1. MOVES On-Road Fuel Types

Fuel Type ID	Fuel Type Description
1	Gasoline
2	Diesel Fuel
3	Compressed Natural Gas (CNG)
5	Ethanol (E85)
9	Electricity

Each fuel type has a fuel subtype, as listed in Table 3-2. For each fuel type with multiple subtypes, the market share of each subtype for any single month and year in an inventory analysis must sum to 1.0.

Table 3-2. MOVES On-Road Fuel Subtypes

Fuel Subtype ID	Fuel Type ID	Fuel Subtype Description
10	1	Conventional Gasoline (CG)
11	1	Reformulated Gasoline (RFG)
12	1	Gasohol (E10)
13	1	Gasohol (E8)
14	1	Gasohol (E5)
15	1	Gasohol (E15)
20	2	Conventional Diesel Fuel
21	2	Biodiesel (BD20)
22	2	Fischer-Tropsch Diesel (FTD100)
30	3	CNG
50	5	Ethanol
51	5	Ethanol (E85)
52	5	Ethanol (E70)
90	9	Electricity

The FuelFormulation table contains the fuel property characteristics for the fuel subtypes marketed in the subject EI analysis area. It is among four MOVES fuels-related input tables that must be kept consistent between the fuel types within the scope of the EI. These are:

- AVFT (fuel type capability distributions by model year and source type).
- FuelFormulation (fuel properties for each fuel subtype supplied).
- FuelSupply (market share of each fuel subtype).
- FuelUsageFraction (fuel type usage fractions for flex-fuel vehicles).

By design, MOVES requires that the FuelFormulation and FuelSupply input tables include all five on-road mobile fuel types available in MOVES, regardless of the on-road mobile project scope. At least one fuel subtype for each of the five fuel types is required for each MOVES run (i.e., fuel formulations and total "1.0" market shares for each fuel type); otherwise, errors will occur.

Table 3-3 provides an example of fuelformulation and fuelsupply table input data meeting the MOVES requirement for including all five on-road mobile fuel types with total market shares.

Table 3-3. Sample MOVES FuelFormulation and FuelSupply tables

Table	Column Header	FuelType 1	FuelType 2	FuelType 3	FuelType 5	FuelType 9
Fuel Formulation	FuelFormulationID	19702	30585	28001	27002	90
Fuel Formulation	fuelSubtypeID	12	21	30	51	90
Fuel Formulation	RVP	7.77	\N	0	7.7	\N
Fuel Formulation	sulfurLevel	19.64	5.85	7.6	8	0
Fuel Formulation	ETOHVolume	9.56	\N	0	74	\N
Fuel Formulation	MTBEVolume	0	\N	0	0	\N
Fuel Formulation	ETBEVolume	0	\N	0	0	\N
Fuel Formulation	TAMEVolume	0	\N	0	0	\N
Fuel Formulation	aromaticContent	22.22	\N	0	0	\N
Fuel Formulation	olefinContent	8.69	\N	0	0	\N
Fuel Formulation	benzeneContent	0.58	\N	0	0.16	\N
Fuel Formulation	e200	49.64	\N	0	999	\N
Fuel Formulation	e300	84.60	\N	0	999	\N
Fuel Formulation	volToWtPercentOxy	0.3653	\N	0	0.3653	0
Fuel Formulation	BioDieselEsterVolume	\N	4.86	\N	\N	\N
Fuel Formulation	CetaneIndex	\N	\N	\N	\N	\N
Fuel Formulation	PAHContent	\N	\N	\N	\N	\N
Fuel Formulation	T50	202.53	\N	0	999	\N
Fuel Formulation	T90	319.75	\N	0	999	\N
Fuel Supply	fuelRegionID	178010000	178010000	178010000	178010000	178010000
Fuel Supply	fuelYearID	2019	2019	2019	2019	2019
Fuel Supply	monthGroupID	7	7	7	7	7
Fuel Supply	FuelFormulationID	19702	30585	28001	27002	90
Fuel Supply	marketShare	1.0	1.0	1.0	1.0	1.0
Fuel Supply	marketShareCV	\N	\N	\N	\N	\N

Modelers can effectively set up MOVES to model fewer fuel types by adjusting the AVFT and FuelUsageFraction table inputs. For example, an EI project with its scope limited to gasoline and diesel, with alternative fuel vehicle usage assumed to be of insignificant impact and treated as de minimis. In this case, the model year fuel fraction inputs of the AVFT table would be set to zero for CNG and electricity and renormalized for only gasoline, diesel, and flex-fuel vehicles (vehicles with the capability to be powered by either gasoline or E85). This would limit the model output to only gasoline, diesel, and E85. In this example, the flex fuel vehicle fuel usage in the FuelUsageFraction table would need to be set to 100% gasoline. Thus, the MOVES output would effectively only include results for gasoline and diesel vehicles.

MOVES counties are associated with fuel regions defined by fuel rule jurisdictions and/or distribution networks and may consist of one or more counties. In county scale modeling, MOVES assigns fuel supply market shares to the county via its' associated fuelRegionID in the FuelSupply table (see Table 3-3).

Table 3-4 shows the MOVES fuel regions for Texas with brief details on the pertinent fuel rules and/or distribution networks involved, as well as the affected counties.

Table 3-4. Texas Fuel Regions by Year in MOVES

Year(s)	MOVES fuel region ID[1]	TTI code	Counties[2]	Defining Rule Description[3]
1999 to 2060	300000000	R1	132 (Western)	Federal 9.0 RVP limit (RVP waiver available for E10)
1999 to 2060	178010000	R2	95 (Central, Eastern) (89 starting in 2024)	State 7.8 RVP limit (no RVP waiver) (six DFW counties switched to RFG in November 2023)
1999 to 2060	370010000	R3	1 (El Paso)	State 7.0 RVP (no RVP waiver)
1999 to 2060	1370011000	R4	12 (18 starting in 2024) (DFW, HGB)	RFG (six DFW counties added to the DFW RFG area in November 2023)
1999 to 2060	178000000	R5	3 (Beaumont-Port Arthur [BPA])	Federal 7.8 RVP limit (RVP waiver okay for E10)
1999 to 2060	100000000	R6	11 (Southern)	Same as for R1, except for the distribution network
1990	300000000	R1, R3	133 (Western)	Federal 9.0 RVP limits all counties
1990	100000000	R2, R4, R5, R6	121 (Eastern, Southern)	Federal 9.0 RVP limits all counties

[1] The Texas county IDs by MOVES fuel region ID may be found in the MOVES database table "regioncounty".
[2] RFG counties include DFW - Dallas, Denton, Collin, and Tarrant, with the addition of Ellis, Johnson, Kaufman, Parker, Rockwall, and Wise starting in 2024; and HGB - Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller. BPA counties are Hardin, Jefferson, and Orange.
[3] See https://www.tceq.texas.gov/airquality/mobilesource/vetech/fuelprograms.html#rvp1 for the list of 95 Texas counties under the State 7.8 RVP limit rule. Note - R2, R4, R5, and R6 counties also require TxLED fuel (October 2005 start), the effects of which must be incorporated via post-processing of MOVES output.

Importantly, since new fuel regulations were enacted after 1990, the grouping of counties by MOVES fuelRegionIDs for 1990 is different from 1999 and later years. Also, in 2024, the DFW RFG counties were expanded from the original four counties to ten DFW counties requiring RFG. In addition, note that MOVES excludes the years 1991 through 1998.

MOVES assigns fuel formulations to years and months via the fuelyearID and monthgroupID as specified in the fuel supply table (see Table 3-3). Fuel formulations in

MOVES represent three periods during the year: summer, winter, and the two shoulder months between summer and winter, which are assigned the same formulations. The fuel formulations for each season may vary, particularly for gasoline, which has distinct requirements for summer and winter seasons. The following are the months associated with each season in MOVES:

- Summer: May through September (month IDs 5, 6, 7, 8, 9).
- Winter: November through March (month IDs 11, 12, 1, 2, 3).
- Shoulders: April and October (month IDs 4, 10).

For more information on the fuel properties of the MOVES FuelFormulation table and the MOVES FuelSupply table, see the EPA's *Fuel Supply Defaults* report [4]

3.1.2 Texas Fuel Type Details

Texas complies with the various federal and state fuel controls that vary by region or county groups (see Table 3-4). These control standards include:

- Limits on summertime gasoline volatility to reduce volatile organic compounds (VOC).
- Increasingly tightened gasoline and diesel sulfur standards to reduce particulate matter (PM).
- RFG emissions performance standards to reduce VOC, nitrogen oxides (NO_x), and air toxins.
- Wintertime gasoline minimum oxygenate requirement to reduce carbon monoxide (CO).
- Gasoline benzene limit to reduce benzene.
- Renewable fuel standards promote the consumption of domestically produced renewable fuels in place of imported petroleum.
- TxLED formulation for reducing NO_x. (Since MOVES do not include the effects of the TxLED program, emissions adjustments are made to incorporate TxLED effects in the 110 central and eastern counties in the program [5].)

Table 3-5 provides a more comprehensive listing of fuel rules applicable in Texas over time starting in 1990, which MOVES mainly incorporates the effects of.

Table 3-5. Federal and State Fuels Controls in Texas.

Program	Start	Control/Standard	Geographic Coverage
Federal Controls on Gasoline Volatility[1]	1990	Max summertime RVP, 9.0 psi	All 254 counties.
Federal Controls on Gasoline Volatility[1]	1992	Max summertime RVP, 7.8 psi Max summertime RVP, 9.0 psi	1-hr ozone counties[2] Remainder of state
El Paso Oxygenated Gasoline[3]	1992	Winter control period minimum weight percent oxygen 2.7%	El Paso, CO nonattainment county
Federal RFG[4]	Phase I 1995	Performance standard reductions: VOC, Toxics	DFW and HGB 1-hr ozone nonattainment counties
El Paso Low RVP[5]	1996	Max summertime RVP, 7.0 psi	El Paso County
Federal RFG	Phase II 2000	Performance standard reductions: VOC, NO_x, Toxics	DFW and HGB 1-hr ozone nonattainment counties
Regional Low RVP[6]	2000	Max summertime RVP, 7.8 psi	95 Texas counties[6]
Tier 2 Low Sulfur Gasoline[7]	2004-2006 phase in	Refinery 30 ppm annual average, 80 ppm refinery gate, and 95 ppm downstream per-gallon caps	National
Federal Low Sulfur Highway Diesel	1993 - 2006	500 ppm max[8] 15 ppm max, with provisions[9]	National
Texas Low Emission Diesel[10]	2005	Low aromatic HC and high cetane number to control NO_x	110 counties: 95 counties and 15 1-hr ozone counties
National Renewable Fuel Standard[11]	2006	Renewable fuel in gasoline and diesel transportation fuels, produced/imported	National
Mobile Source Air Toxic (MSAT) Rule[12]	2011	Gasoline benzene limit: 0.62 volume % annual average; 1.3 volume % maximum annual average (2012)	National
Tier 3 Low Sulfur Gasoline[13]	2017	Refinery 10 ppm annual average, maintains Tier 2 caps	National
Fuels Regulatory Streamlining[14]	2021	Simplified the summer VOC standards by establishing a 7.4 psi RVP standard for RFG.	HGB (8), DFW (4)
Federal RFG[15]	2024	Expansion from four to 10 DFW counties due to reclassification from serious to severe	DFW (10)

[1] 40 CFR § 80.27. Controls and Prohibitions on Gasoline Volatility.
[2] BPA: Hardin, Jefferson, Orange; DFW: Collin, Denton, Dallas, Tarrant; HGB: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller; and El Paso County.
[3] 30 Texas Administrative Code (TAC) § 114.100 Oxygenated Fuels.
[4] 40 CFR § 80.41 Standards and Requirements for Compliance (federal RFG).
[5] 30 TAC §§ 115.252. Control Requirements (for gasoline RVP).
[6] 30 TAC § 114.301. Control Requirements for RVP. See the rule for a list of 95 central and eastern Texas counties.
[7] Control of Air Pollution From New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements; Final Rule, EPA, February 10, 2000. Note that the typical pre-control average sulfur content is about 300 ppm.
[8] 40 CFR § 80.29. Controls and Prohibitions on Diesel Fuel Quality. (Prior years unregulated.)
[9] 40 CFR § 80.500. What are the Implementation Dates for the Motor Vehicle Diesel Fuel Sulfur Control Program?; 40 CFR § 80.520. What are the Standards and Dye Requirements for Motor Vehicle Diesel Fuel?
[10] 30 TAC § 114.312-319. Low Emission Diesel (LED) Standards. Covers 95 Regional Low RVP and 1-hr ozone counties.
[11] 40 CFR § 80.1100 Subpart K — Renewable Fuel Standard. Renewable fuels reduce the fossil fuel in motor vehicle fuel (produced from grain, starch, oil seeds, vegetable, animal, or fish materials; or natural gas produced from a biogas source.)
[12] Control of Hazardous Air Pollutants From Mobile Sources; Final Rule, EPA, 2007.
[13] Control of Air Pollution From Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards; Final Rule, EPA, 2014.
[14] 40 CFR § 60. Fuel Regulatory Streamlining.
[15] 40 CFR Parts 52 and 81. … Reclassification of Areas Classified as Serious for the 2008 Ozone National Ambient Air Quality Standards; Final Rule 2022.

By year and month, the MOVES gasoline and diesel defaults for the Texas fuel regions provide fairly reasonable estimates of fuel formulations and supplies reflective of the regulatory landscape for Texas fuels starting with 1990. Based on a comparison of the MOVES fuel supply defaults for Texas and the TCEQ fuel survey data summaries, TTI noted some updates to the MOVES defaults that would better reflect Texas fuels, such as the use of gasoline oxygenates.

The Texas retail gasoline survey data reveal a shift from ether-based oxygenates to ethyl alcohol or ethanol in RFG starting in 2006. Ethanol was observed in CG across Texas to varying degrees beginning in the summer of 2008. Based on the 2011 and 2014 TCEQ statewide summer fuel survey summaries, the observed ethanol volumes were assumed to have reached a saturation point of 100% E10 gasoline across the state in 2012. This observation is consistent with the MOVES defaults.

MOVES does not model MTBE oxygenate blends as MTBE was replaced with ethanol in oxygenate blends to provide an approximation of fuel effects over the range of analysis years. To model an equivalent oxygenate effect for MTBE, the ethanol volume with oxygen weight percent identical to that of the observed MTBE volume is used instead of MTBE. Note that this approach only estimates the ethanol emissions that would not have occurred instead of directly estimating the MTBE emissions.

In comparing the Texas fuel survey observations with MOVES fuel defaults, in light of MOVES limitations, the following observations were made:

- For gasoline oxygenate blends, MOVES currently features only ethanol. Thus, the effects of other gasoline oxygenate blends, as observed in Texas fuel surveys, such as MTBE (discontinued in Texas in 2006), may be approximated using ethanol.
- For CG counties, the MOVES E10 saturation year of 2012 is realistic for Texas; however, the Texas phase-in of E10 gasoline, with substantial market shares, began later (2008) than depicted in MOVES (1999).
- For RFG counties, MOVES RFG for 1999 and later years is E10, which is reflected in Texas RFG observations for 2006 and later years; Texas RFG survey summaries for 1999 through 2005 contain mainly ether-based oxygenate blends, although they are like the MOVES E10 RFG in terms of weight percent oxygen content.
- MOVES default ester blend diesel (biodiesel) is B3.4 (diesel blended with 3.4% ester). For all years starting with 2011 and later, the national default data is based

on the EIA's national average fuel consumption data (for 2011 through 2019). It must be noted that data are also available by state and year.

- Gasoline and diesel sulfur standard phase-ins in MOVES adequately represent Texas observations.

3.2 Data Sources

This section summarizes the data sources the TTI team acquired to develop Texas-based localized fuel formulation inputs for MOVES.

The fuel formulation inputs development process uses Texas-based local fuel survey data from TCEQ and EPA. Additionally, to combine the average gasoline parameters by grade into composite (weighted average) gasoline parameters and to incorporate biodiesel estimates into the diesel formulation inputs, the TTI team included the Texas fuel sales and energy consumption summaries from the Energy Information Administration (EIA). These data sources are listed in Table 3-6.

Table 3-6. Data Sources for Texas Local Fuel Formulation Inputs Development.

Source[1]	Data Type	Period	Available for[2]	Used for	Fuel Types
TCEQ	Texas, statewide retail outlet gasoline and diesel fuel surveys (typically includes a minimum of three sampled stations per each of the 25 TxDOT districts)	Summer	2005- 2023 triennially (plus 2003[2] and 2007)	Fuel formulations	Both gasoline and diesel from each station
US EPA	Dallas and Houston retail outlet RFG compliance surveys (typically include hundreds of samples from each RFG area)	Summer, winter	2002-2020	Fuel formulations	Gasoline
US EIA	Texas, Prime Supplier Sales Volumes, motor gasoline, by grade and formulation (CG and RFG)	Annual	1983-2021	CG and RFG fractions by grade	Gasoline
US EIA	Texas, Refiner Motor Gasoline Sales Volumes, through retail outlets, by grade	Annual	1994-2021	Gasoline fractions by grade	Gasoline
US EIA SEDS[3]	Texas, transportation sector, consumption, physical units	Annual	1960-2020	Ester volumes in biodiesel	Distillate fuel oil, biodiesel

[1] One additional source (for defaults) is the MOVES database.
[2] TCEQ 2003 survey data was for nonattainment and near nonattainment areas rather than statewide.
[3] State Energy Data System (SEDS) – Available at: https://www.eia.gov/state/seds/

Previously, TTI also utilized fuel survey data from the National Institute for Petroleum and Energy Research (NIPER). This data source was previously available and used from the 1990s to 2009 for summer and winter data and included the Texas cities of Dallas, Houston, San Antonio, Amarillo, and El Paso. However, NIPER was acquired by TRW Petroleum Technologies in the late 1990s, which was then developed by the Northrop Grumman Mission Systems (NGMS) in 2002. NGMS discontinued this data source in 2009; thus, it is no longer used and is mentioned for informational purposes only.

Table 3-7 It includes contact information for agency staff members who can help with fuel survey data and links to access the EIA downloadable data for motor gasoline sales volumes by grade and biodiesel consumption volume estimates.

Table 3-7. Data Source Contacts or Download Links

Data	Staff	Contact Information / Link
TCEQ fuel surveys	Michael Regan Jamie Zech	michael.regan@tceq.texas.gov (512)-239-2988 jamie.zech@tceq.texas (512)-239-3935
EPA fuel compliance surveys	Robert Anderson Kurt Gustafson (Director, Fuels Compliance Policy Center)	Anderson.Rober@epa.gov (734)-214-4280 Gustafson.Kurt@epa.gov (202)-343-9219
EIA refiner motor gasoline sales volumes through retail outlets	-	See note 1 infoctr@eia.gov (202) 585-8800
EIA prime supplier sales volumes of petroleum products	-	See note 2 infoctr@eia.gov (202) 585-8800
EIA energy consumption (for biodiesel)	-	See note 3

[1]The EIA's Refiner Motor Gasoline Sales Volumes page is available at:
https://www.eia.gov/dnav/pet/pet_cons_refmg_d_STX_VTC_mgalpd_a.htm
[2]The EIA's Prime Supplier Sales Volumes page is available at:
http://www.eia.gov/dnav/pet/pet_cons_prim_dcu_stx_a.htm
[3]The EIA's State Energy Data System (SEDS): 1960-2020 (complete) is available at:
https://www.eia.gov/state/seds/seds-data-complete.php?sid=TX#CompleteDataFile

The following sections provide some detail on the data sources listed in Table 3-6.

3.2.1 TCEQ Fuel Surveys

Historically, the TTI team has acquired and reviewed all the TCEQ fuel survey reports with attached analyzed sample summaries and re-processed them, as needed, for use in EPA emission rate models (earlier MOBILE and current MOVES models). The sampling plan was designed for statewide coverage, balanced by the TxDOT district, and included a minimum of three retail fuel station locations per district and four samples per station (one each for regular, mid-grade, and premium gasoline and diesel). These surveys have been relatively consistent in the number of locations and samples drawn. For example, the 2020 survey sampled gasoline and diesel fuel from 91 stations across all 25 TxDOT districts [6]. Until 2020, these TCEQ fuel surveys were conducted solely by the Eastern Research Group (ERG), while the laboratory analysis of the sample data was performed by Southwest Research Institute (SwRI). For the 2023 fuel survey, the TTI team was involved in conducting the surveys with ERG and SwRI acting as subcontractors [7].

In the earlier surveys, the analyzed sample results were processed to produce average fuel formulations for gasoline and diesel by each TxDOT district, then assigned the district-level inputs to their associated counties (the EPA's old MOBILE series used county IDs rather than fuelRegionIDs for assigning fuels inputs geographically) [8]. The standard process of calculating average properties by gasoline grade was used, and then a weighted average was produced using Texas gasoline sales volume proportions by grade.[10] District fuel formulation summaries were provided in final reports for each survey and included attachments with spreadsheets of analyzed fuel sample data in various processing stages. Individually analyzed sample summary data were included, allowing replication of the ERG-processed results and re-processing if needed.

With the release of MOVES, average gasoline formulations were produced by the six MOVES fuel regions for Texas. Initially, these results were produced by the TxDOT district and assigned to district-associated counties, as before [8]. A step was added to calculate the average fuel properties across counties by MOVES fuel region. Starting with the 2020 fuel study, the process for calculating the gasoline property inputs by MOVES fuel region was updated. County Federal Information Processing Standards (FIPS) codes were assigned to each sampling result based on the location of the sampling station. The county-to-fuel region mapping information was then exported from MOVES, and a MOVES fuel region was assigned to each sample based on the county of the sampling station.

The required fuel parameters were averaged by fuel region and gasoline grade (regular, mid-grade, and premium grade), and a weighted average across all three grades for

[10] The sales proportions by grade were estimated from latest available EIA, Texas, Refiner Motor Gasoline Sales Volumes, through retail outlets.

each fuel region was produced. The gasoline grades were weighted based on the latest EIA refiner motor gasoline sales data [6]. While the refiner sales data is still preferred, it has inconsistent availability; thus, the TTI team replaced the data source with the EIA's Texas Prime Supplier Sales Volumes dataset, which is more consistently available and produces similar results. More information is discussed in Section 3.2.3.

The diesel formulation Inputs were produced from survey samples retrieved at the exact location as the gasoline data, and the MOVES default biodiesel ester volume input value was added. The TCEQ diesel survey sample data needs to include information on biodiesel ester content.

The 2017, 2020, and 2023 fuel study reports are available on TCEQ's *Air Quality Research and Contract Reports: On-Road Vehicles* webpage[11].

3.2.2 EPA RFG Surveys

Upon request, the EPA provided the EPA RFG compliance survey data for Dallas and Houston. The TTI team typically requested the Texas RFG data twice a year, once in the fall for the summer season sample data and once early the following year, to get the entire prior year of data (both summer and winter data). The RFG data was in the form of analyzed sample summaries (for as many as 400 to 500 samples for some years) provided in a single spreadsheet, including the fuel parameter values per individual sample, along with the date, season, area (e.g., Dallas, Houston), and fuel grade information. All the MOVES fuel formulation parameters needed are included in the EPA RFG data sets, except for the winter season RVP.

Due to the recent streamlining of the EPA's fuels compliance program[12], this RFG survey samples data source ended in 2020, the last year of the data. The EPA providers of the RFG survey data indicated they would need to determine what data can be shared from the new streamlined compliance program; however, at the time of preparing this report, they have not yet returned a decision to the TTI team on what can be provided.

[11] The TCEQ's Air Quality Research and Contract Reports: On-Road Vehicles page is available here: https://www.tceq.texas.gov/airquality/airmod/project/pj_report_mob.html

[12] Regulatory announcement of EPA's Fuels Regulatory Streamlining Rule: https://www.epa.gov/sites/default/files/2020-10/documents/420f20047.pdf

3.2.3 EIA Sales and Consumption Volumes

As listed in Table 3-6, EIA data were used to populate the CG and RFG fractions by grade and the gasoline fractions by grade for the gasoline fuel type. In contrast, the EIA's SEDS data were used to populate the ester volumes in the biodiesel fuel type. The spreadsheet summaries are downloadable from the following EIA websites:

- The Texas Refiner Motor Gasoline Sales Volumes Through Retail Outlets: https://www.eia.gov/dnav/pet/pet_cons_refmg_d_STX_VTC_mgalpd_a.htm
- Texas Prime Supplier Sales Volumes of Petroleum Products: http://www.eia.gov/dnav/pet/pet_cons_prim_dcu_stx_a.htm.
- EIA Texas annual consumption estimates from the SEDS: https://www.eia.gov/state/seds/sep_use/total/csv/use_TX.csv

For producing Texas gasoline sales fractions by grade, the "Refiner Motor Gasoline Sales Volumes" data, which provides annual sales volume by grade, is preferred as the sales proportions by grade for total motor gasoline through retail outlets can be calculated. However, the data source has some significant gaps (2012 to 2016, 2020, and 2021), and there was a 90% decrease in volumes from the year 2011 (5,649.5 thousand gallons per day) to the year 2017 (613.8 thousand gallons per day), as seen in Figure 3-1.

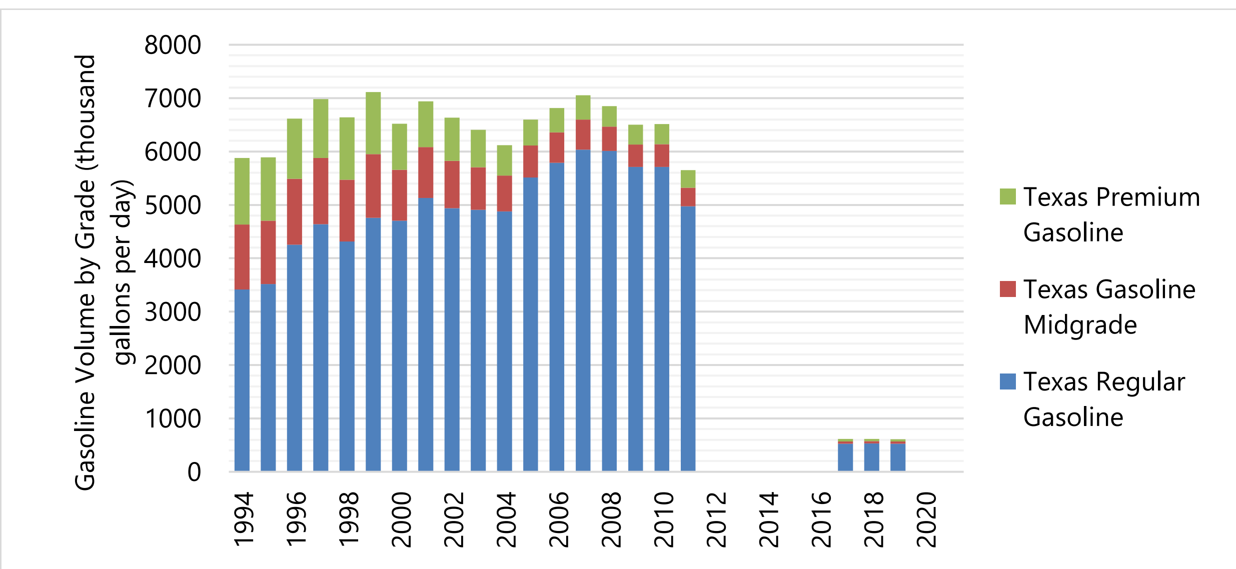

Figure 3-1. Texas Total Refiner Gasoline Volumes by Grade from the Refiner Motor Gasoline Sales Volumes

Due to inconsistency in the annual availability of the refiner sales data, the "Prime Supplier Sales Volumes" data, which is more consistently available and produces similar results in terms of gasoline grade weight fractions, has become the more reliable data source. After consulting with EIA Fuels, the TTI team replaced the refiner sales data with the prime supplier sales data to calculate sales proportions by grade for conventional, reformulated, and total motor gasoline. A snippet of this dataset is shown in Figure 3-2.

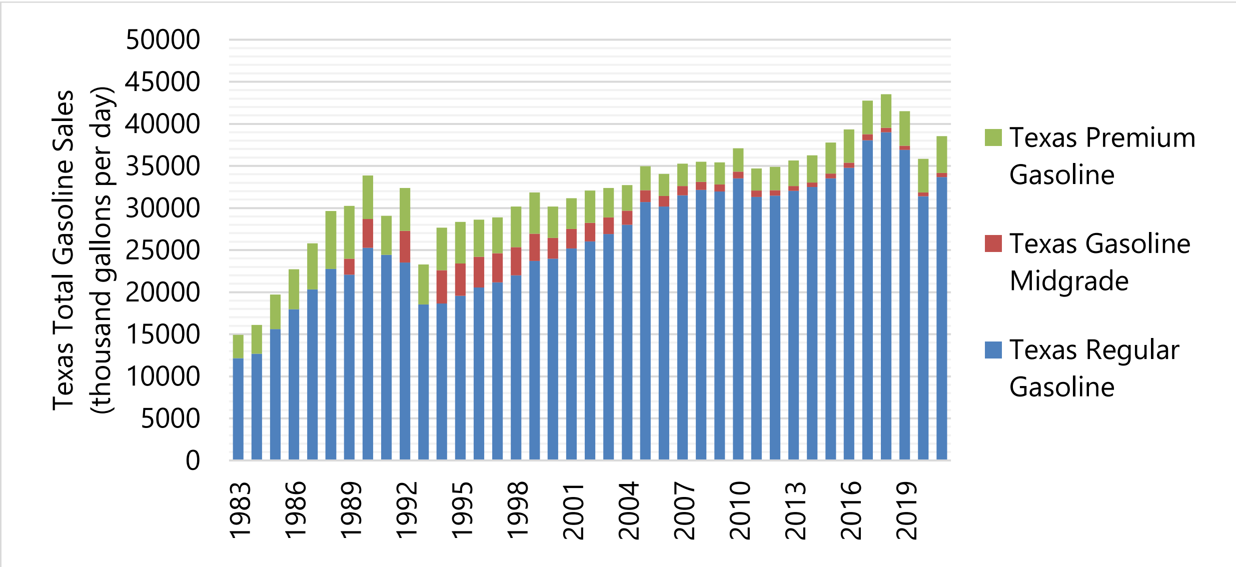

Figure 3-2. Texas Gasoline Sales by Grade from Texas Prime Supplier Sales Data.

The EIA SEDS distillate fuel oil and biodiesel summaries by state (Excel spreadsheet) report data for all years, including 1960 through 2021, with a 2.5-year lag on the annual updates to the data set. The annual biodiesel proportions blended in petroleum diesel are calculated by dividing the biodiesel consumed by the transportation sector (MSN[13]: BDACP) over the distillate fuel oil (inclusive of biodiesel) consumed by the transportation sector (MSN: DFACP). The 1960 through 2020 trend of annual biodiesel proportions of petroleum diesel is available in Figure 3-3.

[13] Mnemonic Series Names (MSN) are five-character codes in the State Energy Data System's Data Series Name. A list of MSNs is available at https://www.eia.gov/state/seds/CDF/Codes_and_Descriptions.xlsx.

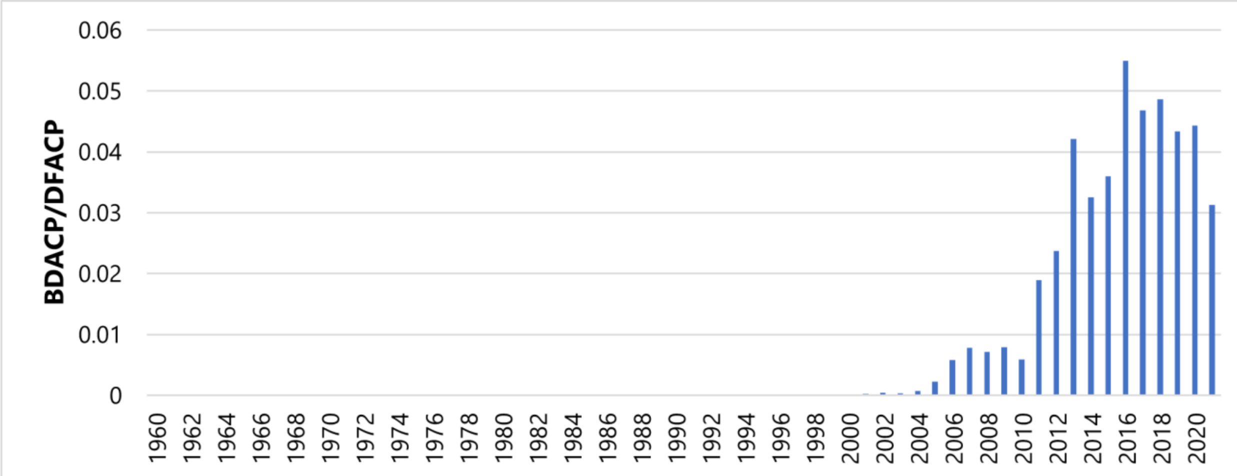

Figure 3-3. Annual Biodiesel Proportions of Transportation Sector Distillate Fuel Oil Sales from the SEDS Data.

3.3 Methodology and Procedures

This section provides the main assumptions for developing local fuel formulation and fuel supply input parameters for MOVES using the updated methodology, a general overview of the method, and the basic steps in the process. Lastly, details for each step are provided.

3.3.1 Main Assumptions

The TTI team aims to produce local fuel formulation inputs primarily based on the available TCEQ and EPA local survey data. When fuel parameter data is unavailable, the TTI team used other data, such as MOVES defaults, as substitutes. First, historical and current-year inputs are produced, followed by future-year inputs.

The TTI team assumed that the local data discussed in the previous sections, in combination with MOVES defaults or other data as needed, is sufficient to produce reasonable fuel formulation inputs to MOVES for SIP and conformity emissions analyses and reflective of the regulatory environment of Texas. The exception was for the TxLED program's effects, which must be incorporated by post-processing MOVES output.

The TTI team's basic methodology and assumptions are as follows:

1. Fuel types - the market share impact for alternative fuels in Texas is assumed to be negligible. Therefore, local inputs are developed only for the two predominant fuels: gasoline and diesel.

2. Geographical variation –

    a. **Gasoline** - the six MOVES fuel regions for Texas (Table 3-4) are suitable for gasoline and used for developing regional average gasoline inputs, except that within the RFG region (DFW and HGB), fuelformulations are prepared individually.

    b. **RFG versus CG** - Since the EPA RFG compliance program surveys include many more samples for each year (available for 2012 through 2020) and for both summer and winter, the EPA-provided analyzed survey data is used to produce RFG inputs (individually for DFW and HGB RFG areas). The TCEQ 3-year cycle summer survey data is applied for summer CG inputs for the five non-RFG fuel regions. For summer CG inputs for non-survey years, the nearest survey year local inputs are used (or the earlier year data where there is a middle non-survey year), and in the case of Tier 3 gasoline sulfur content for transitional years (between 2017 and 2020 survey years) sulfur is set to the MOVES default.

    c. **Diesel** – Ultra Low Sulfur Diesel (ULSD) has shown relatively stable sulfur content statewide over multiple recent TCEQ summer surveys. The statewide average diesel formulation is produced from the TCEQ survey data (and applied to all months of the survey calendar year). Inputs for non-survey years are selected similarly to gasoline.

3. Gap filling - Since the local information does not include all the necessary information to complete the Texas fuel formulations for each year, other info is used to complete the fuel formulation input data sets.

    a. **Biodiesel ester volume** - EIA energy consumption data for Texas is used to estimate biodiesel volumes in diesel fuel for Texas by calendar year. Values less than 1% are assumed to be negligible and set to zero.

    b. **Winter gasoline parameters** – MOVES defaults are used for winter CG formulations and RVP for RFG formulations.

    c. **Shoulder gasoline parameters** – if needed, the MOVES defaults are used.

    d. **Future years** – the latest local formulations produced (per above) are used, with regulated properties set to expected future year values (i.e., reflecting consistency with regulatory standards or limits). For CG, MOVES defaults are used for the future year's summer RVP, sulfur content, and benzene content; MOVES defaults are used for the forthcoming year's diesel and RFG sulfur content.

e. **Other requirements** – since MOVES requires all five on-road fuel types to be input, even though alternative fuels may not be modeled, MOVES default fuel formulation inputs for the alternative fuels (E85, CNG, and electricity) are used to complete the fuel formulation inputs data set.

3.3.2 Procedure Overview

After receiving the newly available data, the TTI team updates the local fuel formulation inputs. This ensures that the latest available inputs are readily available when needed.

Starting in 2002 and until 2020, the EPA has provided summer and winter RFG sample data for Dallas and Houston each year, as previously discussed in Chapter 3.2.2. These RFG fuel formulation inputs were developed more frequently versus the statewide gasoline and diesel formulation inputs derived from the TCEQ triennial fuel survey data, which was previously discussed in Chapter 3.2.1. Whenever new (triennial - starting with 2005) gasoline and diesel summer survey data is acquired (usually later in the year of the survey), the TTI team reviews and re-processes the information, if needed, to produce the latest gasoline and diesel fuel formulation input updates for each of the six Texas fuel regions, for the survey year. For the Dallas and Houston RFG fuel areas, the area-specific EPA RFG sample data are processed separately each year to produce the RFG inputs for EI development. These latest available Texas statewide updates serve as the basis for future-year local fuel formulation input estimates, which are used in future-year EI analyses after being further processed by setting the parameters identified in the prior section to their expected future values.

The TTI team generally processed the data into an input format using Excel spreadsheets to process the survey sample data into averages and MySQL database scripts to populate fuel input database tables and make updates (e.g., for MOVES defaults needed, etc.). The original survey data and sales/consumption data required for the inputs development process were provided in Excel spreadsheets, and any MOVES defaults used were pulled from the current MOVES MySQL database. Tab-delimited text file versions are manually created once the local inputs are processed and produced using Excel. MySQL scripts are used to build and populate a database of MOVES FuelFormulation and FuelSupply tables with the tab-delimited text file-formatted local data and to update the tables with any MOVES defaults needed or as otherwise required.

The following steps briefly outline the primary method for developing/updating the Texas local fuel formulation inputs to MOVES for use in SIP and conformity EIs.

- **Step 1** – ***Check the current process for developing local fuel formulations***. Review and verify that the current assumptions and process (as laid out in the previous section) for developing Texas and local fuel formulation inputs to MOVES are up to date. The current process is detailed in the latest TTI statewide EI development report [9] sponsored by TCEQ.
- **Step 2** – ***Acquire the latest data***. Get the latest available data, including the local fuel survey data from TCEQ and EPA, the motor gasoline sales volume data and transportation sector energy consumption data for Texas from EIA, and the current MOVES database (for any defaults needed).[14]
- **Step 3** – ***Review newly acquired data sets***. Review each data set obtained for the fuel formulation inputs development to check for anomalous values, missing data, and values that must be calculated, if any, and determine the level of processing needed. Compare new and previously provided data sets to check if there were any processing changes or data format changes that need to be accounted for. Replicate the ERG process of producing the average regional inputs from the summary or summaries of individual sample parameters.
- **Step 4** - ***Update process parameters derived from EIA data***. Using the EIA gasoline sales data for Texas, update the fuel grade fractions (regular, mid-grade, premium) of total motor gasoline and compare them to prior estimates for reasonability. Do this for both prime supplier and refiner sales data. Also, perform for CG and RFG individually using prime supplier data. Using the EIA's Texas energy consumption estimates (for transportation sector biodiesel and distillate fuel oil), update the biodiesel ester volume content of diesel fuel estimate for the latest calendar year and compare it to prior calendar year estimates.
- **Step 5** – ***Process TCEQ summer gasoline and diesel sample analysis results***. To the extent needed, process the pertinent parameters from the ERG report into average gasoline fuel formulations by the Texas MOVES fuel regions. Process

[14] Except for the defaults from the MOVES database, all the data sets are provided in Excel spreadsheets or "csv" files that open into Excel spreadsheets.

appropriate diesel sample data from the ERG report into one average diesel fuel formulation for the state and compare minimum, maximum, and average content values to prior survey results. (The extent of the fuels data processing needed is dependent on the sort of processing performed by ERG, which has been refined in response to emission model changes or other needs over the years [e.g., currently averages by six MOVES fuel regions are directly produced, whereas previously averages were produced by 25 districts]). Assign MOVES FuelFormulationIDs per the current coding scheme, provided in a later section.

- **Step 6** – ***Process EPA summer and winter RFG sample analysis results***. Process the pertinent RFG fuel parameters from the EPA-provided RFG summary spreadsheet into average RFG fuel formulations, individually for Dallas and Houston RFG areas. To have the latest available inputs for the summer ozone season readily available, essentially on demand for transportation conformity practitioners, this step has been performed each year in the fall as soon as EPA provided the data. The latest inputs are typically compared to prior estimates. Assign MOVES FuelFormulationIDs according to the current coding scheme, with separate IDs for Dallas and Houston.
- **Step 7** – ***Combine MOVES FuelFormulation input data from steps 5 and 6 into a single summary***. MOVES defaults for alternative fuels (E85, CNG, electricity), and defaults for missing shoulder and winter formulations may be added to the summary here or later via the county database (CDB) builder query. From this summary, the inputs for future years may be created by duplicating these latest available local inputs and updating them with expected future year values and unique FuelFormulationIDs. A corresponding set of FuelSupply records are prepared, typically using monthgroupID 7 for summer, monthgroupID 1 for winter, and the MOVES monthgroupIDs for shoulders (4 and 10). Set the fuelyearID of the current survey year FuelFormulation inputs to the year of the survey and set fuelyearID to the next year for the future year inputs. Convert the FuelFormulation and FuelSupply inputs to a tab-delimited format.
- **Step 8** – ***Produce a comprehensive database of Texas fuel formulation inputs, synchronized with releasing the TCEQ survey results every three years***. Write and execute MySQL scripts to create a Texas MOVES fuels inputs database with MOVES FuelFormulation and FuelSupply tables populated with the inputs from step 7 for the survey year and future years. If any default formulations needed to complete the set were not yet included, they could be

added in this step or later when building CDBs. This database will populate CDBs with the fuel inputs to MOVES for emissions analyses for the survey year (current year) and/or future years. Remember to check for the latest available RFG formulations and biodiesel volumes before using the database to create CDBs since they are updated annually and supersede the previously developed RFG and biodiesel inputs for current and future years.

- **Step 9** – ***Produce subsequent, yearly RFG and biodiesel ester volume estimates***. Follow steps 4 and 6 to produce these annual RFG fuel formulation and biodiesel estimate inputs using any new data available each year after the TCEQ survey year. When creating CDBs for years after the TCEQ survey year, use the later (current or future year) inputs, as appropriate.

3.3.3 Step Details

When fuel inputs are being prepared or updated for a SIP EI development project or in preparation for their later use, it is important to ensure that the sponsor is informed about the assumptions, sources, and processes involved, particularly in cases where changes or refinements have occurred. In conformity inventories, it is typically expected that the fuel inputs development process aligns with the latest SIP EI process while allowing for the possibility of updating the inputs with the latest available formulations.

3.3.3.1 Updating the Process Parameters from EIA Data

Processing EIA Sales Data

These are the two EIA sales data sources the TTI team has considered and used for sales fractions by gasoline fuel grade:

- Texas Refiner Motor Gasoline Sales Volumes Through Retail Outlets.
- Texas Prime Supplier Sales Volumes of Petroleum Products - Motor Gasolines by Grade and Formulation.

The refiner statistics are preferred over the prime supplier data, although the two data sets produce similar results for grade proportions of total motor gasoline. The TTI team used refiner sales to retail outlet statistics in earlier works. In 2017, the refiner data was withheld for several years. Hence, the TTI team consulted with EIA fuels experts and found that the prime supplier data approximated the refiner to retail outlets data. Since the prime supplier data was more reliably published each year, the TTI team switched to that data set. The TTI team downloads and processes the datasets annually.

Table 3-8 contains a sample of the latest available download of refiner sales to retail outlets through 2021, which shows the data gaps (for 7 of the 12 years) and about a 90% reduction between the 2011 and 2017 values. The calculated fuel grade fractions from these tabulated values range as follows: Regular 86.0-88.1%; Midgrade 6.1-6.5%; Premium 5.8-7.5%.

Table 3-8. Texas Refiner Motor Gasoline Sales Volumes Through Retail Outlets

Year	Regular Gasoline (Thousand Gallons per Day)	Midgrade Gasoline (Thousand Gallons per Day)	Premium Gasoline (Thousand Gallons per Day)
2010	5,713.0	421.6	377.6
2011	4,974.7	347.8	327.1
2012			
2013			
2014			
2015			
2016			
2017	528.2	39.6	46.1
2018	533.6	37.6	42.1
2019	527.5	38.2	43.2
2020			
2021			

Table 3-9 is a sample of Texas prime supplier sales volumes by grade and formulation (CG and RFG) for the same set of 12 years. Note that only two years of the 12 have missing data. For this sample, the calculated fuel grade fractions for CG, RFG, and their total are as follows:

- CG: Regular 89.6-92.1%; Midgrade 1.0-2.0%; Premium 5.9-9.2%.
- RFG: Regular 85.0-88.2%; Midgrade 1.4-2.5%; Premium 9.5-13.7%.
- Total: Regular 87.4-90.3%; Midgrade 1.2-2.2%; Premium 7.5-11.4%.

Table 3-9. Texas Prime Supplier Sales Volumes of Petroleum Products Motor Gasoline by Grade and Formulation (Thousand Gallons per Day)

Year	Regular CG All Sales/ Deliveries by Prime Supplier	Regular RFG All Sales/ Deliveries by Prime Supplier	Midgrade CG All Sales/ Deliveries by Prime Supplier	Midgrade RFG All Sales/ Deliveries by Prime Supplier	Premium CG All Sales/ Deliveries by Prime Supplier	Premium RFG All Sales/ Deliveries by Prime Supplier
2010	20,545.9	12,959.2	447.3	374.8	1,312.2	1,454.4
2011	18,410.4	12,922.5	405.1	325.1	1,233.8	1,397.3
2012	18,984.3	12,465.4	393.7	273.1	1,341.4	1,416.0
2013	19,130.1	12,912.5	335.8	225.7	1,436.9	1,619.0
2014			230.2	289.3	1,421.6	1,824.6
2015	19,230.3	14,303.8	254.2	297.1	1,684.1	2,024.5
2016	20,080.7	14,693.0	290	315.1	1,819.9	2,148.0
2017	23,170.2	14,884.4	385.3	317.6	1,896.4	2,122.7
2018	23,436.6	15,565.9				
2019	21,075.0	15,836.2	241.3	262.4	1,821.4	2,262.8
2020	17,262.7	14,121.0	227.0	232.9	1,735.7	2,245.5
2021	17,892.2	15,792.4	228.5	251.9	1,841.0	2,539.4

Comparing the fuel grade fractions between data sets, we see similar splits between regular and higher grades but a shift from midgrade to a heavier premium weighting in the prime supplier data.

Processing EIA energy consumption data

The EIA SEDS provides energy consumption data for 1960 through 2021 (the latest available). The data is available in June with about a 2.5-year lag in publication. The download website provides links to descriptive information, including notes and documentation, data and methodology changes, codes, and descriptions.

The data, downloaded in the spreadsheet "use_all_phy.csv," used to estimate biodiesel ester volumes of diesel needed for updating the Texas diesel FuelFormulation inputs to MOVES, is coded as:

- BDACP (biodiesel consumed by the transportation sector).
- DFACP (distillate fuel oil, including biodiesel, consumed by the transportation sector).

- The units are "thousand barrels."

The first three columns of the spreadsheet provide information on the publication year and status, the state, as well as the MSN (which is a five-character data code where the first and second characters describe an energy source [i.e., BD for biodiesel], the third and fourth characters describe an energy sector or an energy activity [i.e., AC for transportation sector consumption], and the fifth character describes a type of data [i.e., P for data in the physical unit]). The remaining columns contain the data values for each year from 1960 through 2021. Filtering the data for Texas and the two MSN codes listed provides the data needed to estimate the biodiesel volume by year. Note that the DFACP data includes biodiesel, so BDACP divided by DFACP provides the biodiesel fraction of the total, which, for percentages of 1.0 or more, we use as Texas MOVES diesel FuelFormulation input in the "BioDieselEsterVolume" field.

Table 3-10 shows a sample of the biodiesel and diesel consumption statistics for Texas.

Table 3-10. Texas Biodiesel Volume Estimates for Diesel FuelFormulation Inputs from EIA SEDS Biodiesel/Diesel Consumption Statistics for Texas

Year	BDACP	DFACP	Calculated Biodiesel Ester (%)
2010	686	115,544	0.59%
2011	2,339	123,477	1.89%
2012	2,900	122,040	2.38%
2013	5,467	129,756	4.21%
2014	4,775	146,862	3.25%
2015	5,254	145,823	3.60%
2016	7,909	143,858	5.50%
2017	6,943	148,219	4.68%
2018	7,867	161,822	4.86%
2019	7,155	164,815	4.34%
2020	6,364	143,473	4.44%
2021	4,768	152,183	3.13%

3.3.3.2Processing TCEQ Summer Gasoline and Diesel Survey Results

The TCEQ fuel survey data from multiple years (2003, 2005, 2007, 2008, 2011, 2014, 2017, 2020, and 2023) is available in an Excel spreadsheet. The data encompasses both gasoline and diesel fuels. However, unlike other sources, the parameters for the same year were dispersed across different sheets and Excel files. Before this project, the fuel data acquired by the TTI team for EI analyses had yet to be comprehensively consolidated. Therefore, it was necessary at this stage of the work to reduce the data from these multiple files into a comprehensive database. Table 3-11 provides a complete list of the year, file name, and corresponding sheets used to obtain the required data.

Table 3-11. TCEQ Fuel Survey Data Source by Year.

Year	File Name	Sheet Name
2003	TX HAP Fuel Parms_2003	NTI Inputs
2003	ergdiesel2003	Diesel
2005	TX HAP Fuel Parms_2005	Parameters
2005	Final_D2_report2005	2005 Diesel Report
2007	Attachment 2 _Gasoline Test Results	GASOLINE, Contams, E200, E300
2007	Attachment 3_Diesel Analysis Results 2007_revised_v02	DSL
2008	MOBILE6 HAP data inputs deliverable 6b	Sheet 1
2008	Attachment 5a_August2008_workup 1	Summary, Contams, T50, T90 data from Attachment 2 file
2008	Attachment 3b_Rev1_ERG_Dieselfuel_rptdate_062608	Sheet1
2011	Summer2011_gasoline_noDHAdata1stSampling	2011 June Sampling Gasoline
2011	Summer2011_Gasoline_MOVES_Summary_REVISED	Summer2011_Gasoline_MOVES_Summa
2011	Summer2011_Gasoline_Contams	
2011	Summer2011_Gasoline_E200	
2011	Summer2011_Gasoline_E300	
2014	Attachment 2 July2014_GasolineDataReport_NoDHAData	July-gasoline
2014	Attachment4 Summer2014_R1_Gasoline_Summary_Revision	Summer2014_R1_Gasoline_Summary_
2014	July2014_DieselFuelDataReport	July-diesel
2014	June2014_DieselFuelDataReport	June 2014 - diesel fuel
2017	ATTACH_2_Rev1ERG2017_1stSet_OtherData_07-26-17_Gas	Gasoline
2017	ATTACH_5a_Round2_Gasoline_Diesel	R2_Gas_OTH
2017	ATTACH_4b_R1_Diesel	Diesel
2020	Attachment 4a - Fuel Parameter Data for MOVES2014b_REVISED_TTIedits	R1 gas, R1 DSL
2023	Appendix E1- Updated Fuel Parameter Files for MOVES3 and TexN	R1 gas, R1 DSL

The TTI team combined the collected data into two spreadsheets, one for gasoline and another for diesel. The need for separate spreadsheets arose from different parameters for each fuel type. Additionally, several modifications were applied to the original raw data collected in these two spreadsheets, as outlined below:

- A new source column was added to the dataset to provide information about the source file from which each record was extracted. (e.g., EPA_RFG\2002, where EPA_RFG is the folder name and 2002 is the year of that record).
- The survey date information was divided into three columns: date, month, and year. An additional 'survey day' column was added to identify whether the survey was performed on a weekday or a weekend.
- The raw data included geographical information such as survey area, city, and zip codes. Through the FIPS, the corresponding county and TxDOT district names were derived from the zip code and added to the database as two new separate columns.
- A few location names were missing from the diesel survey data. The TTI team retrieved these missing fields by manually matching them with the address provided.
- Several records in the TCEQ gasoline raw data were missing. These records were either the T50 and T90 or E200 and E300 values. To address this, the following correlations were applied to fill in the gaps as documented in EPA's *Regional Fuels and the Fuel Wizard in the MOVES4* report [4]:
    - T50= 2.0408 * (147.91 – E200)
    - T90= 4.5454 * (155.47 – E300)

  The TTI team investigated the ERG's methodologies to calculate E200 and E300 temperatures in the 2023 Summer Fuels Field Study. ERG calculated these temperatures through interpolation instead of using fixed correlations. While these interpolated numbers may be more accurate, this methodology requires a complete set of evaporative temperatures from T50 through T100, which may only be possible in some cases. In addition, the temperature difference between methodologies was very minor. Thus, the TTI team continued to use the correlations listed above.
- The database's 'tceq_diesel_with_ffid' and 'tceq_gasoline_with_ffid' tables included Valongside the raw data.

3.3.3.3 Processing EPA Summer and Winter RFG Survey Results

The EPA RFG compliance survey data was obtained in separate Excel spreadsheets for each year from 2002 to 2020. The fuel parameters and their respective recorded data from 2002 to 2020 were merged into a single spreadsheet by aligning the headers. Subsequently, additional modifications were made to the original raw data, as detailed below:

1. A new source column was added to the dataset to provide information about the source file from which each record was extracted. (e.g., EPA_RFG\2002, where EPA_RFG is the folder name and 2002 is the year of that record).
2. The survey data was divided into three columns: date, month, and year. An additional 'survey day' column was added to identify whether the survey was performed on a weekday or a weekend.
3. The raw data included geographical information such as survey area, city, and zip codes. Through the FIPS, the county and TxDOT district names were derived from the zip code and added to the database as two new separate columns.

The "cleaned_epa_data_with_ffid" table in the database was generated by filtering out the blank or missing MOVES parameter rows by:

1. Records from the EPA raw data for 2012 were filtered out if they contained other parameters but needed to include information related to Area, Date, City, FIPS, County, Season, or Grade.
2. A total of 184 records from the years 2012, 2014, 2016, 2017, and 2019 were filtered out due to missing summer RVP values.
3. 44 records from the years 2012, 2016, and 2017 were excluded from the dataset as they were missing sulfur values and other required MOVES parameters.
4. Blank cells for RVP Winter values were replaced with the default MOVES winter season RVP values. This replacement was done using the following query:

```
SELECT a.fuelyearID, a.monthgroupid, a.fuelregionid, b.fuelsubtypeid,
b.RVP FROM `movesdb20221007`.`FuelSupply` a,
`movesdb20221007`.`FuelFormulation` b

WHERE a.FuelFormulationID IN

(SELECT a.FuelFormulationID FROM movesdb20221007.FuelSupply
```

WHERE a.fuelregionid in (1370011000)

and a.marketshare > 0

and a.monthgroupid=1

and a.fuelyearid in (2011,2012,2013,2014,2018))

and b.fuelsubtypeid =12

and a.FuelFormulationID=b.FuelFormulationID

5. All the remaining blanks in the dataset were replaced with the value "Null."
6. FuelSubTypeIDs were assigned based on the criteria outlined in Chapter 3.1.1.
7. FuelFormulationIDs were assigned using the methodology described later in the Chapter 3.3.3.4.

3.3.3.4Combining the MOVES FuelFormulation input data

The FuelFormulation table contains various parameters such as RVP, Sulphur Level, ethanol volume, Methyl Tertiary Butyl Ether (MTBE) volume, Ethyl Tertiary Butyl Ether (ETBE) volume, Tertiary Amyl Methyl Ether (TAME) volume, Aromatic content, Olefin content, Benzene content, E200 value (percent of fuel distilled off at 200°F), E300 value (percent of fuel distilled off at 300 °F), Volume-to-Weight Percentage of Oxygen, BioDiesel Ester volume, Cetane Index, Polycyclic Aromatic Hydrocarbon (PAH) content, T50 (50% volume distillation temperature), and T90 (90% volume distillation temperature). Additionally, the table includes two additional parameters: FuelFormulationID and FuelSubTypeID. An example of the FuelFormulation table was shown earlier in Table 3-3.

FuelSubTypeID

The FuelSubTypeID for CG is 10, while for Diesel, it is 20. The FuelSubTypeID varies based on the ethanol volume, as indicated Table 3-12.

Table 3-12. Ethanol Volume Range and the Corresponding FuelSubTypeID

ETOHVolume range	0-0.1	0.10 – 6	6 – 9	9 - 12.5	12.5 - 17.5	17.5 - 50.5	50.5 - 70.5	70.5 - 100
FuelSubTypeID	10 (CG)	14	13	12	15	18*	52	51

* fuelSubTypeID = 18 or ethanol (E20) is only available up until MOVES14b. This fuelSubTypeID was removed in MOVES3.

FuelFormulationID

Depending on the survey year or MOVES fuel year, the TTI scheme for producing FuelFormulationIDs produces a four or 5-digit number. These Texas fuelformulationIDs were designed to incorporate information indicating fuel year, season, and fuel region (to include unique DFW and HGB RFG area distinctions). The fuel years that these local fuelformulationIDs cover currently span 2002 through 2020, and 2021+ as future years.

Table 3-13 and Table 3-14 provide the keys to TTI's unique fuel formulation IDs for Texas gasoline and diesel formulations assigned to the survey, the sample data, and the resulting local fuel formulation inputs to MOVES. Table 3-13 describes abbreviated region codes used in the IDs, with separate codes for DFW and HGB RFG areas.

Table 3-13. TTI Fuel Region Code by MOVES FuelRegionID and FuelYearID.

FuelRegionID	TTI fuel region label	TTI fuel region code for FuelYearID <= 2019	TTI fuel region code for FuelYearID >= 2020	Description	Number of counties in region/area
300000000	R1	01	1	Fed. 9.0 RVP limit (E10 RVP waiver)	132 (Western Texas)
178010000	R2	02	2	State 7.8 RVP limit (no RVP waiver)	95 (Eastern Texas)
370010000	R3	03	3	El Paso 7.0 RVP limit (no RVP waiver)	1 (El Paso County)
1370011000	R14	14	8	RFG - DFW	**1999 – 2023:** 4 (DFW) **2024 – 2060:** 10 (DFW)[1]
1370011000	R24	24	9	RFG - HGB	8 (HGB)
178000000	R5	05	5	Fed. 7.8 RVP limit (E10 RVP waiver)	3 (BPA)
100000000	R6	06	6	R1 with a different distribution network	11 (Southern Texas)

[1]Beginning on November 7, 2023, the Dallas RFG covered area will expand from the current four counties to all ten counties in the 2008 ozone NAAQS NA. [10]

Table 3-14 describes fuel development of the fuelformulationIDs, using the abbreviated region code from Table 3-13, and abbreviated coding for fuel year and season. These IDs include historical fuel years 2002 through 2020 and 2021+ for future years. As needed, these IDs may be appended to incorporate new fuel survey data and processed inputs as they become available and are developed.

Table 3-14. Description of FuelFormulationID Digits.

Fuel type	FuelYear ID	Total Digits	Digit Number	Description[1]	Examples
Gasoline	2010 through 2019	5	1st, 2nd	2-digit fuel year designator (11 through 19)	**11103** - El Paso 2011 winter CG **15724** - HGB 2015 summer RFG **19102** - TX 7.8 region 2019 winter CG
			3rd	1-digit season ID (1 -winter; 7 - summer)	
			4th, 5th	2-digit fuel region designator[1]	
Gasoline	2020 and 2021+	4	1st, 2nd	2-digit fuel year designator (20 and 21)	**2078** - DFW 2020 summer RFG **2115** - Fed. 7.8 region 2021 and later winter CG
			3rd	1-digit season ID (1 -winter; 7 - summer)	
			4th	1-digit fuel region designator[1]	
Diesel (all biodiesel)	2011 through 2020	5	1st, 2nd	"30" - first two digits of all diesel FFIDs	**30166** - Texas 2016 ULSD biodiesel **30116** - Texas 2011 ULSD biodiesel **30206** - Texas 2020 ULSD biodiesel
			3rd, 4th	2-digit fuel year designator (YY)	
			5th	"6" (e.g., roughly 6 ppm ULSD sulfur level)	
Diesel (all biodiesel)	2021+	5	1st, 2nd	"30" - first two digits of all diesel FFIDs	**30600** - Texas 2021 and later (future years) 6 ppm ULSD biodiesel
			3rd, 4th, 5th	"600" - for 6 ppm expected future year sulfur	

[1]See Table 3-13 for more information on the fuel region designator. Note that for survey data between the years 2002 and 2009, only the last single digit was utilized as the fuel year designator in the FuelFormulationID.

Appendix 2-A provides a complete listing of the Texas counties with county name, FIPS, TxDOT district, district code, gas rule code or label, and MOVES fuelregionID. This is the table TTI used to assign district and gas rule codes and MOVES fuelregionID to all 254 Texas Counties and their corresponding TxDOT districts.

It must be noted that starting on November 7th, 2023, six new RFG regions will be added to the DFW area, expanding the current four RFG counties to all ten counties that are in nonattainment for the 2008 ozone NAAQS [10]. Thus, for the years 2024 through 2060, the table in Appendix 2-B will be used instead.

3.4 Comprehensive Database and Processing Scripts

Based on the procedures outlined for developing fuel parameter inputs to MOVES, the TTI team enhanced the overall process while retaining the essential calculations. The TTI team created a comprehensive database that houses detailed results from laboratory analyses of each fuel sample derived from publicly available local surveys. The database encompasses all the necessary information, such as Texas gasoline consumption estimates by grade and Texas biodiesel versus distillate fuel oil sales, to facilitate the processing of fuel property data into complete the FuelFormulation and FuelSupply table (see Table 3-3) inputs to MOVES. These inputs are organized by fuel region, year, and month. The database incorporates the following:

- All sample identification, location, and date information, including the survey name. County names were added if missing.
- All sample fuel parameter data, including the units of measurement.
- Annual Department of Energy (DOE) gasoline consumption by grade data for the state of Texas.
- Annual DOE transportation sector biodiesel and distillate fuel oil consumption data for the state of Texas.

The TTI team created the database to maximize flexibility for future utilization. The TTI team expects to update the database annually or triennially as new survey data and other essential information become available. This ensures efficient and timely processing and utilization of the most recent data for MOVES emissions analyses.

In addition, MySQL scripts were developed to process the existing gasoline and diesel sample data into the required FuelFormulation and FuelSupply inputs for MOVES. These scripts are attached as *Appendix 2-C*. These scripts ensure a streamlined and automated process for processing and integrating data. The TTI team plans on utilizing these scripts with each subsequent update to the database. These scripts use local survey data to generate the inputs whenever available. If local survey data is absent, the scripts will use MOVES default or other information as needed. The scripts follow the existing procedures with any agreed-upon refinements to be updated where necessary.

4 REGISTRATION AND AVFT

The topics covered in this chapter was performed under Task 3.3 of this study. The technical memo was submitted to the TCEQ project manager on November 15th, 2023.

This chapter documents the TTI team's updated methods and automated procedures for developing MOVES vehicle age distributions and AVFT inputs for on-road EIs using local registration data. It includes the following sections:

1. Introduction – A brief overview of Texas vehicle registration-related inputs,
2. Data sources – An overview of the Texas Department of Motor Vehicles (TxDMV) 2021 registration data and the three datasets that were produced from it.

3. Methodology and Procedures – Provides details of the main assumptions and typical steps in the current process of applying the referenced data sources in developing and updating complete age distribution and AVFT input data sets for historical and future year emissions analyses,
4. Comprehensive Database and Processing Scripts – Describes the new database developed and Python scripts written to produce it.
5. QA/QC

4.1 Introduction

For over 20 years, TTI has produced vehicle registration, age distribution, and AVFT (previously for MOBILE, diesel sales fraction inputs were developed instead) inputs for EPA's official on-road emissions models (MOBILE and MOVES) to support the TCEQ development of SIP emission goals. These inputs were produced and updated using the latest available vehicle registration data. When local data was unavailable (e.g., for particular vehicle types or model years), the TTI team utilized the EPA emissions model default data or other data sets, as needed, as secondary data sources for developing complete input data.

Currently, the TTI team develops the vehicle registration-related inputs using a combination of analyzed Texas-based local vehicle registration data and MOVES defaults in an Excel-based approach (previously, it was performed using codes written in the Visual Basics language). Due to the limitations of the current approach, maintaining and updating it requires considerable effort and resources. Therefore, developing standardized protocols and applying a more automated and streamlined approach to data analysis, processing, and distribution of inputs to modelers is critical. This work provides a defensible and reproducible standard process for developing vehicle registration data-related input parameters.

4.1.1 Overview of Vehicle Registration-Related Inputs Produced

In March 2022, the TTI team received the 2021 year-end Texas vehicle registration data from the TxDMV through the TxDOT, which is attached in Appendix 3-A. Using this raw vehicle registration data and other data as needed, the following datasets were created:

- **2021 Vehicle Registration Dataset by Vehicle Category and SUT**:

- This dataset presents the population and ratio of vehicles registered by model year within each of the 254 counties in Texas.
- It includes 31 age classes ranging from 0 to 30, 20 vehicle weight categories, seven registration categories, and 11 MOVES SUT types (excluding SUT 53 and 62)[15]. Table 4-1 shows how each vehicle category is mapped to the registration and MOVES SUT types.
- Attached as *Appendix 3-A. Registration/Registration Dataset/registration_outputs/2021_Registration_Dataset.csv*.

Table 4-1. Mapping of Vehicles Category in Vehicle Registration Dataset to MOVES SUT ID and Registration Category

#	VEHICLE_CATEGORY	MOVES SUT ID	REGISTRATION_CATEGORY_NUM
1	MOTORCYCLES	11	2
2	PASSENGER	21	1
3	TRUCKS BETWEEN 6001 AND 8500	31, 32	3
4	TRUCKS LESS THAN 6000	31, 32	3
5	DIESEL TRUCKS >10000	41, 42, 43, 51, 52, 54	4
6	DIESEL TRUCKS >14000	41, 42, 43, 51, 52, 54	4
7	DIESEL TRUCKS >16000	41, 42, 43, 51, 52, 54	4
8	DIESEL TRUCKS >19000	61	5
9	DIESEL TRUCKS >26000	61	5
10	DIESEL TRUCKS >33000	61	5
11	DIESEL TRUCKS >60000	61	5
12	DIESEL TRUCKS >8500	41, 42, 43, 51, 52, 54	4
13	GAS TRUCKS >10000	41, 42, 43, 51, 52, 54	6
14	GAS TRUCKS >14000	41, 42, 43, 51, 52, 54	6
15	GAS TRUCKS >16000	41, 42, 43, 51, 52, 54	6
16	GAS TRUCKS >19000	61	7
17	GAS TRUCKS >26000	61	7
18	GAS TRUCKS >33000	61	7
19	GAS TRUCKS >60000	61	7
20	GAS TRUCKS >8500	41, 42, 43, 51, 52, 54	6

[15] The population of MOVES SUT 53 (single-unit long-haul vehicle) is estimated using local MOVES SUT 52 (single-unit short-haul vehicle) multiplying with a ratio developed from local VMT-mix dataset. The population of MOVES SUT 62 (combination long-haul vehicle) is estimated using local MOVES SUT 52 (combination short-haul vehicle) multiplying with a ratio developed from local VMT-mix dataset.

- **Age Distribution Dataset**:
    - This dataset displays the ratio of vehicle counts based on vehicle age (or model year) for each SUT and regional unit.
    - Various levels of regional units are included, such as the entire Texas region, counties, TxDOT Districts, TTI Districts, MPO, Council of Governments (COG), and NA based on the NAAQS.
    - The files consist of 31 age classes ranging from 0 to 30 and 13 SUT types.
    - The analysis year of the dataset ranges from 1990 and 1999 to 2060. The data was derived using the 2021 registration dataset for MOVES SUT 11, 21, 31, 32, 52, 53, 61, and 62 and the corresponding year MOVES3 default dataset for MOVES SUT 41, 42, 43, 51, and 54.
    - Attached as *Appendix 3-B. ageDistribution/ageDistribution_outputs*.
- **AVFT**:
    - This dataset provides the ratio of vehicle counts according to fuel type and engine tech distribution for each SUT and model year.
    - It includes 38 vehicle combination types comprising 13 SUT and 5 fuel types. The definitions of SUTs and fuel types are listed in Table 4-2.
    - The dataset spans 101 years, ranging from 1960 to 2060. The data was compiled using the 2021 registration dataset and MOVES default dataset.
    - Attached as *Appendix 3-C. AVFT/avft_outputs*.

Table 4-2. Definition of MOVES SUT and Fuel Type ID

SUT ID	sourceTypeName	fuelTypeID	fuelTypeName
11	Motorcycle	1	Gasoline
21	Passenger Car	2	Diesel Fuel
31	Passenger Truck	3	CNG
32	Light Commercial Truck	5	Ethanol (E-85)
41	Other Buses	9	Electricity
42	Transit Bus		
43	School Bus		
51	Refuse Truck		
52	Single Unit Short-haul Truck		
53	Single Unit Long-haul Truck		
54	Motor Home		
61	Combination Short-haul Truck		
62	Combination Long-haul Truck		

Table 4-3 lists the file names of each dataset type, all saved in CSV file format. A total of nine different files were generated. Table 4-4 shows the structure of each file, outlining the specific columns and their respective data. Each file varies in the number of rows based on the classification method used for vehicle category, regional unit, as well as vehicle age or model year. It is important to note that the 2021 Texas registration data and the corresponding year MOVES3 default age distribution data for some MOVES SUTs were utilized to ensure the completion of the dataset.

Table 4-3. File Names of the Processed Datasets.

#	File	File name
1	Registration Dataset by Vehicle Category and SUTs	2021_Registration_Dataset.csv
2a	Age Distribution Dataset - Texas	2021_ageDistribution_WHOLE_mvs3.csv
2b	Age Distribution Dataset - County	2021_ageDistribution_COUNTY_mvs3.csv
2c	Age Distribution Dataset – District	2021_ageDistribution_DISTRICT_mvs3.csv
2d	Age Distribution Dataset - TTI District	2021_ageDistribution_TTI_DISTRICT_mvs3.csv
2e	Age Distribution Dataset - COG	2021_ageDistribution_COG_mvs3.csv
2f	Age Distribution Dataset - MPO	2021_ageDistribution_MPO_mvs3.csv
2g	Age Distribution Dataset - NA	2021_ageDistribution_Nonattainment_mvs3.csv
3	AVFT - Texas	2021_AVFT_mvs3.csv

Table 4-4. Basic Structure of the Processed Datasets.

#	File	Number of Areas	Number of Vehicle categories	Number of Age Groups or Model Year	Number of rows
1	Registration Dataset by Vehicle Category and SUT	254	20[a]	31	147,552
2a	Age Distribution Dataset - Texas	1	13	31	25,389
2b	Age Distribution Dataset - County	254	13	31	6,448,806
2c	Age Distribution Dataset - District	25	13	31	634,725
2d	Age Distribution Dataset – TTI District	25	13	31	634,725
2e	Age Distribution Dataset - COG	24	13	31	609,336
2f	Age Distribution Dataset - MPO	23	13	31	583,947
2f	Age Distribution Dataset - NA	20	13	31	507,780
3	AVFT	1	35[b]	101	3,535

[a] Refer to Table 4-1.

[b] This value represents the different SUT, fuel type, and engine tech combinations.

4.2 Data Sources

This chapter briefly describes the TxDMV 2021 registration data that the TTI team acquired in March 2022. This data was used to develop Texas age distribution, avft, and SUT population inputs for MOVES3.

The raw 2021 registration data contains three sheets in a single Excel file—AGEPERKN, GASPERKN, and DSLPERKN—all of which provide information about the number of registered vehicles categorized by vehicle category:

- The AGEPERKN sheet categorizes vehicles based on vehicle types, such as passenger vehicles and motorcycles.
- The GASPERKN sheet categorizes gasoline vehicles by weight, with categories like GAS>8500 for gasoline vehicles over 8,500 lbs but under 10,000 lbs, which is the next category.
- The DSLPERKN sheet categorizes diesel vehicles by weight, with categories like DIESEL>10000 for diesel vehicles over 10,000 lbs but under 14,000 lbs, which is the next category.

Each of the three sheets contains nine vehicle categories, resulting in a total of 27 vehicle categories, as shown in Table 4-5.

Table 4-5. Vehicle Categories in AGEPERKN, GASPERKN, and DSLPERKN

#	AGEPERKN	#	GASPERKN	#	DSLPERKN
1	PASSENGER	10	GAS > 8500	19	DIESEL > 8500
2	MOTOR-CYCLES	11	GAS > 10000	20	DIESEL > 10000
3	TRUCKS <= 6000	12	GAS > 14000	21	DIESEL > 14000
4	TRUCKS > 6000 <= 8500	13	GAS > 16000	22	DIESEL > 16000
5	TOTAL TRUCKS <= 8500	14	GAS > 19000	23	DIESEL > 19000
6	GAS TRUCKS > 8500	15	GAS > 26000	24	DIESEL > 26000
7	DIESEL TRUCKS > 8500	16	GAS > 33000	25	DIESEL > 33000
8	TOTAL TRUCKS > 8500	17	GAS > 60000	26	DIESEL > 60000
9	TOTAL TRUCKS	18	GAS_TOTAL	27	DIESEL_TOTAL

In addition to grouping vehicles by category, they were also categorized based on county, model year, and vehicle age. The raw dataset contains information for all 254 counties in Texas, provided in the format "county name – three-digit county number," where the county number is assigned by alphabetical order of the county's name. The model year of vehicles ranges from "1989 and OLDER" and 1990 through 2022. However, the information for the year 2022 is incomplete as the data extraction occurred in July 2022, which is before the end of 2022. Therefore, the 2022 model year registration data was excluded from the input development. In total, the dataset contains 33 model years. The TTI team then matched the counties within the 2021 registration data with corresponding TxDOT Districts, TTI Districts, MPO, COG, and nonattainment status according to the NAAQS.

The file containing information on the 254 counties and their respective TxDOT Districts, TTI Districts, MPOs, COGs, and nonattainment status can be found in *Appendix 3-D. Supporting Files/Geo_mapping.csv*.

4.3 Methodology and Procedures

4.3.1 Vehicle Registration Data by Vehicle Category and SUT

The TTI team converted and combined the AGEPERKN, GASPERKN, and DSLPERKN sheets from the raw registration dataset into one single file.

4.3.1.1 Adjusting Vehicle Age

The raw dataset contains data on the number of vehicles spanning from '1989 or older' up to 2022. However, due to the incompleteness of the data for the year 2022, it was excluded from the dataset. In the MOVES framework, 31 age categories ranging from 0 to 30 serve as input data. Therefore, the TTI team merged the vehicles manufactured before and equal to 1991—specifically those with model years '1991,' '1990,' and 'OLDER'—into a single vehicle age of 30. The age of a vehicle is determined based on its corresponding model year information, as defined in Table 4-6.

Table 4-6. Model Year and Corresponding Vehicle Age in Dataset

Model year In raw data	Vehicle AGE	Model year In raw data	Vehicle AGE
2022	Removed	2005	16
2021	0	2004	17
2020	1	2003	18
2019	2	2002	19
2018	3	2001	20
2017	4	2000	21
2016	5	1999	22
2015	6	1998	23
2014	7	1997	24
2013	8	1996	25
2012	9	1995	26
2011	10	1994	27
2010	11	1993	28
2009	12	1992	29
2008	13	1991	30
2007	14	1990	30
2006	15	Older	30

4.3.1.2 Addressing Missing Data

The 'GASPEKN' sheet in the raw database needed vehicle information from Loving County. This missing data posed challenges in developing SUT 61-related information. To address this issue, the TTI team assumed that the vehicle count for SUT 61 in Loving

County remained consistent with the previous 2019 dataset[16]. Subsequently, the TTI team extracted the SUT 61 data for Loving County from the 2019 registration data and merged it with the new dataset.

4.3.1.3Detailed Procedure Description

The TTI team processed the registration data by vehicle category and SUTs from the raw 2021 registration data. The steps include:

1. Read the raw registration data from all three sheets and filter out the data from the year 2022 due to its incompleteness.
2. Combine the 1991, 1990, and “Older” vehicle counts into the model year 1991.
3. Reformat the county name and numbers into separate columns.
4. Revise the tables into a pivot format with columns 'COUNTY_NAME,' 'CountyNum,' 'MODEL_YEAR,' 'AGE,' 'PROGRAM,' 'VEHICLE_CATEGORY,' 'CATEGORYT_VEHICLE.'
5. Merge the AGEPERKN, GASPERKN, and DSLPERKN tables into one single table.
6. Map the 'VEHICLE_CATEGORY' to 'sourceTypeID' and 'REGISTRATION_CATEGORY_NUM' using the information shown in Table 4-10.
7. Calculate the total vehicle population by different categorical fields (sourceTypeID and registration category ID).

The final registration dataset is attached as *Appendix 3-A. Registration/registration_outputs/2021_Registration_Dataset.csv*.

4.3.2 Age distribution

The Age Distribution dataset provides information on the ratio of vehicle counts within each vehicle age category to the total number of vehicles, categorized by regional unit and SUT. Seven separate Age Distribution result files were generated based on different restricted units: the entire state of Texas, county-level, TxDOT Districts-level, TTI Districts-level, COG-level, MPO-level, and designated NA-level. The TTI team utilized the

[16] The previous 2019 dataset was extracted in December 2019. The oldest model year on this dataset is “1989 and OLDER” and the latest is 2019.

NA designations from 2021 to compile this dataset. The TTI team excluded SO_2 NAs[17] from the NA list used for this dataset. The files within each level's dataset contain age classes ranging from 0 to 30.

The Age Distribution dataset was derived from the Registration by Vehicle Category dataset (see Section 4.3.1) and MOVES default values. The Age Distribution dataset specifically requires information for 13 SUT categories. However, the Registration by Vehicle Category dataset only provides data for 8 SUT categories. To address this discrepancy, the TTI team utilized MOVES default values to fill in the data gaps for the remaining 5 SUT categories in the Age Distribution dataset. The 13 SUT categories in the Age Distribution dataset and their corresponding sources are listed in Table 4-7.

Table 4-7. SUT Categories in the Age Distribution Dataset and their Corresponding Sources and Regional Unit Levels

SUT	SUT - Emission Source Type	Data source	TxDMV Vehicle Category	Level
11	Motorcycle	Texas Local	Motorcycle	County
21	Passenger Car	Texas Local	Passenger	County
31	Passenger Truck	Texas Local	Truck ≤ 6000	County
32	Light Commercial Truck	Texas Local	6000 < Truck ≤ 8500	County
41	Other Buses	MOVES3 Default	-	County
42	Transit Bus	MOVES3 Default	-	County
43	School Bus	MOVES3 Default	-	County
51	Refuse Truck	MOVES3 Default	-	County
52	Single Unit Short-haul Truck	Texas Local	Truck ≤ 19000	County
53	Single Unit Long-haul Truck	Texas Local	Truck ≤ 19000	Statewide
54	Motor Home	MOVES3 Default	-	County
61	Combination Short-haul Truck	Texas Local	19000 < Truck	County
62	Combination Long-haul Truck	Texas Local	19000 < Truck	Statewide

The SUT categories sourced from the 2021 registration data included 11, 21, 31, 32, 52, 53, 61, and 62. The age distribution ratios from the MOVES defaults were utilized for the remaining SUT categories, namely 41, 42, 43, 51, and 54. The TTI team then merged the

[17] A list of Texas counties that are in nonattainment or in maintenance for each CAP on the NAAQS is available here: https://www3.epa.gov/airquality/greenbook/anayo_tx.html

20 categories from the Registration by Vehicle Category dataset into the 8 SUT categories required by the Age Distribution dataset.

When conducting MOVES simulations for years other than 2021, data is obtained from two sources: the 2021 registration dataset via the Registration by Vehicle Category dataset and MOVES defaults, as required. The locally collected registration data is the primary input for SUT categories in the 2021 registration dataset. However, for SUT categories not included in the 2021 registration dataset, the MOVES default data corresponding to the simulated year will be utilized instead. Table 4-7 provides an overview of the available local Texas registration data.

For more details, refer to Page 58 of TTI's 2020 *On-Road Mobile Source Annual, Summer Weekday, and Winter Weekday EIs* report [11] and page 135 of TTI's *EI Estimation Utilities Using MOVES: MOVES2014aUtl* User's Guide [12].

4.3.2.1 Separating Vehicle Counts by Regional Units

Seven separate Age Distribution datasets were created for each regional unit, encompassing the entire state of Texas and county-level, TxDOT district-level, TTI district-level, COG-level, MPO-level, and NA-level datasets. More information is available in *Appendix 3-B. ageDistribution/ageDistribution_outputs*.

Table 4-8 provides a breakdown of each level's areas, vehicle categories, and age groups. The number of rows of data available for each level is shown.

Table 4-8. Age Distribution Dataset File List

Levels	Number of Areas	Number of Vehicle Categories	Number of Age Groups	Number of rows
Texas	1	13	31	403
County	254	13	31	102,362
District	25	13	31	10,075
COG	24	13	31	9,672
MPO	23	13	31	9,269
NA	20	13	31	8,060

4.3.2.2 Summing Up the AgeFraction

The Age Distribution dataset's AgeFraction column provides information on the proportion of vehicles within specific age groups for each combination of SUT and regional levels. To minimize any discrepancies that could arise due to rounding, the TTI team converted all age fractions to 9 decimal places and then adjusted the most significant fraction among the age fractions within each group. This was done to ensure that the sum of age fractions by SUT and regional level would equal 1.0, thus maintaining a complete distribution.

4.3.2.3Detailed Procedure Description

The following steps were taken to process the ageDistribution data from the raw 2021 registration data:

1. Read the raw registration data from all three sheets and filter out the data from the year 2022 due to its incompleteness.
2. Combine 1991, 1990, and Older vehicle count data into the model year 1991.
3. Reformat the county name and numbers to separate columns.
4. For the entire state of Texas level, the vehicle categories were mapped to SUT using the information provided in Table 4-7. For example, SUT = 21 for the category PASSENGER. Each SUT in the following pairs shares the same value: 31 and 32, 52 and 53, 61 and 62.
5. For the entire state of Texas, calculate the fraction of the corresponding model year and SUT individually by dividing the vehicle count for each model year of the SUT by the total vehicle count across all model years. The equation for this calculation is shown below:

$$ageFraction_{SUT,MY} = \frac{vehicle\_count_{SUT,MY}}{\sum_{MY} vehicle\_count_{SUT}}$$

   Where,

   SUT is the sourceTypeID;

   MY is the model year.

6. For County, MPO, COG, Non_Attainment, TxDOT District, and TTI District levels, the vehicle categories were mapped to SUTs 11, 21, 31, 32, 52, and 61 using the information provided in Table 4-7. Subsequently, the ageFraction was calculated using the equation listed in Step 5. For Loving County, the 2019 registration count data were used instead.

7. For County, MPO, COG, Non_Attainment, TxDOT District, and TTI District levels, the SUTs 53 and 62 information were imported from the entire state of Texas and calculated for all levels.
8. MOVES3 default data was imported and filtered for all analysis years with SUTs 41, 42, 43, 51, and 54 for all levels. The filtered default data was then combined with the local *ageDistribution* file. The MOVES default *ageDistribution* table is attached as *Appendix 3-B. ageDistribution/Input/moves3_sourcetypeagedistribution.csv*.
9. QA/QC was performed to ensure that the summation of the ageFraction for each SUT over the modelYearID equals 1 with 9 digits after the decimal.

The final ageDistribution files are attached in *Appendix 3-B. ageDistribution/ageDistribution_outputs*.

4.3.3 AVFT

As per EPA's *MOVES3 Technical Guide* [13], the AVFT table allows users to customize the distribution of vehicles capable of utilizing various fuels and technologies for each model year. This customization includes defining the proportion of vehicles using diesel, gasoline, E-85, CNG, and electricity for each vehicle type and model year. For instance, if the registration data in a specific county indicates a higher number of diesel vehicles in operation than those in the default AVFT table for a particular source type, the AVFT table can be adjusted accordingly. It's crucial to note that modifications to the AVFT table should only be made if local data is available. If local data is utilized for the present model year (i.e., model year for age ID 0), it can also be assumed to be applicable for all future year years. The TTI team prepared the AVFT dataset to illustrate the ratios of vehicle counts across different fuel types, categorized by SUT and year.

4.3.3.1 Availability of Fuel Type and SUT Combinations

In MOVES, not all fuel types are applicable for every SUT category. For example, there is no CNG-powered motorcycle (SUT ID: 11). Table 4-9 shows the fuel type(s) available for each specific SUT category. In total, there are 38 combinations of SUT categories and fuel types within the dataset. For SUTs 52, 53, and 61, the TTI team calculated the values based on the gasoline and diesel data retrieved from the 2021 Texas Registration Data. The remaining were retrieved from the MOVES3 AVFT default values.

Table 4-9. Fuel Types in MOVES3 for Each SUT

SUT	Gasoline	Diesel	CNG	E-85	Electricity
11	X				
21	X	X		X	X
31	X	X		X	X
32	X	X		X	X
41	X	X	X		
42	X	X	X		
43	X	X	X		
51	X	X	X		
52	X	X	X		
53	X	X	X		
54	X	X	X		
61	X	X	X		
62		X			

4.3.3.2Extrapolating the Missing Model Years

The 2021 registration data only included in the dataset covers vehicles with model years ranging from 1990 to 2022, with any vehicles manufactured before 1990 (i.e., 1989) categorized as "OLDER". In addition, the data for the model year 2022 needs to be completed, as it was extracted before the end of 2021 and was omitted. Due to the requirement of covering model years 1960 to 2060 in the AVFT tables, the 2021 registration data alone couldn't provide information for a significant portion of the required model years.

Therefore, the TTI team utilized the 2021 registration data for SUT categories 52, 53, and 61, covering model years 1990 to 2021. Data was extracted from the MOVES default values to complete the AVFT tables with the remaining information. Figure 4-1 shows how the data sources were integrated to finalize the AVFT table, with blue tiles indicating default MOVES AVFT data, yellow tiles representing the 2021 registration data, and grey tiles depicting inferred data. In the inferred data, values from the model year 2021 were used to populate all future years from 2022 to 2060, while values from the model year 'OLDER' were used to populate past years from 1960 to 1989.

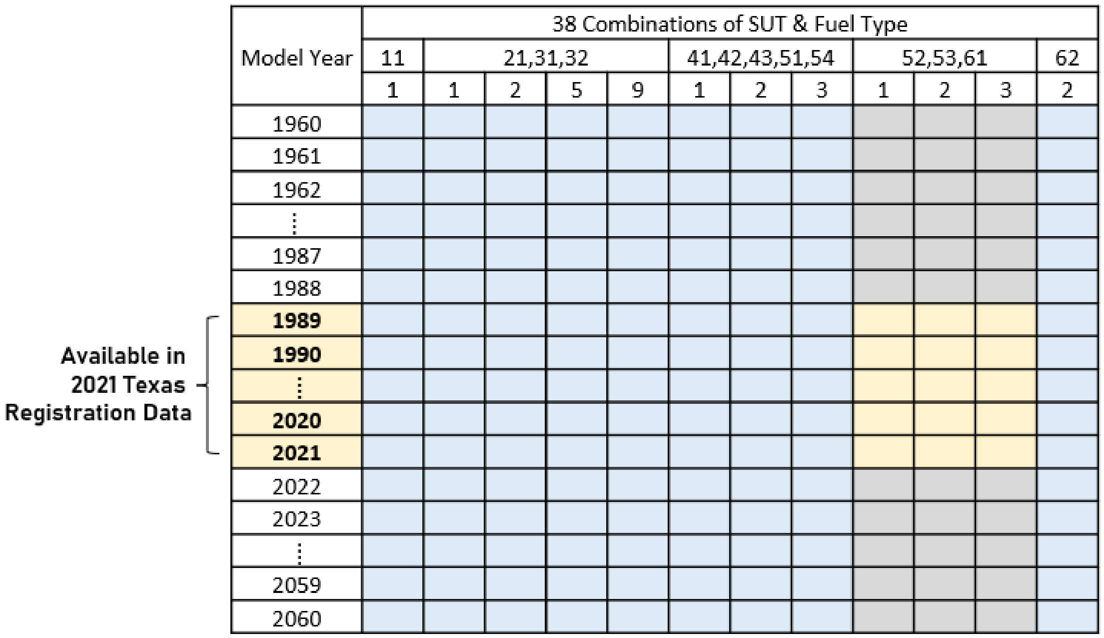

Figure 4-1. Data Sources Used to Populate the AVFT Dataset

Blue tiles indicating default MOVES AVFT data, yellow tiles representing the 2021 registration data, and grey tiles depicting inferred data.

4.3.3.3Detailed Procedure Description

The following steps were taken to process the *AVFT* from the 2021 registration data:

1. Read the raw registration data with all three sheets and filter out the data of the last and incomplete registration year 2022.
2. Combine model years 1991, 1990, and "OLDER" vehicle population into model year 1991.
3. Reformat the county name and numbers to separate columns.
4. Calculate the gasoline and diesel vehicle fraction over the total value of vehicles for SUTs 52, 53, and 61 separately for each model year. The equation of this calculation is shown below:

$$fuelEngFraction_{SUT,MY,FT} = \frac{vehicle\_count_{SUT,MY,FT}}{\sum_{FT} vehicle\_count_{SUT,MY}}$$

Where,

SUT is the sourceTypeID;

FT is the fuel type;

MY is the model year.

5. Extend the model year to 1960- 2060 for SUTs 52, 53, and 61. The model year 2021 values were used to populate all future years from 2022 to 2060, while the 'OLDER' model year values were used to populate past years from 1960 to 1989.

6. Import the MOVES default *samplevehiclepopulation* table and filter for SUTs other than 52, 53, and 61. The filtered default data is then combined with the local data.

   It is important to note that the default *fuelEngFraction* information in the MOVES3 default database is not stored in the AVFT table. The table containing this information is '*samplevehiclepopulation*,' which consists of 8 columns. The required columns are: 'sourceTypeID,' 'modelYearID,' 'fuelTypeID,' 'engTechID,' and 'stmyFraction.'

   Notably, a column "stmyFuelEngFraction" differs from the *fuelEngFraction* for the AVFT data. The "stmyFraction" column contains the data needed for the *fuelEngFraction*.

7. Check for any SUT/FT pairs that are not in the TTI VMT-Mix data and remove the corresponding *fuelEngFraction*. Afterward, renormalize the removed value(s) to other fuel types for that SUT to ensure that the fuelEngFraction for the SUT in any model year can be summed to 1 for its fuel types. In this case, fuelTypeID 3 (CNG) should be removed for SUTs 41, 42, 43, 51, 52, 53, 54, and 61.

8. Perform QA/QC to ensure the summation of the fuelEngFraction for each SUT and the modelYearID over the fuelTypeID equals 1 with 9 digits after the decimal.

The final AVFT table is attached as *Appendix 3-C. AVFT/avft_outputs/mvs3_avft_final.csv*.

4.4 Comprehensive Database and Processing Scripts

This section discusses in detail the data structure and Python scripts for producing the three datasets: (i) the 2021 Vehicle Registration Dataset by Vehicle Category and SUT, (ii) Age Distribution Data, and (iii) AVFT.

4.4.1 Vehicle Registration Data by Vehicle Category and SUT

The processed vehicle registration dataset file provides information on the number of vehicles and the corresponding ratio of vehicles categorized by county and vehicle category. It offers detailed insights into the distribution of vehicles across different counties and vehicle categories within specified age ranges. It covers 254 counties, 20 vehicle categories, 11 SUTs, and 31 vehicle age classes ranging from 0 to 30.

This dataset contains 11 columns as follows:

- **COUNTY_NAME** – This column specifies the name of the Texas county where the vehicle was registered.
- **CountyNum** – This column specifies the number of Texas counties in the registration record by alphabetical sequence of county names.
- **MODEL_YEAR** – This column specifies the model year of the registered vehicle. It includes 31 unique model years from 1991 to 2021. Model years 1990 and earlier are aggregated into the 1991 data.
- **AGE** – In this column, the age of the registered vehicle is indicated. The age is calculated based on the *MODEL_YEAR* value. For instance, a vehicle with a model year of 2021 would have an age of zero in 2021. Note that vehicles with model years 1991 and earlier are labeled 30 years old.
- **PROGRAM** – This column specifies the data source retrieved among the sheets: AGEPERKN, DSLPERKN, and GASPERKN. It indicates from which sheet the data in this column was obtained.
- **VEHICLE_CATEGORY** – This column specifies the category of the vehicle. For example, “PASSENGER”, “MOTORCYCLE”, or “GAS TRUCK >8500”.
    - From the AGEPERKN sheet, the categories are:
        - “TOTAL TRUCKS <= 8500” is the summation of the categories “TRUCKS <= 6000” and “TRUCKS > 6000 <= 8500”;
        - “TOTAL TRUCKS > 8500” is the summation of the categories “GAS TRUCKS > 8500” and “DIESEL TRUCKS > 8500”, which overlaps with “GAS_TOTAL” in the GASPERKN sheet and “DIESEL_TOTAL” in the DSLPERKN sheet;
        - “TOTAL TRUCKS” sums all truck categories.
    - From the GASPERKN sheet:
        - “GAS_TOTAL” sums all other categories in the sheet.

- From the DELPERKN sheet:
  - "DIESEL_TOTAL" sums all other categories in the sheet.

To avoid calculation dependencies and excesses, the categories 'TOTAL TRUCKS <= 8500,' 'TOTAL TRUCKS > 8500,' 'TOTAL TRUCKS,' 'GAS TRUCKS > 8500,' 'DIESEL TRUCKS > 8500,' 'GAS_TOTAL,' and 'DIESEL_TOTAL' were excluded from further analysis. All other vehicle categories listed in Table 4-5 are present here.

- **CATEGORY_VEHICLE** – This column specifies the total number of registered vehicles that match the *COUNTY_NAME, VEHICLE_ CATEGORY, MODEL_YEAR*, and *AGE* criteria.
- **sourceTypeID** – This column specifies the MOVES SUT of the registered vehicle. Table 4-10 provides a comparison of MOVES SUT or SUTs with the vehicle category or categories reported in the TxDMV data. The following eight SUTs were applicable: 11, 21, 31, 32, 41, 42, 43, 51, 52, 54, and 61. It's important to note that for SUT 53, the TTI's *Emissions Estimation Utilities for MOVES-based EIs* [14] calculates the SUT population factors by fuel type, dividing the fuel type vehicle miles traveled (VMT) mix for SUT 53 by the fuel type VMT mix for SUT 52. Regarding SUT 62, the utility calculates the SUT population factors by fuel type, dividing the fuel type VMT mix for SUT 62 by the fuel type VMT mix for SUT 61, thereby creating a ratio of long-haul trucks and short-haul trucks, respectively. Thus, all SUTs 53 and 62 information is identical across all Texas counties.

Table 4-10. MOVES SUT, TTI Registration Category by TxDMV Vehicle Category

Registration Category	SUT	Vehicle Category
1	21	Passenger
2	11	Motorcycles
3	31 & 32	Total Trucks <=8500
4	41, 42, 43, 51, 52, & 54	Diesel > 8500, Diesel > 10000, Diesel > 14000, Diesel > 16000
6	41, 42, 43, 51, 52, & 54	Gas > 8500, Gas > 10000, Gas > 14000, Gas > 16000
5	61	Diesel > 19000, Diesel > 26000, Diesel > 33000, Diesel > 60000
7	61	Gas > 19000, Gas > 26000, Gas > 33000, Gas > 60000

- **REGISTRATION_CATEGORY_NUM** – This column indicates the registration category number from 1 to 7. The classification relation between the registration category number and the vehicle category is also shown in Table 4-10.
- **TOTAL_sourceTypeID** - This column specifies the total number of registered vehicles that match the *COUNTY_NAME, MODEL_YEAR, sourceTypeID*, and *AGE* criteria.
- **TOTAL_REGISTRATION_CATEGORY_NUM** – This column specifies the total number of registered vehicles that match the *COUNTY_NAME, MODEL_YEAR, REGISTRATION_CATEGORY_NUM*, and *AGE* criteria.

The Python script to process the *Registration* data from the raw 2021 registration data is attached as *Appendix 3-A. Registration /Script*.

4.4.2 Age Distribution

Each level's dataset contains five columns as follows:

- **RegionID** – This column includes a regional ID specific to the regional level. For instance, in the COG-level dataset, it is referred to as COG_ID, while in the MPO-level dataset, it is called MPO_ID, and so on. A comprehensive list of regional-level IDs can be found in *Appendix 3-D. Supporting_Files/Geo_mapping.csv*.
- **yearID** - This column specifies the year of the dataset. For all rows in these datasets, the YEARID is 2021.
- **sourceTypeID** – This column specifies the SUT ID for the registered vehicle. All 13 SUTs in MOVES are included in the results.
- **ageID** - This column specifies the age of the registered vehicle. The AgeID values range from 0 to 30 and align with the age categories used in the vehicle Registration Datasets mentioned earlier.
- **ageFraction** – This column indicates the percentage of registered vehicles within each age group, categorized by SUT and regional level. It provides information on the proportion of vehicles within a specific age for each combination of SUT and region.

The Python script to process the *ageDistribution* data from the raw 2021 registration data is attached as *Appendix 3-B. ageDistribution/Script*.

4.4.3 AVFT

The AVFT dataset has five columns as follows:

- **souceTypeID** – This column specifies the 13 SUT IDs listed in Table 4-7.
- **modelYearID** - This column specifies the vehicle's model year, which ranges from 1960 to 2060.
- **fuelTypeID** – This column specifies the vehicle's fuel type ID. There are six types of fuels available in the AVFT dataset.
- **engTechID** – This column specifies the vehicle's *engTechID*. Refer to Table 4-11 to match the vehicle's *fuelTypeID* to its corresponding *engTechID*.

Table 4-11. Available Fuel Types and Corresponding engTechIDs

FuelTypeID	Fuel	engTechID
1	Gasoline	1
2	Diesel	1
3	CNG	1
5	E-85	1
9	Electricity	30

- **fuelEngFraction** – This column specifies the proportion of each fuel type within a specific source type and model year combination. The sum of the *fuelEngFraction* values for each *souceTypeID* and *modelYearID* must equal 1.0. For example, for vehicles with *sourceTypeID* 52 (Single Unit Short-haul Truck) and *modelYearID* 1990, the *fuelEngFraction* for *fuelTypeID* 1 (gasoline) and 2 (diesel) are 0.5398 and 0.4602, respectively. Adding both *fuelEngFraction* together yields 1.0.

The Python script to process the *AVFT* data from the raw 2021 registration data is attached as *Appendix 3-C. AVFT/Script*.

4.5 QA/QC

The TTI team performed QA/QC to ensure the reliability and accuracy of the three prepared dataset files. The TTI team compared the outputs generated using 2019 registration data using the new scripts to the ones generated using the previous methodology for anomalies. If any discrepancies or anomalies were discovered, the TTI team thoroughly investigated to identify their root causes and resolve them appropriately. The addressed fields and criteria are shown in the registration dataset by vehicle category and SUT Table 4-12. For the ageDistribution files, the addressed fields and criteria are shown in

Table 4-13. For the AVFT files, the addressed fields and criteria are shown in

Table 4-14.

Table 4-12. QA/QC Fields and Criteria of The Registration Dataset

Field Number	Criteria Details	QA/QC Pass Criteria
1	Check the number of unique values of the COUNTY_NAME column	254
2	Check the values of the CountyNum column following the corresponding COUNTY_NAME value in alphabetical sequence.	True
3	Check if the AGE column values fall in the range (0, 30)	True
4	Check the number of unique values of the VEHICLE_CATEGORY column	20
5	Check if the SUT, REGISTRATION_CATEGORY_NUM, and VEHICLE_CATEGORY mapping is accurate and correct in the Python code.	True

Table 4-13. QA/QC Fields and Criteria of the ageDistribution Tables

Field Number	Criteria Details	QA/QC Pass Criteria
1	Check if the tables exist for each regional level	True
2	Check the Number of records for each yearID should >0	True
3	Number of records by sourceTypeID/yearID for each yearID and group of counties ID	31
4	Group of counties ID, sourceTypeID, yearID, ageID, ageFraction not NULL	True
5	sourceTypeID unique values for all yearID and levels	All 13 SUTs
6	yearID unique values	1990, 1999- 2060
7	ageID should be in range (0, 30)	True
8	0 <= ageFraction <= 1	True
9	Sum (ageFraction) by sourceTypeID/yearID (rounded to 9 decimals) for each yearID and group of counties ID	1.0

Table 4-14. QA/QC Fields and Criteria of the AVFT Table

Field Number	Criteria Details	QA/QC Pass Criteria
1	Check if the table exists for the MOVES3 version	True
2	The number of unique values of sourceTypeID	All 13 SUTs
3	Check the modelYearID for each sourceTypeID	1960- 2060
4	Check if the fuelTypeID for each sourceTypeID exists in the TTI VMT-Mix data.	True
5	Check fuelEngFraction summation for sourceTypeID/modelYearID round to 9 significant digits:	1.0

5 TXLED

This chapter discusses the TTI team's updated methodologies to develop the TxLED post-processing factors.

This chapter documents the TTI team's updated methods and automated procedures for developing TxLED factors for on-road EIs. It includes the following sections:

1. Introduction – A brief overview of TxLED, a description of the methodology based on the 2001 memo [15], and an overview of the 2023 EPA guidance,
2. Data sources – An overview of the data used to develop the TxLED factors,
3. Methodology and Procedures – Provides details of the updated methodology and procedures based on the January 2023 Guidance [16],
4. Comprehensive Database and Processing Scripts – Describes the new database developed and Python scripts written to produce it.
5. QA/QC

5.1 Introduction

The TxLED program is an initiative by the state of Texas to reduce harmful emissions from diesel-powered vehicles and equipment. The program aims to improve air quality and public health by reducing NOx emissions from diesel-powered motor vehicles and non-road equipment [17].

As MOVES does not account for the impacts of the TxLED program, the calculated TxLED adjustment factor needed to be applied to the NOx emission rates from diesel vehicles for all 110 affected TxLED counties. To accomplish this, a post-processing utility utilizing a look-up table for on-road rates was employed to incorporate the impact of TxLED on NOx emissions from diesel vehicles within the 110 TxLED counties.

Since 2006, TTI has produced the TxLED adjustment factor for EPA's official on-road emissions models (MOBILE and MOVES) for SIP and conformity EI analyses using the approach developed by TCEQ based on information about the TxLED effects on diesel vehicle NOx emissions, as documented in EPA's memorandum from September 2001 [15]. In January 2023, the EPA published its *Guidance on Quantifying NOx Benefits for Cetane Improvement Programs for Use in SIPs and Transportation Conformity* [16] report, which affects how TxLED factors are calculated.

5.1.1 2001 Memorandum Methodology

TTI has utilized the approach documented in EPA's TxLED Benefits Memorandum from September 2001 to develop TxLED factors for adjusting diesel vehicle NOx emission rate results from EPA mobile source models (MOBILE and MOVES) for over 20 years. Previously, until the release of the January 2023 guidance [16], the TTI team developed the TxLED factors on Excel spreadsheets using the TCEQ-developed procedure based on the methodology described in the 2001 memorandum.

TCEQ developed the procedure followed by the TTI team to align with the 2001 memo's [15] specified percent NOx reductions for diesel vehicles (4.8% for 2002 and newer and 6.2% for earlier model years) applied to Texas (refer to Table 5-1). This process generated composite NOx adjustment factors specific to each diesel SUT, organized by analysis year and applicable to all TxLED counties. The TTI team used MOVES inventory mode, which runs with model year output, incorporating key inputs such as the latest available Texas statewide SUT age distributions and AVFT. VMT and vehicle population inputs were set as dummy values or placeholders, as the crucial factor was not the total quantity of VMT but the proportions of VMT and, consequently, NOx emissions, categorized by model year. The MOVES model year output was imported into a spreadsheet, where adjustment factors were applied to diesel SUT NOx emissions (i.e., for 2002 and newer and 2001 and older). Model year-adjusted NOx emissions were summed for each diesel-powered source type, and total unadjusted NOx was compared to total TxLED-adjusted NOx to derive composite TxLED adjustment factors for each diesel SUT. Key local inputs included Texas statewide age distributions and AVFT, generated using TTI standard procedures involving a combination of local data and MOVES defaults as needed. Meteorological inputs were irrelevant for diesel, and a statewide diesel fuel formulation applicable to the analysis year was used. Notably, TCEQ conducted early comparisons using different, realistic age distribution inputs, finding minimal differences in resulting TxLED factors and opting for the 'statewide' TxLED factors solution. An example of the TxLED adjustment factor for each SUT, as determined using the TTI methodology, is illustrated in Table 5-2.

Table 5-1. TxLED Fuel Benefits Based on Nationwide Average Fleet Characteristics.

Model Year Grouping	TxLED Factor Reduction	TxLED Factor Adjustments
2001-and-Older	6.20%	93.80%
2002-and-Newer	4.80%	95.20%

Source: EPA, September 2002. TxLED Fuel Benefits – Memorandum. [15]

Table 5-2. TxLED Adjustment Factors Summary

Diesel Fuel SUT	2020 Reduction	2020 Adjustment
Passenger Car	4.92%	0.9508
Passenger Truck	5.23%	0.9477
Light Commercial Truck	5.27%	0.9473
Other Buses	5.32%	0.9468
Transit Bus	4.98%	0.9502
School Bus	5.19%	0.9481
Refuse Truck	5.21%	0.9479
Single Unit Short-Haul Truck	4.86%	0.9514
Single Unit Long-Haul Truck	4.87%	0.9513
Motor Home	5.44%	0.9456
Combination Short-Haul Truck	4.94%	0.9506
Combination Long-Haul Truck	5.08%	0.9492

Source: TCEQ, March 2021. The TCEQ procedure used MOVES3 and the latest available data (i.e., statewide age distributions and local AVFT inputs based on year-end 2018 TxDMV vehicle registration data).

5.1.2 Overview of the New 2023 EPA Guidance

In January 2023, the EPA published a new guidance document for quantifying NOx benefits for cetane improvement programs for use in SIPs and transportation conformity. The cetane improvement program calls for cetane additives in diesel fuel to increase the cetane number. The cetane increase reduces NOx emissions from heavy-duty highway diesel engines and specific diesel-powered nonroad engines. There are three types of cetane improvement programs:

1. Total cetane number standard - Sets a per-gallon minimum value for the sum of base cetane number and the increase in cetane number due to additives.

2. Cetane number increase standard - Sets a per-gallon minimum value for the increase in cetane number due to the use of additives
3. Cetane additive concentration standard - Sets a per-gallon minimum value for the concentration of a particular type of cetane improver additive.

This new 2023 guidance has yet to create any further requirements. However, it updates and supersedes the 2004 *Guidance for Quantifying NOx Benefits for Cetane Improvement Programs for Use in SIPs and Transportation Conformity* document [18] on how to calculate emissions reductions in 2021 and beyond from both highway engines and nonroad engines. This guidance should help state and local air quality agencies with existing cetane improvement programs approved in their SIPs or considering adopting similar programs.

The equations introduced in the 2023 guidance document are discussed below.

5.1.2.1 Per-Vehicle NOx Benefits Methodology

The per-vehicle NOx benefits of cetane improver additives are generally represented as a percent reduction in NOx emissions for a given increase in cetane number, which can be calculated using the following equation (henceforth known as EQ1):

$$(\%NO_x)_{pv} = k \times 100\% \times \{1 - \exp[-0.015151 \times AC + 0.000169 \times AC^2 + 0.000223 \times AC \times RC]\}$$

Where,

$(\%NO_x)_{pv}$ = Per-vehicle percent reduction in NOx emissions;

k = Constant representing the fraction of NOx inventory associated with cetane-sensitive diesel trucks or nonroad engines, as described later in this section;

AC = Additized cetane where the increase in cetane number due to the use of additives;

RC = Reference cetane where the natural (unadditized) cetane number of the fuel before implementation of the cetane program

If the diesel fuel already contains some cetane improver additives before implementing a cetane improvement program. In such cases, the calculation of $(\%NOx)_{pv}$ (EQ 1) requires an additional step:

$$(\%NOx)_{pv} = [(\%NOx)_{pv}]_A - [(\%NOx)_{pv}]_B$$

Where,

$[(\%NOx)_{pv}]_B$ = Per-vehicle percent reduction in NOx emissions due to the use of additives before implementation of the cetane improvement program;

$[(\%NOx)_{pv}]_A$ = Per-vehicle percent reduction in NOx emissions due to the use of additives after implementing the cetane improvement program.

The "k" constant for the area for that year for highway vehicles (henceforth known as EQ2):

$$k_{onroad\ area} = VMT_{HD\ Diesel\ MY2002\ and\ older}/VMT_{HD\ Diesel\ All\ MY}$$

Where,

$k_{onroad\ area}$ = the constant "k" for the specific area and year;

$VMT_{HD\ Diesel\ MY2002}$ and older = the VMT attributable to heavy-duty diesel highway vehicles (regulatory classes 41-49) in the area and in the analysis year that is MY 2002 or older;

$VMT_{HD\ Diesel\ All\ MY}$ = the VMT attributable to all heavy-duty diesel highway vehicles (regulatory classes 41-49) in the area and the analysis year.

The constant "k" for the area for that year for nonroad diesel engines (henceforth known as EQ3):

$$k_{nonroad\ area} = (f_{Diesel\ pre\text{-}1988} + f_{Diesel\ Tier\ 0} + f_{Diesel\ Tier\ 1} + f_{Diesel\ Tier\ 2})/f_{Diesel\ Total}$$

Where,

$k_{nonroad\ area}$ = the constant "k" for nonroad diesel engines for the specific area and year;

$f_{Diesel\ Tier\ X}$ = the number of nonroad diesel engines certified to pre-1988, Tier 0, Tier 1, and Tier 2 emissions standards in the area in the analysis year;

$f_{Diesel\ Total}$ = the total number of nonroad diesel engines for the specific area and analysis year.

There are three options for specifying a value for RC:

1. the average from the most recent year before program implementation can be used as the default RC value in areas with existing survey data.

2. A survey of diesel fuel parameters can be conducted in the program area before implementing the cetane improvement program.
3. A default RC value of 47 to represent highway diesel fuel can be used. For nonroad diesel fuel, you may use a default RC value of 45 through the calendar year 2007 and a default RC value of 47 afterward.

AC is calculated using the following equation (henceforth known as EQ4) once the program has been implemented:

$$AC = AC_m + BC - RC$$

Where,

AC = Value of additized cetane used to calculate $(\%NOx)_{pv}$ via EQ 1;

AC_m = Value of additized cetane measured after program implementation; generally total cetane of additized fuel minus BC, but can also be measured using additive concentration as a proxy property;

RC = Reference cetane; the natural (unadditized) cetane number of diesel fuel before implementation of the cetane program (see discussion above);

BC = Base cetane; the cetane number of the unadditized base fuel after implementation of the cetane program.

5.1.2.2 Calculating in-use Fleet-wide NOx Benefits

Fleet-wide NOx benefit (henceforth known as EQ5):

$$(\%NO_x)_{fw} = (\%NO_x)_{pv} \times F1 \times F2 \times F3 \times F4$$

Where,

$(\%NO_x)_{fw}$ = Fleet-wide percent reduction in NOx emissions;

$(\%NO_x)_{pv}$ = Per-vehicle percent reduction in NOx emissions from equation (EQ 1);

F1 = Program factor representing 2-stroke engines (see Table 5-3);

F2 = Program factor representing nonroad fuel (see

Table 5-4);

F3 = Program factor representing vehicle migration (see Table 5-5);

F4 = Program factor representing proxy fuel properties (see

Table 5-6).

Table 5-3. Conditions for Determining the Default Value of Program Factor, F1

Condition	The default value of F1
General distribution of cetane improver additives through the system of terminals, pipelines, and service stations	1.0
Use of cetane improver additives in a centrally fueled fleet with an identifiable and measurable number of 2-stroke and 4-stroke engines	(number of 4-stroke engines)/(number of 2stroke and 4-stroke engines)

Table 5-4. Conditions for Determining the Default Value of Program Factor, F2

Condition	The default value of F2
Use of cetane improver additives in highway diesel fuel	1.0
Use of cetane improver additives in off-highway diesel fuel, where the NOx benefits of cetane improver additives on nonroad engines have been measured and used to estimate a value for $(\%NO_x)_{pv}$ that supersedes equation (EQ 1)	(Volume of off-highway fuel used in nonroad engines) / (volume of off-highway fuel used in nonroad engines and heaters)[1]
Use of cetane improver additives in off-highway diesel fuel, where the NOx benefits of cetane improver additives on nonroad engines have not been estimated	0.0

[1]"Heaters" include any fuel combustion unit designed to produce heat instead of work, including residential heating units, industrial boilers, etc

Table 5-5. Conditions for Determining the Default Value of Program Factor, F3

Condition	The default value of F3
Use of cetane improver additives in nonroad engines	1.0
Use of cetane improver additives in highway engines, where the total square mileage of the area within which the mandated cetane improver additive program applies is:	
Less than 50 mi^2	0.3
51 -300 mi^2	0.5
301 -1200 mi^2	0.6
1201 -2800 mi^2	0.7
2801 -7800 mi^2	0.8
7801 -70,000 mi^2	0.9
Above 70,001 mi^2	1.0

Table 5-6. Conditions for Determining the Default Value of Program Factor, F4

Condition	The default value of F4
The program requires the use of ASTM test procedure D613 for measuring base cetane number (BC) and additized cetane number (ACm)	1.0
The program allows the use of cetane index (see Appendix 4 of guidance document [16]) and/or additive concentration (with a known response function) as proxy properties for representing cetane number measurements via ASTM D613	1.0
The program allows regulated parties to avoid measuring the base cetane number (BC) by assuming that BC equals RC.	
RC > 47	0.8
44 = RC < 47	0.9
RC < 44	1.0
The program allows the use of other proxy properties whose measured values are corrected for known bias in comparison to the D613 cetane number and whose uncertainty is established to be equivalent to D613	1.0

In

Table 5-6, it was mentioned that some programs allow the use of proxies. The use of these "proxy properties" introduces additional uncertainties and potential bias into the calculation of $(\%NO_x)_{pv}$ (EQ 1). Thus, the fleet-wide NOx benefits should be adjusted to account for the use of proxy properties. The guidance document listed two primary proxy properties available:

1. Cetane index (ASTM D4737) - Used to estimate the natural cetane number. It requires the measurement of fuel distillation properties T10, T50, and T90, as well as the measure of fuel density. The Cetane index is then calculated from the following equation:

$$CI = 45.2 + 0.0892 \times (T10 - 215) + \{0.131 + 0.901 \times [\exp(-3.5 \times (D - 0.85)) - 1]\} \times (T50 - 260) + \{0.0523 - 0.420 \times [\exp(-3.5 \times (D - 0.85)) - 1]\} \times (T90 - 310) + 0.00049 \times [(T10 - 215)^2 - (T90 - 310)^2] + 107 \times [\exp(-3.5 \times (D - 0.85)) - 1] + 60 \times [\exp(-3.5 \times (D - 0.85)) - 1]^2$$

Where,

CI = Cetane index;

T10 = Distillation property via ASTM D86: temperature in Fahrenheit at which 10vol% has evaporated;

T50 = Distillation property via ASTM D86: temperature in Fahrenheit at which 50vol% has evaporated;

T90 = Distillation property via ASTM D86: temperature in Fahrenheit at which 90vol% has evaporated;

D = Density in g/ml at 15 oC, via ASTM D1298

2. Additive concentration - Along with a cetane response function such as those in Appendix 3 of the guidance document [16], additive concentration can be used to estimate the increase in cetane number due to cetane improver additives.

5.1.2.3 Calculating Tons of NOx Reduced

The reduction in NOx emissions that results from the cetane improvement program depends broadly on the percent reduction in NOx and that portion of the program area's NOx inventory that is affected by cetane improver additives, given in the equation below (henceforth known as EQ6):

$$NO_x \text{ tons reduced} = \text{Diesel } NO_x \text{ inventory} \times (\%NO_x)_{fw} \times \text{Volume fraction affected}$$

Where,

NO_x tons reduced = Daily or annual tons of NOx reduced within the geographic boundaries of the cetane improver program area;

Diesel NOx inventory = Total daily or annual tons of NOx generated by diesel engines within the geographic boundaries of the program area, assuming the cetane additive program is not in effect;

$(\%NO_x)_{fw}$ = Fleet-wide percent reduction in NOx from equation EQ5;

Volume fraction affected = Fraction of the diesel fuel volume that contains cetane improver additives within the program area (see Table 5-7)

The calculation of NOx emissions reduced using equation EQ6 may need to consider other factors depending on the form of the cetane improver program. For instance:

1. If the cetane improver program only applies for a portion of the year (e.g., summer months only), then the "Diesel NOx inventory" should likewise represent only that same portion of the year.

2. If the cetane improver additive program applies to both highway and nonroad engines, then equation EQ6 should be used twice to calculate NOx tons reduced separately for both highway and nonroad, and the results are summed.
3. If the cetane improver additive program applies to specific centrally fueled fleets, then the "Diesel NOx inventory" in EQ6 should represent those fleets.

Table 5-7. Conditions for Determining "Volume Fraction Affected" in EQ6

Condition	Volume fraction affected
The Cetane improver additive program applies to all fuel within area X, and "Diesel NOx inventory" also represents area X	1.0
The Cetane improver additive program applies to all fuel within area X, and "Diesel NOx inventory" represents larger area Y.	Fuel consumed in area X ÷ Fuel consumed in area Y
The Cetane improver additive program applies to specific fleets within area X	Fuel consumed by fleets ÷ Fuel consumed in area X

For highway diesel vehicles, the fuel consumed within a given area can be calculated from the diesel engine VMT associated with that area and fuel economy rates for each diesel vehicle weight class for the calendar year being modeled.

5.2 Data Sources

Based on the latest 2023 *Guidance on Quantifying NOx Benefits for Cetane Improvement Programs for Use in SIPs and Transportation Conformity* document [16], the TTI team developed the TxLED factors using data collected through the TCEQ's Texas Fuel Field Study, previously described in detail in Chapter 3.2.1. As VMT information is required, the TTI team downloaded the latest available Highway Performance Monitoring System (HPMS) data for the following regions: DFW, HGB, and state of Texas.

5.3 Methodology and Procedures

Based on the 2023 guidance [16], the TTI team updated the existing TxLED adjustment factor methodology. The new methodology is as follows:

1. The cetane index numbers were retrieved from the latest TCEQ Texas Fuel Survey [7]. Since the information collected was on the TxDOT district level, the cetane index numbers for all counties within the district were assumed to be equal.

2. Then, the county's AC value was calculated using EQ2. Based on the definition, the AC value is the difference between the cetane number and the RC. Thus, a county's AC value is its cetane index number minus the default RC value of 47.

3. Each county's "k" constant was calculated for each of the nine heavy-duty diesel fuel SUTs[18] using EQ2. The total VMT for each of these SUTs were summed by county and model year. Then, the model years were grouped into 2002-and-older and 2003-and-newer. The county's "k" constant for the SUT is the total VMT of vehicles 2002 or older over the total VMT of all vehicles.

4. The per-vehicle percent reduction in NOx, $(\%NO_x)_{pv}$, for each SUT and county was calculated using EQ1.

5. Then, using EQ5, the fleet-wide percent reduction in NOx, $(\%NO_x)_{fw}$, for each SUT and county were calculated with F1 through F4 values as follows:

   a. F1 – The TTI team assumed the general distribution of cetane improver additives through the system of terminals, pipelines, and service stations. Thus, the program factor representing 2-stroke engines is equal to 1.0.

   b. F2 – The TTI team assumed the use of cetane improver additives in highway diesel fuel; thus, the program factor representing nonroad fuel is equal to 1.0.

   c. F3 – The TTI team calculated the land and water areas for the 110 TxLED counties. The land area in the 110 counties totals 97,854 sq-mi, whereas the water area totals 5,181 sq-mi. Thus, the total land and water area for the 110 counties is 93,035 sq-mi. Since the area subjected to TxLED exceeds 70,000 sq-mi (refer to Table 5-5), the program factor representing vehicle migration discount is equal to 1.0.

   d. F4 – Since the cetane index was used as a proxy property for representing cetane number measurements via ASTM D613, the program factor representing the use of proxy fuel properties defaults to 1.0.

6. Finally, using EQ6, the total NOx reduction is calculated. The volume fraction affected is 1.0, as all areas within the 110 TxLED counties are affected.

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[18] School buses, transit buses, other buses, motor homes, refuse trucks, single-unit short- and long-haul trucks, and combination short- and long-haul trucks.

5.4 Comprehensive Database and Processing Scripts

The TTI team did not create a comprehensive database for TxLED adjustment factors as it pulls information from the fuels database previously discussed in Chapter 3.4. The TTI team developed a Python script to generate TxLED factors using information from the TCEQ fuel survey data and latest available HPMS activity data. The steps were described in detail in Chapter 5.3. The script outputs the TxLED reduction factor by SUT for each of the 110 counties.

The Python scripts are attached as Appendix 4-A.

5.5 QA/QC

Due to the change in methodology from the 2001 to 2023 guidances, the TxLED factors and their associated NOx benefits underwent substantial changes. For example, the TTI team analyzed old and current methodologies using 2019 VMT and 2020 Texas fuel survey data The resultant NOx emissions benefits under the old and current methodologies are shown in Table 5-8. It can be observed that the benefits calculated under the old methodology are substantially higher than those under the current one.

Table 5-8. 2019 Summer Weekday On-Road NOx Emissions (tons per day)

Subject Area	Without TxLED	With TxLED (2001 memo)	Benefit (2001 memo)	With TxLED (2023 Guidance)	Benefit (2023 Guidance)	Benefit Decrease from 2023 Guidance
10-County DFW	105.52	102.22	3.30	105.47	0.05	3.25
8-County HGB	83.93	81.36	2.57	83.89	0.04	2.53
Bexar County	29.15	28.27	0.88	29.13	0.01	0.87
The remaining 91 Eastern Texas Counties	187.78	180.89	6.89	187.67	0.11	6.79
110 TxLED Subject Counties	406.38	392.73	13.65	406.17	0.21	13.43

The difference arises because, under the old methodology, NO_x emissions from diesel vehicles manufactured in 2001 and older were adjusted by 6.2%, while vehicles manufactured in 2002 and newer were adjusted by 4.8%. However, it's important to note that the current methodology does not specify the exact percent reduction by model year. Instead, it relies on a uniform formula that heavily considers the county's cetane index within the diesel fuel and the VMT of diesel vehicles in determining the NO_x reduction percentage. Under the current methodology, the average NO_x reduction for

2002-and-older diesel vehicles was only 1.5%, and for 2003-and-newer vehicles, the reductions were close to 0%. Thus, the TTI team must state that the factors produced under the old guidance cannot be used to QA/QC the script's output.

The TTI team used an Excel spreadsheet to calculate the TxLED factor to QA/QC the TxLED factors calculated by the Python Script. The results matched perfectly.

6 VISUALIZATION

In previous chapters, the TTI team explained the methodologies and scripts (MySQL or Python) used to develop the Texas-based MOVES modeling parameters. The scripts allow the TTI team to process any database updates quickly. However, while the scripts are provided as part of the deliverables, a user must know the programming language to use them effectively. Thus, the TTI team decided to develop tools to aid in this process, allowing users to check and download the data visually.

The TTI team developed a series of visualization dashboards on Tableau. The development of these dashboards was not part of the grant activity description; it was extra work that the TTI team decided to perform, as it added value to this study. Historically, the modeling input parameters were developed as needed and shared through electronic postings or email. The TTI team believes this dashboard will eliminate the need for interested parties to request county or district-specific input parameters from TCEQ or TTI. For example, an MPO requiring a conformity determination could go to these dashboards, select the desired county, district, or NA, and download the input parameters of the selected year without needing to go through the data acquisition process. The scripts and data to prepare these input parameters were already QA/QC'd, making documentation more accessible.

This chapter covers the homepage and the three sets of dashboards developed.

6.1 HOMEPAGE

The homepage provides a brief description of how the dashboards are to be used and how to download data from them. It also serves as a hub that links users to the other dashboards. The homepage is currently hosted on the Texas A&M University's Tableau server[19]; upon receiving authorization from the TCEQ project manager, the TTI team plans to make these dashboards available on the Texas Air Quality Portal page. Figure 6-1 shows a snapshot of the homepage.

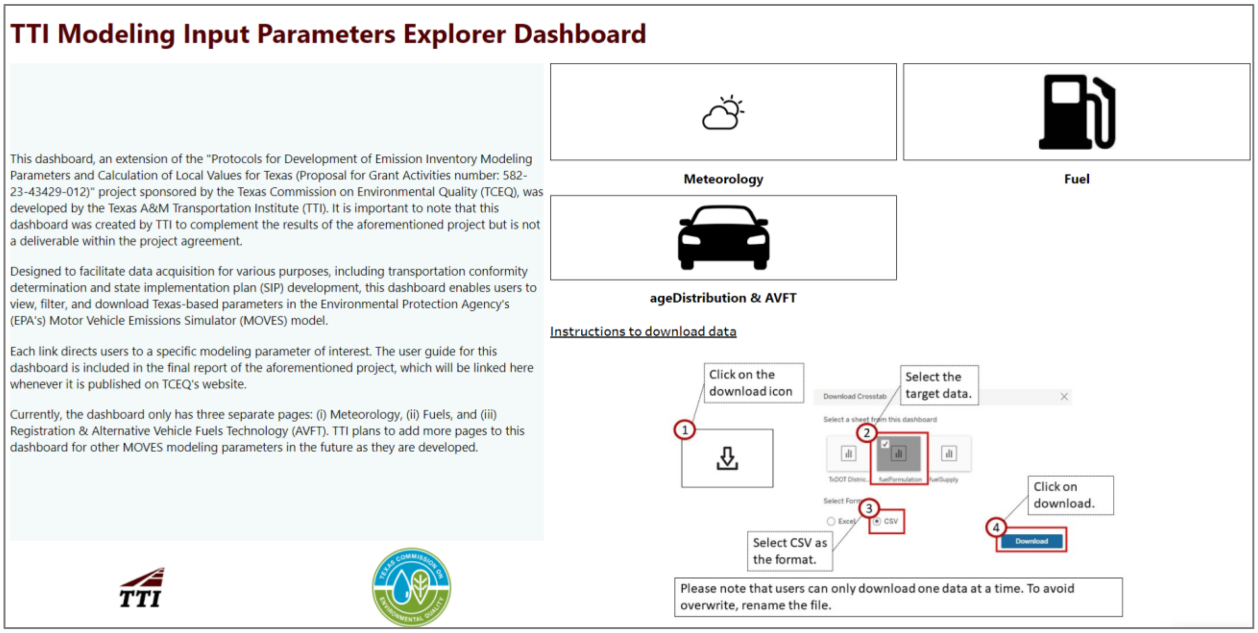


Figure 6-1. Overview of the Modeling Parameter Dashboard

The top-right corner of the homepage shows a set of icons that serve as links to the three dashboards. By clicking on any of these, users are directed to the corresponding dashboard. In the future, the TTI team plans to add more MOVES input parameters or post-processing factors, such as TxLED, to this dashboard whenever they are developed.

6.2 Meteorology Dashboard

The meteorology dashboard[20] lets users visualize and analyze meteorological data, including temperature, humidity, and barometric pressure, across different seasons and regional levels (i.e., county, district, MPO, and NA) in Texas. Users can also download the data in MOVES input format based on their spatial and data selection preferences.

[19] The Modeling Parameter Dashboard's homepage can be accessed through this link: https://tableau.tamu.edu/t/TTI/views/ModelingParameter_Fuels_Dashboard/HomePage?%3Aembed=y&%3Aiid=1&%3AisGuestRedirectFromVizportal=y. It is currently coupled with the Fuels Dashboard.

[20] The meteorology dashboard is current hosted on the Texas A&M University's Tableau server, and can be accessed using this link: https://tableau.tamu.edu/#/site/TTI/views/TCEQ_Modeling_Parametersv2/MetDataExplorer?:iid=1.

Figure 6-2 shows a screenshot of the meteorology dashboard developed by the TTI team. The data input for this dashboard is provided in Appendix 1-C.

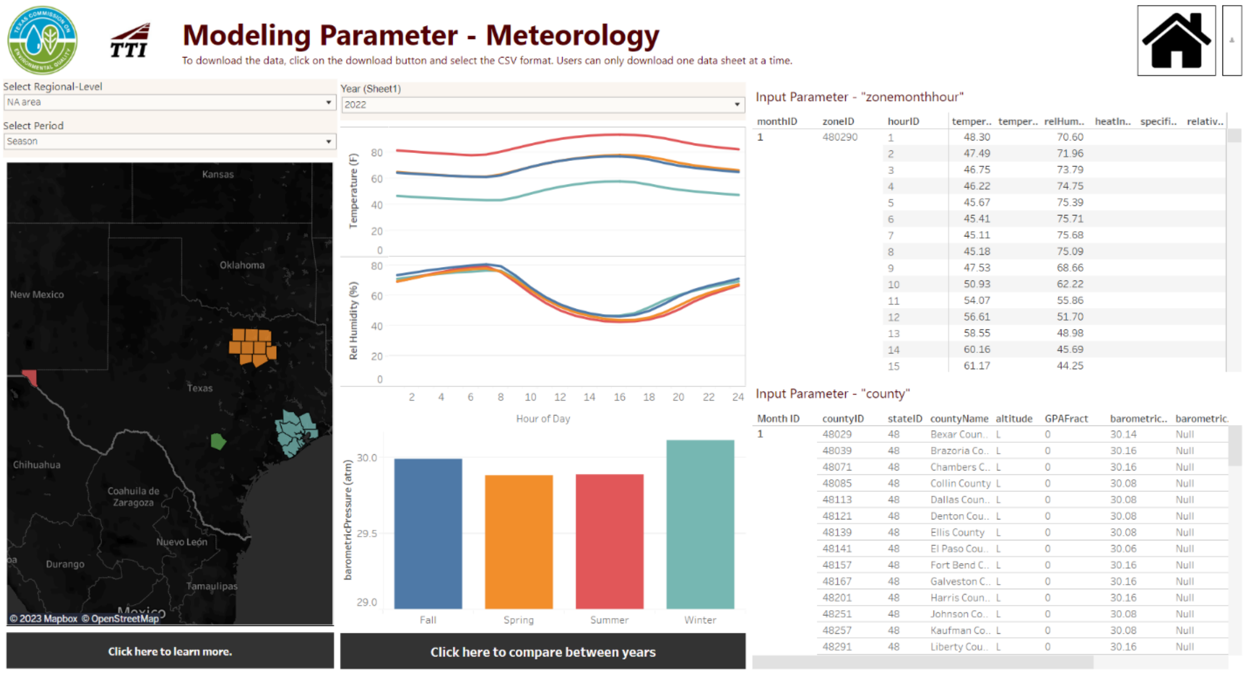


Figure 6-2. Overview of the Meteorology Dashboard

A snapshot of the dashboard's landing page is shown in Figure 6-3. The landing page contains brief details of the dashboard and how to operate it.

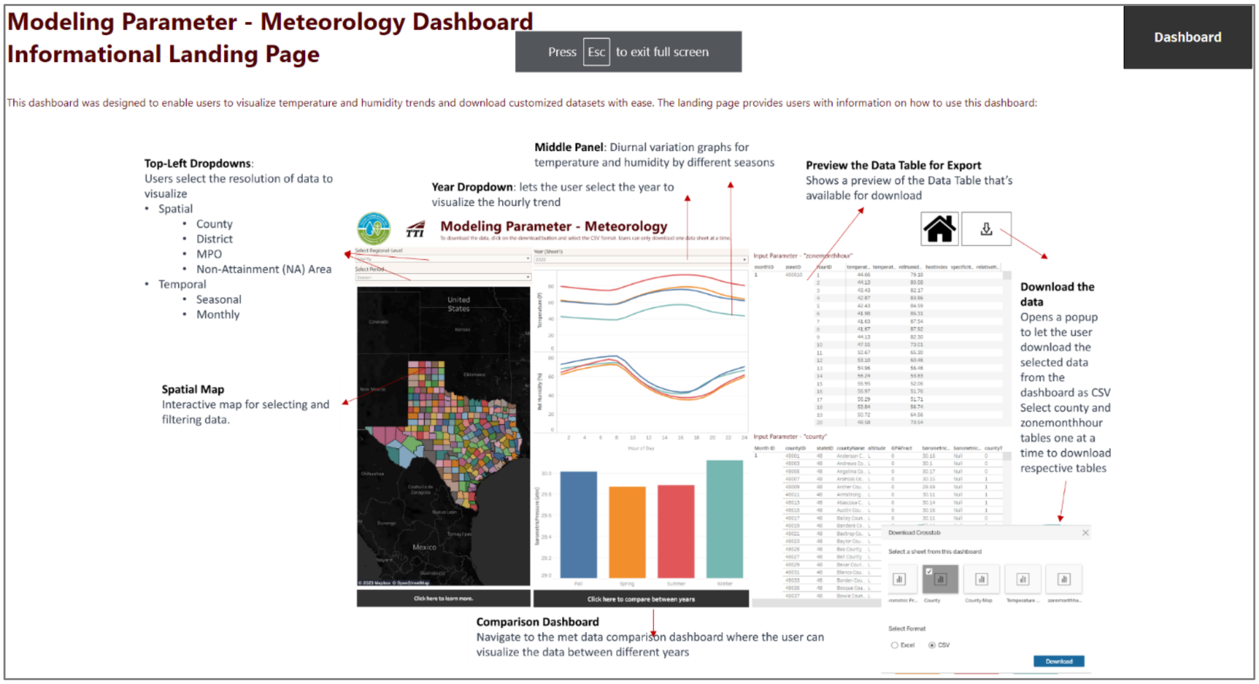


Figure 6-3. Overview of the Meteorology Dashboard Landing Page

The meteorology dashboard has six main components, as listed below:

- Home Button – This button appears on the top-right corner of the dashboard in the shape of a house icon. Clicking this button directs the user to the homepage.
- Regional-level and Period Filter – These filters let users set the spatial and temporal resolution of the data on the dashboard. The regional-level filter lets users select among county, district, MPO, and NA options, whereas the period filter allows users to select between seasonal and monthly.
- Year filter – This filter lets users select the meteorology year. The options are 2011, 2012, 2014, 2016, 2017, 2019, and 2022.
- Map - This interactive map allows users to select and filter data by specific regions. Clicking on a region will filter the dashboard for only data pertaining to that region.
- Graphical Data Visualization – This panel shows the trend of temperature and humidity over a day for different seasons or months and the year (based on the previous selection). The seasons or months are marked by color legends, as shown in Figure 6-4. It also plots and compares the barometric pressure across different periods for the selected year, as shown in Figure 6-5.

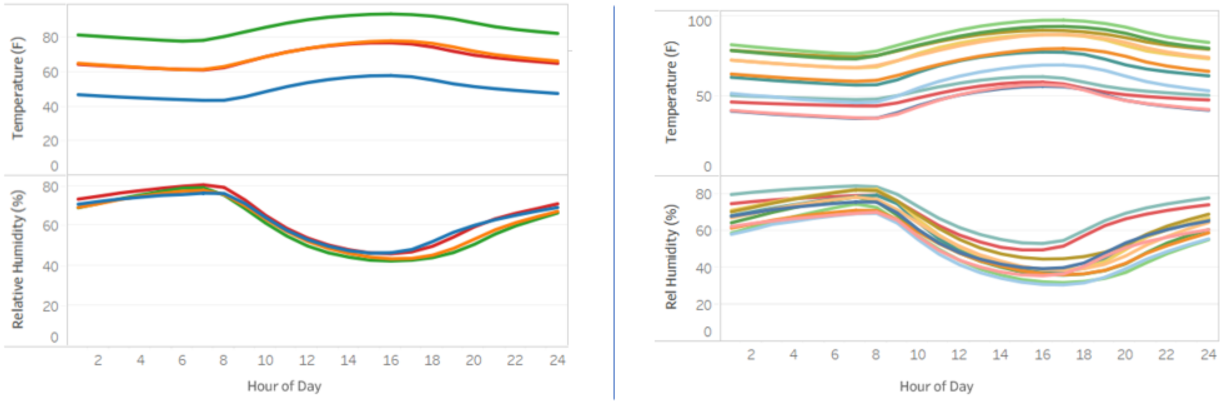


Figure 6-4 Diurnal Variation Graphs of Temperature and Relative Humidity by Season (left) and Month (right)

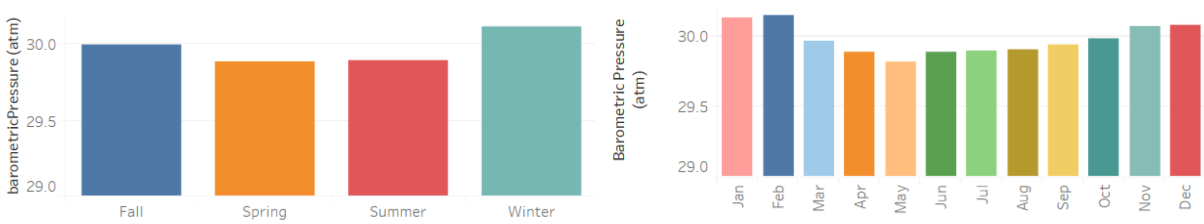


Figure 6-5 Seasonal (left) and Monthly (right) Plots of Barometric Pressure

- Data Preview – The panels on the right side of the dashboard preview the data tables in MOVES input format before downloading the data based on spatial and temporal resolution selection. The top previews the temperature and humidity table, whereas the bottom previews the barometric pressure table.
- Landing Page – Clicking the button “Click here to learn more” navigates you to the landing page, which provides information helpful for using the meteorology dashboard. To get back to the dashboard from this page, click on the “Dashboard” button in the upper right corner.
- Compare between Years – By clicking the "Click here to compare between years" button, users can navigate to a secondary dashboard to compare meteorological data across different years for a more thorough analysis. As depicted in Figure 6-6, the main panel compares the hourly variation of temperature and relative humidity for selected years and seasons, which can be toggled and filtered using various filters and maps.

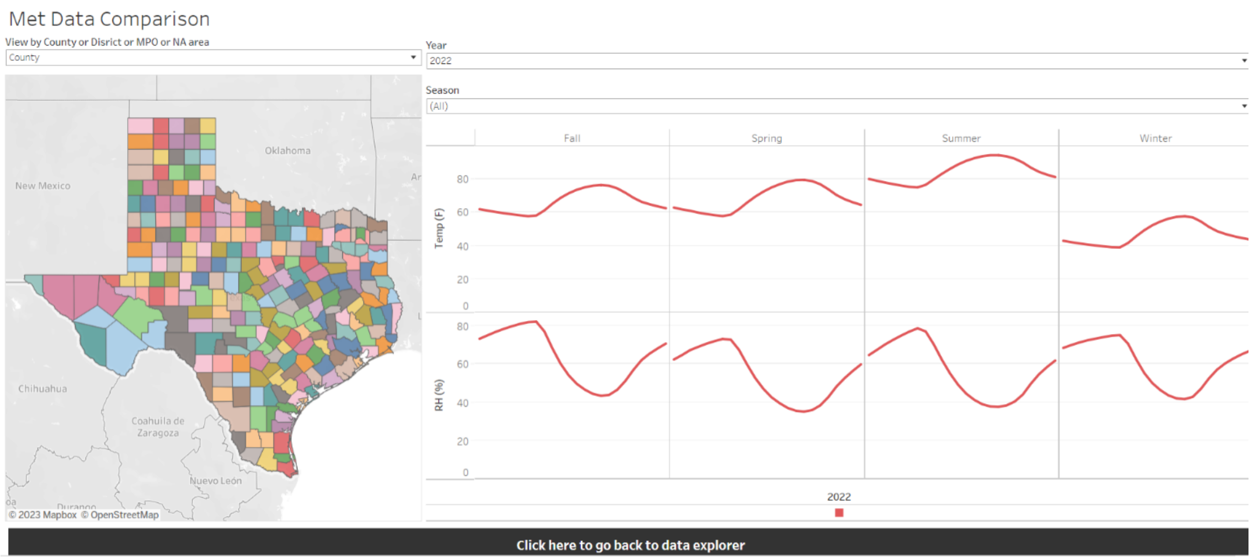


Figure 6-6 Description of Met Data Comparison Dashboard

- Download Button – As shown in OBJ, a window will appear by clicking the download button. To download the data, the user must choose either the " Temperature and RH table" or "Barometric Pressure" options. Note that the user can only download from one sheet at a time, so they may want to rename the file as they are being downloaded to avoid overwriting, as they would need to download fuel formulation and supply separately. The user must select the CSV format instead of Excel to download the data in MOVES format.

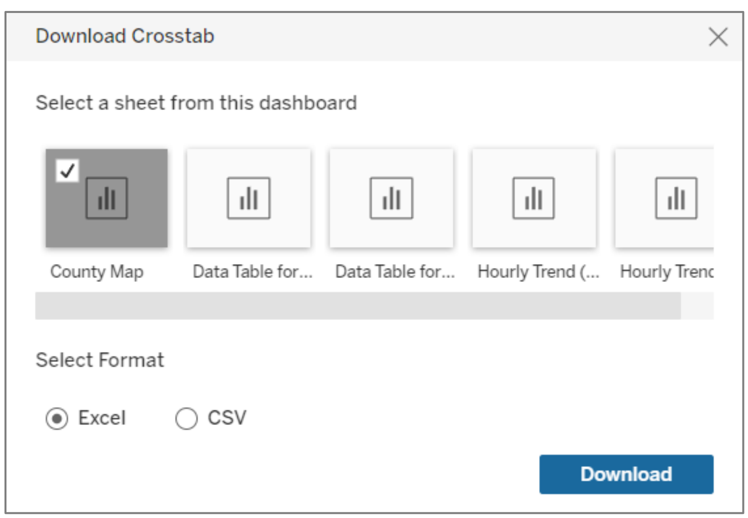
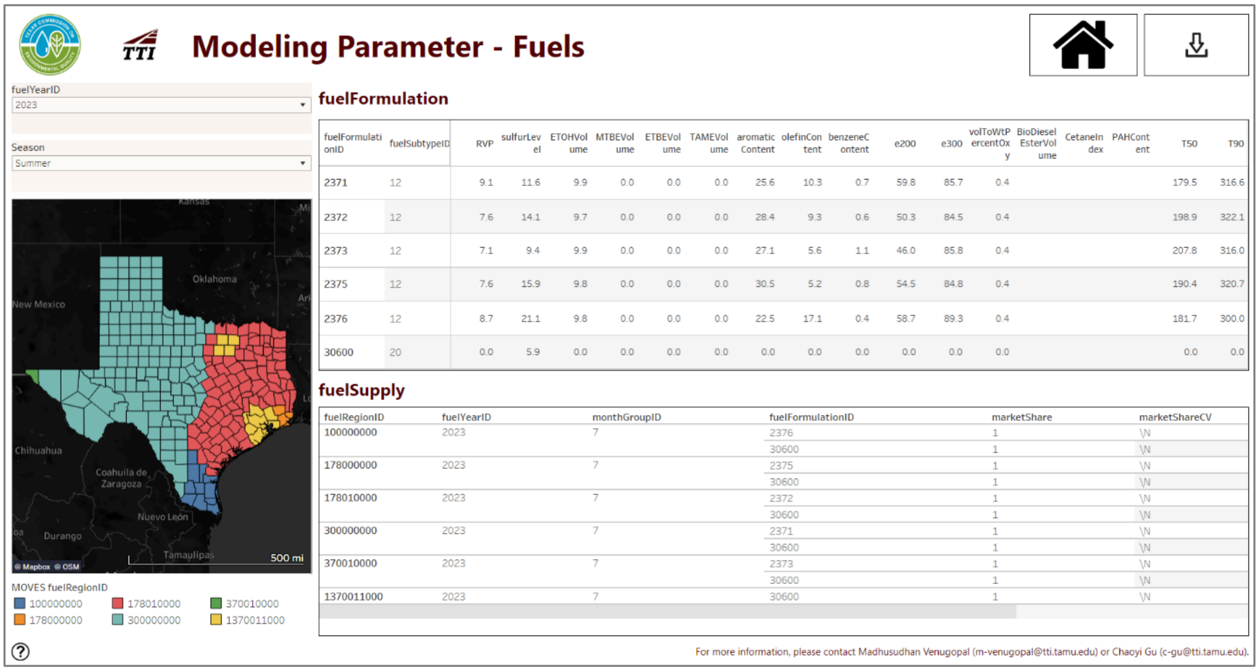


Figure 6-7. Meteorology Data Download Window

6.3 Fuels Dashboard

fuels dashboard[21] displays the fuel formulation and supply information in the same format as they appear in MOVES. Figure 6-8 shows a screenshot of the Fuels Dashboard. The input files used to develop this dashboard are attached in Appendix 2-B.



fuelFormulationID	fuelSubtypeID	RVP	sulfurLevel	ETOHVolume	MTBEVolume	ETBEVolume	TAMEVolume	aromaticContent	olefinContent	benzeneContent	e200	e300	volToWtPercentOxy	BioDieselEsterVolume	CetaneIndex	PAHContent	T50	T90
2371	12	9.1	11.6	9.9	0.0	0.0	0.0	25.6	10.3	0.7	59.8	85.7	0.4				179.5	316.6
2372	12	7.6	14.1	9.7	0.0	0.0	0.0	28.4	9.3	0.6	50.3	84.5	0.4				198.9	322.1
2373	12	7.1	9.4	9.9	0.0	0.0	0.0	27.1	5.6	1.1	46.0	85.8	0.4				207.8	316.0
2375	12	7.6	15.9	9.8	0.0	0.0	0.0	30.5	5.2	0.8	54.5	84.8	0.4				190.4	320.7
2376	12	8.7	21.1	9.8	0.0	0.0	0.0	22.5	17.1	0.4	58.7	89.3	0.4				181.7	300.0
30600	20	0.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				0.0	0.0

fuelRegionID	fuelYearID	monthGroupID	fuelFormulationID	marketShare	marketShareCV
100000000	2023	7	2376	1	\N
			30600	1	\N
178000000	2023	7	2375	1	\N
			30600	1	\N
178010000	2023	7	2372	1	\N
			30600	1	\N
300000000	2023	7	2371	1	\N
			30600	1	\N
370010000	2023	7	2373	1	\N
			30600	1	\N
1370011000	2023	7	30600	1	\N

Figure 6-8. Overview of the Fuels Dashboard

The fuels dashboard contains the following:

- Home Button – This button appears on the top-right corner of the dashboard in the shape of a house icon. The user will be directed to the homepage by clicking on this button.
- County Map – This map is color-coded based on the MOVES fuel region ID. The user can click on any county to filter out fuel formulation and supply information not about the selected county.
- Fuel Year ID and Month Group ID Filters – These filters allow the user to select the year and month of the data, referring to the year when the Summer Fuel Field Study was conducted (i.e., 2011, 2014, 2017, 2020, 2023).

[21] The fuels dashboard is currently hosted on the Texas A&M University's Tableau server and is accessible using this link: https://tableau.tamu.edu/#/site/TTI/views/ModelingParameter_Fuels_Dashboard/FuelsDashboard?:iid=2.

- fuelFormulation Table – This table shows the available fuel formulation based on selected filters. The information is organized according to MOVES. Only gasoline and diesel formulations are provided, but to run MOVES, the MOVES defaults for said other fuels will be needed.
- fuelSupply Table – This table shows the available fuel supply based on selected filters. The information is organized according to MOVES. Only gasoline and diesel formulations are provided, but to run MOVES, the MOVES defaults for said other fuels will be needed.
- Download Button – By clicking on the "Download" button at the bottom of the dashboard, a window similar to it, will appear on the screen. The user can download the filtered fuel formulation or supply data by selecting "fuelFormulation" or "fuelSupply." Note that the user can only download from one sheet at a time, so they may want to rename the file as they are being downloaded to avoid overwriting, as they would need to download fuel formulation and supply separately. The user must select the CSV format instead of Excel to download the data in MOVES format.
- Landing Page – By clicking on the question mark symbol on the bottom-left of the dashboard, users can navigate to a landing page with information on how to use this dashboard, as seen in Figure 6-9.

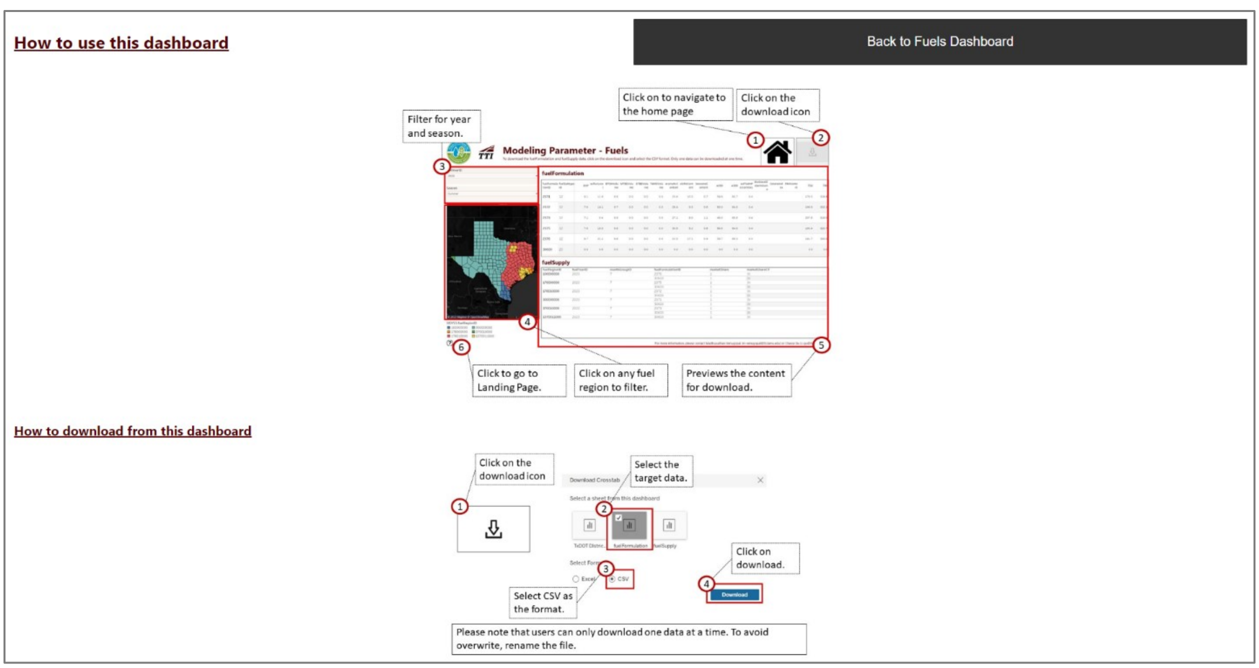


Figure 6-9. Overview of the Fuels Dashboard Landing Page

6.4 Registration – Age Distribution and AVFT Dashboard

The age distribution and AVFT dashboard[22] visualizes the ageDistribution and AVFT input parameters graphically and in a format akin to MOVES. Figure 6-10 shows an overview of the age distribution and AVFT dashboard. The input files used to develop this dashboard are attached in Appendix 3-B and 3-C.

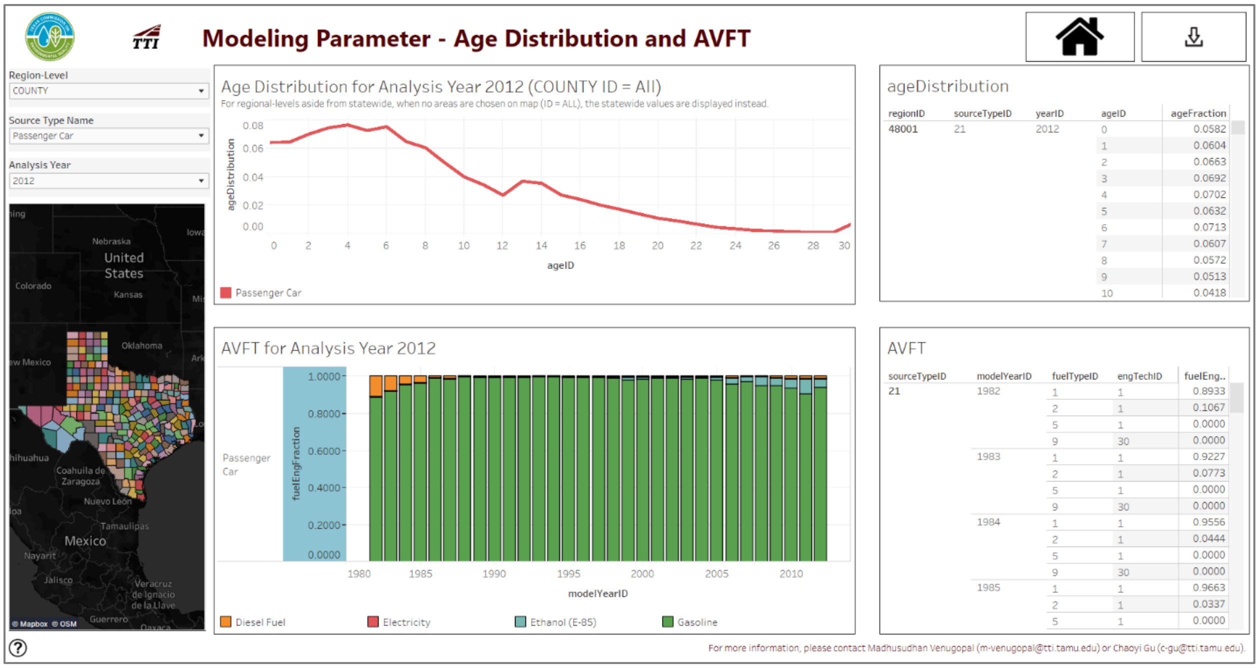


Figure 6-10. Overview of the Age Distribution and AVFT Dashboard

The registration and AVFT dashboard contains the following:

- Home Button – This button appears on the top-right corner of the dashboard in the shape of a house icon. The user will be directed to the homepage by clicking on this button.
- Region-Level, Source Type, and Analysis Year Filters – These filters allow the users to select the region-level (i.e., state, county, district, COG, MPO, or NA [refer to Chapter 4.3.2.1 for more information]), source use type (i.e., motorcycle, passenger cars, etc.), and analysis year (i.e., 1990, 1999 – 2060). Among them, only the source use type filter allows for multiple selections.

[22] The age distribution and AVFT dashboard is currently hosted on the Texas A&M University's Tableau server and is accessible using this link: https://tableau.tamu.edu/#/site/TTI/views/ageDistribution_AVFT_Dashboard/Dashboard?:iid=3.

- Map – The visuals are based on the region level selected (i.e., Figure 6-10 shows a map of the NA based on the chosen region level). The map serves as a filter where users can click on any region on the map to filter for only information pertaining to that region.
- ageDistribution Graph – This graph shows the ageDistribution of the selected source type(s) and analysis year by ageID. Multiple source types can be selected using the filter. When no regions are selected on the map, the default information shown is the statewide ageDistribution.
- ageDistrbution table – This table shows the ageDistribution information in MOVES specifications. (Data may be downloaded to MOVES specifications, discussed later.)
- AVFT Graph – This graph shows a stacked fuelEngFraction bar chart of the selected source type and analysis year by model year. The fuelEngFraction values of the different fuel types add up to 1 for each model year. Multiple graphs for each source type will be shown if multiple source types are selected. By selecting an analysis year, the dashboard automatically shows the 31 model years leading up to the analysis year (i.e., for the analysis year 2012, model years 1982 through 2012 are shown).
- AVFT table – This table shows the fuelEngFraction information similarly to MOVES. Like the AVFT graft, the dashboard automatically shows the 31 model years leading up to the analysis year by selecting an analysis year.
- Download Button – By clicking on the "download" icon (downward pointing arrow), a window similar to Figure 6-6, will appear. To download the ageDistribution or AVFT data, the user must choose either the "ageDistribution" or "AVFT" options (selecting the "ageDistribution (Chart)" or "AVFT (Chart)" options will download the graphics, which are not in MOVES format). Note that the user can only download from one sheet at a time, so they may want to rename the file as they are being downloaded to avoid overwriting, as they would need to download ageDistribution and AVFT separately. The user must select the CSV format instead of Excel to download the data in MOVES format.
- Landing Page – By clicking on the question mark symbol on the bottom-left of the dashboard, users can navigate to a landing page with information on how to use this dashboard, as seen in Figure 6-11.

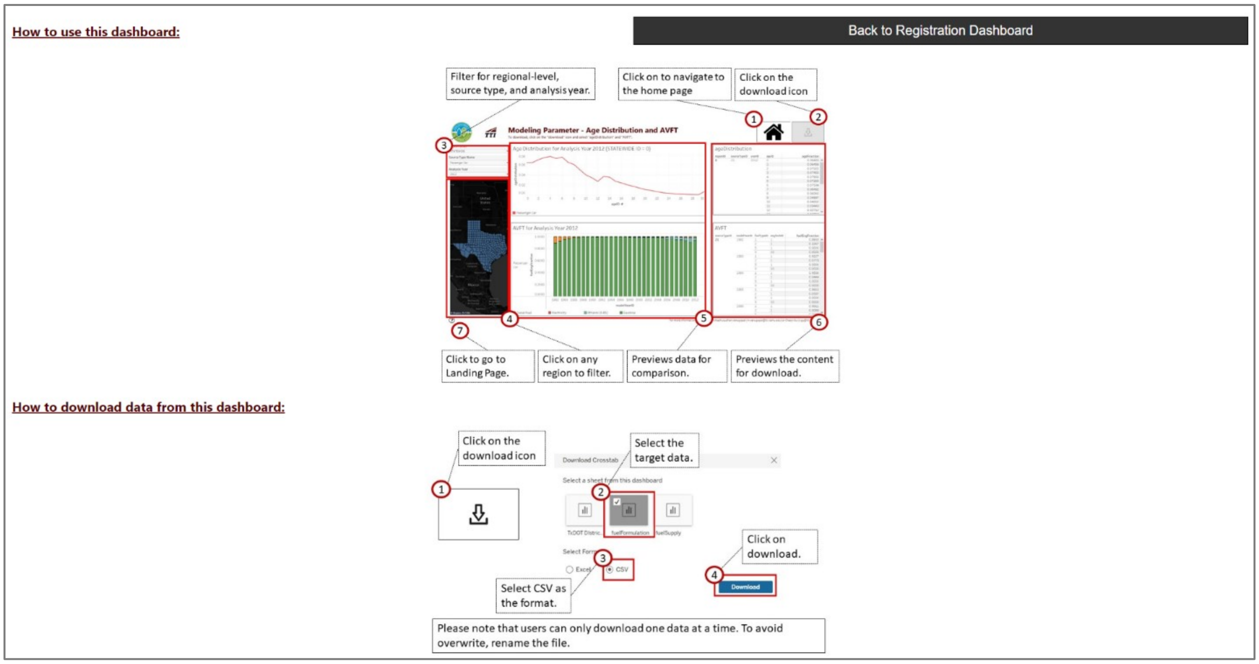


Figure 6-11. Overview of the Age Distribution and AVFT Dashboard Landing Page

6.5 Next Steps

In the long term, the TTI team plans to add more modeling input parameters, such as TxLED, to the dashboard and continue to build on it to create a one-stop shop for all Texas-based MOVES input parameters. In addition, the TTI team also planned on expanding on the currently available dashboards by adding information, such as links to the data sources and calculation methodologies, to the landing page.

7 REFERENCES

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[17] TCEQ, "Texas Low Emission Diesel (TxLED) Program," 15 December 2022. [Online]. Available: https://www.tceq.texas.gov/airquality/mobilesource/txled.

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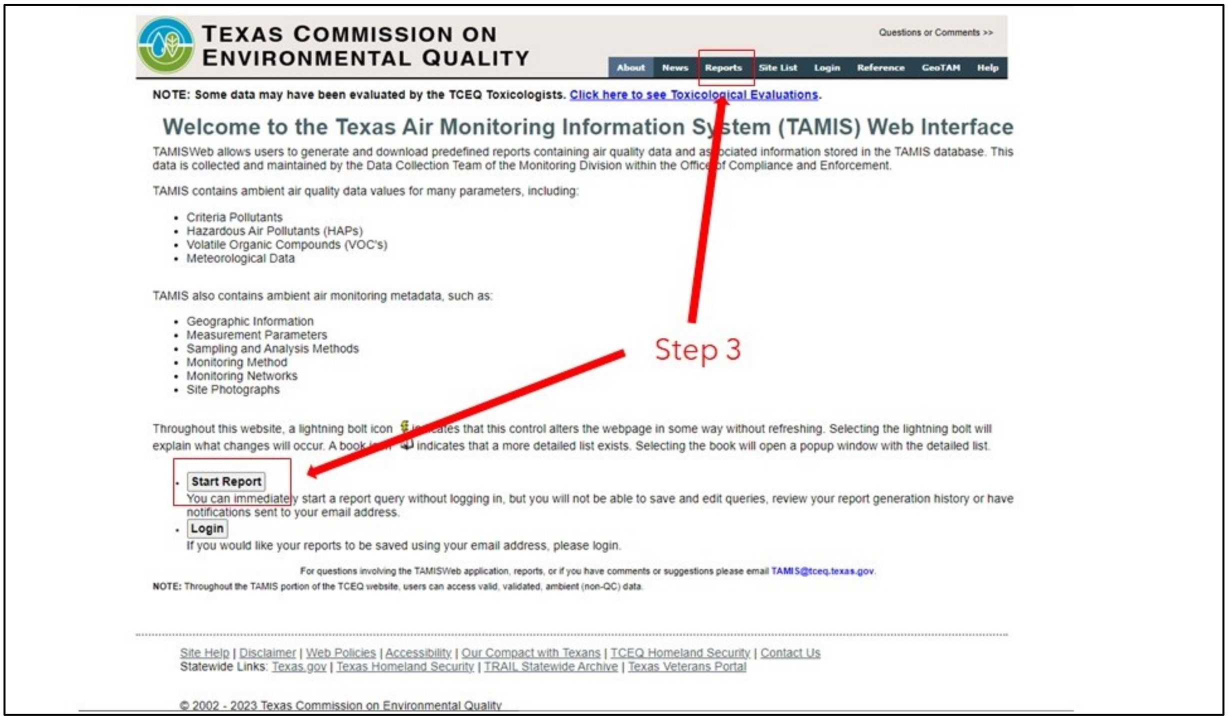
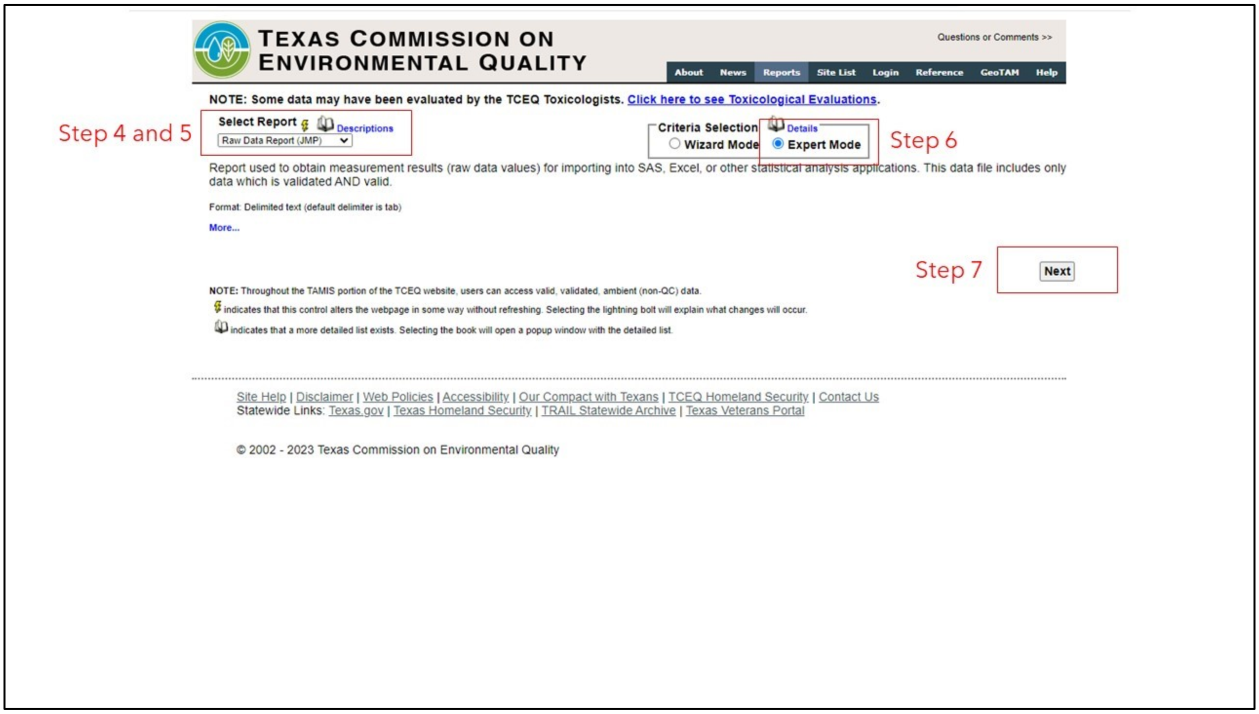
APPENDIX 1-A: STEPS TO DOWNLOAD TCEQ'S TAMIS AIR QUALITY DATA

The TTI research team followed the following steps to download 2022 TCEQ's TAMIS Air Quality Data:

1. Go to the Texas Air Monitoring Information System (TAMIS) Web Interface: https://www17.tceq.texas.gov/tamis/index.cfm?fuseaction=home.welcome



2. Login (optional)
3. Click "Start Report" or Click "Reports"



4. Go to “Select Report” Box
5. Choose “Raw Data Report (JMP)” from the dropdown menu
6. Select “Expert Mode” under “Criteria Selection”

   *Expert Mode allows the user to see all choices under one screen

7. Click “Next”
8. Select the desired date range in the Start (inclusive) and End (Exclusive) boxes.

   * Start date is included, and end date is excluded. For example, the start date for 2022 full-year data is 1/1/2022; the end date is 1/1/2023.

9. Select the Report Format from the click button as “Excel.”
10. Select the sample duration from the dropdown box as “1 HOUR.”
11. Select the target list from the dropdown box as “Meteorological Parameters (16 parameters)”

    * if files are too large to be downloaded at once. Select one from the “Individual Parameters” box to download them separately.

12. Select the site from the multiple selection boxes.

* if files are too large to be downloaded simultaneously for all sites. Select several sites from the box to download them separately.

13. Click the "Create Report" Button

14. Click the "Report File" link to save the .txt file

15. Save data to the local computer.

```
AQS Raw Data (RD) Transaction Report, Version 1.6, 3/11/2011
Run By: TAMIS User
Run Date: 06/25/2023 05:28:29,  Run Time:    328.00 seconds
Fields Delimited by: Tab  Action: I  Caution!  This report does not use the pipe (|) delimiter required in AQS Transactior
Measurements reported from: 01/01/2022 00:00:00 up to but not including: 01/01/2023 00:00:00
Sample Duration Code: 1  Report in AQS Units: N
Report only valid data: Y  Validation levels included (0,1,2,3): 3
Only allow AQS codes: N  Column headings included: Y
Report Missing Measurements: N  Check for Negative Measurements: N
Comment:
Transaction Type        Action  State Cd        County Cd       Site ID Parameter Cd    POC     Dur Cd  Unit Cd Meth Cd Da
RD      I       48      013     1090    62101   01      1       015     040     20220101        00:00   71.5358
RD      I       48      013     1090    62101   01      1       015     040     20220101        01:00   71.2658
RD      I       48      013     1090    62101   01      1       015     040     20220101        02:00   71.1475
RD      I       48      013     1090    62101   01      1       015     040     20220101        03:00   71.06
RD      I       48      013     1090    62101   01      1       015     040     20220101        04:00   70.4925
RD      I       48      013     1090    62101   01      1       015     040     20220101        05:00   70.295
RD      I       48      013     1090    62101   01      1       015     040     20220101        06:00   70.0158
RD      I       48      013     1090    62101   01      1       015     040     20220101        07:00   69.9
RD      I       48      013     1090    62101   01      1       015     040     20220101        08:00   70.8742
RD      I       48      013     1090    62101   01      1       015     040     20220101        09:00   72.6833
RD      I       48      013     1090    62101   01      1       015     040     20220101        10:00   73.7475
RD      I       48      013     1090    62101   01      1       015     040     20220101        11:00   76.5167
RD      I       48      013     1090    62101   01      1       015     040     20220101        12:00   77.075
RD      I       48      013     1090    62101   01      1       015     040     20220101        13:00   78.7742
RD      I       48      013     1090    62101   01      1       015     040     20220101        14:00   80.9758
RD      I       48      013     1090    62101   01      1       015     040     20220101        15:00   80.3875
RD      I       48      013     1090    62101   01      1       015     040     20220101        16:00   78.2175
RD      I       48      013     1090    62101   01      1       015     040     20220101        17:00   75.9725
RD      I       48      013     1090    62101   01      1       015     040     20220101        18:00   71.6925
RD      I       48      013     1090    62101   01      1       015     040     20220101        19:00   69.8683
RD      I       48      013     1090    62101   01      1       015     040     20220101        20:00   69.7583
RD      I       48      013     1090    62101   01      1       015     040     20220101        21:00   70.5917
RD      I       48      013     1090    62101   01      1       015     040     20220101        22:00   69.0192
RD      I       48      013     1090    62101   01      1       015     040     20220101        23:00   63.1217
RD      I       48      013     1090    62101   01      1       015     040     20220102        00:00   52.2033
RD      I       48      013     1090    62101   01      1       015     040     20220102        01:00   45.5242
RD      I       48      013     1090    62101   01      1       015     040     20220102        02:00   40.9967
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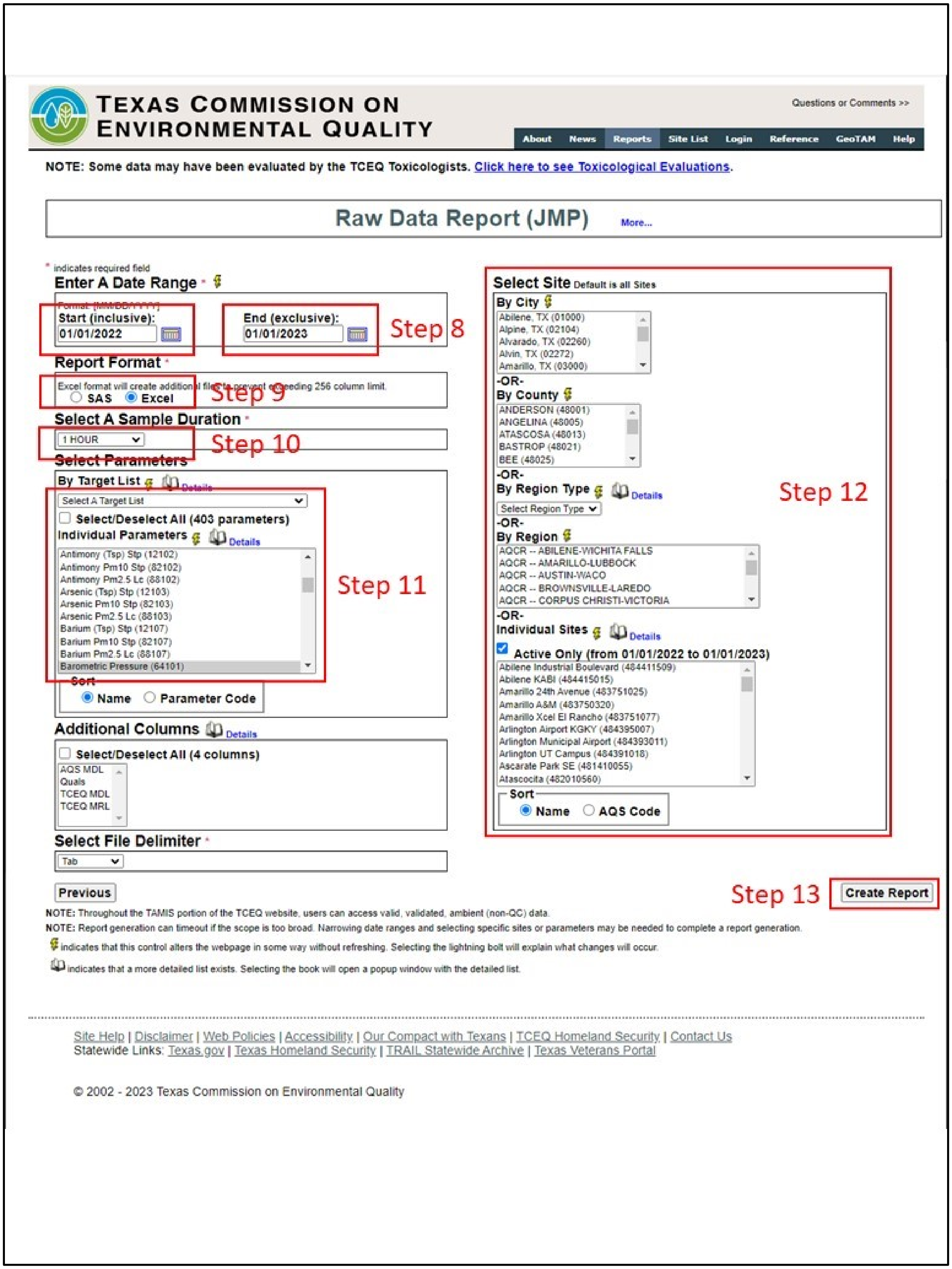
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
Questions or Comments >>
About News Reports Site List Login Reference GeoTAM Help
NOTE: Some data may have been evaluated by the TCEQ Toxicologists. Click here to see Toxicological Evaluations.
Raw Data Report (JMP) More...
* indicates required field
Enter A Date Range *
Start (inclusive): 01/01/2022
End (exclusive): 01/01/2023
Step 8
Report Format *
Excel format will create additional files to prevent exceeding 256 column limit.
SAS Excel
Step 9
Select A Sample Duration *
1 HOUR
Step 10
Select Parameters
By Target List
Select A Target List
Select/Deselect All (403 parameters)
Individual Parameters Details
Antimony (Tsp) Stp (12102)
Antimony Pm10 Stp (82102)
Antimony Pm2.5 Lc (88102)
Arsenic (Tsp) Stp (12103)
Arsenic Pm10 Stp (82103)
Arsenic Pm2.5 Lc (88103)
Barium (Tsp) Stp (12107)
Barium Pm10 Stp (82107)
Barium Pm2.5 Lc (88107)
Barometric Pressure (64101)
Step 11
Sort
Name Parameter Code
Additional Columns Details
Select/Deselect All (4 columns)
AQS MDL
Quals
TCEQ MDL
TCEQ MRL
Select File Delimiter *
Tab
Select Site Default is all Sites
By City
Abilene, TX (01000)
Alpine, TX (02104)
Alvarado, TX (02260)
Alvin, TX (02272)
Amarillo, TX (03000)
-OR-
By County
ANDERSON (48001)
ANGELINA (48005)
ATASCOSA (48013)
BASTROP (48021)
BEE (48025)
-OR-
By Region Type Details
Select Region Type
-OR-
By Region
AQCR -- ABILENE-WICHITA FALLS
AQCR -- AMARILLO-LUBBOCK
AQCR -- AUSTIN-WACO
AQCR -- BROWNSVILLE-LAREDO
AQCR -- CORPUS CHRISTI-VICTORIA
-OR-
Individual Sites Details
Active Only (from 01/01/2022 to 01/01/2023)
Abilene Industrial Boulevard (484411509)
Abilene KABI (484415015)
Amarillo 24th Avenue (483751025)
Amarillo A&M (483750320)
Amarillo Xcel El Rancho (483751077)
Arlington Airport KGKY (484395007)
Arlington Municipal Airport (484393011)
Arlington UT Campus (484391018)
Ascarate Park SE (481410055)
Atascocita (482010560)
Sort
Name AQS Code
Step 12
Previous
Step 13
Create Report
NOTE: Throughout the TAMIS portion of the TCEQ website, users can access valid, validated, ambient (non-QC) data.
NOTE: Report generation can timeout if the scope is too broad. Narrowing date ranges and selecting specific sites or parameters may be needed to complete a report generation.
indicates that this control alters the webpage in some way without refreshing. Selecting the lightning bolt will explain what changes will occur.
indicates that a more detailed list exists. Selecting the book will open a popup window with the detailed list.
Site Help | Disclaimer | Web Policies | Accessibility | Our Compact with Texans | TCEQ Homeland Security | Contact Us
Statewide Links: Texas.gov | Texas Homeland Security | TRAIL Statewide Archive | Texas Veterans Portal
© 2002 - 2023 Texas Commission on Environmental Quality

APPENDIX 1-B: TTI SCRIPTS TO AUTOMATE THE METEOROLOGICAL DATA PROCESSING

This appendix includes TTI's Python scripts to process NCDC's ISD Data and TCEQ's TAMIS data into the 2022 meteorological inputs, supporting files, an example working folder, and a readme file. This appendix is available electronically when requested.

APPENDIX 1-C: 2022 METEOROLOGICAL DATA MOVES INPUT DATABASE

This appendix includes the six MariaDB databases developed from the 2022 Meteorological data. It includes:

- Monthly meteorological MOVES input database:
    - 2022met_monthly_254counties_tceq
    - 2022met_monthly_26districts_254counties_tceq
    - 2022met_monthly_4nonattain_20counties_tceq
- Seasonal meteorological MOVES input database:
    - 2022met_monthly_254counties_tceq
    - 2022met_monthly_26districts_254counties_tceq
    - 2022met_monthly_4nonattain_20counties_tceq

This appendix is available electronically when requested.

APPENDIX 2-A: TEXAS COUNTIES AND THEIR DISTRICT CODES, GAS RULE CODES, AND MOVES FUELREGIONIDS - FUEL YEARS 1999 THROUGH 2023

This appendix contains a table TTI used to assign the district and gas rule codes and the FuelRegionID to counties and FIPS.

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Borden	48033	Abilene	D01	R1	300000000
Callahan	48059	Abilene	D01	R1	300000000
Fisher	48151	Abilene	D01	R1	300000000
Haskell	48207	Abilene	D01	R1	300000000
Howard	48227	Abilene	D01	R1	300000000
Jones	48253	Abilene	D01	R1	300000000
Kent	48263	Abilene	D01	R1	300000000
Mitchell	48335	Abilene	D01	R1	300000000
Nolan	48353	Abilene	D01	R1	300000000
Scurry	48415	Abilene	D01	R1	300000000
Shackelford	48417	Abilene	D01	R1	300000000
Stonewall	48433	Abilene	D01	R1	300000000
Taylor	48441	Abilene	D01	R1	300000000
Armstrong	48011	Amarillo	D02	R1	300000000
Carson	48065	Amarillo	D02	R1	300000000
Dallam	48111	Amarillo	D02	R1	300000000
Deaf Smith	48117	Amarillo	D02	R1	300000000
Gray	48179	Amarillo	D02	R1	300000000
Hansford	48195	Amarillo	D02	R1	300000000
Hartley	48205	Amarillo	D02	R1	300000000
Hemphill	48211	Amarillo	D02	R1	300000000
Hutchinson	48233	Amarillo	D02	R1	300000000
Lipscomb	48295	Amarillo	D02	R1	300000000
Moore	48341	Amarillo	D02	R1	300000000
Ochiltree	48357	Amarillo	D02	R1	300000000
Oldham	48359	Amarillo	D02	R1	300000000
Potter	48375	Amarillo	D02	R1	300000000
Randall	48381	Amarillo	D02	R1	300000000
Roberts	48393	Amarillo	D02	R1	300000000
Sherman	48421	Amarillo	D02	R1	300000000
Bowie	48037	Atlanta	D03	R2	178010000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Camp	48063	Atlanta	D03	R2	178010000
Cass	48067	Atlanta	D03	R2	178010000
Harrison	48203	Atlanta	D03	R2	178010000
Marion	48315	Atlanta	D03	R2	178010000
Morris	48343	Atlanta	D03	R2	178010000
Panola	48365	Atlanta	D03	R2	178010000
Titus	48449	Atlanta	D03	R2	178010000
Upshur	48459	Atlanta	D03	R2	178010000
Bastrop	48021	Austin	D04	R2	178010000
Blanco	48031	Austin	D04	R1	300000000
Burnet	48053	Austin	D04	R1	300000000
Caldwell	48055	Austin	D04	R2	178010000
Gillespie	48171	Austin	D04	R1	300000000
Hays	48209	Austin	D04	R2	178010000
Lee	48287	Austin	D04	R2	178010000
Llano	48299	Austin	D04	R1	300000000
Mason	48319	Austin	D04	R1	300000000
Travis	48453	Austin	D04	R2	178010000
Williamson	48491	Austin	D04	R2	178010000
Chambers	48071	Beaumont	D05	R4	1370011000
Hardin	48199	Beaumont	D05	R5	178000000
Jasper	48241	Beaumont	D05	R2	178010000
Jefferson	48245	Beaumont	D05	R5	178000000
Liberty	48291	Beaumont	D05	R4	1370011000
Newton	48351	Beaumont	D05	R2	178010000
Orange	48361	Beaumont	D05	R5	178000000
Tyler	48457	Beaumont	D05	R2	178010000
Brown	48049	Brownwood	D06	R1	300000000
Coleman	48083	Brownwood	D06	R1	300000000
Comanche	48093	Brownwood	D06	R1	300000000
Eastland	48133	Brownwood	D06	R1	300000000
Lampasas	48281	Brownwood	D06	R1	300000000
Mc Culloch	48307	Brownwood	D06	R1	300000000
Mills	48333	Brownwood	D06	R1	300000000
San Saba	48411	Brownwood	D06	R1	300000000
Stephens	48429	Brownwood	D06	R1	300000000
Brazos	48041	Bryan	D07	R2	178010000
Burleson	48051	Bryan	D07	R2	178010000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Freestone	48161	Bryan	D07	R2	178010000
Grimes	48185	Bryan	D07	R2	178010000
Leon	48289	Bryan	D07	R2	178010000
Madison	48313	Bryan	D07	R2	178010000
Milam	48331	Bryan	D07	R2	178010000
Robertson	48395	Bryan	D07	R2	178010000
Walker	48471	Bryan	D07	R2	178010000
Washington	48477	Bryan	D07	R2	178010000
Briscoe	48045	Childress	D08	R1	300000000
Childress	48075	Childress	D08	R1	300000000
Collingsworth	48087	Childress	D08	R1	300000000
Cottle	48101	Childress	D08	R1	300000000
Dickens	48125	Childress	D08	R1	300000000
Donley	48129	Childress	D08	R1	300000000
Foard	48155	Childress	D08	R1	300000000
Hall	48191	Childress	D08	R1	300000000
Hardeman	48197	Childress	D08	R1	300000000
King	48269	Childress	D08	R1	300000000
Knox	48275	Childress	D08	R1	300000000
Motley	48345	Childress	D08	R1	300000000
Wheeler	48483	Childress	D08	R1	300000000
Aransas	48007	Corpus Christi	D09	R2	178010000
Bee	48025	Corpus Christi	D09	R2	178010000
Goliad	48175	Corpus Christi	D09	R2	178010000
Jim Wells	48249	Corpus Christi	D09	R6	100000000
Karnes	48255	Corpus Christi	D09	R2	178010000
Kleberg	48273	Corpus Christi	D09	R6	100000000
Live Oak	48297	Corpus Christi	D09	R2	178010000
Nueces	48355	Corpus Christi	D09	R2	178010000
Refugio	48391	Corpus Christi	D09	R2	178010000
San Patricio	48409	Corpus Christi	D09	R2	178010000
Collin	48085	Dallas	D10	R4	1370011000
Dallas	48113	Dallas	D10	R4	1370011000
Denton	48121	Dallas	D10	R4	1370011000
Ellis	48139	Dallas	D10	R2	178010000
Kaufman	48257	Dallas	D10	R2	178010000
Navarro	48349	Dallas	D10	R2	178010000
Rockwall	48397	Dallas	D10	R2	178010000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Brewster	48043	El Paso	D11	R1	300000000
Culberson	48109	El Paso	D11	R1	300000000
El Paso	48141	El Paso	D11	R3	370010000
Hudspeth	48229	El Paso	D11	R1	300000000
Jeff Davis	48243	El Paso	D11	R1	300000000
Presidio	48377	El Paso	D11	R1	300000000
Erath	48143	Fort Worth	D12	R1	300000000
Hood	48221	Fort Worth	D12	R2	178010000
Jack	48237	Fort Worth	D12	R1	300000000
Johnson	48251	Fort Worth	D12	R2	178010000
Palo Pinto	48363	Fort Worth	D12	R1	300000000
Parker	48367	Fort Worth	D12	R2	178010000
Somervell	48425	Fort Worth	D12	R2	178010000
Tarrant	48439	Fort Worth	D12	R4	1370011000
Wise	48497	Fort Worth	D12	R2	178010000
Brazoria	48039	Houston	D13	R4	1370011000
Fort Bend	48157	Houston	D13	R4	1370011000
Galveston	48167	Houston	D13	R4	1370011000
Harris	48201	Houston	D13	R4	1370011000
Montgomery	48339	Houston	D13	R4	1370011000
Waller	48473	Houston	D13	R4	1370011000
Dimmit	48127	Laredo	D14	R1	300000000
Duval	48131	Laredo	D14	R6	100000000
Kinney	48271	Laredo	D14	R1	300000000
La Salle	48283	Laredo	D14	R1	300000000
Maverick	48323	Laredo	D14	R1	300000000
Val Verde	48465	Laredo	D14	R1	300000000
Webb	48479	Laredo	D14	R1	300000000
Zavala	48507	Laredo	D14	R1	300000000
Bailey	48017	Lubbock	D15	R1	300000000
Castro	48069	Lubbock	D15	R1	300000000
Cochran	48079	Lubbock	D15	R1	300000000
Crosby	48107	Lubbock	D15	R1	300000000
Dawson	48115	Lubbock	D15	R1	300000000
Floyd	48153	Lubbock	D15	R1	300000000
Gaines	48165	Lubbock	D15	R1	300000000
Garza	48169	Lubbock	D15	R1	300000000
Hale	48189	Lubbock	D15	R1	300000000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Hockley	48219	Lubbock	D15	R1	300000000
Lamb	48279	Lubbock	D15	R1	300000000
Lubbock	48303	Lubbock	D15	R1	300000000
Lynn	48305	Lubbock	D15	R1	300000000
Parmer	48369	Lubbock	D15	R1	300000000
Swisher	48437	Lubbock	D15	R1	300000000
Terry	48445	Lubbock	D15	R1	300000000
Yoakum	48501	Lubbock	D15	R1	300000000
Angelina	48005	Lufkin	D16	R2	178010000
Houston	48225	Lufkin	D16	R2	178010000
Nacogdoches	48347	Lufkin	D16	R2	178010000
Polk	48373	Lufkin	D16	R2	178010000
Sabine	48403	Lufkin	D16	R2	178010000
San Augustine	48405	Lufkin	D16	R2	178010000
San Jacinto	48407	Lufkin	D16	R2	178010000
Shelby	48419	Lufkin	D16	R2	178010000
Trinity	48455	Lufkin	D16	R2	178010000
Andrews	48003	Odessa	D17	R1	300000000
Crane	48103	Odessa	D17	R1	300000000
Ector	48135	Odessa	D17	R1	300000000
Loving	48301	Odessa	D17	R1	300000000
Martin	48317	Odessa	D17	R1	300000000
Midland	48329	Odessa	D17	R1	300000000
Pecos	48371	Odessa	D17	R1	300000000
Reeves	48389	Odessa	D17	R1	300000000
Terrell	48443	Odessa	D17	R1	300000000
Upton	48461	Odessa	D17	R1	300000000
Ward	48475	Odessa	D17	R1	300000000
Winkler	48495	Odessa	D17	R1	300000000
Delta	48119	Paris	D18	R2	178010000
Fannin	48147	Paris	D18	R2	178010000
Franklin	48159	Paris	D18	R2	178010000
Grayson	48181	Paris	D18	R2	178010000
Hopkins	48223	Paris	D18	R2	178010000
Hunt	48231	Paris	D18	R2	178010000
Lamar	48277	Paris	D18	R2	178010000
Rains	48379	Paris	D18	R2	178010000
Red River	48387	Paris	D18	R2	178010000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Brooks	48047	Pharr	D19	R6	100000000
Cameron	48061	Pharr	D19	R6	100000000
Hidalgo	48215	Pharr	D19	R6	100000000
Jim Hogg	48247	Pharr	D19	R6	100000000
Kenedy	48261	Pharr	D19	R6	100000000
Starr	48427	Pharr	D19	R6	100000000
Willacy	48489	Pharr	D19	R6	100000000
Zapata	48505	Pharr	D19	R1	300000000
Coke	48081	San Angelo	D20	R1	300000000
Concho	48095	San Angelo	D20	R1	300000000
Crockett	48105	San Angelo	D20	R1	300000000
Edwards	48137	San Angelo	D20	R1	300000000
Glasscock	48173	San Angelo	D20	R1	300000000
Irion	48235	San Angelo	D20	R1	300000000
Kimble	48267	San Angelo	D20	R1	300000000
Menard	48327	San Angelo	D20	R1	300000000
Reagan	48383	San Angelo	D20	R1	300000000
Real	48385	San Angelo	D20	R1	300000000
Runnels	48399	San Angelo	D20	R1	300000000
Schleicher	48413	San Angelo	D20	R1	300000000
Sterling	48431	San Angelo	D20	R1	300000000
Sutton	48435	San Angelo	D20	R1	300000000
Tom Green	48451	San Angelo	D20	R1	300000000
Atascosa	48013	San Antonio	D21	R2	178010000
Bandera	48019	San Antonio	D21	R1	300000000
Bexar	48029	San Antonio	D21	R2	178010000
Comal	48091	San Antonio	D21	R2	178010000
Frio	48163	San Antonio	D21	R1	300000000
Guadalupe	48187	San Antonio	D21	R2	178010000
Kendall	48259	San Antonio	D21	R1	300000000
Kerr	48265	San Antonio	D21	R1	300000000
Mc Mullen	48311	San Antonio	D21	R6	100000000
Medina	48325	San Antonio	D21	R1	300000000
Uvalde	48463	San Antonio	D21	R1	300000000
Wilson	48493	San Antonio	D21	R2	178010000
Anderson	48001	Tyler	D22	R2	178010000
Cherokee	48073	Tyler	D22	R2	178010000
Gregg	48183	Tyler	D22	R2	178010000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Henderson	48213	Tyler	D22	R2	178010000
Rusk	48401	Tyler	D22	R2	178010000
Smith	48423	Tyler	D22	R2	178010000
Van Zandt	48467	Tyler	D22	R2	178010000
Wood	48499	Tyler	D22	R2	178010000
Bell	48027	Waco	D23	R2	178010000
Bosque	48035	Waco	D23	R2	178010000
Coryell	48099	Waco	D23	R2	178010000
Falls	48145	Waco	D23	R2	178010000
Hamilton	48193	Waco	D23	R1	300000000
Hill	48217	Waco	D23	R2	178010000
Limestone	48293	Waco	D23	R2	178010000
Mc Lennan	48309	Waco	D23	R2	178010000
Archer	48009	Wichita Falls	D24	R1	300000000
Baylor	48023	Wichita Falls	D24	R1	300000000
Clay	48077	Wichita Falls	D24	R1	300000000
Cooke	48097	Wichita Falls	D24	R2	178010000
Montague	48337	Wichita Falls	D24	R1	300000000
Throckmorton	48447	Wichita Falls	D24	R1	300000000
Wichita	48485	Wichita Falls	D24	R1	300000000
Wilbarger	48487	Wichita Falls	D24	R1	300000000
Young	48503	Wichita Falls	D24	R1	300000000
Austin	48015	Yoakum	D25	R2	178010000
Calhoun	48057	Yoakum	D25	R2	178010000
Colorado	48089	Yoakum	D25	R2	178010000
De Witt	48123	Yoakum	D25	R2	178010000
Fayette	48149	Yoakum	D25	R2	178010000
Gonzales	48177	Yoakum	D25	R2	178010000
Jackson	48239	Yoakum	D25	R2	178010000
Lavaca	48285	Yoakum	D25	R2	178010000
Matagorda	48321	Yoakum	D25	R2	178010000
Victoria	48469	Yoakum	D25	R2	178010000
Wharton	48481	Yoakum	D25	R2	178010000

APPENDIX 2-B: TEXAS COUNTIES AND THEIR DISTRICT CODES, GAS RULE CODES, AND MOVES FUELREGIONIDS - FUEL YEARS 2024 THROUGH 2026

This appendix contains a table that TTI used to assign the district and gas rule codes and the FuelRegionID to counties and FIPS.

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Borden	48033	Abilene	D01	R1	300000000
Callahan	48059	Abilene	D01	R1	300000000
Fisher	48151	Abilene	D01	R1	300000000
Haskell	48207	Abilene	D01	R1	300000000
Howard	48227	Abilene	D01	R1	300000000
Jones	48253	Abilene	D01	R1	300000000
Kent	48263	Abilene	D01	R1	300000000
Mitchell	48335	Abilene	D01	R1	300000000
Nolan	48353	Abilene	D01	R1	300000000
Scurry	48415	Abilene	D01	R1	300000000
Shackelford	48417	Abilene	D01	R1	300000000
Stonewall	48433	Abilene	D01	R1	300000000
Taylor	48441	Abilene	D01	R1	300000000
Armstrong	48011	Amarillo	D02	R1	300000000
Carson	48065	Amarillo	D02	R1	300000000
Dallam	48111	Amarillo	D02	R1	300000000
Deaf Smith	48117	Amarillo	D02	R1	300000000
Gray	48179	Amarillo	D02	R1	300000000
Hansford	48195	Amarillo	D02	R1	300000000
Hartley	48205	Amarillo	D02	R1	300000000
Hemphill	48211	Amarillo	D02	R1	300000000
Hutchinson	48233	Amarillo	D02	R1	300000000
Lipscomb	48295	Amarillo	D02	R1	300000000
Moore	48341	Amarillo	D02	R1	300000000
Ochiltree	48357	Amarillo	D02	R1	300000000
Oldham	48359	Amarillo	D02	R1	300000000
Potter	48375	Amarillo	D02	R1	300000000
Randall	48381	Amarillo	D02	R1	300000000
Roberts	48393	Amarillo	D02	R1	300000000
Sherman	48421	Amarillo	D02	R1	300000000
Bowie	48037	Atlanta	D03	R2	178010000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Camp	48063	Atlanta	D03	R2	178010000
Cass	48067	Atlanta	D03	R2	178010000
Harrison	48203	Atlanta	D03	R2	178010000
Marion	48315	Atlanta	D03	R2	178010000
Morris	48343	Atlanta	D03	R2	178010000
Panola	48365	Atlanta	D03	R2	178010000
Titus	48449	Atlanta	D03	R2	178010000
Upshur	48459	Atlanta	D03	R2	178010000
Bastrop	48021	Austin	D04	R2	178010000
Blanco	48031	Austin	D04	R1	300000000
Burnet	48053	Austin	D04	R1	300000000
Caldwell	48055	Austin	D04	R2	178010000
Gillespie	48171	Austin	D04	R1	300000000
Hays	48209	Austin	D04	R2	178010000
Lee	48287	Austin	D04	R2	178010000
Llano	48299	Austin	D04	R1	300000000
Mason	48319	Austin	D04	R1	300000000
Travis	48453	Austin	D04	R2	178010000
Williamson	48491	Austin	D04	R2	178010000
Chambers	48071	Beaumont	D05	R4	1370011000
Hardin	48199	Beaumont	D05	R5	178000000
Jasper	48241	Beaumont	D05	R2	178010000
Jefferson	48245	Beaumont	D05	R5	178000000
Liberty	48291	Beaumont	D05	R4	1370011000
Newton	48351	Beaumont	D05	R2	178010000
Orange	48361	Beaumont	D05	R5	178000000
Tyler	48457	Beaumont	D05	R2	178010000
Brown	48049	Brownwood	D06	R1	300000000
Coleman	48083	Brownwood	D06	R1	300000000
Comanche	48093	Brownwood	D06	R1	300000000
Eastland	48133	Brownwood	D06	R1	300000000
Lampasas	48281	Brownwood	D06	R1	300000000
Mc Culloch	48307	Brownwood	D06	R1	300000000
Mills	48333	Brownwood	D06	R1	300000000
San Saba	48411	Brownwood	D06	R1	300000000
Stephens	48429	Brownwood	D06	R1	300000000
Brazos	48041	Bryan	D07	R2	178010000
Burleson	48051	Bryan	D07	R2	178010000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Freestone	48161	Bryan	D07	R2	178010000
Grimes	48185	Bryan	D07	R2	178010000
Leon	48289	Bryan	D07	R2	178010000
Madison	48313	Bryan	D07	R2	178010000
Milam	48331	Bryan	D07	R2	178010000
Robertson	48395	Bryan	D07	R2	178010000
Walker	48471	Bryan	D07	R2	178010000
Washington	48477	Bryan	D07	R2	178010000
Briscoe	48045	Childress	D08	R1	300000000
Childress	48075	Childress	D08	R1	300000000
Collingsworth	48087	Childress	D08	R1	300000000
Cottle	48101	Childress	D08	R1	300000000
Dickens	48125	Childress	D08	R1	300000000
Donley	48129	Childress	D08	R1	300000000
Foard	48155	Childress	D08	R1	300000000
Hall	48191	Childress	D08	R1	300000000
Hardeman	48197	Childress	D08	R1	300000000
King	48269	Childress	D08	R1	300000000
Knox	48275	Childress	D08	R1	300000000
Motley	48345	Childress	D08	R1	300000000
Wheeler	48483	Childress	D08	R1	300000000
Aransas	48007	Corpus Christi	D09	R2	178010000
Bee	48025	Corpus Christi	D09	R2	178010000
Goliad	48175	Corpus Christi	D09	R2	178010000
Jim Wells	48249	Corpus Christi	D09	R6	100000000
Karnes	48255	Corpus Christi	D09	R2	178010000
Kleberg	48273	Corpus Christi	D09	R6	100000000
Live Oak	48297	Corpus Christi	D09	R2	178010000
Nueces	48355	Corpus Christi	D09	R2	178010000
Refugio	48391	Corpus Christi	D09	R2	178010000
San Patricio	48409	Corpus Christi	D09	R2	178010000
Collin	48085	Dallas	D10	R4	1370011000
Dallas	48113	Dallas	D10	R4	1370011000
Denton	48121	Dallas	D10	R4	1370011000
Ellis	48139	Dallas	D10	R4	1370011000
Kaufman	48257	Dallas	D10	R4	1370011000
Navarro	48349	Dallas	D10	R2	178010000
Rockwall	48397	Dallas	D10	R4	1370011000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Brewster	48043	El Paso	D11	R1	300000000
Culberson	48109	El Paso	D11	R1	300000000
El Paso	48141	El Paso	D11	R3	370010000
Hudspeth	48229	El Paso	D11	R1	300000000
Jeff Davis	48243	El Paso	D11	R1	300000000
Presidio	48377	El Paso	D11	R1	300000000
Erath	48143	Fort Worth	D12	R1	300000000
Hood	48221	Fort Worth	D12	R2	178010000
Jack	48237	Fort Worth	D12	R1	300000000
Johnson	48251	Fort Worth	D12	R4	1370011000
Palo Pinto	48363	Fort Worth	D12	R1	300000000
Parker	48367	Fort Worth	D12	R4	1370011000
Somervell	48425	Fort Worth	D12	R2	178010000
Tarrant	48439	Fort Worth	D12	R4	1370011000
Wise	48497	Fort Worth	D12	R4	1370011000
Brazoria	48039	Houston	D13	R4	1370011000
Fort Bend	48157	Houston	D13	R4	1370011000
Galveston	48167	Houston	D13	R4	1370011000
Harris	48201	Houston	D13	R4	1370011000
Montgomery	48339	Houston	D13	R4	1370011000
Waller	48473	Houston	D13	R4	1370011000
Dimmit	48127	Laredo	D14	R1	300000000
Duval	48131	Laredo	D14	R6	100000000
Kinney	48271	Laredo	D14	R1	300000000
La Salle	48283	Laredo	D14	R1	300000000
Maverick	48323	Laredo	D14	R1	300000000
Val Verde	48465	Laredo	D14	R1	300000000
Webb	48479	Laredo	D14	R1	300000000
Zavala	48507	Laredo	D14	R1	300000000
Bailey	48017	Lubbock	D15	R1	300000000
Castro	48069	Lubbock	D15	R1	300000000
Cochran	48079	Lubbock	D15	R1	300000000
Crosby	48107	Lubbock	D15	R1	300000000
Dawson	48115	Lubbock	D15	R1	300000000
Floyd	48153	Lubbock	D15	R1	300000000
Gaines	48165	Lubbock	D15	R1	300000000
Garza	48169	Lubbock	D15	R1	300000000
Hale	48189	Lubbock	D15	R1	300000000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Hockley	48219	Lubbock	D15	R1	300000000
Lamb	48279	Lubbock	D15	R1	300000000
Lubbock	48303	Lubbock	D15	R1	300000000
Lynn	48305	Lubbock	D15	R1	300000000
Parmer	48369	Lubbock	D15	R1	300000000
Swisher	48437	Lubbock	D15	R1	300000000
Terry	48445	Lubbock	D15	R1	300000000
Yoakum	48501	Lubbock	D15	R1	300000000
Angelina	48005	Lufkin	D16	R2	178010000
Houston	48225	Lufkin	D16	R2	178010000
Nacogdoches	48347	Lufkin	D16	R2	178010000
Polk	48373	Lufkin	D16	R2	178010000
Sabine	48403	Lufkin	D16	R2	178010000
San Augustine	48405	Lufkin	D16	R2	178010000
San Jacinto	48407	Lufkin	D16	R2	178010000
Shelby	48419	Lufkin	D16	R2	178010000
Trinity	48455	Lufkin	D16	R2	178010000
Andrews	48003	Odessa	D17	R1	300000000
Crane	48103	Odessa	D17	R1	300000000
Ector	48135	Odessa	D17	R1	300000000
Loving	48301	Odessa	D17	R1	300000000
Martin	48317	Odessa	D17	R1	300000000
Midland	48329	Odessa	D17	R1	300000000
Pecos	48371	Odessa	D17	R1	300000000
Reeves	48389	Odessa	D17	R1	300000000
Terrell	48443	Odessa	D17	R1	300000000
Upton	48461	Odessa	D17	R1	300000000
Ward	48475	Odessa	D17	R1	300000000
Winkler	48495	Odessa	D17	R1	300000000
Delta	48119	Paris	D18	R2	178010000
Fannin	48147	Paris	D18	R2	178010000
Franklin	48159	Paris	D18	R2	178010000
Grayson	48181	Paris	D18	R2	178010000
Hopkins	48223	Paris	D18	R2	178010000
Hunt	48231	Paris	D18	R2	178010000
Lamar	48277	Paris	D18	R2	178010000
Rains	48379	Paris	D18	R2	178010000
Red River	48387	Paris	D18	R2	178010000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Brooks	48047	Pharr	D19	R6	100000000
Cameron	48061	Pharr	D19	R6	100000000
Hidalgo	48215	Pharr	D19	R6	100000000
Jim Hogg	48247	Pharr	D19	R6	100000000
Kenedy	48261	Pharr	D19	R6	100000000
Starr	48427	Pharr	D19	R6	100000000
Willacy	48489	Pharr	D19	R6	100000000
Zapata	48505	Pharr	D19	R1	300000000
Coke	48081	San Angelo	D20	R1	300000000
Concho	48095	San Angelo	D20	R1	300000000
Crockett	48105	San Angelo	D20	R1	300000000
Edwards	48137	San Angelo	D20	R1	300000000
Glasscock	48173	San Angelo	D20	R1	300000000
Irion	48235	San Angelo	D20	R1	300000000
Kimble	48267	San Angelo	D20	R1	300000000
Menard	48327	San Angelo	D20	R1	300000000
Reagan	48383	San Angelo	D20	R1	300000000
Real	48385	San Angelo	D20	R1	300000000
Runnels	48399	San Angelo	D20	R1	300000000
Schleicher	48413	San Angelo	D20	R1	300000000
Sterling	48431	San Angelo	D20	R1	300000000
Sutton	48435	San Angelo	D20	R1	300000000
Tom Green	48451	San Angelo	D20	R1	300000000
Atascosa	48013	San Antonio	D21	R2	178010000
Bandera	48019	San Antonio	D21	R1	300000000
Bexar	48029	San Antonio	D21	R2	178010000
Comal	48091	San Antonio	D21	R2	178010000
Frio	48163	San Antonio	D21	R1	300000000
Guadalupe	48187	San Antonio	D21	R2	178010000
Kendall	48259	San Antonio	D21	R1	300000000
Kerr	48265	San Antonio	D21	R1	300000000
Mc Mullen	48311	San Antonio	D21	R6	100000000
Medina	48325	San Antonio	D21	R1	300000000
Uvalde	48463	San Antonio	D21	R1	300000000
Wilson	48493	San Antonio	D21	R2	178010000
Anderson	48001	Tyler	D22	R2	178010000
Cherokee	48073	Tyler	D22	R2	178010000
Gregg	48183	Tyler	D22	R2	178010000

County	FIPS	TxDOT District	District Code	Gas Rule Code	FuelRegionID
Henderson	48213	Tyler	D22	R2	178010000
Rusk	48401	Tyler	D22	R2	178010000
Smith	48423	Tyler	D22	R2	178010000
Van Zandt	48467	Tyler	D22	R2	178010000
Wood	48499	Tyler	D22	R2	178010000
Bell	48027	Waco	D23	R2	178010000
Bosque	48035	Waco	D23	R2	178010000
Coryell	48099	Waco	D23	R2	178010000
Falls	48145	Waco	D23	R2	178010000
Hamilton	48193	Waco	D23	R1	300000000
Hill	48217	Waco	D23	R2	178010000
Limestone	48293	Waco	D23	R2	178010000
Mc Lennan	48309	Waco	D23	R2	178010000
Archer	48009	Wichita Falls	D24	R1	300000000
Baylor	48023	Wichita Falls	D24	R1	300000000
Clay	48077	Wichita Falls	D24	R1	300000000
Cooke	48097	Wichita Falls	D24	R2	178010000
Montague	48337	Wichita Falls	D24	R1	300000000
Throckmorton	48447	Wichita Falls	D24	R1	300000000
Wichita	48485	Wichita Falls	D24	R1	300000000
Wilbarger	48487	Wichita Falls	D24	R1	300000000
Young	48503	Wichita Falls	D24	R1	300000000
Austin	48015	Yoakum	D25	R2	178010000
Calhoun	48057	Yoakum	D25	R2	178010000
Colorado	48089	Yoakum	D25	R2	178010000
De Witt	48123	Yoakum	D25	R2	178010000
Fayette	48149	Yoakum	D25	R2	178010000
Gonzales	48177	Yoakum	D25	R2	178010000
Jackson	48239	Yoakum	D25	R2	178010000
Lavaca	48285	Yoakum	D25	R2	178010000
Matagorda	48321	Yoakum	D25	R2	178010000
Victoria	48469	Yoakum	D25	R2	178010000
Wharton	48481	Yoakum	D25	R2	178010000

APPENDIX 2-C: SCRIPT TO PROCESS REQUIRED FUELFORMULATION AND FUELSUPPLY INPUTS FOR MOVES

This appendix includes the script developed by TTI to process the required FuelFormulation and FuelSupply inputs for MOVES. This appendix is available electronically when requested.

APPENDIX 3-A. REGISTRATION

The appendix includes the final outputs of each process and the input files, scripts, intermediate calculation results, and folder structures for the Python script to work correctly.

Appendix 3-A. Registration includes 4 folders:

1. ***2021 Raw Registration Data***: this folder contains the raw 2021 registration data from TxDMV
2. ***Calculation_intermediates***: this folder contains the calculation intermediate results of the registration data processing
3. ***Registration_outputs***: this folder contains the 2021 registration dataset by vehicle category and SUTs.
4. ***Scripts***: this folder contains the Python script for producing the outputs from the inputs.

This appendix is available electronically.

APPENDIX 3-B. AGEDISTRIBUTION

The appendix includes the final outputs of each process and the input files, scripts, intermediate calculation results, and folder structures for the Python script to work correctly.

Appendix 3-B. ageDistribution includes 4 folders:

1. ***Input***: this folder contains the raw 2021 registration data from TxDMV. 2019 registration data for Loving County, MOVES3 default ageDistribution table, and other supporting files.
2. ***Calculation_intermediates***: this folder contains the calculation intermediates results of the registration data processing
3. ***ageDistribution_outputs***: this folder contains the ageDistribution table in MOVES3 format for all levels.
4. ***Scripts***: this folder contains the Python script to produce the outputs from the inputs.

This appendix is available electronically.

APPENDIX 3-C. AVFT

The appendix includes the final outputs of each processing and the input files, scripts, calculation intermediates, and folder structures for the Python script to work properly.

Appendix 3-C. AVFT includes 4 folders:

1. ***Input***: this folder contains the raw 2021 registration data from TxDMV. TTI VMT-Mix data, MOVES3 default *samplevehiclepopulation* table, and other supporting files.
2. ***Calculation_intermediates***: this folder contains the calculation intermediates results of the registration data processing
3. ***ageDistribution_outputs***: this folder contains the ageDistribution table in MOVES3 format for all regional levels.
4. ***Scripts***: this folder contains the Python script to produce the outputs from the inputs.

This appendix is available electronically.

APPENDIX 3-D. SUPPORTING_FILES

The appendix includes the final outputs of each process and the input files, scripts, intermediate calculation results, and folder structures for the Python script to work properly.

Appendix 3-D. Supporting_Files includes 3 files that are used in the processing:

1. Geo_mapping.csv: the mapping file for the county data to MPO, COG, TxDOT District, TTI District, and NA.
2. MOVES3_sourcetypeagedistribution.csv: the default age distribution data from MOVES3.
3. MOVES_samplevehiclepopulation.csv: the default fuelEngFraction data from MOVES3.

This appendix is available electronically.

APPENDIX 4-A. TXLED SCRIPTS

The appendix includes the Python script developed to produce the TxLED factors based on the fuel formulation input. This appendix is available electronically.